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White Paper: Lessons learnt and policy recommendations

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Executive Summary

Europe's buildings agenda is entering a new phase. The policy direction is no longer in question: deep renovations must accelerate, renewables and electrification must be integrated at scale, and the pathway towards a zero-emission building stock by 2050 must remain socially legitimate. What is now decisive is **delivery**: whether national and local systems can turn targets and funding into completed renovations that perform in practice, and whether performance can be verified in ways that are proportionate, trusted, and usable for governance.

This deliverable consolidates empirical evidence generated across **seven (7) real-world pilots**, alongside the new "**Price-Comfort**" **indicator** developed during the project, and translates these insights into lessons learnt, policy implications, and strategic recommendations for policymakers and practitioners at different governance levels. It also provides adoption guidelines for market actors aiming to replicate and scale Efficient, Sustainable, and Inclusive Energy-oriented renovation solutions.

The project pilots cover a wide range of contexts- multi-family buildings, district-scale monitoring, public buildings, schools, "system-critical" municipal facilities (e.g., pools), prosumer households, and households vulnerable to energy poverty- and were implemented under real constraints of permitting, procurement, supply chains, data governance, and user engagement. This diversity enabled a robust assessment of what must evolve, highlighting that technological innovation alone is insufficient without **corresponding adaptations** in **governance models** and **renovation ecosystem coordination**.

Across pilots and countries, a consistent message emerges: Technology availability is rarely the bottleneck. The binding constraints are the operational conditions that determine whether projects can be **delivered predictably** and **verified credibly**- administrative throughput (permitting and subsidy compatibility), procurement design and sequencing, commissioning discipline, data interoperability, monitoring feasibility, and the capacity of households, municipalities, and small institutions to navigate complex renovation processes. In other words, the enabling environment must shift from programme availability to **delivery reliability**.

The national chapters show how this plays out in distinct country contexts:

France illustrates the frontier challenge of a mature policy environment: the main gains now come from *reducing "deep renovation penalties"* created by fragmented documentation pathways, stabilising interoperability in digital ecosystems, and mainstreaming post-renovation evidence routines under increasingly stringent minimum energy performance standards.

Greece demonstrates how delivery constraints- photovoltaic system permitting and grid connection, procurement fragility, supplier volatility, and weak interoperability across building datasets- can delay or dilute outcomes even when funding and technical solutions exist, making *"delivery operating systems"* and *governance-grade data backbones* decisive for a *credible National Building Renovation Plan*.

Latvia provides a high-impact lesson for public buildings; envelope renovations can leave performance gaps if ventilation and control are not upgraded and verified in parallel; *"healthy indoor environments"* must therefore become a measurable, procurement-embedded renovation outcome, especially for public institutions such as schools. Notably, FORTESIE also achieved demonstrable real-life policy uptake during implementation: Latvia's **Ministry of Climate and Energy** developed and published "***National guidelines on sustainable ventilation solutions***" to promote energy efficiency, directly reflecting pilot-derived insights and reinforcing the integration of indoor air quality into renovation governance.

Poland shows why complex tertiary facilities need differentiated governance. In high-humidity buildings, ventilation effectiveness and moisture control are *asset-integrity* and *safety conditions*, requiring *outcome-based procurements*, *inflation-resilient budgeting*, *mandatory commissioning*, and *operational verification* beyond energy performance certificate snapshots.

Portugal demonstrates that equity and feasibility depend on differentiated pathways and *analogue-compatible administration*: Vulnerable, dispersed, and low-density contexts require managed delivery models, *empowered One-Stop Shop capacity*, *contingency governance* for degraded dwellings, and *tiered monitoring* designed around *connectivity realities*.

Spain highlights the structural implications of *decentralised governance* and *climate diversity*: Permitting surge capacity, interconnection of regional registries, and renovation traceability embedded into energy performance certificates and permitting ecosystems become prerequisites for fair implementation of minimum energy performance standards and credible national reporting.

From these country experiences, the deliverable synthesises cross-country national-level lessons that are highly actionable:

(**i**). **operational clarity** in **transposition** and secondary rules;

(**ii**). **permitting** and **grid connection** treated as renovation infrastructure;

(**iii**). commissioning and proportionate post-renovation verification as **standard completion conditions**;

(**iv**). financing designed to **reward integrated packages** and **evidence creation**;

(**v**). One-Stop Shops and intermediaries positioned as **delivery capacity** (**not** "**soft support**");

(**vi**). procurement resilience embedded through **multi-supplier** strategies, **substitution-friendly** specifications, and **explicit contingencies**;

(**vii**). **governance-grade data** with renovation **traceability** and interoperable **identifiers** as a prerequisite for fair minimum energy performance standards and credible trajectories;

(**viii**). **privacy-by-design** and visible citizen benefits as conditions for monitoring uptake;

(**ix**). differentiated pathways and delegated-management options to **prevent renovation-driven exclusion**; and

(**x**). **workforce strategy** treated as renovation strategy, aligned with integrated renovation, commissioning, controls, and digital monitoring and verification skills.

Beyond national policy, the deliverable reframes what is required at other governance levels. For **regional** and **local authorities**, the pilots support a shift **from one-off project management** to operating a **repeatable delivery system**: portfolio-based zero-emission building pathways, procurements that buy verified outcomes, continuity-aware scheduling for public facilities, One-Stop-Shop-enabled citizen support, and lightweight but usable local data loops to target, monitor, and improve programmes over time.

For **civil society** and **citizen/ consumer organisations**, the evidence is equally clear: trust, comprehension, and perceived fairness materially determine participation, especially when monitoring, data sharing, or future obligations are involved. Civil society actors therefore become part of the enabling infrastructure by improving renovation literacy (digital energy performance certificates, building renovation passports and logbooks), supporting inclusion for digitally excluded groups, and strengthening legitimacy through transparent communication and equity safeguards.

For **industry** and **market actors**, the deliverable highlights a market transition already underway: competitive advantage will increasingly come from the ability to deliver integrated packages with low disruption, high quality assurance, and verifiable outcomes. This requires interoperable digital monitoring and verification modules, performance-oriented contracting and guarantees, robust onboarding and remote diagnostics, multi-supplier readiness, and participation in standardisation efforts that reduce procurement friction and increase investor confidence. The longer-term disruptive potential lies in the convergence of digital monitoring and verification, performance-based renovation models (including the certification scheme based on the "Price-Comfort" indicator developed during FORTESIE), and enabling tools such as the FORTESIE app and Marketplace, alongside incentive mechanisms (including the FORTESIE "Green Euro") that can help **normalise evidence creation**, **user engagement**, and **performance accountability** as standard practice.

Overall, the deliverable positions FORTESIE's contribution as a practical bridge between the European Union's "Renovation Wave" and "Fit-for-55" direction and the operational reality of implementation. Its central proposition is straightforward and future-proof: Europe will meet its buildings decarbonisation objectives only if renovation governance evolves from "**measures installed**" to "**outcomes verified**", supported by delivery-grade administrative pathways, interoperable data infrastructures, and equity-ready implementation models. The recommendations and adoption guidelines presented here are designed with the intention to support such a shift, so that Efficient, Sustainable, and Inclusive Energy-oriented renovation services can scale credibly, competitively, and fairly across diverse building types and territorial realities on the road to 2050.

Keywords: Efficient, Sustainable, and Inclusive Energy (ESIE) renovations; National Building Renovation Plans (NBRPs); Minimum Energy Performance Standards (MEPS); Zero-Emission Buildings (ZEBs) pathways; Digital Measurement & Verification (M&V); Interoperable building-performance data (EPBD Article 22); Renovation traceability and Building Renovation Passports (BRPs); One-Stop Shops (OSS) as delivery intermediaries; Performance-based procurement and contracting (EnPC/ ESCO models); Energy Performance Certificate (EPC); "Price-Comfort" certificates; Equity safeguards for vulnerable households and low-density territories.

Abbreviations/ Acronyms

€G	Green Euro
ADENE	Portuguese Energy Agency
API	Application Programming Interface
BACS	Building automation and control systems
BIM	Building Information Modelling
BIPV	Building-Integrated Photovoltaic
BRP	Building Renovation Plan
BSO	Building Stock Observatory
CBDC	Central Bank Digital Currency
CEE	Certificats d'Économies d'Énergie (France)
CEEAG	Climate, Energy, and Environmental Aid Guideline
CEN	European Committee for Standardisation
CF	Cohesion Fund
CO_2	Carbon Dioxide
CRES	Centre for Renewable Energy Sources (Greece)
CSIC	Spanish National Research Council
CTE	Technical Building Code (Spain)
DBL	Digital Building Logbook
DGA	Data Governance Act
DPE	Diagnostic de Performance Énergétique (France)
EC	European Commission
$EE1^{st}$	Energy Efficiency First
EED	Energy Efficiency Directive
EEOS	Energy-Efficiency Obligation Scheme
EnPC	Energy Performance Contracting
EMS	Energy Management Systems
EPBD	Energy Performance of Buildings Directive
EPC	Energy Performance Certificate
ERDF	European Regional Development Fund
ESCO	Energy Service Company
ESF+	European Social Fund Plus

ESIE	Efficient, Sustainable, and Inclusive Energy
ETICS	External Thermal Insulation Composite System
ETS	Emissions Trading System
EU	European Union
EVO	Efficiency Valuation Organisation
EV	Electric Vehicle
GDP	Gross-Domestic Product
GDPR	General Data Protection Regulation
GHG	Greenhouse Gas
HVAC	Heating, Ventilation, and Air-Conditioning
IDAE	Institute for the Diversification and Saving of Energy
IETCC	Eduardo Torroja Institute for Construction Sciences (Spain)
IEQ	Indoor Environmental Quality
IGF	General Inspectorate of Finance (France)
IoT	Internet-of-Things
IPMVP	International Performance Measurement and Verification Protocol
JTF	Just Transition Fund
LED	Light-emitting diode
LoRaWAN	Long-Range Wide Area Network
LTRS	Long-Term Renovation Strategy
MEPS	Minimum Energy Performance Standard
MITERD	Ministry for Ecological Transition and the Demographic Challenge (Spain)
MIVAU	Ministry of Housing and Urban Agenda (Spain)
M&V	Monitoring and Verification
NBRP	National Building Renovation Plan
NECP	National Energy and Climate Plan
nZEB	Nearly Zero-Energy Building
OSS	One-Stop Shop
PPE	Multiannual Energy Plan (France)
PRTR	Recovery, Transformation, and Resilience Plan (Spain)
PVC	Polyvinyl chloride
RE2020	Réglementation environnementale (France)

RED	Renewable Energy Directive
RES	Renewable Energy Sources
RITE	Reglamento de Instalaciones Térmicas en los Edificios (Spain)
RRF	Recovery and Resilience Facility
SCE	Sistema de Certificação Energética (Portugal)
SCF	Social Climate Fund
SHP	Society of Hellenism and Philhellenism (Greece)
SME	Small- and Medium-sized Enterprise
SNBC	National Low-Carbon Strategy (France)
SRI	Smart Readiness Indicator
VAV	Variable Air Volume
XPS	Extruded polystyrene
ZEB	Zero-Emission Building

1. Introduction

Climate change represents one of the most pressing and complex challenges of the 21st century. The continued rise in global temperatures, driven primarily by greenhouse gas (GHG) emissions from human activities, together with increasing climate variability, poses substantial risks to ecosystems, economies, and public health (Zeng et al., 2025). Immediate, coordinated, and sustained action is essential to mitigate these impacts through the transition to renewable energy, the widespread implementation of energy-efficiency measures, and the adoption of sustainable development practices across all sectors of society.

The buildings and construction sectors play a central role in this transition; together, they account for approximately 30% of global final energy consumption and 27% of energy-related carbon dioxide (CO_2) emissions (United Nations Environment Programme, 2025). Energy demand associated with these sectors continues to grow as global floor area expands and reliance on energy-intensive appliances increases. Improving the performance of buildings is therefore indispensable for achieving climate neutrality. Decarbonising the buildings sector requires not only greater integration of renewable energy sources (RES) but also a fundamental redesign of energy systems at both the building and district levels. As electricity generation becomes increasingly low-carbon, the electrification of end-uses traditionally reliant on fossil fuels- particularly heating, cooling, and mobility- becomes a crucial strategy for economy-wide emissions reductions (IEA, 2022). This transformation is expected to reshape energy demand patterns, especially with the projected increase in electric vehicles (EVs) and heat pumps, both central to delivering clean and efficient building- and district-level services.

Heat pumps have emerged as a cornerstone technology for low-carbon heating. Powered by clean electricity, they significantly reduce emissions compared with fossil-fuel systems while improving energy security by reducing reliance on imported fuels (International Energy Agency, 2022). Their high efficiency- delivering three to five units of heat per unit of electrical input- makes them superior to hydrogen or biomass-based alternatives. When combined with building-integrated photovoltaic (BIPV) systems or other RES, heat pumps offer a fully renewable heating and cooling solution (Tzani et al., 2022). Beyond efficiency, their flexibility enhances the stability of the wider energy system: integrated with smart grids, renewable generation, and energy storage, they can support demand-response services and facilitate higher shares of renewable energy. Nonetheless, high upfront costs and electricity pricing structures remain barriers to large-scale deployment, underscoring the importance of supportive policy frameworks (Papantonis, Tzani, Burbidge, Stavrakas, Bouzarovski, & Flamos, 2022; Wemhoener et al., 2019).

Buildings also play an essential role in supporting the transition to clean mobility. With most EV charging occurring at homes and workplaces, the integration of charging infrastructure into building design- alongside smart charging and shared-use solutions- can lower costs, reduce grid impacts, and strengthen system resilience (Akomea-Frimpong et al., 2025; Ramsebner et al., 2023). Equally, behavioural change complements technological uptake: modest actions, such as adjusting indoor temperatures or adopting energy-conscious practices and lifestyles, can reduce heating and cooling demand by up to 10% by 2030, reinforcing progress towards a net-zero buildings sector (IEA, 2022; Intergovernmental Panel on Climate Change, 2023).

In alignment with the Paris Agreement, the European Commission (EC) launched the "European Green Deal" in 2019, setting a target to reduce net GHG emissions by at least 55% by 2030 (compared to the 1990 levels) and to achieve climate neutrality by 2050 (European Commission, 2019; Tzani et al., 2023). Given that buildings account for 40% of the European Union (EU)'s final energy consumption and 36% of energy-related emissions, the sector's decarbonisation is central to meeting these goals. While emissions from buildings have declined since 1990 through energy-efficiency improvements and the deployment of renewable heating technologies, approximately 75% of Europe's building stock remains energy-inefficient and requires renovation by 2030 to stay aligned with the EU's climate objectives and respective targets (European Commission, 2024).

Recognising this, the EC recommends a 90% reduction target in GHG emissions by 2040, with the buildings sector expected to deliver up to 92% of the required savings (Hesse & Braungardt, 2024). Yet national projections indicate that current policies are insufficient: existing measures would reduce building-related emissions by only 42% by 2030 and 53% by 2040, revealing a substantial gap between ambition and implementation. Key performance indicators- carbon dioxide (CO_2) emissions reduction, energy savings, renewable energy uptake, and renovation rates- remain more than 40% below the required trajectories (Amorocho et al., 2024).

To bridge this gap, the EU has adopted a comprehensive policy package: The "Renovation Wave" strategy (2020) (European Commission (EC), 2020a) aims to at least double annual energy renovation rates by 2030. Recent revisions of the Energy Efficiency Directive (EED) in 2023 (European Commission (EC), 2023c) and the Energy Performance of Buildings Directive (EPBD) in 2024 (European Commission (EC), 2024), introduce more stringent performance requirements, strengthen minimum energy performance standards (MEPS), promote the phaseout of fossil-fuel boilers, and mandate that all new buildings achieve zero-emission status by 2030, with the existing building stock following by 2050.

1.1. The vision of FORTESIE

Considering the rapidly evolving European policy landscape, the FORTESIE project[1] was launched in late 2022 to design, demonstrate, validate, and replicate innovative renovation packages in the buildings sector, supported by smart performance-based guarantees and financing models. The project contributes to laying the foundations for the common realisation of both the "Renovation Wave" strategy and the "Built4People[2]" partnership's objectives. Its overarching ambition is to enable a transformative shift towards renovation practices and Efficient, Sustainable, and Inclusive Energy (ESIE) use- achieving not only improved energy performance but also broader climate, societal, and comfort-related benefits aligned with the Paris Agreement.

FORTESIE is built on the premise that sustainable growth must also be inclusive and fair. This requires a profound shift in how fiscal and monetary policies are designed and implemented. At the same time, individual well-being, comfort, and usability must be preserved and enhanced to secure the widespread adoption of technologies and services needed for achieving decarbonisation in Europe. Within this context, the project has been developing renovation packages that combine advanced construction materials and technologies (such as prefabricated facades, BIPV systems, and heat pumps), innovative digital tools for the measurement and verification of energy performance, and attractive financing and contractual frameworks (including smart performance guarantees and targeted engagement techniques) to elevate the overall value proposition of energy performance contracting (EPC)(Santini et al., 2020; Tzani et al., 2021; Tzani & Stavrakas, 2022).

To achieve this, FORTESIE brings together a diverse and interdisciplinary set of methodologies and tools designed to:

i. Develop **collaborative business models** that strengthen the "Renovation Wave" strategy by capturing value and revenue streams across the full stakeholder landscape.
ii. Design **novel incentivisation** and **behavioural change models** that stimulate long-term user engagement and support the adoption of energy-efficient and climate-friendly behaviours.

[1] https://fortesie.eu/.
[2] https://built4people.eu/.

iii. Integrate an **innovative digital currency concept- the Green Euro** (€G)- envisioned as a potential retail Central Bank Digital Currency (CBDC), to support financing, reward mechanisms, and the creation of an inclusive narrative around climate action, thus revolutionising the financing of renovation activities.

iv. Provide **targeted feedback** and **recommendations** to policy and business stakeholders based on insights from the project's technical, financial, and behavioural developments.

v. Map and analyse the **stakeholder ecosystem** to understand the complex interactions across the value chain and to inform a robust engagement and replication strategy.

These activities have been implemented across seven versatile real-life use cases (pilots), following a structured three-phase pilot programme. The renovation packages demonstrated and validated in these pilots are being customised for replication in additional partner countries, enabling immediate market uptake and broader scalability.

Finally, the project has developed an online marketplace[3], functioning as an online One-Stop Shop (OSS) for promoting integrated renovation packages and services for ESIE use. This digital platform offers first-level guidance, connects consumers to the relevant value-chain actors, and streamlines access to the FORTESIE packaged renovation solutions- facilitating greater transparency, simplicity, and uptake of building-level renovation services.

1.2. Scope of the deliverable

This deliverable presents the consolidated lessons learnt and policy recommendations generated within the project's Task 6.4. Its purpose is to synthesise the technical, financial, behavioural, and market insights emerging from the project's development and demonstration activities, and to translate them into actionable guidance for policymakers, industry stakeholders, and energy agencies at the European, national, and local levels. More specifically, the deliverable aims to:

- **Synthesise findings** from the FORTESIE pilots(Garcia et al., 2023), highlighting the performance of the demonstrated renovation packages, the challenges encountered during implementation, and the conditions required for successful replication and scale-up.
- **Derive cross-cutting lessons learnt** on the deployment of advanced construction technologies, digital measurement and verification tools, ESIE-oriented renovation approaches, and smart performance-based guarantees.
- **Assess the current policy and regulatory landscape**, identifying gaps, obstacles, and enabling factors that influence the market uptake of integrated renovation solutions.
- **Provide targeted policy recommendations** aligned with the EU's climate and energy objectives- including the "Renovation Wave" strategy (European Commission (EC), 2020a), the EPBD (European Commission (EC), 2024), the EED (European Commission (EC), 2023c), and the Renewable Energy Directive (RED) (European Commission (EC), 2023b), the "EU Agenda for Cities: Driving Growth and Prosperity" (European Commission (EC), 2025), and the "Built4People[4]" partnership- with a focus on accelerating high-quality, performance-driven renovations.
- **Formulate methodological guidelines for replication**, offering practical advice for public authorities, energy service companies (ESCOs), construction firms, small- and medium-sized enterprises (SMEs), and other market actors seeking to adopt or adapt the FORTESIE renovation packages and digital tools.

[3] https://fortesie-marketplace.eurodyn.com/.
[4] https://built4people.eu/.

- **Highlight complementarities and synergies** with other EU-funded projects and initiatives, enhancing the visibility and coherence of FORTESIE's outcomes within the broader European research and innovation ecosystem.

Taken together, these elements position the deliverable as a strategic bridge between the project's empirical results and the policy, market, and stakeholder environments where integrated renovation solutions must be deployed. Its ambition is to support evidence-based decision-making and contribute to a more efficient, sustainable, and inclusive renovation market across Europe.

1.3. Structure of the deliverable

This deliverable is organised to provide a coherent and evidence-based pathway from contextual analysis to concrete recommendations and lessons learnt from the FORTESIE pilot-relevant activities.

Following the introductory section, which outlines the purpose and scope of the work, **Section 2** presents a comprehensive overview of the EU's policy, regulatory, and market landscape relevant to building renovations, energy efficiency, digitalisation and financing. This analysis establishes the broader context in which the FORTESIE solutions operate and highlights the legislative and financial drivers that shape their potential for market uptake.

Section 3 describes the working approach adopted under the FORTESIE Task 6.4 for the completion of this deliverable. It explains how evidence from the FORTESIE pilots, cross-project thematic activities, stakeholder engagement, and EU-level developments was systematically collected, analysed, and synthesised to support the development of robust, actionable recommendations. This section ensures methodological transparency and clarifies how key insights of this deliverable were formulated.

As next, **Section 4** presents key lessons learnt from the FORTESIE pilot activities. It examines implementation and operational experiences across different building types and contexts, highlighting successes, challenges, and enabling conditions. These insights form the empirical foundation for understanding how integrated renovation packages perform in real environments.

Section 5 Error! Reference source not found.translates these findings into policy recommendations aimed at EU, national, and regional/ local authorities, as well as industry stakeholders, energy agencies, and civil society organisations. Recommendations address technological, regulatory, financial, and behavioural dimensions, with an emphasis on supporting the future deployment of ESIE solutions.

Finally, **Section 6** provides methodological adoption guidelines for practitioners and market actors seeking to replicate or scale the FORTESIE approaches. It summarises practical considerations, necessary conditions and transferable practices derived from the pilot experience, positioning the project's outputs for broader exploitation.

Together, these sections offer a structured and comprehensive narrative that moves from context to evidence, from analysis to recommendations, and ultimately from demonstration to wider adoption pathways for FORTESIE's tools and services.

2. Relevant policy and market conditions in the European Union

The EU has established an increasingly ambitious and comprehensive regulatory environment, with proper legislative frameworks in place to accelerate decarbonisation in the buildings sector and to align energy use with climate neutrality objectives. This evolving policy landscape, driven by the "European Green Deal" (European Commission (EC), 2020a), the "Fit-for-55" package (European Commission (EC), 2021a), the "EU Agenda for Cities: Driving Growth and Prosperity" (European Commission (EC), 2025), and the "Renovation Wave" strategy (European Commission (EC), 2020a), defines the regulatory, financial, and market conditions under which renovation solutions such as those developed in FORTESIE must operate. Understanding existing frameworks is essential for identifying the barriers and opportunities that influence the uptake of integrated renovation packages, the deployment of smart performance-based guarantees, and the broader transition to ESIE uses.

This section provides an overview of the most relevant EU directives, strategies, and market drivers shaping the renovation ecosystem, laying the foundation for the policy recommendations developed later in this deliverable.

2.1. The "Renovation Wave" strategy and the "Fit-for-55" package

The EU has placed decarbonisation in the buildings sector at the core of its climate and energy policy agenda. Two flagship initiatives shape this direction: the "Renovation Wave" strategy (European Commission (EC), 2020a) and the "Fit-for-55" package (European Commission (EC), 2021a). Together, they define the regulatory, financial, and market framework in which renovation projects such as FORTESIE are expected to operate, scale, and deliver measurable impact.

Launched in 2020 as part of the "European Green Deal" (European Commission (EC), 2019), the "Renovation Wave" strategy (European Commission (EC), 2020a) aims to at least double annual energy renovation rates by 2030 and ensure that renovations become deeper, more efficient, and more affordable. The strategy acknowledges that approximately 75% of the EU's building stock is energy inefficient and that only around 1% undergoes energy-related renovations each year. Without a significant acceleration, the EU will be unable to meet its 2030 and 2050 climate targets. Overall, the "Renovation Wave" strategy (European Commission (EC), 2020a) sets out measures across the whole renovation chain that aim to increase the rate and depth of renovations. The measures relate to the following areas:

1) Strengthening information, legal certainty and incentives for public and private owners and tenants to undertake renovations.
2) Ensuring adequate and well-targeted funding.
3) Increasing technical assistance to regional and local actors.
4) Promoting renovation interventions for smart buildings and digital friendly renovations
5) Ensuring that the construction sector is fit to drive sustainable renovations and uses sustainable materials
6) Using renovation as a lever to address energy poverty
7) Promoting the decarbonisation of heating and cooling

These priorities strongly align with the FORTESIE's overarching vision: integrated renovation packages, digital measurement and verification, prefabricated facade elements, heat pumps, and user-centred design all contribute to accelerating renovation depth and quality.

In addition, the "Fit-for-55" package, adopted progressively between 2021 and 2023, translates the EU's 55% emissions-reduction target for 2030 into a binding legislative framework. It reshapes the energy and buildings landscape through a series of revised directives and regulations, including:

- the recast Energy Performance of Buildings Directive (**EPBD**) (European Commission (EC), 2024),
- the revised Energy Efficiency Directive (**EED**) (European Commission (EC), 2023c),
- the revised Renewable Energy Directive (**RED**) (European Commission (EC), 2023b),
- the extension of the Emissions Trading System (**ETS**) to the buildings and transport sectors (ETS2) (European Commission (EC), 2023a),
- the new **Social Climate Fund** (**SCF**) (European Commission (EC), 2021b),
- and reforms to energy taxation and infrastructure instruments.

For buildings, the implications are transformative: "Fit-for-55" introduces strengthened minimum energy performance requirements, mandates a rapid phaseout of fossil-fuel heating systems, promotes the uptake of renewables in buildings, and requires Member States to create long-term renovation strategies with national targets and binding trajectories. Public buildings and worst-performing buildings face accelerated renovation obligations, while the SCF aims to reduce risks related to the phenomenon of energy poverty.

Although distinct in scope and format, the "Renovation Wave" strategy and the "Fit-for-55" package are deeply interconnected. The "Renovation Wave" strategy provides the strategic vision and societal justification for transforming Europe's building stock, while the "Fit-for-55" package delivers the legal mechanisms, market signals, and financing structures that turn that vision into operational reality. For renovation actors, such as ESCOs, building owners, technology providers, municipalities, and financial intermediaries, this synergy creates both opportunities (e.g., increased funding streams, clearer regulatory pathways, expanding demand for renovation packages, a stronger emphasis on digitalisation and performance verification) and challenges (e.g., compliance with stricter standards, workforce shortages, upfront financing needs, the necessity for interoperable digital tools and robust monitoring frameworks).

Within FORTESIE, these EU-level regulatory frameworks have been defining the policy and market context in which the project's solutions must be deployed and replicated. The "Renovation Wave" strategy underscores the need for affordable, scalable, user-centred renovation packages, while the "Fit-for-55" package amplifies demand for technologies such as heat pumps, BIPV, digital monitoring and verification (M&V) systems, and performance-based guarantees. Together, both initiatives validate the central vision of FORTESIE: an integrated, digitalised, and performance-driven approach to building renovation capable of supporting Europe's transition towards ESIE uses (Arsenopoulos et al., 2025; Papantonis, Stavrakas, Burbidge, et al., 2025).

2.2. Energy Performance of Buildings Directive

The EPBD (European Commission (EC), 2024)regulation provides the main policy framework guiding decarbonisation in Europe's buildings sector. Initially introduced to improve energy efficiency in buildings while balancing climate, comfort, and cost, the directive has evolved to align with the EU's broader climate-neutrality goals. The most recent revision, which entered into force in May 2024, strengthens the EU's commitment to a zero-emission building stock by 2050 and places a strong emphasis on renovation, social inclusion, and data transparency. Member States now have two years to transpose the directive's requirements into national law and close existing policy gaps.

2.2.1. National Building Renovation Plans

The directive requires the establishment of "National Building Renovation Plans (NBRPs)[5]" as strategic instruments for modernising the entire building stock, across both public and private sectors. These plans

[5] https://energy.ec.europa.eu/topics/energy-efficiency/energy-performance-buildings/national-building-renovation-plans_en.

must set out national trajectories, measurable indicators, and policy measures for transforming existing buildings into Zero-Emission Buildings (ZEBs). Submitted every five years, NBRPs will include investment needs, progress milestones, and expected benefits, in alignment with each country's "National Energy and Climate Plan (NECP)[6]" and are intended to ensure transparency, continuity, and long-term policy stability.

2.2.2. Minimum Energy Performance Standards

To accelerate renovations, the EPBD regulation (European Commission (EC), 2024) introduces mandatory MEPS for non-residential and residential buildings. By 2030, Member States must upgrade at least 16% of the worst-performing non-residential buildings, increasing to 26% by 2033. Residential buildings must follow a progressive trajectory to reduce average primary energy consumption by at least 16% by 2030 and 20-22% by 2035, eventually achieving over 55% reduction by mid-century. Accurate and comprehensive building-stock data are essential for identifying low-performing segments and tracking progress towards these goals.

2.2.3. Zero-Emission Buildings

From 2028, all new public buildings must meet ZEB standards, with the same requirement applying to all new constructions by 2030. ZEBs must eliminate on-site fossil-fuel emissions and minimise operational GHG outputs. They should also be equipped to interact dynamically with energy systems, optimising consumption, generation, and storage, where feasible. Member States retain the flexibility to adapt ZEB definitions to their specific climatic and structural contexts.

2.2.4. Building Renovation Passports and Energy Performance Certificates

The recast EPBD regulation establishes "Building Renovation Passports (BRPs)" as tailored, step-by-step plans to guide building owners towards deep renovations. These digital roadmaps must be deployed by 2026 and maintained in national registries. In parallel, "Energy Performance Certificates (EPCs)" have been strengthened:

- adoption of a harmonised "A-G" scale, with "A+" reserved for buildings exceeding ZEB performance,
- expanded scope for EPC obligations (e.g., major renovations, rental contracts),
- clearer and more actionable recommendations, and
- additional indicators on indoor air quality and renewable integration.

These measures aim to make EPCs a more reliable and comparable tool across the EU.

2.2.5. Smart readiness and system inspections

The recast EPBD regulation (European Commission (EC), 2024) strengthens the role of the "Smart Readiness Indicator (SRI)" as a tool for assessing a building's capacity to monitor, control, and optimise its energy use through automation, digitalisation, and demand-response capabilities. The SRI provides a structured evaluation of how effectively buildings can interact with occupants and the wider energy system, thereby supporting flexibility, comfort, and operational efficiency.

Under the updated provisions, large non-residential buildings are expected to undergo mandatory SRI assessments by 2027, signalling a significant step towards mainstreaming smart technologies across the building stock. The scheme aims to create a transparent and comparable framework for assessing smart readiness, helping building owners and operators prioritise digital upgrades that deliver measurable energy and comfort benefits.

[6] https://commission.europa.eu/energy-climate-change-environment/implementation-eu-countries/energy-and-climate-governance-and-reporting/national-energy-and-climate-plans_en.

The directive also reinforces the requirements for regular inspections of heating, ventilation, and air-conditioning (HVAC) systems. These inspections are intended to ensure sustained performance, verify compliance with updated energy-efficiency standards, and promote early detection of system inefficiencies. Together, the SRI and strengthened inspection frameworks support a more data-driven, performance-oriented approach to building operation and renovation across the EU.

2.2.6. Data infrastructure for energy performance

One of the most transformative updates is the establishment of comprehensive national building data infrastructures. These must aggregate and integrate data from:

- EPCs,
- BRPs,
- SRI assessment, and
- HVAC system inspections.

Databases must be machine-readable, interoperable, and user-accessible, with annual reporting to the EU "Building Stock Observatory (BSO)". By ensuring transparency and harmonised data management, the EPBD regulation seeks to improve policymaking, streamline administrative processes, and support investment decisions.

The recast EPBD regulation (European Commission (EC), 2024) strongly reinforces the need for integrated, digital, and performance-driven renovation solutions, which is at the heart of FORTESIE. The directive's requirements for deep renovations, digital building-stock data, EPC improvements, and smart readiness, directly align with the project's innovative renovation packages, digital measurement and verification tools, and value-chain engagement strategies. By enabling better data availability and clearer renovation trajectories, the EPBD supports the wider market uptake and replicability of the FORTESIE ESIE-oriented solutions.

2.3. The Energy Efficiency Directive

The EED (European Commission (EC), 2023c), first adopted in 2012, remains one of the EU's core legislative instruments for driving the energy transition. Its main objective is to reduce overall energy consumption across Member States and promote more efficient energy use in all sectors. The most recent revision, adopted in 2023, significantly strengthens the EU's long-term commitment to climate neutrality by introducing more ambitious energy-efficiency targets aligned with the "European Green Deal" (European Commission (EC), 2019) and the "Fit-for-55" package (European Commission (EC), 2021a).

For the buildings sector, the EED provides a comprehensive framework for improving the performance of public and private buildings, guiding national investment strategies, and supporting the deployment of energy-efficient technologies and renovation measures. Several key provisions of the directive directly influence the design, implementation, and monitoring of renovation policies, including the "Energy Efficiency First (EE1st)" principle, national energy-savings obligations, and binding requirements for the renovation of publicly owned buildings. These elements are essential for achieving deep and sustained reductions in energy demand and are highly relevant to the integrated renovation approaches demonstrated in the FORTESIE project.

2.3.1. The "Energy Efficiency First" principle

For the first time, the 2023 recast of the EED (European Commission (EC), 2023c) introduces the EE1st principle as a binding legal obligation. This principle requires Member States to systematically prioritise energy-efficiency solutions in all major policy, planning, and investment decisions, both within the energy system and in non-energy sectors. In practical terms, this means assessing energy-saving measures and demand-side solutions before considering supply-side or infrastructure-oriented alternatives.

In the buildings sector, applying the EE1st principle ensures that efficiency measures, such as high-performance insulation, advanced control systems, and low-energy construction materials, are treated as primary investments. Implementing the principle effectively reduces long-term costs, improves indoor comfort and health, and contributes to emissions reductions. To fully operationalise the EE1st principle, comprehensive cost-benefit assessment methodologies that capture environmental, social, and economic co-benefits are essential.

2.3.2. Energy Savings Obligations

The recast EED regulation (European Commission (EC), 2023c) introduces progressively stronger energy savings obligations for Member States. Annual final energy savings must increase from 0.8% in 2024 to 1.9% by 2028, sustaining a steady downward trend in energy demand across the economy. These obligations require governments to implement a mix of regulatory, financial, and behavioural measures to achieve measurable and verifiable reductions.

Importantly, the directive incorporates a strong social dimension. A dedicated share of cumulative energy savings must benefit households experiencing energy poverty, including vulnerable consumers and low-income groups. By integrating social fairness into the energy efficiency framework, the EED ensures that the transition to a low-carbon energy system delivers equitable outcomes and helps mitigate disparities across regions and population groups.

2.3.3. Renovation of publicly owned buildings

The EED regulation also strengthens requirements for the renovation and energy performance of public buildings. Member States must reduce the overall energy consumption of public bodies by 1.9% annually compared with the 2021 levels. This necessitates robust data collection and regular monitoring across the full portfolio of public assets, reported through NECPs[7].

Additionally, at least 3% of the total floor area of heated or cooled buildings owned by public authorities must be renovated each year to meet nearly-zero or zero-emissions building standards. Alternative pathways, such as phased compliance through BRPs, may be used until 2040. Transparency is further supported by the requirement for Member States to maintain a public inventory of government-owned buildings above 250 m², including floor area, energy consumption, and performance attributes.

Public procurement rules complement these renovation obligations. Authorities must purchase or lease only high-performance, energy-efficient products, services, and buildings. In all cases, decisions must respect the EE1st principle, ensuring that public investments accelerate the transition to an efficient, low-carbon building stock.

Overall, the strengthened EED framework reinforces the need for holistic, performance-driven renovation approaches, which is a core ambition of FORTESIE. Its emphasis on energy savings, public-sector leadership, digital monitoring, and inclusive outcomes creates a favourable environment for the adoption of integrated renovation packages, smart performance-based guarantees, and ESIE-oriented business models. The directive’s provisions also highlight the importance of robust measurement, verification, and digitalisation practices, all of which are central to the solutions demonstrated within the project.

[7] https://commission.europa.eu/energy-climate-change-environment/implementation-eu-countries/energy-and-climate-governance-and-reporting/national-energy-and-climate-plans_en.

2.4. Renewable Energy Directive

Renewable energy remains a cornerstone of Europe's transition to climate neutrality, as the energy sector accounts for more than three-quarters of total GHG emissions. Since the adoption of the RED regulation (European Commission (EC), 2023b) in 2009, the EU has nearly doubled the share of renewables in final energy consumption, driven by long-term policy targets and sustained market transformation. Successive revisions have raised the Union's ambition, culminating in the 2023 update, which established a binding target of at least 42.5% renewables in total energy consumption by 2030, alongside an aspirational target of 45%.

Despite this progress, the deployment of renewable energy in heating and cooling continues to lag behind the power sector, even though these end-uses represent roughly half of the EU's final energy demand. To address this imbalance, the latest revision of the RED regulation introduces strengthened measures to accelerate renewable integration in heating, cooling, and buildings, and introduces new sector-specific provisions to decarbonise both buildings and industry.

2.4.1. Renewable heating and cooling

Member States are now required to ensure a steady year-on-year increase in the share of renewables used for heating and cooling: at least 0.8% annually between 2021-2025, rising to 1.1% between 2025-2030. Once a country reaches a renewable share exceeding 60% in these uses, the annual growth obligation may be paused to reflect market maturity. Member States may also count waste heat, waste cold, and renewable electricity toward their targets, provided that minimum thresholds for renewable content are met.

2.4.2. District heating and cooling

The directive reinforces the role of district energy systems in enabling large-scale renewable integration. It sets an indicative target to increase the renewable and waste heat share in district heating and cooling by 2.2% annually from 2021 to 2030. To promote competition and innovation, district system operators are required to allow third-party renewable suppliers to access their networks under transparent and non-discriminatory conditions. In addition, consumers must receive clear information on system performance and the renewable content of supplied heat, helping to improve market confidence and transparency.

2.4.3. Renewable energy in buildings

A dedicated provision establishes an indicative EU-wide target of 49% renewable energy use in buildings by 2030, supporting the ambition set out in the recast EPBD. Member States are required to define national trajectories to achieve this target, with the flexibility to account for waste heat and cold where appropriate. These obligations are integrated into the NECPs[8], ensuring coherence between building-sector policies and broader decarbonisation pathways.

The directive's strengthened provisions for renewable heating, cooling, and buildings directly support the integrated renovation solutions developed in FORTESIE. The project's emphasis on heat pumps, BIPV systems, smart energy management, and performance-based guarantees aligns closely with the directive's focus on increasing renewable shares in the built environment. The RED regulation, thus, reinforces the need for holistic renovation packages that combine efficiency, digitalisation, and renewable integration- core elements of the ESIE framework advanced by the project.

[8] https://commission.europa.eu/energy-climate-change-environment/implementation-eu-countries/energy-and-climate-governance-and-reporting/national-energy-and-climate-plans_en.

2.5. Governance Regulation

The EU "Governance Regulation" (European Commission (EC), 2018) establishes the overarching framework for planning, monitoring, and reporting progress towards the Union's climate and energy objectives. Its core purpose is to ensure that all Member States contribute effectively to the EU's long-term commitments under the Paris Agreement, while promoting transparency, accountability, and policy consistency across Europe. A central innovation of the Regulation is the introduction of NECPs as the main strategic instruments for guiding medium- and long-term national climate and energy policies. The NECPs consolidate goals, trajectories, and measures across the Regulation's five key dimensions, namely: (i). decarbonisation, (ii). energy efficiency, (iii). energy security, (iv). internal energy market integration, and (v). research, innovation, and competitiveness.

Member States submitted their first NECPs[9] in 2019 and were required to update them by mid-2024. Although delays have been widespread, the NECPs remain the backbone of Member States' commitments and are crucial for assessing the credibility of national pathways towards the EU's 2030 and 2050 climate targets. To ensure continuous progress, the Governance Regulation requires biennial progress reports, allowing the EC to track national implementation and evaluate collective EU-level performance. When national trajectories deviate significantly from the agreed benchmarks, the EC may request corrective measures, ensuring that progress towards the target of climate neutrality remains on track.

The buildings sector holds a central position within the EU Governance Regulation because it contributes significantly to both energy-efficiency and decarbonisation goals. The NECPs must therefore include measurable renovation milestones, expected reductions in energy consumption and emissions, indicators for building-sector modernisation, and assessments of economic, social, and environmental benefits.

These requirements ensure coherence between the Governance Regulation and the provisions of the EED and EPBD regulations. Together, they create a unified policy environment that supports long-term planning, investment certainty, and the scale-up of renovation solutions across the EU.

Overall, the Governance Regulation reinforces the need for robust data, monitoring, and verifiable performance outcomes, all of which are integral to the FORTESIE project's approach. The project's digital measurement and verification tools, integrated renovation packages, and policy-relevant insights can directly support the evidence base required for the update of the NECPs, national renovation trajectories, and building-sector planning. By aligning its solutions with the regulation's reporting and monitoring requirements, FORTESIE contributes to improving national data quality, supporting more informed policymaking, and strengthening the EU's progress towards climate neutrality.

2.6. EU taxonomy, State Aid Guidelines, and other financing instruments

Achieving the EU's climate and energy objectives requires unprecedented investments in the modernisation of Europe's building stock. Deep renovations, renewable heating and cooling systems, digital measurement and verification tools, and integrated energy-efficiency solutions all demand substantial capital deployment from both public and private sectors. To steer these investments and ensure they contribute to climate neutrality, the EU has established several interlinked financial and regulatory frameworks, notably the EU taxonomy for sustainable activities, the updated State Aid Guidelines, and a range of EU-level financing instruments. Together, they shape the financial environment in which renovation solutions, such as those developed through FORTESIE, must be deployed and scaled.

[9] https://commission.europa.eu/energy-climate-change-environment/implementation-eu-countries/energy-and-climate-governance-and-reporting/national-energy-and-climate-plans_en.

2.6.1. The "EU Taxonomy" regulation

The "EU Taxonomy" (European Commission (EC), 2020b) is a classification system that defines which economic activities can be considered environmentally sustainable. It is designed to guide private investments towards activities that are consistent with the EU's climate and environmental objectives, improve market transparency, and reduce the risk of greenwashing. In the buildings sector, the taxonomy sets technical screening criteria for both new construction and renovation activities. Renovation works qualify as environmentally sustainable if they achieve at least 30% reduction in primary energy demand, or compliance with the national definition of "major renovation".

Additional criteria include requirements on indoor environmental quality, material sustainability, and consideration of lifecycle GHG emissions. These standards place strong emphasis on verifiable energy savings and transparent performance data, reinforcing the need for robust M&V mechanisms, which is at the heart of the FORTESIE project.

2.6.2. State Aid Guidelines

The "Climate, Energy and Environmental Aid Guidelines (CEEAG)" (European Commission (EC), 2022), revised in 2022, provide the framework under which Member States may support investments in building renovations and clean energy without distorting competition in the internal market. The guidelines create favourable conditions for scaling high-impact renovation solutions by allowing aid for:

- deep renovation of public and private buildings,
- installation of heat pumps and renewable-based HVAC systems,
- digitalisation of buildings through smart controls and energy-management systems,
- high-efficiency district heating and cooling upgrades,
- OSS-based and integrated renovation services, and
- EPCs.

A key innovation is the increased flexibility for Member States to design targeted support for vulnerable consumers and energy-poor households, ensuring that the green transition is socially fair. This aligns with FORTESIE's commitment to inclusiveness and its work with diverse building types, including social housing and socially relevant public buildings.

2.6.3. EU-level financing instruments

Complementing the EU Taxonomy (European Commission (EC), 2020b) and CEEAG (European Commission (EC), 2022), several EU-level financing mechanisms support renovation and sustainable energy investments, namely:

Recovery and Resilience Facility

The "Recovery and Resilience Facility (RRF)[10]" is currently the single largest source of public funding for building renovations in Europe, channelling significant resources towards energy efficiency, renewable heating, and digitalisation across Member States' national recovery plans.

Cohesion Policy Funds

The Cohesion Policy Funds are EU funding instruments aimed at reducing economic, social, and territorial disparities between Member States and regions. The main funds, for the period 2021-2027, are the "European Regional Development Fund (ERDF)[11]", the "Cohesion Fund (CF)[12]", and the

[10] https://reforms-investments.ec.europa.eu/recovery-and-resilience-facility-1_en.
[11] https://commission.europa.eu/funding-tenders/find-funding/eu-funding-programmes/european-regional-development-fund-erdf_en.
[12] https://ec.europa.eu/regional_policy/funding/cohesion-fund_en.

"European Social Fund Plus (ESF+)[13]", supplemented by the "Just Transition Fund (JTF)[14]" and other specific funds. These funds support a wide range of projects from infrastructure and environmental projects to education, skills, and job creation, with funding decisions managed by national and regional authorities. These funds also support renovation strategies at regional and local levels, including social housing upgrades, public building improvements, and capacity-building activities.

Social Climate Fund

The SFC is a new EU fund established to help make the green transition fair for vulnerable citizens and small businesses by addressing the potential negative impacts of the new EU's "ETS2". Created in response to the ETS2 extending carbon pricing to buildings and road transport, the fund will provide direct income support and fund investments in areas like energy efficiency, cleaner heating, and zero- and low-emission mobility solutions. The SCF will operate from 2026 to 2032, channelling nearly €87 billion to Member States through national "Social Climate Plans". In this context, the SCF will provide targeted financial support to low-income and vulnerable households to mitigate the distributional impacts of carbon pricing and improve access to energy-efficient renovation solutions.

InvestEU programme

The "InvestEU" programme aims to support sustainable investments, innovation, and job creation in Europe. With the EU budget guarantee provided to International and National promotional banks, the programme aims to trigger more than €372 billion in private investments to high EU policy priority areas. In this context, the "InvestEU" programme will mobilise private investments by offering EU guarantees that reduce risk for financial institutions, and will support energy efficiency loans, ESCO models, performance-based renovation schemes, and digital building solutions.

Horizon Europe

As the EU's flagship research and innovation programme, the "Horizon Europe" programme supports demonstration projects like FORTESIE that bring integrated renovation packages, digital M&V, and innovative financing concepts (e.g., performance guarantees, digital currencies) closer to market deployment.

Overall, the combination of the EU Taxonomy, the "CEEAG" framework, and existing and new EU-level financing instruments can create a robust supportive ecosystem for the large-scale uptake of integrated, digital, performance-driven renovation solutions, which is the core focus of FORTESIE. Specifically:

- **Taxonomy criteria** could reinforce demand for transparent, verifiable energy savings, directly supporting FORTESIE's digital M&V tools and smart performance-guarantee models.
- "**CEEAG**" **provisions** could enable public and private financial support for deep renovations, heat pumps, renewable HVAC systems, digital controls, and OSS-based services, mirroring the technologies and business models demonstrated in the FORTESIE pilots.
- **EU-level financing instruments** could provide practical pathways for replication, scale up, and adoption of the project's solutions across different building segments and Member States.

Collectively, these frameworks could significantly strengthen the business case for FORTESIE's renovation models, reduce investment risks, ensure social inclusiveness, and contribute to the development of mature, sustainable markets for ESIE-oriented renovation packages.

[13] https://european-social-fund-plus.ec.europa.eu/en.
[14] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/finance-and-green-deal/just-transition-mechanism/just-transition-funding-sources_en.

2.7. Standardisation, Digitalisation, and the European Energy Data Space

Digitalisation has become one of the most powerful enablers of the EU's transition towards a climate-neutral building stock. Beyond the regulatory obligations set out in the EPBD(European Commission (EC), 2024), EED (European Commission (EC), 2023c), and RED (European Commission (EC), 2023b) regulations, a broader EU-wide transformation is underway to modernise data governance, harmonise technical standards, and ensure secure and interoperable access to energy and building-stock data. These developments shape the operational environment for integrated renovation solutions and digital measurement and verification tools such as those developed within FORTESIE.

2.7.1. The EU Energy Data Space

The EU "Energy Data Space" is a flagship initiative under the European strategy for data aimed at creating a secure, interoperable, and trustworthy framework for exchanging energy-related data across Member States. Its main objectives include:

- enabling transparent and efficient access to energy consumption and production data,
- supporting new energy services (flexibility, demand response, digital energy services),
- facilitating the integration of distributed energy resources,
- improving investment decisions through reliable and harmonised data, and
- reducing administrative burdens for both public authorities and private actors.

For buildings, the Energy Data Space will facilitate seamless access to smart-meter data, on-site renewable generation data (e.g., BIPV output), heating and cooling performance data, measurement and verification datasets, and building operation data from digital controls and automation systems. This is especially relevant for performance-based business models, ESCO contracts, and digital measurement and verification frameworks- which are at the heart of FORTESIE- which require consistent and secure access to verifiable energy data.

2.7.2. Standardisation and interoperability

Standardisation plays a crucial role in enabling the digital transformation of Europe's building stock. "CEN", "CENELEC", and "ISO" committees are actively developing and updating technical standards that support:

- Building Information Modelling (BIM) information management ("EN ISO 19650" series),
- BIM data dictionaries and data templates supporting interoperable building information ("EN ISO 23386"/ "EN ISO 23387"),
- energy performance assessment ("EN ISO 52000" series),
- building automation and control functions ("EN 15232"),
- HVAC system performance and indoor environmental quality ("EN 16798" series),
- semantic interoperability and data exchange formats ("IFC", "CityGML", linked data standards).

These standards ensure that digital devices, sensors, building automation systems, and data platforms communicate reliably and consistently. Interoperability is crucial for avoiding vendor lock-in, reducing transaction costs, and enabling multi-stakeholder collaboration within renovation processes. For FORTESIE, such a standardisation ecosystem could directly support the replicability and scalability of the project's digital tools and renovation packages across different markets and technical environments.

2.7.3. Digital Measurement and Verification

Reliable digital measurement and verification processes are essential for quantifying real energy savings, supporting performance guarantees, and ensuring compliance with criteria of the EU Taxonomy. While the "EPBD" regulation provides overarching requirements for performance data, operational measurement and verification practices draw primarily on:

- o the "International Performance Measurement and Verification Protocol (IPMVP)",
- o guidance from the "Efficiency Valuation Organisation (EVO)",
- o national measurement and verification schemes (e.g., France, Germany, Nordics), and
- o emerging harmonisation initiatives in the EU.

Digital measurement and verification processes leverage advanced metering, Internet-of-Things (IoT) sensors, automated reporting and analytics to produce accurate, verifiable, and timely evidence of energy performance improvements. These capabilities underpin performance-based contracting and could be central to the renovation packages demonstrated in FORTESIE.

2.7.4. Digital Building Lifecycle Tools

The digitalisation of building lifecycle management is accelerating through the adoption of:

- BIM for planning, design, and renovation;
- digital twins for real-time monitoring and optimisation;
- IoT-enabled platforms for operational insights and predictive maintenance;
- OSS-based services that streamline information, documentation, and stakeholder interactions.

These tools enable more accurate renovation design, reduce costs, and support the integration of digital measurement and verification and performance-based guarantees. FORTESIE's online marketplace aligns closely with this trend, offering a digital interface that connects consumers with renovation services and value-chain actors.

2.7.5. "Data Governance Act" and access rules

The EU's digital transformation is supported by several horizontal data governance frameworks, including:

- the European "Data Governance Act (DGA)",
- the "Data Act",
- the "General Data Protection Regulation (GDPR)",
- national data-access and energy-data portability rules, and
- emerging requirements for secure, consent-based sharing of consumer energy data.

These frameworks ensure that building and energy data can be exchanged in a secure, interoperable, and privacy-compliant manner. For FORTESIE, robust data governance could enable digital measurement and verification processes, support transparent performance guarantees, and facilitate the operation of its digital marketplace and renovation services.

Overall, the EU's broader digitalisation and standardisation agenda could establish favourable conditions for the deployment of the FORTESIE's renovation solutions. By enabling interoperable data, secure access to performance information, standardised digital practices, and advanced building lifecycle tools, this policy and technical environment enhances the replicability, scalability and market readiness of the FORTESIE's integrated ESIE renovation packages.

2.8. Implications for FORTESIE

The evolving EU policy, regulatory, and market landscape could create a highly favourable environment for the deployment and replication of the renovation solutions developed within FORTESIE. The combined effect of the EPBD recast, the EED, the RED, the EU Governance Regulation, the EU Taxonomy, CEEAG, and emerging digitalisation initiatives strengthens demand for integrated, digital, and performance-driven approaches to building renovations. Several key implications arise for the FORTESIE overarching architecture, services, renovation packages, digital tools, and business models.

2.8.1. Strong demand for integrated and performance-oriented renovation solutions

The strengthened MEPS requirements under the recast EPBD, the transition to ZEBs, and the “Renovation Wave” strategy calling for deep, scalable renovation significantly increase the market need for integrated building upgrades. FORTESIE’s prefabricated facades, BIPV systems, heat pumps, digital measurement and verification processes, and performance-based guarantees could directly respond to these requirements. The alignment between policy ambition and the FORTESIE concept could significantly improve both market readiness and potential investor confidence.

2.8.2. Increasing relevance of digital measurement, verification, and smart energy solutions

Mandatory national building databases, digital EPCs, BRPs, the EU Energy Data Space, and the expansion of smart building functionalities collectively elevate the importance of transparent performance data. FORTESIE’s digital measurement and verification framework, smart guarantees, and behavioural-driven digital engagement tools could therefore be, not only technically relevant, but also structurally necessary to meet future regulatory expectations and financing criteria (including compliance with the EU Taxonomy).

2.8.3. Enhanced financing opportunities for FORTESIE-type renovation models

The EU Taxonomy and the revised CEEAG could enable both public and private financial support for novel renovation solutions, digitalisation, and renewable-based HVAC systems. The “RRF”, “ERDF”, “InvestEU” programme, and the upcoming “Social Climate Fund” programme could also create concrete pathways for scaling integrated renovation packages, particularly in public-sector buildings, energy-poor households, and social housing. FORTESIE’s business models, including performance-based contracts, OSS support, and digital marketplaces, are well placed to leverage these funding mechanisms.

2.8.4. Greater focus on social fairness and inclusiveness

The “Renovation Wave” strategy, the EED provisions for vulnerable consumers, the upcoming Social Climate Fund, and national renovation strategies emphasise fairness, affordability, and protection of low-income households. FORTESIE’s behavioural models, user-centric engagement, and inclusive ESIE concept respond directly to these priorities. This strengthens the societal relevance and policy legitimacy of the project’s outcomes.

2.8.5. Improved replicability through standardisation and interoperability

EU-wide digitalisation initiatives, including the EU Energy Data Space, BIM standardisation, interoperable data formats, and digital lifecycle tools, could enhance the replicability of FORTESIE renovation packages beyond the pilot sites. Standardised data structures and building information practices reduce administrative burdens and ease the deployment of digital measurement and verification processes across different contexts, supporting scalability and cross-border uptake.

2.8.6. Strategic alignment with long-term renovation plans and national energy and climate plans

NBRPs and NECPs require Member States to outline clear trajectories for building renovations, ZEB deployment, and decarbonisation (Chatterjee et al., 2022). FORTESIE’s results- technical, financial, behavioural, and policy-related- can directly inform these trajectories, offering practical solutions and evidence to support implementation at national, regional, and local levels. The EU’s existing policy and market evolution strongly validates the central vision of FORTESIE: a holistic, technology-enabled, performance-driven, and socially inclusive approach to building renovations. The alignment between the project’s innovation components and upcoming regulatory, financial, and digital frameworks could position FORTESIE as a relevant, timely, and scalable contribution to Europe’s transition towards ESIE uses.

3. Working approach

The preparation of this deliverable followed a structured working approach (**Figure 1**) designed to meet the objectives of the FORTESIE Task 6.4.

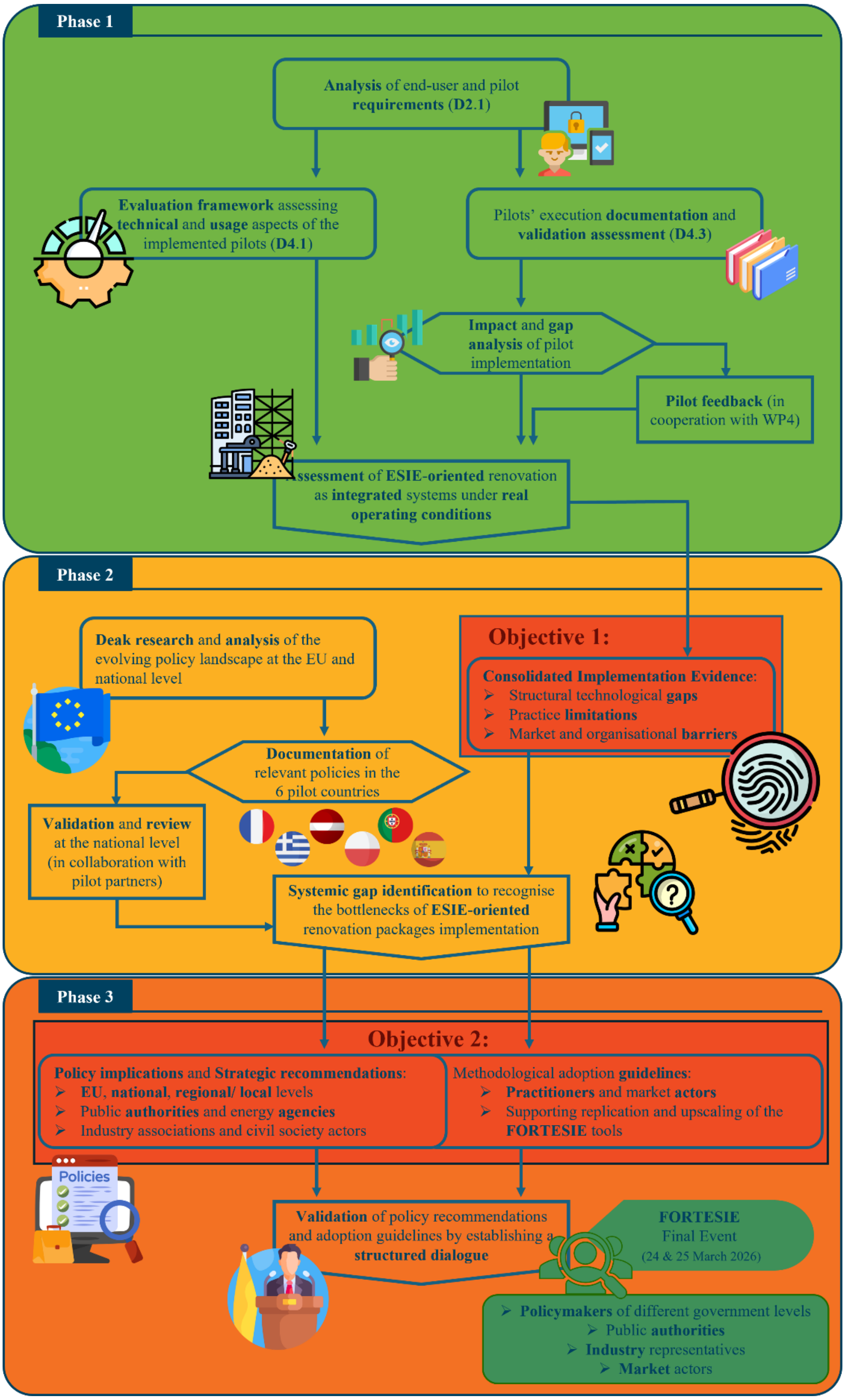

Figure 1. Working approach followed to extract lessons learnt and policy recommendations, based on the practical evidence derived from the FORTESIE pilots.

Given that Task 6.4 sits explicitly at the interface of technology, business models, and policy, the approach needed to capture the full breadth of evidence generated across FORTESIE while ensuring that the final outputs are directly usable by policymakers, market actors, and civil society stakeholders. The objective was therefore twofold: to **consolidate implementation evidence** from the project's **demonstrations**, and to **translate** that **evidence** into **strategic guidance** that can support the wider uptake of ESIE-oriented renovation services across Europe.

The **first phase** focused on collecting and synthesising evidence from the seven (7) FORTESIE pilots. Each pilot provided real-world insights into the deployment of integrated renovation packages, the operation of digital M&V workflows, the interaction between building users and smart/ performance-oriented service concepts, and the practical constraints that shape delivery along the renovation value chain (e.g., permitting, procurement sequencing, user access and engagement, and digital monitoring feasibility). This pilot evidence was complemented by technical outputs related to key solution components, including prefabricated façade elements, BIPV systems, heat pumps, digital control solutions, and behavioural/ engagement tools. Treating these elements jointly (rather than as separate technical strands) enabled an assessment of how ESIE renovation packages function in practice as integrated systems under real operating conditions.

Building on the pilot synthesis, the **second phase** consisted of a structured cross-analysis of results and insights generated across WP2-WP5. This step consolidated findings on: (i). *gaps in existing technological offerings* and *interoperability constraints*; (ii). *limitations in current standards*, *data practices*, and *digital frameworks*; and (iii). *market* and *organisational barriers affecting scalability* (including *transaction costs*, *fragmented responsibilities*, and *uneven capacity across the value chain*). These findings were cross-checked against the project's value-chain analysis, business model development activities, behavioural and consumer-engagement work, and replication and scalability assessments. This cross-WP integration ensured that the recommendations and guidelines presented in this deliverable are not isolated pilot observations, but reinforced conclusions grounded in technological maturity, user needs, financial conditions, and market readiness.

In parallel, a dedicated analytical stream aligned the project findings with the evolving European policy and market landscape described in Section 2. This alignment was necessary to ensure that the deliverable speaks directly to the regulatory and implementation context in which stakeholders will operate during the next EPBD cycle. The analysis explicitly examined how FORTESIE outcomes relate to: the recast EPBD and its requirements on NBRPs, MEPS trajectories and building-performance databases; the revised EED and the EE1st principle; RED provisions affecting renewables integration in buildings; sustainable finance and eligibility logics (e.g., EU Taxonomy-related expectations); and the emerging digitalisation agenda, including the EU "Energy Data Space". This step supported a concrete identification of where policy ambition and on-the-ground delivery conditions diverge, and where regulatory clarity, data governance, and operational guidance are most needed to enable performance-based and digitally supported renovation models.

The findings from pilot evidence, cross-WP integration, and policy alignment were then examined through a systemic gap-identification lens. This step focused on identifying the bottlenecks that most consistently limit delivery and scaling: where technical solutions exist but are difficult to deploy reliably; where current financing and programme designs unintentionally favour fragmented measures over integrated packages; where digitalisation is constrained by weak interoperability, limited monitoring feasibility, or insufficient trust and consent mechanisms; and where ESIE-oriented innovations could realistically shift practices, expectations, and investment decision-making. This ensured that FORTESIE results are positioned within a transformation pathway for renovation markets, rather than treated as stand-alone technical demonstrations.

These insights were synthesised into two main outputs: (**i**). **policy implications** and **strategic recommendations**, and (**ii**). **methodological adoption guidelines**. Strategic policy recommendations were formulated as actionable messages for decision-makers at EU, national, and regional/ local levels (including public authorities, energy agencies, industry associations, and civil society actors), focusing on the enabling conditions required for scaling ESIE-oriented renovation services. In parallel, implementation lessons were translated into adoption guidelines intended for practitioners and market actors, such as ESCOs, renovation service providers, OSS operators, public building owners, and municipalities, supporting replication and scaling of the tools, approaches, and engagement methods developed in FORTESIE. These guidelines reflect not only technical findings, but also the organisational, behavioural, and operational realities observed during implementation and monitoring.

Finally, during the **third phase,** the consolidated findings, draft policy recommendations, and methodological adoption guidelines developed were presented and discussed at the FORTESIE final event, co-hosted in Brussels in March 2025 in coordination with the sister project DEDALUS[15] and organised as a side event of the BRIDGE Initiative[16] General Assembly. This last phase served as an external validation and refinement step, enabling structured dialogue with policymakers, public authorities, industry representatives, and other relevant stakeholders active in the European ecosystem. By situating the event within the BRIDGE community, the project ensured that its conclusions are examined not only within the consortium but also through the lens of peer projects, funding representatives, and market actors engaged in related innovation streams. Discussions focused on stress-testing the practicality, clarity, and policy relevance of the proposed recommendations and adoption guidelines, identifying areas requiring further clarification, alignment, or prioritisation. Feedback collected during this event informed the final consolidation of the deliverable’s conclusions, strengthening their credibility, applicability, and alignment with real-world governance and market conditions.

Overall, throughout the process, interim outputs and conclusions were also validated within the consortium, through two consultation rounds with pilot coordinators and technical partners, to ensure accuracy, representativeness, and practical relevance. This working approach ensured that the deliverable’s conclusions are grounded in real implementation evidence, strengthened through cross-project synthesis, and aligned with current and emerging European policy frameworks, supporting both future exploitation and wider adoption of FORTESIE solutions in the EU’s renovation markets.

[15] https://dedalus-horizon.eu.
[16] https://bridge-smart-grid-storage-systems-digital-projects.ec.europa.eu.

4. Lessons learnt from real-life pilot implementation

The analysis of the seven FORTESIE pilots was carried out using a structured assessment framework designed to capture the full breadth of technical, operational, behavioural, financial, and regulatory dimensions that influence the performance and replicability of integrated renovation solutions.

This framework ensured that each pilot was examined consistently, despite the diversity of building types, ownership structures, climatic conditions, and renovation contexts involved. The assessment considered the design and implementation of renovation packages, the functioning of technological components, the effectiveness of digital measurement and verification systems and processes, user engagement and behavioural responses, the applicability of business and financing models, and any policy or administrative factors that shaped project execution.

By applying these criteria systematically across all pilots, the framework enabled the identification of both site-specific insights and cross-cutting lessons, providing a robust empirical basis for the recommendations and methodological guidelines presented in the subsequent sections.

4.1. Pilot-specific lessons learnt

4.1.1. Pilot 1: Unleashing Green Cultural Experience in Greece

Short description

The Museum of the "Society of Hellenism and Philhellenism (SHP)" is located in the historical centre of Athens and operates as a cultural institution showcasing the evolution of philhellenism from the Renaissance to modern times. The building consists of four exhibition floors (approximately 133 m² each), an office space, and a storage area, situated within a densely built urban environment characterised by elevated air pollution levels and urban heat-island effects.

The building presents several architectural and operational constraints that influence its energy performance. Many windows are covered internally with plasterboard to accommodate exhibition needs, reducing natural daylight, and limiting ventilation. The walls contain approximately 5 cm of extruded polystyrene (XPS) insulation between brick layers, while traditional lighting fixtures and ageing window frames contribute to heat loss and increased energy demand. Air circulation relies on a limited number of operable windows located mainly in the stairwell and auxiliary spaces.

Renovations that were implemented

The renovation package implemented under FORTESIE aimed to enhance the building's thermal envelope, increase renewable energy generation, and improve indoor environmental quality. Key interventions included the installation of external thermal insulation on the northern façade and the deployment of a mechanical ventilation system with heat recovery, which significantly improved indoor comfort.

The roof was transformed into a terrace with a pergola fitted with PV panels, enabling on-site renewable electricity production. The project also planned to install smart PV-integrated windows on the upper floors with sufficient solar exposure. However, technical and procurement constraints required the initial plan to be revised. Instead, high-performance multi-layered windows with improved thermal characteristics were procured for the top floors, replacing the most inefficient glazing and enabling comparative assessments with the original windows retained on lower floors.

Continuous monitoring of environmental parameters and energy performance was enabled through the installation of air-quality sensors and energy meters on each floor. Monitoring was initially conducted locally using a "Raspberry Pi" system and later fully integrated into the "Esthesis" platform[17] developed

[17] https://www.eurodyn.com/rnd-product/esthesis/.

by European Dynamics, allowing secure data storage, real-time visualisation and enhanced analytics to support digital measurement and verification processes.

Challenges from field implementation

Pilot implementation revealed several practical challenges, offering valuable insights for future renovation initiatives in cultural and small institutional buildings.

1. A major challenge involved **procurement** and **supply-chain disruptions**. The original supplier of smart PV-integrated windows failed to deliver, forcing a complete reassessment of the procurement process. Identifying alternative providers proved difficult, as several companies did not respond, while the eventual supplier imposed strict dimensional and installation constraints. These demonstrated the need for diversified supplier engagement, early technical due diligence, and realistic procurement time buffers.

2. The project also experienced **regulatory issues** related to connecting the rooftop PV system to the national grid. At the time of installation, Greece lacked a clearly defined legal framework for grid-connected PV systems in this building category, requiring the project team to wait for updated regulations before submitting the necessary documentation. This highlighted the importance of early engagement with regulatory authorities and the need to anticipate potential permitting complexities when planning renewable energy interventions.

3. **Human-resource limitations** further influenced the pilot's progress. Participation in the project's activities, stakeholder engagement, and data-collection tasks were conducted as parallel activities. This reflects a common challenge: limited administrative and technical capacity, which underscores the value of external technical assistance, OSS-based services, or local renovation support hubs.

4. **Financial pressures** also emerged due to **inflation**, **rising material costs**, and **increasing logistical expenses**. These factors required adjustments to renovation plans and reduced the scope of certain interventions. This experience illustrates the importance of contingency budgeting, robust financial forecasting, and flexible resource allocation to accommodate unforeseen cost escalations.

Despite these challenges, the pilot generated **positive technical** and **operational insights**. External insulation of the northern façade produced measurable reductions in heat loss, validating envelope improvements. Integration of the "Esthesis" platform enhanced the museum's ability to monitor energy use and indoor environmental conditions, strengthening future performance-based approaches. The comparative window assessment across floors also provides valuable empirical evidence on the performance impacts of high efficiency glazing in buildings with heritage or architectural constraints.

Key transferable lessons

Building on the challenges encountered during implementation, the following transferable lessons are formulated as **recommended solutions** or **practical mitigation strategies** to support smoother replication of similar renovation initiatives in cultural, heritage-sensitive, and small public buildings across Europe.

I. Future renovation projects involving innovative or non-standard building components should adopt **multi-supplier procurement strategies** from the outset. Pre-qualifying alternative suppliers and conducting early technical vetting can reduce dependency risks, prevent implementation delays, and allow rapid substitution if a primary supplier fails to deliver.

II. Renewable-energy interventions in small public buildings should be preceded by **early** and **continuous engagement** with permitting and grid-connection authorities. Clarifying regulatory requirements at the planning stage and initiating approval processes in parallel with technical design can significantly reduce delays linked to evolving legal frameworks. More **agile** and **standardised procedures** for small-scale PV installations would further accelerate deployment.

III. Renovation schemes targeting small cultural institutions should systematically include **external technical** and **administrative support mechanisms,** such as OSS-based services, renovation facilitation offices, or dedicated technical assistance teams. These structures can compensate for limited in-house capacity, support procurement and permitting tasks, and ensure consistent participation in monitoring and reporting activities.

IV. Projects involving innovative materials, imported components, or volatile supply chains should integrate **robust financial planning practices**, including contingency reserves and flexible budget allocations. This approach enhances resilience to inflation, unexpected cost increases, and logistical disruptions, reducing the likelihood of scope reductions during implementation.

V. The integration of digital platforms should be considered a core element of renovation design rather than an **optional add-on**. Early planning for sensor deployment, data integration, or platform operation strengthens performance tracking, supports future performance-based contracting models, and enables evidence-based optimisation of building operation after renovation.

4.1.2. Pilot 2: Green, Comfortable, and Sustainable Homes in France and Spain

4.1.2.1. Pilot 2a: Building Blocks in Asturias, Spain

Short description

The Spanish sub-pilot, coordinated by García Rama, focuses on multi-residential buildings undergoing deep renovation in Asturias. The initial demonstration site, located in the city of Gijón, was later deemed ineligible due to incompatibilities with public-subsidy requirements. As a result, the pilot leader reopened the selection process and identified an alternative building within its renovation portfolio. The new pilot site consists of two residential blocks in the “San Vicente” neighbourhood of El Entrego in the region of Asturias in Spain, constructed in 1958 and comprising 36 dwellings.

Due to challenges in engaging homeowners for the installation of monitoring sensors, with only one apartment in the San Vicente neighbourhood agreeing to participate, the pilot site was expanded to include two additional buildings undergoing renovation and implementing the FORTESIE business model. These buildings, also multi-dwelling residential properties, are located at León XIII 16 (built in 1958, 9 apartments) and Avenida de Oviedo 7-9 (built in 2003, 98 apartments) in Gijón. With their inclusion, the pilot case reached its target of monitoring 10 apartments.

These buildings exhibit typical pathologies associated with mid-20th-century construction: lack of thermal insulation, pronounced thermal bridges, high rates of heat loss, moisture infiltration and condensation, deteriorated façade coatings, insufficient acoustic protection, and ageing windows and entrance doors.

The local climate, characterised by year-round humidity, mild winters, cool summers, and frequent rainfall, exacerbates these comfort issues. The primary users in this sub-pilot are the residents of the participating dwellings, with an initial target of at least ten households installing indoor environmental and energy sensors.

Renovations that were implemented

The renovation strategy focused on comprehensive envelope upgrades to improve thermal performance, comfort, and building durability. Key interventions included:

- Installation of façade insulation, which varied depending on the building: an External Thermal Insulation Composite System (ETICS), an insulated sandwich panel or a ventilated façade with mineral wool.
- Insulation of the under-roof space to reduce heat losses.
- In the San Vicente neighbourhood: Replacement of communal-area windows (staircases, landings) with energy-efficient glazing ones.
- In the San Vicente neighbourhood: Replacement of main entrance doors to improve airtightness and security.
- In the San Vicente neighbourhood: Installation of PV systems on each block, with an expected annual output of around 33,000 kWh per building, providing substantial shared electricity cost reductions.
- In Avenida de Oviedo 7-9: Replacement of all apartment windows.
- In Léon XIII, 16: The existing balcony galleries have been fully enclosed using a uniform system of white polyvinyl chloride (PVC) exterior frames and double thermal glazing.

Renovation works officially began in October 2024, following the installation of scaffolding and the removal of deteriorated façade materials to ensure proper ETICS application. The renovation site was organised for construction materials, and preliminary technical assessments of the façade were completed to determine appropriate installation methods and machinery.

Residents' participation in the monitoring activities- critical to the FORTESIE's measurement and verification objectives- has been lower than anticipated. To reach the contractual target of ten monitoring users, the team expanded sensor installation to additional multi-family buildings in Gijón undergoing façade renovation under the same turnkey model.

The portion of the FORTESIE budget available to García Rama financed the accredited external technician responsible for preparing and submitting all technical documentation required by the Municipality to obtain construction permits for the renovation of the San Vicente neighbourhood, the procurement and installation of monitoring equipment, and the technical support for measurement and verification activities. All renovation works were financed directly by homeowners.

Challenges from field implementation

Implementation of the Spanish sub-pilot revealed several operational, administrative, and social challenges which provide important insights for future deployment of similar renovation models.

1. **Pilot-building eligibility** and need for **early screening:** The originally selected building in Gijón was ruled ineligible due to interaction with a public subsidy scheme. This required reopening the search for an alternative site, delaying the start of activities and necessitating adaptation of preparatory work already completed. This underscores the need for early and thorough eligibility screening- both technical and administrative- when selecting demonstration buildings.

2. **Administrative delays** due to **municipal staffing gaps:** Progress at the new pilot site was hindered by the temporary absence of the municipal architect responsible for verifying technical documentation and issuing renovation permits. The three-month vacancy halted the permitting process entirely. This demonstrates how municipal staffing capacity- especially in small or resource-constrained authorities- can significantly impact project timelines, even when technical preparations are complete.

3. **Adaptation** of **preparatory work** to **new buildings:** Energy assessments, EPCs, architectural plans, and licence applications had been prepared for the original pilot building. After the shift to El Entrego, much of this preparatory work required revision. This highlighted the value of maintaining flexible documentation templates and workflows when pilot-building substitution remains possible.

4. **Social** and **behavioural barriers** to **resident participation** in **monitoring:** A persistent challenge has been limited residents' willingness to install indoor environmental sensors. Concerns included privacy, unfamiliarity with digital tools, and low perceived benefits from participation. To address this, the pilot team expanded recruitment to other buildings under renovation within García Rama's portfolio. This broadened engagement strategy remains ongoing. The experience points to the importance of clear trust-building communication and user-friendly installation procedures in multi-family contexts.

5. **Complexity of coordinating monitoring technology supply**, **installation, and data integration:** Coordinating the deployment of monitoring equipment in dispersed multi-family buildings involved not only scheduling and on-site logistics but also securing technology providers capable of delivering reliable devices, completing installations on time, and exporting data in the required project formats. Inadequate hardware performance, oversized equipment, and delays in data-export processes can critically undermine monitoring objectives and prevent integration with central data platforms such as the FORTESIE's "Data Module", requiring a late-stage change of provider. This underscores the importance of early technical due diligence, clearly specified interoperability and data-format requirements, and contractual safeguards covering equipment performance, installation timelines, and data delivery obligations.

Key transferable lessons

Building on the challenges observed during implementation, the following transferable lessons are formulated as **recommended solutions** or **practical mitigation strategies** to support the replication and scaling of deep renovation initiatives in multi-residential buildings across Europe.

I. Demonstration buildings should be selected through **early**, **multi-dimensional eligibility screening**, covering not only **technical suitability** but also **administrative constraints** and interactions with existing subsidy schemes. This reduces the risk of **late-stage ineligibility** and prevents the duplication of preparatory work such as EPCs, architectural studies, and permit applications.

II. Renovation planning in multi-family buildings should explicitly account for **local administrative capacity constraints**, particularly in municipalities where permitting relies on a limited number of technical staff. Building realistic time buffers into schedules and maintaining early, continuous contact with permitting authorities can reduce the impact of unforeseen staffing gaps.

III. Project teams should adopt **modular** and **adaptable documentation workflows**, allowing energy assessments, technical studies, and permitting files to be efficiently adjusted if pilot buildings need to be substituted. This flexibility is particularly important in programmes operating across multiple buildings or portfolios under renovation.

IV. Achieving sufficient resident participation in monitoring activities requires **structured trust-building strategies**, including clear communication on data privacy, transparent explanation of benefits, and simplified, low-effort installation procedures. In multi-family contexts, engagement strategies should be designed as an integral part of the technical deployment rather than as a secondary activity.

V. When participation levels in a single building prove insufficient, renovation programmes should be designed with the option to **aggregate monitoring across multiple comparable buildings** within the same renovation pipeline. This approach preserves statistical relevance and supports robust measurement and verification without over-relying on a single site.

VI. Digital monitoring deployments should be supported by **early technical due diligence** and **contractual safeguards**, ensuring that monitoring hardware, data formats, interoperability requirements, and data-delivery timelines are clearly specified and enforceable. This reduces the risk of late-stage technology replacement and protects integration with central project data platforms.

4.1.2.2. Pilot 2b: Individual Houses in Grand Est, France

Short description

The French sub-pilot, led by Oktave, is situated in the region of Grand Est and focuses on single-family homes undergoing deep energy renovation. Oktave operates as a regional renovation support service, providing homeowners with technical expertise, administrative assistance, and financial guidance throughout the renovation process. In a typical year, the organisation facilitates around 200 renovation projects, making it a well-established actor in the French building renovation ecosystem.

Within FORTESIE, Oktave aimed to deploy smart meters and complementary monitoring devices across a representative sample of recently renovated homes to gather high-quality post-renovation data. This monitoring initiative is designed to support a deeper understanding of energy performance improvements, comfort conditions, and behavioural aspects following renovation interventions.

Most buildings considered for participation were constructed between the 1940s and 1970s, although eligible homes span a broader period (late 1800s to 1980s). Typical dwellings consist of two floors of approximately 60 m² each. Construction practices vary; older homes rely on sandstone or red brick masonry, whereas more recent buildings use concrete. Many of the dwellings lack adequate insulation, retain outdated fuel boilers, use basic ventilation systems, and include windows that are 30-40 years old. Heating demand is high, and energy expenditures- often above €3,000 per year- are common due to reliance on fuel oil.

The families living in these homes represent the primary end-users of the pilot. Households typically consist of two adults and two or three children, with average annual incomes above €50,000. Across the planned pilot homes, roughly 200 residents were expected to participate, although it was anticipated that around 50 would engage directly with the FORTESIE mobile application.

Renovations that were implemented

From the approximately 200 renovation projects conducted annually by Oktave, 50 properties were identified as suitable candidates for integration into FORTESIE. All 50 dwellings received FORTESIE-funded monitoring equipment, enabling detailed data collection covering indoor temperature, humidity, energy consumption, and overall comfort. Within this group, 12 houses were selected to benefit from supplementary FORTESIE funding for specific renovation measures. These include:

- building-envelope improvements (enhanced insulation for roofs, walls or floors).
- replacement of old windows with high-performance glazing.
- installation of modern ventilation systems.
- replacement of oil boilers with efficient heat pumps for space heating and domestic hot water.
- targeted interventions addressing moisture, drafts, or poor indoor air quality.

Before the renovations, detailed energy audits were conducted for each home. These audits included blower-door tests, architectural measurements, energy-bill analysis, "LINKY[18]" smart-meter data, and assessments of expected consumption in kWh/m², accompanied by CO_2 estimates across six categories: heating, cooling, domestic hot water, auxiliary systems, lighting, and appliances. This baseline provides the foundation for evaluating the improved performance of homes after renovation and feeding validated data into FORTESIE's digital infrastructure.

Challenges from field implementation

Implementation of the French sub-pilot highlighted several operational, technical, and behavioural challenges relevant to large-scale data-driven renovation programmes.

1. **Extensive homeowner engagement requirements:** Because France already operates a highly funded national renovation framework, the FORTESIE budget was refocused towards financing monitoring equipment rather than renovation works. This required extensive outreach to a large cohort of homeowners. Contacting households individually and explaining the objectives and requirements of the project proved labour-intensive and time-sensitive. Households undergoing renovation were often preoccupied with construction decisions and coordination with contractors, leading to low engagement. A key lesson is that post-renovation outreach- after the stress of construction- may yield higher participation rates.

2. **Technical integration challenges**, especially with regards to Application Programming Interface (API), sensors, and Long-Range Wide Area Network (LoRaWAN)**:** Technical difficulties emerged early in the deployment process. The development of the "LINKY" API, essential for retrieving consumption data from French smart meters, experienced delays. Additional challenges arose from integrating monitoring sensors into the LORAWAN radio network. The pilot's sensor provider, "MESH", launched a new commercial product line during the pilot, requiring additional testing and adjustments to ensure network compatibility. This experience underscores the need for early coordination with technology providers, robust pre-deployment testing, and careful planning when homeowners are expected to self-install equipment.

3. **Recruitment** and **behavioural barriers:** Initial recruitment efforts revealed behavioural obstacles to voluntary participation. Even with an initial target list of 60 households, only 20 expressed interests in the first phase. This points to the need for well-designed communication materials that clearly articulate the benefits of participation. It also suggests that former

[18] "Linky" refers to a nationwide smart electricity meter deployment by the grid operator "Enedis".

renovation clients, who have already experienced the process and are curious about its impact, may be more receptive than homeowners currently involved in construction works. Multiple engagement channels, like emails, calls, information sessions, or webinars, may improve uptake.

4. **Logistical complexity** and **timing constraints:** Coordinating hardware delivery, explaining installation steps, and ensuring that monitoring devices were installed correctly created logistical challenges, especially when households were geographically dispersed or had limited availability. This highlights the value of providing extremely simple installation procedures, remote troubleshooting options, and possibly technical assistance for homes that require additional support.

These challenges have generated actionable insights that feed directly into the FORTESIE policy recommendations and methodological guidelines.

Key transferable lessons

Building on the operational, technical, and behavioural challenges observed during implementation, the following transferable lessons are formulated as **recommended solutions** or **practical mitigation strategies** to support the design and rollout of large-scale monitoring initiatives and renovation programmes targeting private homeowners.

I. Homeowner engagement strategies should be deliberately aligned with the **post-renovation phase**, when construction-related stress and cognitive overload have subsided. Contacting households after renovation completion increases receptiveness, improves response rates, and enables more meaningful engagement with monitoring and feedback tools.

II. Digital monitoring deployments must be preceded by early coordination with technology providers and **comprehensive pre-deployment testing** of **APIs**, **sensors**, and **communication networks**. This is particularly critical in contexts where data flows depend on third-party systems (e.g., national smart-meter APIs) and where households are expected to self-install equipment.

III. Recruitment efforts benefit significantly from clear, value-oriented communication materials that explain participation benefits in concrete terms, e.g., comfort, insights into energy savings, improved control. These materials should be complemented by **diversified engagement channels**, such as follow-up calls, webinars, and targeted information sessions, to accommodate different homeowner preferences.

IV. Former renovation clients constitute a strategically important target group for monitoring initiatives, as they are more likely to be curious about renovation outcomes and less constrained by ongoing construction decisions. Prioritising this group can improve **participation rates** and **data reliability** in voluntary monitoring schemes.

V. Monitoring solutions deployed in geographically dispersed private homes should prioritise extreme simplicity of installation, combined with **robust remote-support mechanisms**. Clear step-by-step guidance, minimal hardware requirements, and accessible troubleshooting channels are essential to ensure correct installation and sustained data collection without intensive on-site intervention.

4.1.2.3. Pilot 2c: Urban Residential District in Valladolid, Spain

Short description

Another Spanish sub-pilot, led by Veolia, is located in the FASA district of Valladolid (Spain), a large 1950s-1960s residential neighbourhood consisting of 20 residential blocks, a 14-storey tower building, a district heating plant, and a range of shared open spaces and community facilities. The district covers approximately 29,000 m², of which around 36,500 m² constitute built area and 24,700 m² are conditioned residential spaces. In total, the district comprises 398 dwellings and hosts between 720 and 750 residents, most of whom are above 65 years of age.

In 2018, the district underwent an extensive retrofit under the EC-funded Horizon 2020 project "REMOURBAN[19]". This included the installation of biomass boilers supported by a gas backup unit, the development of a new district heating network with 20 substations, the deployment of energy management systems at district, building, and dwelling levels, and significant envelope upgrades involving roof and façade insulation.

Common areas were also equipped with light-emitting diode (LED) lighting, and the broader urban infrastructure received improvements, including the installation of PV systems. One residential block remained unrenovated, preserving pre-retrofit conditions, and creating a unique opportunity for comparison with the renovated buildings.

Renovations that were implemented

Within FORTESIE, no new physical renovations were carried out. Instead, the pilot focused on assessing the performance and effectiveness of the interventions that took place during the "REMOURBAN" project, through enhanced digital monitoring and occupant engagement.

Existing monitoring infrastructure provided a strong foundation for this analysis. Approximately 845 sensors installed during the 2018 retrofit have been collecting operational data for more than a year and a half, tracking variables such as heating circuit temperatures, flow rates, pressures, solar radiation, boiler performance, gas consumption, and district heating energy demand. All data streams are processed through VEOLIA's "Hubgrade[20]" remote management system.

To complement the existing dataset, new indoor environmental sensors measuring temperature, humidity, and CO_2 were deployed in the non-renovated building and are now being installed in one of the renovated blocks. These devices were distributed directly to residents, encouraging convenient and decentralised participation. This allows the project to compare pre- and post-retrofit conditions under similar climatic and occupancy profiles.

Given the district's demographic profile, the pilot also incorporates a strong behavioural and engagement component. The FORTESIE application is being introduced to enhance awareness of energy use and promote behavioural change, although participation depends heavily on the effectiveness of the ongoing engagement activities.

Challenges from field implementation

Implementation in the FASA district provided valuable insights for large-scale monitoring initiatives and resident-focused engagement approaches.

1. **Resident cooperation** and **trust-building:** Initial reluctance to accept sensor installation, driven by privacy concerns and unfamiliarity with monitoring devices, highlighted the importance of transparent communication, clear explanations of data use, and reassurance regarding non-intrusiveness.

[19] https://cordis.europa.eu/project/id/646511.

[20] https://www.veolia.com/en/solutions/hubgrade-digital-solutions-ecological-transformation-cities-and-industries.

2. **Demographic-specific communication needs:** With the majority of residents being older adults, engagement required simplified explanations, patient guidance, and repeated support. Tailored communication significantly improved understanding and willingness to participate.

3. **Logistical complexity** of **accessing dwellings:** Coordinating installation schedules across multi-residential buildings proved challenging. VEOLIA mitigated this by delivering sensors directly to residents and providing instruction for correct placement, demonstrating the value of flexible installation methods.

4. **Integrating new sensors** with **existing digital systems:** Adding new devices to an already extensive monitoring network required careful interoperability checks and alignment with the "Hubgrade's" data-processing workflows. Early testing and close cooperation with technology providers were essential.

5. Need to **broaden engagement:** Engagement depended heavily on tailored communication and patient, repeated support, given the district's predominantly elderly population. Ensuring participation required clear explanations and trust-building, and simplified installation procedures rather than expanding recruitment beyond the pilot site.

Key transferable lessons

Building on the implementation challenges observed in the FASA district, the following transferable lessons are formulated as **recommended solutions** or **practical mitigation strategies** for the deployment of digitally enabled monitoring and engagement solutions in large, previously renovated residential districts.

I. Trust-building and acceptance of indoor monitoring technologies require early, transparent, and **personalised communication**, particularly in districts with established communities. Clear explanations of data usage, privacy safeguards, and **non-intrusive installation methods** should be provided well in advance of deployment to reduce hesitation and resistance.

II. Engagement strategies must be explicitly adapted to **demographic characteristics**, especially in neighbourhoods with a high proportion of elderly residents. Simplified explanations, patient follow-ups, and repeated clarification significantly improve understanding, confidence, and willingness to participate in digital initiatives.

III. Monitoring deployment in multi-residential buildings benefit from **flexible installation models**, including **resident-led placement** supported by clear instructions and remote guidance. This approach reduces logistical complexity, minimises disruption, and increases participation without requiring intensive on-site coordination.

IV. When introducing new monitoring devices into districts with existing digital infrastructures, **early interoperability testing** and close coordination with platform operators are essential. Ensuring compatibility with legacy systems avoids data gaps, integration failures, and delays in analytical workflows

V. Sustained participation in digitally enabled pilots depends more on depth of engagement within the existing community than on expanding recruitment beyond the pilot boundaries. **Continuous reassurance**, **simplified procedures**, and **visible responsiveness** to residents' concerns are more effective than broadening the geographical scope of participation.

4.1.3. Pilot 3: Green, Comfortable, and Sustainable Homes in Portugal

Short description

The Portuguese pilot, coordinated by Just a Change, focuses on rehabilitating homes for households facing severe housing deprivation and chronic energy poverty. Many of these dwellings are in poor condition, failing to meet even the most basic standards of safety, comfort, or health. Structural deterioration is widespread, with common issues including damaged roofs, moisture infiltration, unstable flooring, and degraded walls. Renovations therefore prioritised restoring essential structural elements, such as roofs, floors, windows, insulation, and doors, alongside ensuring access to fundamental services such as running water, electricity, and adequate lighting.

Just a Change operates in both metropolitan and rural areas, each presenting distinct vulnerabilities. Large cities such as Lisbon and Porto face soaring housing costs, growing social exclusion, and high unemployment, while rural regions suffer from depopulation and isolation. Many elderly residents in these areas live alone on very low pensions and lack formal or informal support networks, making housing conditions a direct determinant of well-being.

The homes selected for the pilot are typically more than 50 years old and built using traditional construction techniques, such as masonry walls, wooden floors, and tiled roofs. These buildings often exhibit significant problems: water infiltration, mould, deteriorated flooring, insufficient insulation, and poor ventilation. House sizes are modest, generally below 100 m^2, with one-storey houses in urban areas and one two-storey home in rural settings. The beneficiaries are usually elderly individuals living alone in dwellings that do not protect them from cold, humidity, or rainfall. Many lack piped water or sufficient lighting, and their homes frequently fail to offer a safe or comfortable environment. 16 beneficiaries in total participated in the FORTESIE pilot.

Renovations that were implemented

At the outset of the pilot, detailed information on existing energy systems and consumption patterns was unavailable, as house selection had been finalised only recently. To establish a reliable baseline, Just a Change conducted on-site assessments using portable sensors to measure indoor temperature, humidity, and other environmental parameters, in cases where data were available. This approach was necessary because most homes lacked internet access or the technical infrastructure required to support fixed monitoring equipment. Pre- and post-intervention interviews with residents were also conducted to evaluate improvements in comfort, health, and daily living conditions.

The pilot aimed to renovate ten houses across a wide geographic spread, encompassing both urban and rural locations. Renovation works have now been completed in Porto, Viana do Castelo, Murça, Golegã, Alvaiázere, Odemira, Tomar, Famalicão, Vila Pouca de Aguiar, and Lagoa. All renovations and solar panel installations are fully finalised.

Renovation activities were carried out by volunteer teams coordinated by Just a Change. Each team was led by an experienced volunteer and supervised by a professional master builder to ensure operational quality and compliance with safety standards. Work typically involved repairing or replacing roofs, floors, and windows, strengthening structural elements, installing insulation where feasible, updating electrical and water systems, and addressing moisture and air-quality issues.

For digital monitoring, MESH sensors were deployed across all renovated homes as planned. A different type of sensor was installed in the Porto dwelling, and it is successfully transmitting data to the FORTESIE platform. However, the deployment and ongoing operation of the MESH sensors have been challenging. Beneficiaries' limited digital skills and the significant distance between buildings hindered troubleshooting and follow-up visits. Many residents were unable to maintain or reset devices, resulting in interruptions to data transmission, and reducing the volume of data available for performance analysis.

Challenges from field implementation

Implementation of the pilot revealed a wide range of operational, technical, and social challenges, shaped by the vulnerabilities of the target population and the geographical dispersion of the selected homes. The complexity of working with elderly beneficiaries- with limited digital and technical literacy- living in remote areas, combined with resource limitations, supply-chain delays, and technical obstacles, affected both renovations and digital data collection. These experiences provide valuable insights for future replication of renovation programmes addressing energy poverty in dispersed territories.

1. **Operational** and **geographical challenges:** Geographical dispersion proved to be one of the most significant constraints. With homes located far from operational hubs, the frequency of on-site visits was limited, reducing the team's ability to monitor renovations, support beneficiaries, and troubleshoot sensor issues. Many homes required <u>extensive restoration</u> due to severe deterioration, and the <u>uncovering</u> of additional <u>structural problems</u> mid-construction required extra materials, labour, and time.

2. **Administrative** and **social engagement challenges:** Collecting essential baseline information (e.g., electricity bills, documentation, consumption data) was hindered by beneficiaries' low digital and administrative literacy. Many elderly occupants relied exclusively on paper-based documents, which required in-person visits and coordination with utility providers. <u>Social vulnerabilities</u>, such as living alone, limited support networks, and low technological familiarity, also complicated communication, prolonged interactions, and increased the need for personalised support.

3. **Technical** and **monitoring challenges:** Several technical obstacles impeded the deployment and operation of monitoring equipment. Sensor delivery delays, late identification of connectivity issues, lack of mobile network coverage, and the need for additional gateways, SIM cards, and routers created complexity and additional costs. The <u>limited technical capacity</u> of both beneficiaries and the renovation team led to accidental tampering with devices and reduced ability to maintain or reset equipment remotely. These challenges resulted in interruptions in data transmission and constrained the volume of data available for pre- and post-renovation analyses.

4. **Sectoral** and **supply-chain challenges:** The pilot was affected by Portugal's broader shortage of skilled labour, which created <u>delays</u> and required <u>renewed recruitment efforts</u>. Supply-chain issues further disrupted timelines, particularly for critical elements such as windows and doors. These delays affected sequencing, slowed progress on several sites, and required adjustments to renovation schedules. Additionally, changes in partner availability forced the team to reorganise plans for renewable energy integration and energy certification, including launching new procurement processes.

Key transferable lessons

Building on the challenges encountered during implementation, Pilot 3 offers a set of transferable lessons that function as **recommended solutions** or **practical mitigation strategies** for renovation programmes targeting vulnerable households in dispersed and resource-constrained contexts.

I. Renovation programmes in **geographically dispersed areas** should integrate **decentralised operational models**, including partnerships with local actors, regional coordinators, or community organisations, to reduce reliance on **frequent long-distance site visits** and to ensure continuous local presence for oversight and troubleshooting.

II. Low digital and administrative literacy among vulnerable beneficiaries requires the design of **analogue-compatible processes** alongside digital tools. **Paper-based documentation pathways**, direct liaison with utility providers, and face-to-face support should be treated as core components of programme design rather than exceptional measures.

III. Digital monitoring in energy-poor households must be preceded by early technical feasibility assessments, including checks on mobile coverage, power availability, and connectivity requirements. Where permanent connectivity is uncertain, **portable** or **low-maintenance monitoring solutions** and **simplified data-collection protocols** should be prioritised.

IV. Renovation planning for severely degraded buildings should include **enhanced technical diagnostics** and **contingency allowances**, recognising that hidden structural issues are likely to emerge once works begin. This reduces delays, avoids repeated re-scoping, and increases resilience to unforeseen construction challenges.

V. Supply-chain risks and labour shortages can be mitigated through **diversified sourcing strategies**, **early procurement** of **critical components**, and **flexible sequencing** of renovations to progress despite delays in specific materials or trades.

VI. Financial frameworks supporting renovations for vulnerable households should incorporate **explicit contingency reserves** and **adaptive budgeting mechanisms**, enabling programmes to absorb cost escalations without compromising the scope or quality of essential interventions.

VII. Reliance on single partners for specialised services (e.g., renewable energy installations or certification) should be avoided. **Redundant partnerships** and **alternative procurement pathways** increase programme robustness and reduce the risk of disruption when partner availability changes.

4.1.4. Pilot 4: Green and Comfortable Households Through Prosumer Engagement in Portugal

Short description

Pilot 4 focuses on renovating ten single-family homes owned by prosumer members of the renewable energy cooperative Coopérnico. These households belong to an engaged community of citizens who both produce and consume renewable electricity. Coopérnico leads the pilot, supported by Just a Change, which identifies suitable homes, defines renovation scopes, and coordinates with local contractors.

The selected dwellings are located across Portugal- from Lisbon and Porto to rural regions. Most homes are more than 15 years old and have never undergone major energy-efficiency upgrades. Typical construction types include reinforced concrete structures with masonry brick or stone walls. Two newer homes (2007 and 2019) were included due to their still insufficient performance. Renovations focused on improving thermal comfort, energy performance, and indoor environmental quality.

Renovations that were implemented

Following the selection of the ten houses, Coopérnico presented each homeowner with the renovation measures developed jointly with Just a Change. The interventions focused primarily on improvements to the building envelope: insulation of external walls and the roof or attic, replacement of inefficient windows and doors, and upgrades to enchance thermal performance and durability.

A procurement process was launched to obtain quotations from local construction companies and material suppliers. This phase took longer than expected, as quotations arrived progressively and required careful consolidation. Once the budgets were finalised, Coopérnico discussed the financial feasibility of each improvement measure with homeowners.

Several Coopérnico members opted to co-finance additional upgrades beyond the €10,000 allocated per household, particularly regarding ecological attic insulation. Five households purchased materials themselves and performed part of the installation voluntarily. This strong homeowner involvement expanded the scale of renovation measures and reflected the high commitment within the cooperative community.

Formal contracts between Coopérnico, Just a Change, and each homeowner marked the beginning of renovations. All major interventions have now been completed.

To support the assessment of renovation impacts, MESH environmental sensors were installed across all participating homes. Coopérnico and MESH held an online meeting with the homeowners to explain installation procedures and monitoring expectations. In two houses with central heating systems, additional controllers and gateways were installed to enrich the data profile. Coopérnico also installed one sensor in its office to better supervise network performance and monitor data transmission in real time.

Several technical issues arose during deployment: some sensors demonstrated shorter-than-expected battery life, LORAWAN network coverage proved unreliable in specific regions, and two households required sensor replacements. To address this, MESH provided additional gateway devices to stabilise communication. After these adjustments, monitoring became more consistent and aligned with the FORTESIE's measurement and verification needs.

Challenges from field implementation

Implementation of Pilot 4 provided valuable insights into the operational, behavioural, and technical complexities of conducting household renovations within a prosumer cooperative.

1. **High levels** of **beneficiary engagement:** Homeowners were highly motivated, frequently requesting additional upgrades and actively co-financing improvements. While this engagement strengthened outcomes, it required Coopérnico to maintain near-continuous communication, provide detailed technical explanations, and mediate expectations to fit within available budgets. This level of involvement significantly increased the organisational efforts required to maintain alignment and decision clarity.

2. **Procurement delays** due to **trust** and **coordination challenges** with **construction companies:** Contractors were often cautious when approached by clients with whom they had no prior working relationship. This hesitation affected the speed and responsiveness of budget preparation

and technical clarifications, delaying the consolidation of renovation plans. To mitigate this, Coopérnico developed technical specification documents to support clearer communication between homeowners and suppliers. However, the experience demonstrated that building confidence with service providers early in the process is essential to avoid disruptions in procurement workflows.

3. **Technical difficulties** with **sensor deployment** and **connectivity:** The installation of MESH sensors was hindered by unstable LORAWAN network coverage, unexpected device malfunctions, and shorter-than-expected battery life. Corrective actions, including the installation of gateway devices and replacement of faulty sensors, required additional support and coordination. These issues highlighted the need for early digital infrastructure assessment and adaptable measurement and verification planning.

4. **Varied digital literacy affecting correct sensor installation** and **maintenance:** Although an online training session was provided to support participants during the installation process, the operation and maintenance of the monitoring equipment still required periodic follow-up. Coopérnico had to provide repeated guidance and remote troubleshooting to stabilise data transmission. This experience demonstrates that even highly engaged prosumers may need tailored support when interacting with new digital tools to ensure data transmission and reliability.

Key transferable lessons

Building on the challenges encountered during implementation, Pilot 4 offers a set of key transferable lessons that function as **recommended solutions** or **practical mitigation strategies** for renovation programmes targeting prosumer households and citizen-led energy communities. Rather than repeating operational difficulties, these lessons translate the pilot experience into actionable guidance for designing, coordinating, and scaling cooperative-based renovation initiatives in a more robust and efficient manner.

I. High levels of beneficiary engagement can be harnessed more effectively by structuring decision-making through clear renovation packages, predefined upgrade options, and staged opt-in points. This approach preserves **homeowner motivation** while preventing scope creep, reducing coordination burdens, and maintaining budgetary control.

II. Balancing **fixed renovation budgets** with homeowners' aspirations can be facilitated by formally anticipating **voluntary co-financing**. Defining clear rules, templates, and contractual arrangements for additional investments allows programmes to expand renovation depth without creating uncertainty, delays, or inequities among participants.

III. Procurement delays linked to contractor hesitation can be mitigated through **early trust-building measures**, including advance market engagement, standardised technical specifications, and transparent contracting frameworks. These actions increase contractor confidence, improve responsiveness, and **stabilise procurement timelines**.

IV. Providing **accessible**, **non-technical guidance materials**, such as concise specification documents, checklists, and visual explanations, helps beneficiaries navigate procurement processes, understand technical requirements, and make informed decisions, reducing misunderstandings and implementation errors.

V. Monitoring technologies should be deployed only after **early assessment** of digital infrastructure readiness, including network coverage and device interoperability. **Pilot testing** and **staged rollouts** reduce the risk of data gaps, equipment replacement, and late corrective actions.

VI. Differences in **digital literacy** can be addressed by designing monitoring systems that combine simple installation procedures with repeated guidance, remote support, and clear troubleshooting pathways. Even highly engaged prosumers benefit from layered support mechanisms that stabilise data collection over time.

VII. Continuous, transparent communication across all project phases remains a **central mitigation strategy**. Regular updates, clear explanations of constraints and choices, and responsive feedback loops reinforce trust, maintain alignment among stakeholders, and support smooth implementation in cooperative renovation models.

4.1.5. Pilot 5: Green and Comfortable Working Environments in Greece

Short description

Pilot 5 is located at the headquarters of the "General Secretariat of Information Systems for Public Administration" of the Greek Ministry of Digital Governance in Athens. The building complex, originally constructed in the 1960s for industrial use and converted into offices in the late 1990s, consists of two basements and five above-ground floors with a total area of approximately 30,000 m². It accommodates roughly 930 daily users and includes diverse functional spaces such as 168 offices, meeting rooms, a canteen, a computer lab, an amphitheatre, a fitness area, and several technical rooms. The structure is reinforced concrete with internal gypsum partitions and ceiling panels, and it underwent roof waterproofing in 2015.

With an average workforce age of 55-60, staff expressed concerns regarding indoor environmental quality-specifically temperature, humidity, lighting, CO_2 levels, and overall air quality. While both employees and the building owner were informed about the FORTESIE mobile application, user participation levels were uncertain. The renovation packages deployed in this pilot focused on improving energy management, enhancing HVAC efficiency, and integrating renewable energy generation.

Renovations that were implemented

Renovations have been fully completed, involving the installation of an extensive suite of monitoring, control, and optimisation technologies. A total of 103 energy meters were installed across lighting circuits and motion-controlled electrical panels to capture granular consumption data. Additionally, 23 variable-frequency drives were added to regulate fan speeds in HVAC units, supporting more efficient system operation.

To address indoor environmental quality, 194 air-quality sensors were deployed throughout office areas to continuously monitor CO_2 levels and enable automated ventilation adjustments. A central component of the renovation was the deployment of an advanced energy management platform capable of supervising and controlling all connected systems, analysing operational conditions, and enabling predictive optimisation of building performance.

Finally, an 85-kW rooftop PV installation was completed to increase on-site renewable energy generation and reduce grid dependency. Together, these measures form a comprehensive renovation service demonstrating how integrated smart technologies can significantly improve energy performance in large public buildings.

Challenges from field implementation

Implementation revealed several operational and administrative challenges that shaped the project timeline and highlighted important considerations for large-scale public-sector renovations.

1. **Material procurement challenges disrupted** the **workflow** and **sequencing** of **activities:** Although delays were relatively short, the size and complexity of the installations meant that even minor postponements had cascading effects on subsequent tasks. Procuring large volumes of specialised equipment required coordination with suppliers capable of handling high-demand orders, and the experience demonstrated the need for renovation teams to anticipate such delays and incorporate adequate time buffers into project planning.

2. **Bureaucratic permitting procedures**- particularly for the photovoltaic systems- **introduced substantial delays:** While the PV installation was completed on schedule, the connection to the national grid remained pending due to slow and highly procedural administrative steps. Coordinating with multiple government bodies proved challenging, with many actions falling outside the direct control of the technical partners. This highlighted the importance of initiating permit-related processes as early as possible- ideally in parallel with technical work- to prevent long periods of inactivity after installation is complete.

3. **Coordination** with **government agencies required persistent follow-up** and **communication:** Navigating public-sector administrative structures demanded sustained engagement to prevent stagnation and ensure progress. Even with proactive management, several stages of the permitting process remained inherently slow, demonstrating that technical teams must plan for regulatory unpredictability when undertaking energy upgrades in large public buildings.

Despite these challenges, the pilot successfully demonstrated the value of **integrated smart-building renovation packages** and provided essential insights for future upgrades in similar **public-sector facilities**.

Key transferable lessons

Building on the challenges encountered during implementation, Pilot 5 provides a set of key transferable lessons that operate as **recommended solutions** or **practical mitigation strategies** for future smart-renovation projects in large public-sector office buildings. These lessons translate administrative and operational constraints into actionable guidance for improving planning, coordination, and delivery of complex, technology-intensive renovations.

I. Procurement risks in large public buildings can be mitigated by **embedding explicit time buffers** and alternative sequencing options into renovation schedules, recognising that even short delivery delays may propagate across multiple dependent installation tasks.

II. Permitting and regulatory bottlenecks- particularly for renewable energy systems- should be addressed through the very early initiation of **administrative procedures**, ideally before on-site renovations begin, and by assigning clear responsibility for continuous follow-up with relevant authorities.

III. Running **technical** and **administrative workflows** in parallel significantly reduces the risk of post-installation inactivity, ensuring that completed systems can become operational without prolonged delays caused by unresolved permits or approvals.

IV. Effective coordination with government agencies requires structured, ongoing communication mechanisms rather than **ad hoc interactions**. Regular check-ins, documented exchanges, and clear escalation paths help maintain momentum even when processes are slow or fragmented.

V. Selecting suppliers with demonstrated experience in large-scale, **complex public-building projects** reduces exposure to material shortages, delivery uncertainty, and coordination failures, thereby strengthening overall project resilience.

4.1.6. Pilot 6: Comfortable and Sustainable Public Pool in Poland

Short description

Pilot 6 focuses on the renovation of a public swimming pool complex located in the town centre of Góra Kalwaria, in the Masovian Voivodship of Poland. Constructed in 1999 based on a mid-1980s architectural design, the facility is a major local amenity, employing around 20 people and receiving approximately 110,000 visitors each year. The building is situated in a residential urban district surrounded primarily by single-family homes and has a structural composition of concrete, glass, and timber. The main pool hall is covered by a single-pitched roof formed by galvanised trapezoidal metal sheeting mounted on glued-laminated timber girders, while other areas rely on reinforced concrete or steel trusses. Insulation levels vary significantly across the envelope, reflecting partial upgrades carried out during earlier thermal modernisation.

The total facility exceeds 5,200 m², with the swimming pool portion- where the FORTESIE interventions focus on- covering more than 4,050 m². This area includes a sports pool, recreational pool attractions, a restaurant, gym, and several commercial rental units. Technical areas on the lower-level house essential machinery, including ventilation rooms, the heating substation, water-treatment filtration systems, pumping equipment, and other mechanical infrastructure supporting the pool's operation.

A detailed technical assessment prior to renovation identified several critical shortcomings. The ventilation system was unable to maintain appropriate humidity levels in the recreational pool hall, resulting in frequent periods of 80-90% relative humidity; conditions that pose serious risks to structural timber elements and accelerate material degradation. Insufficient warm-air protection around glazed surfaces led to condensation issues, and the slide tower area lacked meaningful humidity control. One of the air handling units, affected by pressure losses due to an undersized bypass and exchanger deterioration, could not maintain adequate supply airflow, especially when increasing the intake of fresh outdoor air. Measurements also revealed significant air infiltration of around 1,900 m³/h and an overall lack of moisture-management capacity. Collectively, the findings showed that comprehensive modernisation, and not incremental repairs, was necessary to restore safe, efficient, and resilient pool operations.

Renovations that were implemented

The FORTESIE renovation packages introduced a large-scale modernisation of the facility's mechanical, electrical, and energy systems. Central to the intervention was the full refurbishment or replacement of the two key air-handling units serving the sports (N1/W1) and the recreational (N2/W2) pool areas. These upgrades were complemented by new ventilation ducts, pump sets, and electrical switchboards to ensure reliable delivery of conditioned air and improved control of humidity and temperature in critical zones.

The heating system underwent a comprehensive upgrade through the installation of a new multifunctional substation equipped with a control cabinet and domestic hot-water buffer tank. Heat submeters were also installed and integrated into the building's data-exchange architecture, enabling improved performance monitoring and energy accounting. Electrical upgrades included the installation of a new switchgear, signal and control wiring, grounding systems, and equipotential bonding to enhance electrical safety and ensure compatibility with the upgraded mechanical systems.

To support energy optimisation and contribute to the building's sustainability goals, a rooftop PV installation was mounted, increasing the availability of on-site renewable electricity. In addition, digital sensors were deployed to support continuous monitoring of environmental and operational parameters, feeding into data-driven analysis and performance verification. Together, these interventions constituted a holistic renovation strategy aimed at modernising a highly specialised facility while improving indoor environmental quality, reducing operational energy demand, and increasing the building's long-term resilience.

Challenges from field implementation

Implementation of the pilot revealed a range of administrative, financial, and operational challenges that significantly influenced project progression and highlighted key considerations for future renovation initiatives in complex public buildings.

1. **Administrative** and **bureaucratic delays** extended approval **timelines** and **hindered decision-making:** Because the project took place within a public-sector institutional context, all major decisions required navigating lengthy governmental procedures, council voting cycles, and formal documentation protocols. These processes slowed approvals, created uncertainty, and compounded delays associated with funding decisions. The experience underscored the necessity of <u>anticipating extended administrative timelines</u>, engaging experts familiar with public-sector processes early, and embedding procedural flexibility into project planning.

2. **Tendering** and **contractor selection proved more complex than anticipated** due to the pilot's **specialised nature:** Identifying a contractor with the appropriate qualifications, experience, and capacity to undertake the implemented renovations was challenging. Initial eligibility requirements inadvertently restricted the pool of potential bidders, leading to limited responses and necessitating adjustments to procurement conditions. The need to refine tender criteria, broaden contractor eligibility, and account for the high level of technical complexity highlighted the importance of <u>accurate project scoping</u>, as well as consultation with institutions that operate similar facilities.

3. **Financial pressures** and **cost increases created strain** on the project's **budget:** Inflation, rising material and equipment prices, and unforeseen logistical expenses introduced significant financial challenges. These factors exposed gaps in the original cost estimates and constrained the flexibility of the renovation plan. The experience demonstrated the need for detailed cost forecasting, inflation-resilient budgeting, and <u>dedicated contingency reserves</u>- particularly in specialised buildings with high material and labour requirements. Awareness of <u>public budgeting cycles</u> and their <u>procedural constraints</u> also proved essential for navigating financial approvals.

4. **Stakeholder** and **community engagement** required **sustained communication** and **trust building:** Engaging pool users and the local community- particularly through surveys and

information activities- proved valuable for understanding user needs and sustaining support during renovation planning. Given that renovations required temporary closure of the pool, maintaining open communication helped preserve trust and manage expectations. The positive engagement experience demonstrated the importance of involving users early and ensuring their perspectives inform renovation decisions.

5. **Timing** the **temporary facility closure** posed **significant operational planning challenges:** Renovation activities required shutting down the pool for a limited period, but determining the optimal timing was complicated by seasonal variations in pool use and construction efficiency. Closing too early or too late risked reducing user engagement or exposing the building to weather-related inefficiencies. Coordinating construction schedules to minimise disruption while ensuring favourable conditions for technical works proved essential to achieving a balanced implementation timeline.

Key transferable lessons

Building on the challenges encountered during implementation, Pilot 6 provides a set of transferable lessons that function as **recommended solutions** or **practical mitigation strategies** for future renovation initiatives in large, technically complex public facilities such as swimming pools and leisure infrastructures.

I. Lengthy administrative and approval procedures should be anticipated as a structural characteristic of public-sector projects and addressed through early **initiation of all formal processes**, realistic timeline planning, and continuous coordination with institutional decision-makers.

II. Procurement risks in specialised facilities can be reduced by improving upfront project scoping, consulting operators of comparable infrastructures, and designing tender criteria that balance technical rigor with sufficient flexibility to attract a **broader pool** of **qualified contractors**.

III. Financial uncertainty linked to inflation, material volatility, and logistical complexity requires robust cost forecasting, **dedicated contingency reserves**, and a clear understanding of public budgeting cycles to prevent implementation delays or scope reductions.

IV. Sustained and transparent communication with users and local communities **mitigates resistance** to **disruption**, strengthens trust, and ensures that renovation decisions reflect **actual operational** and **comfort needs**, particularly when temporary facility closures are required.

V. Renovation scheduling should strategically align technical requirements with **seasonal conditions** and **user behaviour patterns**, allowing closures to be planned in a way that minimises disruption while maximising construction efficiency and long-term operational benefits.

4.1.7. Pilot 7: Comfortable, Inclusive, and Sustainable Green School in Latvia

Short description

Pilot 7 was implemented in the "9th Secondary School of Riga", Latvia, a public educational building constructed in 1972 and located in the Vidzeme suburb, an area characterised by medium-density urban development. While the school underwent a comprehensive envelope renovation in 2022- including façade, roof, and foundation insulation, as well as replacement of windows and external doors- indoor environmental quality, and particularly ventilation performance, remained a critical concern.

This challenge reflects a well-documented national issue. Recent studies by the Latvian Health Inspectorate indicate that approximately 27% of classrooms nationwide suffer from insufficient ventilation, leading to elevated CO_2 concentrations and inadequate air exchange rates. These conditions are directly linked to reduced cognitive performance, discomfort, and negative impacts on pupils' health and well-being. Despite the scale and urgency of the problem, schools in Latvia continue to face limited dedicated financial support for ventilation upgrades, as well as bureaucratic and procedural barriers that slow down implementation.

The school comprises four floors with a total area of 5,258 m² and includes 37 classrooms, typically between 50 and 70 m². The school hosts approximately 315 pupils aged 7-18, supported by 38 teachers and 23 technical staff. Occupancy patterns vary significantly throughout the day and across the academic year, making stable indoor air quality and thermal comfort essential for effective learning and teaching conditions. The building is connected to Riga's district heating network, operated by AS "Rīgas Siltums", which provides thermal energy for space heating. This centralised supply forms the foundation of the building's thermal systems and dictated the technical approach to the FORTESIE interventions.

Renovations that were implemented

The FORTESIE renovation package focused on addressing indoor environmental quality through targeted system-level optimisation rather than structural alterations. The core intervention involved the installation of an innovative heating adjustment and control system, enabling more precise thermal regulation across classrooms and common areas. This system introduced new controllers, thermostatic elements, and hydraulic balancing components, aligning heat supply with actual occupancy and comfort requirements.

In parallel, the pilot implemented a novel approach to improving ventilation performance- introducing innovative control and monitoring technologies that had not previously been deployed in Latvian schools. A distributed network of digital sensors measuring temperature, humidity, and CO_2 levels was installed in representative classrooms and shared spaces. These sensors feed into an integrated control architecture that enables continuous monitoring and data-driven optimisation of indoor air quality.

Crucially, the deployed solution demonstrated that modern, modular technologies can be implemented within existing regulatory and funding frameworks, even in the absence of large-scale, dedicated ventilation investment programmes. By simplifying installation, minimising structural intervention, and relying on real-time performance data, the pilot enabled the school to improve ventilation effectiveness, while navigating existing administrative constraints.

Challenges from field implementation

Implementation of Pilot 7 highlighted several administrative, social, and technical challenges that are representative of public educational buildings in Latvia and beyond.

1. **Systemic underinvestment** and **bureaucratic constraints for ventilation upgrades:** Although insufficient ventilation in schools is widely recognised at national level, the pilot confirmed that schools face significant barriers when attempting to address this issue. Dedicated financial

instruments for ventilation system upgrades are limited, and approval procedures remain lengthy and complex. These constraints often discourage schools from pursuing comprehensive solutions, even when health impacts are well established.

2. **Public-sector procurement** and **administrative delays:** The pilot relied on public procurement procedures involving multiple review stages and formal approvals. These processes extended lead times and delayed the start of technical implementation, demonstrating the importance of early administrative preparation and realistic scheduling when introducing innovative technologies in public schools.

3. **Limited availability** of **school staff** for **engagement activities:** Teachers' demanding schedules and institutional responsibilities constrained participation in engagement and awareness-raising activities. This limited opportunities for interactive feedback and underlined the need for engagement approaches that respect educational routines and minimise additional workload for staff.

4. **Technological novelty** and **first-time deployment risks:** Some ventilation-related components were produced and deployed for the first time in a school context in Latvia. This resulted in additional coordination needs with suppliers and extended production timelines. While ultimately successful, the experience highlighted the importance of close supplier collaboration and risk buffering when introducing innovative solutions in conservative public-sector environments.

Key transferable lessons

Building on the challenges encountered during implementation, Pilot 7 offers a set of transferable lessons that function as **recommended solutions** and **practical mitigation strategies** for renovation programmes in public educational buildings, where administrative procedures, institutional routines, and user dynamics strongly influence implementation outcomes.

I. Data-driven ventilation solutions provide an effective pathway where **traditional funding** and **bureaucratic barriers** persist, enabling measurable indoor air quality improvements without requiring large-scale structural interventions.

II. **Innovative**, **modular technologies** can accelerate implementation in public schools, reducing *administrative burden* and allowing existing *financial support mechanisms* to be used more efficiently.

III. **Early integration** of monitoring and control systems strengthens the case for investment, translating **abstract health** and **comfort concerns** into concrete, measurable performance improvements that support decision-making.

IV. Engagement strategies in educational buildings must be **lightweight** and **non-disruptive**, aligning with school schedules and minimising additional demands on teachers and staff.

V. Close coordination with **technology providers** is essential when deploying novel solutions, ensuring production timelines, system compatibility, and operational reliability are managed effectively.

4.2. Cross-cutting lessons across pilots

The seven FORTESIE pilots- implemented across cultural buildings, single-family homes, multi-residential blocks, vulnerable households, public administration facilities, educational buildings, and specialised recreational infrastructures- offered a unique opportunity to observe how integrated renovation packages perform under real operational conditions.

While Section 4.1 documented **pilot-specific challenges encountered during implementation**, the purpose of this section is different. Building on those experiences, this section synthesises the evidence across all pilots to extract **cross-cutting lessons** that function as **recommended solutions** or **practical mitigation strategies** and **enabling conditions** for future renovation initiatives. Rather than reiterating challenges, the focus here is on identifying what can be done differently- organisationally, technically, administratively, and socially- to anticipate risks, reduce friction, and improve the effectiveness and scalability of renovation programmes.

Despite their diversity in scale, geography, technical characteristics, and user profiles, the pilots revealed a coherent set of systemic patterns, which could shape renovation outcomes across Europe. These patterns illustrate how technical solutions interact with institutional capacity, procurement, and permitting frameworks, contractor availability, user engagement dynamics, digital readiness, and on-site coordination. The pilots consistently demonstrated that successful renovation depends not only on the technologies deployed, but also on the **mitigation strategies** put in place to address **predictable implementation barriers**.

The insights presented in this section are further informed by the project's technical development work, value-chain analyses, behavioural research, and financial assessments. Together, these strands provide a robust basis for identifying **replicable**, **solution-oriented lessons** that apply across building types, climate zones, and governance contexts.

The synthesis below (Table 1) distils these findings into a comparative overview of the FORTESIE pilots, followed by a set of cross-pilot lessons that articulate **actionable responses** to the most frequently encountered implementation challenges. These lessons form a foundation for refining integrated renovation strategies and strengthening future delivery models across Europe.

Table 1. Comparative synthesis of the FORTESIE pilots.

ID	Pilot 1	Pilot 2a	Pilot 2b	Pilot 2c	Pilot 3	Pilot 4	Pilot 5	Pilot 6	Pilot 7
Name	Museum of the "Society of Hellenism and Philhellenism" (Greece)	Building Blocks in Asturias (Spain)	Individual Houses in Grand Est (France)	Urban Residential District in Valladolid (Spain)	Green, Comfortable, and Sustainable Homes (Portugal)	Green and Comfortable Households Through Prosumer Engagement (Portugal)	General Secretariat of Information Systems for Public Administration (Greece)	Comfortable and Sustainable Public Pool (Poland)	Comfortable, Inclusive, and Sustainable Green School (Latvia)
Building type	Cultural building	Multi-family buildings	Single-family homes	Renovated district with one reference block	Dispersed homes of vulnerable households	Single-family prosumer homes	Large public office	Public swimming pool	Public school
Age/ Construction context	Older structure with limited insulation	1950s buildings with structural wear	Mostly 1940-1970s	1960s district retrofitted in 2018	Houses >50 years, structural degradation	Homes >15 years (2 newer)	Industrial 1960s & offices in 1990s	1999 pool based on 1980s design	1972 school, envelope upgraded in 2022
Main renovations during FORTESIE	Insulation, ventilation, PV pergola, glazing	Full ETICS, windows, PV	Monitoring. heat pumps. envelope measures	Digital performance evaluation of prior retrofits	Structural rehabilitation, insulation	Envelope and windows insulation, natural ventilation	Smart energy management, HVAC optimisation, PV	Full HVAC refurb, heating substation, PV	Heating adjustment, ventilation
Digital monitoring scope	Energy meters, indoor air quality, "Esthesis" platform	Indoor sensors	LINKY, indoor sensors	845 legacy sensors, indoor air quality	MESH sensors	MESH sensors & gateways	103 energy meters & 194 indoor air quality sensors	Extensive HVAC & system sensors	Temp/CO_2 sensors & controllers

User profile	Museum staff, visitors	Homeowners & tenants	Homeowners & tenants	Elderly residents	Elderly vulnerable homeowners	Prosumer cooperative members	Public employees (930 users)	Pool users (110,000/yr)	Students & teachers
Key technical challenges	Supplier selection, glazing constraints	Tender adjustments, permit delays	API delays, LORAWAN issues	Sensor acceptance, interoperability	Connectivity issues, remote locations	LoRaWAN instability, sensor reliability	Material delays, PV connection	Complex HVAC refurb, contractor selection	Insufficient ventilation performance; delays linked to first-time deployment
Key administrative challenges	Grid-connection regulation	Municipal permitting capacity	N/A	N/A	Coordination with utilities	Long procurement	Bureaucratic permitting	Governance procedures	Public procurement constraints; limited funding for ventilation upgrades
Engagement challenges	Small staff capacity	Low uptake & expanded recruitment	Low participation during renovations	Elderly residents, privacy	Low digital literacy	High involvement (positive but demanding)	Uncertain engagement	Pool closure impact	Teacher time constraints
Financial pressures	Material cost increases	Owners financed renovations	Monitoring-only budget	N/A	High logistics & labour costs	Co-financing by beneficiaries	Inflation & procurement costs	Inflation, underestimated scope	N/A
What worked well	Strong digital M&V	Flexible pilot selection	Detailed audits & smart meters	Rich sensor dataset	Deep social impact	Strong trust & co-financing	Smart systems integration	Community engagement	Targeted heating upgrades

Key transferable lessons	Supplier vetting & regulation anticipation	Validate eligibility early	Engage households post-renovation	Tailor communication to elderly	Support low digital readiness	Build trust for co-financing	Start permitting early	Forecast complexity & flexible tendering	Use data-driven, modular ventilation solutions to overcome funding & administrative barriers

Cross-pilot lesson #1: Procurement and supply-chain barriers

Across the FORTESIE pilots, procurement and supply-chain disruptions emerged as one of the most consistent risks to timely and predictable renovation delivery. Delays in the provision of key components- including smart windows, ventilation equipment, monitoring devices, PV systems, and façade materials- frequently disrupted work sequencing, extended construction timelines, and required rescheduling or partial reconfiguration of planned interventions.

These issues were particularly pronounced when projects relied on innovative or specialised technologies, or when contractors and suppliers were engaged without prior working relationships. In several cases, slow or incomplete responses from suppliers constrained decision-making and delayed procurement closure.

At the same time, inflation and price volatility increased material costs unexpectedly, reducing budget flexibility and, in some instances, limiting the scope of renovation measures.

Building on these experiences, the pilots point to a set of recommended solutions or practical mitigation strategies that can significantly reduce procurement-related risks in future renovation programmes:

- ✓ **Early engagement** with **multiple suppliers** to avoid single-provider dependency and improve resilience against delivery failures or market shortages.
- ✓ Rigorous **technical** and **commercial vetting** prior to procurement, particularly for novel or non-standard technologies, to ensure feasibility, compatibility, and realistic delivery timelines.
- ✓ Integration of **contingency budgets** and **explicit time buffers** within renovation planning, especially for projects involving innovative solutions, imported components, or complex installation requirements.

Taken together, these measures shift procurement from a reactive bottleneck into a managed risk area, improving predictability and safeguarding the continuity of renovation activities across diverse building types and contexts.

Cross-pilot lesson #2: Bureaucratic and regulatory delays

Across multiple FORTESIE pilots, administrative and regulatory procedures proved to be a decisive factor shaping the project's overall duration. Renovations involving public buildings or grid-connected renewable energy systems were particularly affected by lengthy permitting processes, highly procedural documentation requirements, and decision-making dependencies on understaffed or capacity-constrained municipal authorities.

In several cases, the replacement or temporary absence of key municipal technical personnel led to prolonged standstills, while regulatory uncertainty at the national level- such as evolving rules for PV grid connection- effectively halted progress until updated legal frameworks were clarified. Importantly, these delays occurred even for technically mature and well-established renovation measures, demonstrating that regulatory risk is not limited to innovative technologies alone. The latter was particularly evident in Pilot 7, where ventilation deficiencies were well documented at national level, yet investment pathways and administrative procedures remained fragmented and slow.

Drawing on these experiences, the pilots highlight a set of recommended solutions or practical mitigation strategies to reduce exposure to administrative bottlenecks:

- ✓ Initiating **permitting** and **regulatory procedures** at the earliest possible stage, ideally immediately after the draft design phase, rather than waiting for full technical finalisation.
- ✓ Running **administrative** and **technical workflows** in parallel, allowing permitting progress to advance alongside detailed design and procurement activities.
- ✓ Maintaining continuous, **proactive communication** with public authorities, including regular follow-ups, clarification requests, and early identification of potential approval risks.

Overall, the pilots confirm that proactive regulatory engagement must be treated as a core project activity rather than an auxiliary task. Even routine renovation technologies can be significantly delayed by administrative inertia if permitting risks are not anticipated, actively managed, and embedded into project planning from the outset.

Cross-pilot lesson #3: Capacity limitations in public, social, and community settings

Across the FORTESIE pilots, limited institutional and human-resource capacity emerged as a systemic constraint affecting both implementation speed and overall project quality. Small museums, municipalities, schools, and community organisations often lacked the administrative bandwidth and technical expertise needed to manage procurement processes, coordinate contractors, or engage meaningfully in monitoring and reporting activities. In residential pilots involving vulnerable households, low digital literacy further complicated basic tasks such as documentation collection, sensor installation, and device maintenance, frequently requiring repeated in-person support.

These capacity gaps did not merely slow down individual activities; they placed sustained pressure on pilot teams, increased coordination costs, and reduced the efficiency of otherwise technically sound renovation solutions. Importantly, the pilots demonstrated that without targeted support structures, even well-designed renovation packages risk underperforming due to local capacity constraints rather than technical shortcomings.

Building on these challenges, the pilots point to a set of recommended solutions or practical mitigation strategies that are essential for scaling renovations in capacity-constrained contexts:

- ✓ Embedding **local technical assistance models**, either through dedicated facilitators or trusted intermediaries, to support administrative tasks, procurement coordination, and basic technical decision-making.
- ✓ Deploying **OSS-based services** and **renovation support hubs** to centralise expertise, reduce administrative burden on local actors, and provide continuous guidance throughout the renovation lifecycle.
- ✓ Designing **simplified procedures** and **interfaces** explicitly tailored to non-technical end-users, particularly in social housing, community buildings, and vulnerable households.
- ✓ Investing in capacity-building for **long-term operation**, ensuring that building owners, operators, and occupants can sustain, manage, and benefit from renovation outcomes beyond the project's completion.

Overall, the pilots confirm that strengthening *local capacity is not a secondary or "soft" measure*, but a *core enabler of effective renovation delivery*. Without parallel investments in institutional, social, and digital capacity, even mature renovation technologies struggle to achieve their full potential in real-world settings.

Cross-pilot lesson #4: User engagement challenges and social dynamics

Across all pilots, engaging building users- residents, homeowners, tenants, staff, teachers, or elderly occupants- emerged as one of the most decisive and demanding dimensions of renovation implementation. Reluctance to participate was frequently linked to privacy concerns, mistrust towards monitoring technologies, unfamiliarity with digital tools, limited perceived benefits, or simple engagement fatigue. These barriers were not confined to a specific building type but manifested differently depending on social context, age profile, and institutional setting.

In multi-apartment residential buildings, achieving adequate participation required extensive one-to-one contact with occupants, repeated explanations, and sustained follow-up. In the Latvian school pilot, engagement was constrained by teachers' limited availability and by the fact that younger pupils did not have access to personal digital devices, restricting the use of app-based or digital feedback tools. In dispersed rural contexts and vulnerable households, engagement depended heavily on personalised contact, trust-based relationships, and social support networks, with digital-only approaches proving insufficient.

At the same time, the pilots demonstrated that when trust and engagement are successfully established, user involvement can significantly amplify renovation outcomes. In the Portuguese prosumer pilot, for example, strong trust and clear communication led several households to voluntarily co-finance additional renovation measures, expanding the scope and impact of the intervention beyond initial project assumptions. This illustrates that user engagement is not only a risk factor but also a powerful lever when managed effectively.

Building on these challenges, the pilots point to a set of recommended solutions or practical mitigation strategies that are critical for ensuring meaningful and sustained user participation:

- ✓ **Transparent communication**, clearly explaining objectives, data use, privacy safeguards, and expected benefits from the outset.
- ✓ **Personalised engagement approaches**, recognising that different user groups require different levels of support, interaction, and reassurance.
- ✓ **Age-** and **context-adapted communication materials**, particularly for elderly users, children, or digitally excluded groups.
- ✓ Deliberate **trust-building strategies**, relying on familiar intermediaries, local organisations, or repeated face-to-face contact rather than one-off information campaigns.
- ✓ Sustained engagement **throughout the renovation process**, extending beyond installation phases to include follow-up, feedback, and support during operation.

Overall, the pilots confirm that user engagement cannot be treated as a peripheral activity or a one-time task. Instead, it must be designed as a continuous, resource-intensive process that directly conditions the success, scalability, and long-term acceptance of integrated renovation solutions.

Cross-pilot lesson #5: Digital integration and technical readiness

Digital technologies formed a core component of the FORTESIE renovation packages, supporting monitoring, optimisation, and performance verification across building types. Nevertheless, multiple pilots encountered challenges related to interoperability, network availability, and the technical maturity of digital solutions, which affected deployment timelines and the reliability of collected data.

Recurring issues included delays in API development, incompatibility with local LoRaWAN networks, insufficient or unstable internet connectivity in rural or dispersed buildings, the need for additional gateways or communication hardware, and disruptions caused by unexpected sensor malfunctions or reduced battery life. In several cases, these challenges required late-stage technical adaptations, additional site visits, or changes in deployment strategies, increasing both organisational complexity and costs.

Building on these challenges, the pilots underscore a set of recommended solutions or practical mitigation strategies:

- ✓ Conduct **early digital-readiness assessments**, including evaluation of connectivity conditions, network coverage, and data-integration requirements at the building or district level.

- ✓ Undertake rigorous hardware and network **testing prior to deployment**, particularly when introducing new sensor types, APIs, or monitoring platforms.

- ✓ Design **user-friendly installation** and **operation procedures**, especially in contexts where end-users are expected to self-install devices or perform basic troubleshooting.

Designing digital systems that can operate reliably in low-connectivity environments, while minimising user burden and maintenance requirements, proved essential for ensuring continuous data collection, robust measurement and verification, and meaningful performance evaluation over time.

Cross-pilot lesson #6: Logistical complexity and on-site coordination

Logistical coordination emerged as a recurring challenge across several pilots, particularly those involving geographically dispersed households, large public facilities, or buildings with complex access conditions. The physical distribution of sites, the need to align renovations with ongoing building operations, and the coordination of multiple stakeholders significantly influenced implementation efficiency.

In remote or rural contexts, long-travel distances limited the frequency of on-site visits, complicating baseline data collection, sensor installation, and maintenance activities. In public facilities such as swimming pools and schools, renovations had to be carefully synchronised with operational calendars, seasonal usage patterns, and safety requirements.

Across multiple pilots, coordinating access to individual dwellings, classrooms, or technical rooms added further constraints, increasing organisational effort and extending implementation timelines.

The pilots highlight a set of recommended solutions or practical mitigation strategies emphasising the need to:

- ✓ Adopt **flexible access strategies**, including decentralised installation approaches, remote guidance, or user-supported placement where appropriate.

- ✓ Plan **realistic visit frequencies** and **logistical workflows**, accounting for geographic dispersion, building accessibility, and staff availability.

- ✓ Select **renovation time windows** that **minimise disruption** while ensuring efficient technical execution, particularly in buildings with continuous public use or seasonal operation patterns.

The pilots showed that logistical planning is not an auxiliary task but a core implementation determinant: without explicit access planning, realistic resourcing, and carefully chosen timing, even technically sound renovation and monitoring packages risk delays, incomplete deployment, and reduced data quality.

Cross-pilot lesson #7: Financial pressures and budget management

Financial constraints emerged as a cross-cutting challenge affecting several pilots, driven by inflation, rising material and labour costs, and unforeseen construction issues uncovered during implementation. In multiple cases, these pressures reduced financial flexibility and, in some instances, required adjustments to the scope or sequencing of renovation measures.

Public-sector pilots faced additional constraints linked to rigid financing frameworks, annual budget cycles, and administrative rules governing expenditure approvals. These institutional factors limited the ability to rapidly reallocate funds or respond to emerging technical needs, amplifying the impact of cost volatility. In residential contexts, financial uncertainty also influenced user confidence and acceptance, particularly where households feared unexpected cost escalation.

These experiences highlight a set of recommended solutions or practical mitigation strategies emphasising the need to:

- ✓ Apply **detailed** and **conservative cost forecasting**, explicitly accounting for inflation, material volatility, and technical uncertainty.
- ✓ Include **robust contingency reserves** to absorb unforeseen construction challenges without compromising core renovation objectives.
- ✓ Maintain **transparent** and **continuous communication** with beneficiaries and building owners regarding costs, risks, and potential adjustments.
- ✓ Ensure **sufficient budget flexibility**, allowing projects to respond to supply-chain disruptions or hidden structural issues without reducing overall renovation quality.

The pilots demonstrated that sound financial planning is a critical enabler of successful renovation delivery: projects that integrate contingency planning, cost transparency, and adaptive budgeting are far better positioned to withstand market volatility and deliver resilient, high-quality renovation outcomes.

In general, none of the parties involved in the renovation process, from beneficiaries (households or public buildings) to funders (EU, national or local subsidy schemes) do evaluate abatement costs, e.g., of one kWh or one ton of CO_2. In a context where EU and Member States look for low energy prices to fuel increased gross-domestic product (GDP), the return on investment of renovation projects is long. With the impossibility to raise energy prices (for GDP and social reasons) intense public spending is the sole option to reach the EU's objective of lowering energy consumption and CO_2 emissions. In this context tracking total renovation costs as well as energy consumption before and after renovation are key elements to monitor the efficiency of public spending and to find out which subsidising schemes would be more efficient. During the FORTESIE project, the "Price-Comfort" indicator was created, allowing to track energy consumption before and after renovations, eliminating, thus, rebound or free riding effects. Should this indicator be integrated in public funding, efficacy of public money would be improved.

Cross-pilot lesson #8: Contractor relationships, market capacity, and skill availability

Across the pilots, contractor engagement emerged as a decisive factor influencing both renovation timelines and implementation quality. Several pilots experienced delays during the procurement phase because construction companies were hesitant to respond to requests for quotations when no prior working relationship existed. This reluctance slowed budget preparation, technical clarification, and ultimately the initiation of on-site works.

In parallel, broader structural constraints in the construction sector affected implementation. National and regional labour shortages reduced contractor availability, extended execution timelines, and in some cases required renewed recruitment efforts. These challenges were particularly pronounced in specialised buildings, such as public swimming pools, where highly qualified contractors with experience in complex HVAC, ventilation, or moisture-control systems were required but difficult to secure.

These experiences demonstrate the importance of recommended solutions or practical mitigation strategies to:

- ✓ **Engage contractors early** in the project lifecycle, allowing sufficient time to build trust, clarify expectations, and assess availability.

- ✓ Provide clear, detailed, and standardised **technical documentation**, reducing uncertainty and lowering the entry barrier for contractors unfamiliar with innovative or integrated renovation packages.

- ✓ Design **procurement frameworks** that can adapt to market constraints, balancing flexibility with quality assurance, especially in regions facing labour shortages or limited specialist capacity.

The pilots demonstrated that renovation success depends not only on technical design but also on realistic alignment with market capacity. Early contractor engagement, transparent technical communication, and procurement approaches responsive to real-world skill availability are essential to ensure timely delivery and high-quality outcomes in complex renovation projects.

Cross-pilot lesson #9: Benefits of digital monitoring and performance-based approaches

Across the FORTESIE pilots, digital monitoring and performance-tracking systems proved to be a critical enabler of effective renovation, despite initial deployment challenges. Once operational, sensors and digital platforms significantly enhanced visibility over energy consumption, indoor environmental quality, and system performance, allowing both project teams and building operators to move beyond theoretical savings and assess real, measured outcomes.

Digital monitoring enabled continuous tracking of key indicators, supported verification of renovation impacts, and helped identify operational inefficiencies that would otherwise remain hidden. In several pilots, these insights informed adjustments to system settings, ventilation strategies, or user behaviour, reinforcing the value of data-driven optimisation in both residential and non-residential contexts. Importantly, monitoring tools also increased transparency for end-users and facility managers, strengthening trust in renovation outcomes and fostering greater awareness of building performance.

In the longer term, the availability of reliable post-renovation data created the foundations for performance-based approaches, including measurement and verification frameworks, performance guarantees, and future service-oriented business models. Where users engaged with the data, digital tools also contributed to behavioural change by making energy use and comfort conditions more tangible and understandable.

These findings highlighted a set of recommended solutions or practical mitigation strategies reaffirming that:

- ✓ Digital monitoring and measurement and verification should be embedded as core elements of renovation projects, **rather than** treated as **optional add-ons**.
- ✓ **Reliable performance data** is essential for validating renovation impacts, supporting optimisation, and enabling accountability across stakeholders.
- ✓ **User-facing transparency** enhances trust and engagement, particularly when data is presented in accessible and meaningful ways.

The pilots demonstrated that digital monitoring is not merely a technical enhancement but a strategic asset. When properly designed, deployed, and supported, performance-based digital systems could underpin smarter renovation decisions, enable continuous improvement, and support the transition towards outcome-oriented, data-driven renovation practices across Europe.

Overall, when considered together, the cross-cutting lessons from the seven FORTESIE pilots demonstrate that successful renovations extend well beyond the deployment of technical measures alone. Effective implementation depends equally on robust administrative planning, resilient procurement strategies, inclusive and well-designed user engagement, flexible logistical arrangements, adequate financial buffers, and reliable digital ecosystems. Taken together, these insights provide a solid foundation for developing adaptive, people-centred, and scalable renovation methodologies. They also feed directly into the policy recommendations and practical guidelines presented in **Section 5** and **Section 6**, ensuring that FORTESIE's results can be effectively replicated, transferred, and mainstreamed across Europe's diverse building stock.

4.3. Implications for future renovation activities

The evidence gathered across the FORTESIE pilots, points to a set of strategic implications that can meaningfully shape the next generation of renovation activities across Europe. Rather than reiterating the challenges identified, this section distils actionable implications that inform how future renovation efforts should be designed, financed, governed, and implemented in practice.

1. Renovation activities must differentiate approaches for residential and non-residential buildings

The pilots clearly demonstrate that a "*one-size-fits-all*" renovation approach is ineffective. Residential and non-residential buildings operate under fundamentally different technical, social, and governance conditions, even when similar technologies are deployed. Future renovation activities should therefore adopt explicitly differentiated renovation pathways.

- For **residential buildings**, renovation strategies should prioritise user-friendly technologies, simple and robust installation procedures, and solutions that minimise disruption to everyday life. Rapid-execution envelope measures, compact heating and ventilation systems, and intuitive digital tools are particularly important in these contexts. Financial predictability is critical: households require clear upfront information on costs, timelines, and expected benefits, as well as reassurance that budgets will not escalate due to unforeseen works or supply-chain disruptions. Early and transparent communication remains essential for building trust and sustaining participation.

- For **non-residential buildings**, renovation activities must account for longer administrative and procurement procedures, higher technical complexity, and strict operational constraints. Public offices, schools, cultural facilities, and specialised infrastructures often require extended lead times, detailed technical scoping, and coordination with multiple authorities. Renovation schedules must be aligned with operational calendars, such as school terms, service delivery requirements, or seasonal usage patterns. In these settings, early procurement planning, clear allocation of responsibilities, and the involvement of experienced contractors are indispensable for avoiding delays and ensuring technical reliability.

This differentiation should be systematically embedded into national renovation strategies, funding schemes, and technical guidelines, ensuring that policy frameworks reflect the distinct realities of residential and non-residential building stocks rather than applying uniform assumptions across all contexts.

2. Digital readiness must be assessed and supported from the outset

The FORTESIE pilots confirm that digital tools are increasingly central to performance-based renovation models, yet they also reveal wide variation in digital readiness across building types, locations, and user groups. Connectivity quality, interoperability with existing systems, and users' ability to interact with digital tools cannot be assumed and, if left unaddressed, can undermine otherwise well-designed renovation packages.

Future renovation activities should therefore integrate digital readiness as a core preparatory step, rather than treating monitoring and digital services as add-ons. In practical terms, this implies:

- Conducting **early digital-readiness diagnostics** that assess connectivity conditions, existing metering and control infrastructure, data-exchange requirements, and digital skills of building users or operators.

- Providing **light-touch but targeted** digital support, including user training, installation guidance, and basic troubleshooting mechanisms, tailored to the capabilities of households, facility managers, or public-sector staff.

- Designing **monitoring** and **data-collection solutions** that remain reliable in low-connectivity or resource-constrained environments, for example through buffered data storage, hybrid communication modes, or gateway-supported architectures.

By embedding digital-readiness assessment and support into the design of renovation activities, future deployment can reduce implementation risks, improve data quality, and enable scalable performance-based approaches across a much broader range of buildings and social contexts.

3. Supply-chain resilience and procurement flexibility must be strengthened

The FORTESIE pilots clearly demonstrate that future renovation initiatives must be planned under the assumption that supply chains will remain volatile. Delays, supplier withdrawal, cost inflation, and limited availability of specialised components are no longer exceptional events but structural conditions affecting renovation delivery across Europe.

To reduce vulnerability to these risks, future renovation activities should embed supply-chain resilience directly into procurement design. Based on pilot experience, three measures are particularly critical:

- Adopting **multi-supplier procurement strategies** to avoid dependence on single vendors, especially for specialised or innovative components such as PV-integrated elements, advanced ventilation units, or digital monitoring equipment.

- Implementing **flexible tendering** and **contracting models** that allow adjustments to technical specifications, timelines, or suppliers when market conditions change, without triggering lengthy re-procurement processes.

- Developing and maintaining **validated technology catalogues** that provide procurers with pre-screened products and suppliers, reducing due-diligence burdens and accelerating decision-making.

Embedding these practices into renovation programmes increases robustness against delays and cost escalation, protects project timelines, and enables more predictable implementation- particularly for large-scale, innovative, or publicly funded renovation initiatives.

4. Local capacity and technical assistance must be embedded into renovation frameworks

Evidence from the FORTESIE pilots shows that limited local capacity is a structural barrier to successful renovation, particularly in small public institutions, municipalities, schools, and among vulnerable or digitally excluded households. Even when technical solutions and funding are available, the absence of administrative, technical, and operational support can delay implementation, weaken uptake, and undermine long-term performance.

Future renovation frameworks should therefore integrate capacity support as a core delivery component rather than a complementary service. Three areas are especially important:

- Establishing **local technical assistance hubs** or **expanding OSS-based services** that provide hands-on support for procurement, permitting, financial applications, contractor coordination, digital monitoring, and post-renovation troubleshooting.

- Embedding **targeted social support mechanisms** for vulnerable households, including in-person assistance, simplified documentation processes, and mediation with utilities or service providers to overcome digital and administrative barriers.

- Implementing **structured capacity-building schemes** for facility managers and public-sector staff to ensure effective operation, maintenance, and use of digital systems throughout the building lifecycle.

By embedding local capacity and technical assistance directly into renovation frameworks, future initiatives can move beyond one-off project delivery and achieve durable performance, higher user confidence, and more equitable access to renovation benefits across diverse contexts.

5. Renovation planning must integrate operational continuity and occupant needs

Evidence from the FORTESIE pilots shows that renovation outcomes are strongly influenced by how well intervention schedules align with the operational rhythms of buildings and the daily routines of their users. Even technically sound renovation packages can face resistance, delays, or reduced acceptance if they disrupt core activities or impose prolonged uncertainty on occupants.

Future renovation activities should therefore systematically integrate operational continuity and user impact considerations into the planning phase, including:

- **Aligning renovation schedules** with **building-specific operational calendars** (e.g., school terms and examination periods, seasonal demand in public facilities, household availability in residential buildings).

- Assessing and minimising **disruption to users** by selecting renovation periods with lower occupancy or reduced functional demand.

- Defining realistic and transparent timelines to **avoid prolonged uncertainty** for occupants, particularly in residential and multi-occupancy contexts.

- **Embedding user-impact assessments** early in project design, alongside technical and financial planning.

By treating operational continuity and occupant needs as core planning parameters- rather than secondary constraints- future renovation initiatives can reduce resistance, maintain trust, and improve overall implementation efficiency and social acceptance.

6. Performance-based approaches should become standard practice

Evidence from across the FORTESIE pilots confirms that continuous digital monitoring significantly enhances the credibility, effectiveness, and long-term value of renovation activities. Monitoring systems enabled validation of energy savings, supported the management of indoor environmental quality, and strengthened transparency between building owners, occupants, and service providers.

Future renovation efforts should therefore systematically embed performance-based approaches by:

- **Mandating minimum digital monitoring requirements** for publicly supported renovation projects.
- Linking monitoring outputs to **performance guarantees**, **verification frameworks**, and **outcome-based financing models**.
- Promoting **data-driven building operation practices** that support continuous optimisation of energy use, comfort, and system performance.

By normalising performance-based approaches, renovation markets can move beyond predicted savings towards verified outcomes, accelerating the transition to evidence-based, trust-driven, and investment-ready renovation ecosystems.

7. Renovation solutions must remain adaptable, modular, and scalable

While replicability is essential for accelerating renovation across Europe, evidence from the FORTESIE pilots shows that rigid, one-size-fits-all solutions quickly lose effectiveness when confronted with diverse building typologies, climatic conditions, regulatory frameworks, and user profiles. Successful renovation models must therefore balance standardisation with adaptability.

Future renovation frameworks should explicitly support this balance by:

- Promoting **modular renovation packages** and **service configurations** that can be combined or adjusted to local technical and social conditions.
- Allowing **controlled customisation** of solutions **without undermining standardisation benefits** related to cost efficiency, quality assurance, and scalability.
- Encouraging **scenario-based design approaches** that test how renovation solutions perform under different building uses, occupancy patterns, and regulatory constraints.

By embedding adaptability and modularity into renovation design, future interventions can remain robust, scalable, and resilient across Europe's heterogeneous building stock, while still enabling efficient market uptake and replication.

8. Financial design must anticipate volatility and support long-term affordability

Evidence from all FORTESIE pilots confirms that renovation activities are highly sensitive to financial volatility. Inflation, unforeseen structural issues, fluctuating material prices, unknown or long returns on investment, and rigid administrative budget cycles repeatedly affected project scope, sequencing, and feasibility. These dynamics are likely to persist and must therefore be treated as a structural condition rather than an exception.

Future renovation efforts should respond by:

- Requiring **explicit contingency allocations** and **mechanisms** for dynamic cost updates throughout the project lifecycle.
- Simplifying and streamlining **grant** and **subsidy schemes** to ensure predictable approval timelines and reduce exposure to administrative delays.
- Supporting **low-income** and **vulnerable households** through targeted subsidies, staged renovation pathways, and integrated technical/ financial assistance that reduces upfront financial burden.

Embedding financial resilience into renovation design will reduce vulnerability to market instability, protect renovation quality, and enhance long-term affordability for households and public building operators alike.

5. Implications for policymakers and practitioners at different governance levels

The policy recommendations presented in this section are designed to support the wide deployment and long-term sustainability of the renovation solutions developed and demonstrated within FORTESIE. They respond directly to the project's objectives, which call for the formulation of clear, actionable messages for European, national, and regional/ local policymakers, as well as for industry associations and civil-society organisations engaged in the building-renovation agenda. The purpose is to translate the empirical evidence generated through the project's pilots, together with cross-cutting insights from WP2-WP5 and the broader policy analysis presented in **Section 2** into recommendations that can inform legislative processes, guide implementation efforts, and strengthen the enabling conditions for ESIE-oriented renovation services across Europe.

Recommendations are structured according to each governance level of interest, reflecting the differentiated roles and responsibilities of key policy actors. At the EU level, they aim to support the evolution and effective implementation of core legislative frameworks such as EPBD (European Commission (EC), 2024), EED (European Commission (EC), 2023c), and RED (European Commission (EC), 2023b) regulations, as well as related financial and digital initiatives, including the "EU Taxonomy" (European Commission (EC), 2020b), the CEEAG (European Commission (EC), 2022), the "InvestEU" programme, and the emerging Energy Data Space.

At the national level, they address the practical challenges of policy transposition, regulatory coordination, financing design, and administrative capacity, which are critical to accelerating renovation activity at scale. At the regional and local levels, the recommendations highlight the role of municipalities, energy agencies, and public building owners as frontline implementers and multipliers of innovative renovation approaches. In parallel, selected recommendations are directed at industry stakeholders and other relevant market actors, whose engagement, innovation capacity, and service offerings are essential to the deployment of integrated, digital, and performance-based renovation services.

The framework underpinning these recommendations is grounded in the lessons learnt across the seven FORTESIE pilot sites, where real-life operating conditions exposed technical, organisational, financial, and behavioural barriers that remain insufficiently addressed in current policy settings. These empirical findings are complemented by the identification of systemic gaps in existing technological solutions, digital standards, and renovation market structures. By combining pilot-level evidence with a broader assessment of policy and market conditions, the recommendations seek not only to remove existing obstacles but also to actively support the emergence of new business models, strengthen Europe's renovation value chain, and enable the uptake of innovative ESIE-based services.

Overall, this section provides the bridge between FORTESIE's empirical insights and the policy actions required to unlock large-scale, performance-driven renovation across Europe. The recommendations that follow are therefore intended as guidance for policymakers shaping the frameworks within which renovation actors operate, ensuring that the knowledge generated in FORTESIE contributes meaningfully to Europe's climate, energy, and social objectives.

5.1. Policy implications and strategic recommendations at the Member State level: The FORTESIE pilot countries

At the Member State level, the lessons derived from the FORTESIE pilots point to a clear need for more coherent, operational, and capacity-aware national renovation frameworks. National ministries responsible for energy, housing, finance, digitalisation, and education- together with regulators and national energy agencies- play a decisive role in translating EU-level ambitions into implementable programmes that can scale integrated, performance-based renovation solutions.

5.1.1. France

France has established a robust and highly structured regulatory framework for building renovations, integrating energy performance requirements, climate objectives, digital tools, and financial instruments within a coherent national transition strategy. Renovation policy is embedded in broader climate and energy governance- most notably the "*National Low-Carbon Strategy (SNBC)*[21]", the "*Multiannual Energy Plan (PPE)*"[22], and the forthcoming NBRP under the recast EPBD. The framework spans residential, tertiary, and public buildings and combines minimum performance requirements, certification schemes, digital monitoring platforms, and incentive mechanisms.

The FORTESIE pilot confirmed that France operates in a mature policy environment characterised by high regulatory ambition and substantial public funding capacity. At the same time, it highlights a shift in where the "hard problems" now sit: increasingly, delivery is constrained not by missing policy instruments, but by administrative complexity, behavioural dynamics, and the operational integration of M&V tools into real renovation workflows. These implementation frictions matter because France's model relies on moving from regulatory intent to verified outcomes.

Performance-based requirements and Minimum Energy Performance Standards

In the residential sector, regulation is centred on the "*Diagnostic de Performance Énergétique (DPE)*[23]"- the French EPC- which has become a cornerstone of housing policy. Since the 2021 reform, the DPE relies on a standardised physical calculation method rather than historical energy bills and is legally opposable. Building on this, France has implemented MEPS through the concept of "*décence énergétique*", progressively restricting the rental of the worst-performing dwellings. Properties rated "G" are prohibited from rental from January 2025, followed by "F" in 2028 and "E" in 2034- creating a strong, staged regulatory driver for deep renovations in the rental market.

For new residential and tertiary buildings, the "*Réglementation environnementale (RE2020)*[24]" replaces earlier thermal standards with an environmental framework that adds lifecycle carbon indicators to strengthened energy-efficiency requirements. RE2020 reinforces the shift towards low-carbon and renewable heating solutions and tightens thresholds over time. In parallel, the "*carnet d'information du logement*[25]" documents renovation actions and building characteristics across the lifecycle, strengthening traceability and supporting staged renovation planning.

Regulation for tertiary and public buildings

Non-residential and public buildings are subject to the "*Décret Tertiaire*[26]", which mandates progressive reductions in final energy consumption for buildings exceeding 1,000 m². Targets are set at approximately 40% by 2030, 50% by 2040, and 60% by 2050 relative to a reference period. Compliance is operationalised through the national "*OPERAT*" platform[27], which requires annual reporting and provides structured feedback on performance trajectories.

For public buildings, these obligations translate into concrete renovation and system-upgrade requirements, often delivered through performance-oriented procurement and energy performance contracting. The pilot confirms that these mechanisms can align long-term energy objectives with

[21] https://www.ecologie.gouv.fr/sites/default/files/documents/Projet%20SNBC%20EN.pdf.
[22] https://www.ecologie.gouv.fr/sites/default/files/publications/4pages_PPE_GB_DEF_Web.pdf.
[23] https://www.ecologie.gouv.fr/politiques-publiques/diagnostic-performance-energetique-dpe.
[24] https://www.ecologie.gouv.fr/politiques-publiques/reglementation-environnementale-re2020.
[25] https://www.ecologie.gouv.fr/sites/default/files/documents/carnet_d_information_du_logement.pdf.
[26] https://www.ecologie.gouv.fr/politiques-publiques/eco-energie-tertiaire-eet.
[27] https://operat.ademe.fr/.

public-sector budget constraints- provided that administrative procedures, tendering capacity, and technical coordination are adequately supported.

Smart readiness, monitoring, and digitalisation

France has complemented performance-based regulation with a strong push for digital building management. Under the requirements commonly referred to as the "*décret BACS*[28]", tertiary buildings defined HVAC power thresholds must install building automation and control systems. This supports continuous monitoring, automated control, and performance-oriented operation- moving beyond static compliance towards real-world verification of savings.

The pilot experience reinforces the value of this approach but also highlights practical constraints: interoperability, stable data flows, and user capacity to engage with digital systems often determine whether monitoring yields usable evidence. In other words, the regulatory framework can mandate "equipment", but outcomes depend on the operational ecosystem around onboarding, support, and data integration.

Energy-saving obligations and incentive mechanisms

France implements energy-efficiency obligations through the "*Certificats d'Économies d'Énergie (CEE)*" scheme[29], requiring suppliers and distributors to deliver quantified savings across sectors. The scheme increasingly prioritises comprehensive and multi-measure renovations and includes dedicated provisions for energy-poor households. For public and tertiary buildings, CEE can complement public procurement and grant-based instruments, improving the bankability of performance-based approaches when administrative burden is manageable.

The scheme of CEE gives a strong baseline illustration of energy certificate pitfalls. This French baseline is analysed by two reports[30,31] issued in 2024 by the French Audit Court ("*Cour des Comptes*") and the General Inspectorate of Finance (IGF). Those reports are calling for "*a system that needs reforming because it is complex and costly, with uncertain results*" given the poor results achieved: real energy savings in kWh after renovations are indeed unknown (despite an unproved estimated 6.5% of savings by authorities managing the scheme). Without real kWh saving data, information on saved €/kWh, or abatement costs of CO_2 is not valid. Despite the number of deceptive detected cases remaining low, suspicions of widespread fraud are real. At a macro scale, overall energy consumption continues to rise, as highlighted by the Kaya equation[32]. The current framework obliges energy suppliers (some of which are fully state-owned) to purchase certificates, a yearly expense of €6 billion, yet no robust proof exists that this mechanism delivers measurable efficiency in terms of kWh savings.

Nevertheless, this legal framework provides a valuable starting point for developing an improved scheme. By integrating the "Price-Comfort" indicator developed during FORTESIE based on real ex-post energy consumption, the proposed approach would address the deficiencies of the current CEE system. The scheme's scope could be broadened beyond energy suppliers to also include financial institutions and equipment manufacturers, thereby increasing the demand for certificates. This

[28] https://rt-re-batiment.developpement-durable.gouv.fr/presentation-et-guide-du-decret-bacs-a712.html.

[29] https://www.service-public.gouv.fr/particuliers/vosdroits/F35584.

[30] https://www.ccomptes.fr/sites/default/files/2024-09/20240917-Certificats-economie-energie_0.pdf.

[31] https://www.igf.finances.gouv.fr/files/live/sites/igf/files/contributed/Rapports%20de%20mission/2023/2023-M-095-04%20Rapport%20CEE%20PUBLIC.pdf.

[32] CO_2 emissions (CO_2) and Energy (E) are intimately linked as shown by the Kaya equation (also with world GDP and global Population (Pop): $CO_2 = C \times E \times GDP \times Pop$. By 2050, the term E x GDP x Pop is expected to roughly be equal to one (rising Pop). So, the only way to reduce CO_2 emissions is to reduce C, which is the carbon content of energy (carbon emissions per kWh). This shows that not all energy carriers are equal when considering their impact on climate.

expansion has the potential to raise certificate prices, creating stronger market incentives for renovations and accelerating the renovation wave. At the same time, it would gradually reduce- if not entirely eliminate- the need for public subsidies, as market demand for certificates would replace dependency on public funding.

Renewable energy, heating and cooling, and district systems

France's long-term strategy prioritises decarbonising heating and cooling through renewables and recovered heat. National targets support district heating and cooling expansion alongside heat pumps, solar thermal, biomass, and hybrid solutions. RE2020 reinforces the phase-down of fossil-fuel-only heating in new buildings, while renovation support schemes incentivise low-carbon heat in existing buildings.

The FORTESIE pilot confirms that solutions are largely available; the binding constraints are often administrative sequencing and coordination across actors rather than technology availability.

Quality control, data transparency, and national databases

France has invested heavily in data infrastructures and quality-control mechanisms to underpin performance-based regulation. National systems consolidate information from DPE processes, building logbooks, and tertiary energy declarations, enabling segmentation, targeting, and monitoring. Reforms have strengthened training and certification requirements for diagnosticians and auditors to address trust and reliability concerns.

At the same time, the FORTESIE pilot surfaced persistent operational challenges: heterogeneous devices, supplier changes, API and data-export frictions, and voluntary participation dynamics can undermine timeliness and interoperability. These issues become more consequential as MEPS tighten and verification expectations rise.

Policy implications and strategic recommendations

The FORTESIE pilot confirms that France's renovation challenge is no longer about missing headline instruments- MEPS via "décence énergétique", **"**RE2020", "Décret Tertiaire"/ "OPERAT" platform, and "Décret BACS" are already structurally powerful. The bottleneck is the **delivery chain**: administrative throughput, bundling capacity for deep renovations, and the ability to produce **credible post-renovation evidence** without adding friction that pushes the market back to single-measure upgrades. France's next step should therefore harden the operational architecture that turns regulation and funding into **verified**, **durable outcomes**.

✓ **Make One-Stop Shops operational integrators, including post-renovation verification and monitoring onboarding**

France should *reinforce the operational mandate of OSS-based structures* (notably the network and allied intermediaries) so that support extends beyond advice and funding guidance into *monitoring enrolment*, *device onboarding*, *troubleshooting*, and *data-handling interfaces*. The pilot shows that data continuity and participation improve markedly when trusted intermediaries reduce the cognitive and administrative burden on households and building owners.

✓ **Embed post-renovation verification routines into Minimum Energy Performance Standard enforcement and support schemes**

As rental restrictions widen, legitimacy will depend on demonstrating that renovations deliver *sustained performance in practice*- not only *nominal compliance*. France should *mainstream post-renovation steps* (activation of monitoring where relevant, validation of key performance evidence, and updating of building stock records/ logbooks) as routine elements linked to public support and compliance documentation.

✓ **Remove "deep renovation penalties" by creating a single dossier for multi-measure packages**

While national regulation is strong, administrative friction still nudges actors towards incremental upgrades. France should implement a *single bundled workflow* for multi-measure renovations- one submission pathway, one evidence logic, and reduced duplication between audits, grant documentation, and verification.

✓ **Establish national technical standards for interoperability and data access**

To stabilise digital renovation ecosystems, France should define *minimum requirements* for *device interoperability*, *data-export formats*, *API stability expectations*, and *pre-deployment testing* for solutions used in publicly supported schemes. This will reduce late-stage integration failures and protect the long-term usefulness of monitoring data for national systems.

✓ **Standardise privacy-by-design and resident value propositions to raise monitoring participation without coercion**

Monitoring uptake is often limited by trust and perceived effort, not by technology. France should provide *standard national communication* and *consent materials* (plain language, privacy safeguards, "what you get back"), and make *monitoring benefits tangible* (comfort insights, fault alerts, confirmation of savings).

✓ **Use proportionate incentives that reward evidence-sharing, not gadgets**

If post-renovation data is needed for benchmarking and policy credibility, France should incentivise *participation in evidence creation* rather than pushing complex tech. Options include small grant bonuses, faster processing, or enhanced advisory support for households/ building owners who share anonymised post-renovation performance evidence for a defined period.

✓ **Treat monitoring logistics as a service obligation, with remote support and fallback routes**

To scale, monitoring must be operationally robust: remote onboarding, clear escalation, and fallback modes when connectivity or user capacity fails. France should require service providers to meet *minimum support service levels* (remote diagnostics, replacement protocols, continuity guarantees) and enable lightweight on-site support through intermediaries.

Overall, France's policy framework is already among the EU's most advanced. The high-value improvement now is to make the system **delivery-hard**: fewer deep-renovation penalties, stronger routine evidence, and a digital ecosystem that is interoperable, supportable, and trusted, so that regulatory ambition reliably becomes verified outcomes.

A new certificate scheme, developed within FORTESIE, in particular the "Price-Comfort" indicator, will integrate most of the above recommendations, which could be then expanded at a pan-EU scale.

5.1.2. Greece

Greece is entering a decisive implementation phase for the decarbonisation of its building stock. The recast EPBD (2024) strengthens the EU pathway towards a ZEB stock by 2050 and requires Greece to replace its Long-Term Renovation Strategy (LTRS) with a NBRP, with a draft due by the end of 2025 and a final plan by the end of 2026. The NBRP is expected to operationalise national renovation trajectories in alignment with the updated NECP (published in 2024), specifying renovation targets, investment needs, milestones for non-residential MEPS and residential trajectories, and the policy instruments required to deliver them at scale. In parallel, Greece must adapt its technical and administrative framework (notably the K.En.A.K. regulation- the main legislative instrument and technical framework for the transposition and implementation of the EPBD in Greece, the EPC ecosystem, and inspection/ monitoring practices) to support the emerging EU requirements on ZEBs, BRPs, the SRI, and strengthened databases for building performance (Papantonis, Stavrakas, Tzani, et al., 2025).

The experience of the two Greek FORTESIE pilots shows that the main barriers to achieving verified renovation outcomes are not primarily the availability of technologies, but the operational capacity to deliver complex renovation packages under real-world constraints. The museum pilot in Athens demonstrated how supply-chain failures, permitting uncertainty for PV grid connection, limited in-house capacity, and cost volatility can derail otherwise sound renovation plans, especially in small cultural institutions. The large public-building pilot (Ministry of Digital Governance complex) demonstrated that even when renovation technologies can be deployed at scale- meters, sensors, controls, EMS platforms, and PV systems- the critical path often shifts to procurement sequencing, bureaucratic permitting, and sustained coordination across public authorities. Together, these two realities illustrate Greece's central policy challenge: translating strategic intent into delivery systems that can absorb administrative complexity, reduce transaction costs, and convert upgrades into measurable energy and comfort outcomes.

Performance-based requirements, emerging Minimum Energy Performance Standards, and strategic planning

Greece's current renovation framework is still anchored in pre-recast EPBD instruments and therefore needs structured upgrading to support the new logic of MEPS and the ZEB transition. At present, Greece has not yet established a national definition of ZEBs and has not operationally identified "worst-performing buildings" beyond the EPC class scale itself. This matters because the recast EPBD requires Member States to define MEPS for non-residential buildings and establish a national trajectory for the progressive renovation of the residential stock, anchored in robust data and enforceable thresholds. In Greece, this intersects directly with two structural constraints highlighted by broader national work: limited interoperability across building-related datasets, and the absence of transparent, stable methodologies for renovation-rate estimation. Without a coherent data backbone linking EPCs, permits, technical system inspections, and building registries (including cadastre data), MEPS risk becoming an abstract requirement that cannot be fairly targeted or credibly enforced.

Energy Performance Certificates, inspections, and operational compliance

Greece's EPC system provides an important institutional foundation. The Ministry of Environment and Energy sets the legislative framework, while the Centre for Renewable Energy Sources (CRES) manages the inspectors' registry, the submission platform, and the national EPC database. EPCs are mandatory for new buildings, major renovations, sales and rentals, and for public buildings frequently visited by the public (with the threshold lowered to 250 m²). Heating and cooling system inspections also exist under the K.En.A.K. regulation, with reports uploaded via the same platform used for EPCs. However, the recast EPBD raises the bar by requiring full integration of inspection outputs into the national database for the energy performance of buildings and by strengthening the role of databases in national and EU reporting. Greece's current platform is described largely as statistical in nature and is not yet designed as a fully interoperable, building-level observatory capable of linking EPCs, inspections, BRPs, and emerging SRI information. The broader national gap analysis confirms that data accessibility and format constraints (including reliance on static reports and unstructured exports) further limit the operational reusability of data for targeting, verification, and programme optimisation.

Smart readiness, monitoring, and digitalisation

Greece is actively testing the SRI through ongoing pilots (2024-2025), supported by EU LIFE projects, with the prospect that the SRI could become mandatory for large non-residential buildings in the next phase of the EPBD implementation. The FORTESIE public-building pilot provides concrete proof-of-concept for why this matters: extensive metering, indoor-air-quality sensing, variable-frequency drives, supervisory control via an energy management platform, and on-site PV systems can create a strong basis for performance-based operation and verification. Yet the pilot also shows that digital capability is not merely a technical add-on; it depends on procurement readiness, stable installation sequencing, robust commissioning, and operational arrangements that ensure systems remain functional and used after installation. In the museum pilot, the stepwise integration from local monitoring (Raspberry Pi) into a central platform (Esthesis) demonstrated the value of secure, scalable data management, while also showing that small institutions often lack the staff capacity to treat monitoring and reporting as routine tasks without external support.

Energy efficiency obligations, public-building renovation, and financing instruments

Greece has embedded EE1st principles into national planning and implements an energy efficiency obligation scheme (EEOS) through CRES, complemented by alternative measures and a range of investment programmes. In the public sector, the policy direction is increasingly explicit: energy-saving targets for public bodies, annual renovation requirements (including the 3% floor-area upgrade objective), and dedicated financing tools such as the "ELECTRA[33]" programme (2020-2026) that supports envelope upgrades, HVAC interventions, EMSs, and automation, with targets such as at least class "B" and minimum 30% primary energy and emissions reduction. For households, programmes such as "Exoikonomo-Autonomo[34]" remain the backbone of renovation support, and their future design under the NBRP will be pivotal for aligning social fairness with MEPS-driven ambition. The pilots confirm, however, that financing alone does not guarantee delivery: administrative burden, permitting timelines, procurement fragility, and capacity constraints can delay or dilute outcomes even when funding and technical solutions exist (Spyridaki et al., 2020).

Renewable energy integration and grid-connection realities

Greece's NECP projects a strong rise in renewable energy shares, including in heating and cooling, supported by solar thermal, heat pumps, hybrid systems, and electrification. In principle, this aligns well with EPBD and RED directions. In practice, the Greek pilots show that renewable integration is often constrained by permitting and grid-connection processes rather than by feasibility. In the museum pilot, PV connection delays were driven by regulatory uncertainty for that building category at the time, requiring the project team to wait for updated rules before documentation could proceed. In the public-building pilot, PV installation was completed, but grid connection remained pending due to slow administrative steps involving multiple bodies. These two experiences converge on a clear national policy implication: if Greece wants PV and electrification to function as core decarbonisation levers for

[33] https://greece20.gov.gr/?calls=programma-ilektra-gia-tin-energeiaki-anavathmisi-dimosion-ktirion.

[34] https://exoikonomo2020.gov.gr/.

buildings, then permitting and grid-connection procedures must be designed as a predictable, time-bounded delivery process, not an open-ended administrative sequence (Stavrakas & Flamos, 2020).

Quality control, building-stock data, and national databases

Across broader national stakeholder consultations, Greece's building-stock data ecosystem is characterised by fragmentation, uneven digitisation, conditional access, and limited interoperability across key systems such as the EPC database, cadastre data, permit, and public-building inventories. Timeliness is a structural issue, with some foundational building-stock datasets updated at long intervals, while other datasets (such as HVAC inspection reports) are uploaded irregularly and only partially quality-checked. These constraints are not merely technical; they directly shape policy feasibility (Burbidge et al., 2021; Papantonis, Tzani, Burbidge, Stavrakas, Bouzarovski, Flamos, et al., 2022). A MEPS regime, a credible renovation trajectory, and an evidence-driven NBRP all depend on a national building performance data backbone that can identify priorities, track renovation depth, support verification, and enable fairness safeguards. The Greek case therefore requires a deliberate shift from "data available somewhere" to "data usable for governance", with defined standards, identifiers, access rules, and quality-control mechanisms.

Policy implications and strategic recommendations

The Greek pilots confirm a hard truth that the NBRP must treat as foundational: Greece's **binding constraints** are **delivery constraints**. Technologies exist; what fails is the chain that turns funding and regulation into **commissioned systems**, **functioning permits**, **connected PV**, **usable datasets**, and **sustained operation**. Pilot 1 exposed the fragility of small organisations facing procurement risk and grid-connection uncertainty; Pilot 5 showed that even where scale exists, outcomes hinge on **sequencing**, **commissioning discipline**, and **multi-agency coordination**. Greece's next step is therefore to make the NBRP a **delivery instrument**, not a planning document.

✓ **Build a national "delivery system" for renovations, not parallel programmes**

Greece's immediate priority under the NBRP should be to strengthen the "*delivery system*" that turns funding and regulation into completed, functioning renovations. The NBRP should therefore explicitly recognise delivery capacity as an *investment category*, establishing standard procedures, commissioning and handover protocols, and practical implementation support for both large public facilities and small institutions with limited in-house capacity. This shift will reduce the risk that ambitious targets remain declarative and improve the probability that renovated buildings actually achieve verified energy and comfort outcomes.

✓ **Position One-Stop Shops as implementation operators with delegated capacity, not only advisory points**

Greece should institutionalise and adequately resource OSS-based structures and services as operational intermediaries that actively guide projects through the *end-to-end renovation workflows*. In practice, this means OSS-based services should be mandated and funded to support procurement preparation (technical specifications, tender templates, supplier engagement), permitting navigation (including PV systems/ grid steps), digital documentation (EPC-related processes, building files), and the onboarding of M&V tools where relevant. Embedding OSS support as a standard component of existing programmes would reduce transaction costs and make implementation less dependent on informal networks and individual initiative.

✓ **Create a fast-track pathway for PV and small-scale RES systems permitting and grid connection**

Greece should treat PV and small-scale RES integration in buildings as a mainstream decarbonisation lever and *design permitting* and *grid-connection procedures* accordingly. A fast-track pathway should therefore standardise documentation requirements, clarify responsibilities across agencies, and set time-bounded administrative steps, with early initiation of permitting in parallel with technical design. This is especially important for public buildings and cultural institutions, where delays undermine project credibility and can leave assets stranded in a "*completed but not operational*" state.

✓ **Embed procurement resilience and market-volatility protections into programme rules**

Dependence on a single supplier for innovative components can trigger redesign, dimensional constraints, and major delays, while inflation and logistical costs can force scope reductions. Greece should translate this into procurement rules for publicly supported renovations that encourage multi-supplier strategies, early technical due diligence, and performance-based specifications that allow substitution without restarting design work. For small institutions and heritage-sensitive buildings programmes should allow *realistic time buffers* and *contingency provisions*, and they should promote supplier pre-qualification frameworks to reduce exposure to non-delivery and market volatility.

✓ **Upgrade the national building performance data backbone from "statistics" to governance-grade interoperability**

Greece should implement Article 22 of the EPBD as a practical enabler of MEPS and renovation delivery, *not merely as a reporting requirement*. The national evidence base currently suffers from fragmentation, conditional access, uneven digitisation, limited timeliness, and the absence of harmonised methodologies. The NBRP should therefore set out a *coherent interoperability pathway* linking EPCs, HVAC inspection reports, permit and renovation records, cadastre identifiers, and public-building inventories, supported by *standardised formats*, *metadata*, *quality-control routines*, and *clear access rules*. This is the minimum foundation needed for credible targeting, fair prioritisation, and robust monitoring of national renovation trajectories.

✓ **Make performance verification a programme design requirement for public and tertiary renovations**

Greece should mainstream digital M&V processes as part of quality assurance in publicly funded renovations, particularly in public and tertiary buildings where operational savings and comfort outcomes are central policy objectives. Commissioning, monitoring, and post-renovation optimisation should be treated as *standard deliverables*- proportionate to building size and complexity- rather than optional *"nice-to-have"* features. This will strengthen accountability, improve operational outcomes, and build the evidence base required for MEPS implementation and programme refinement.

✓ **Target capacity building to the actors that determine delivery on the ground**

Greece should align training and technical support with municipal technical services, public-building operators, and small organisations such as cultural institutions, because these actors frequently lack the specialised capacity to manage procurement, permitting, commissioning, and digital monitoring. The NBRP should therefore include structured training and practical support packages on permitting workflows (especially RES), digital documentation and data practices, commissioning, and M&V basics, and performance-based procurement. Coupled with OSS-led toolkits and escalation pathways, this would *reduce implementation delays*, *improve renovation quality*, and *expand the pool of actors* capable of delivering deep renovations consistently across regions.

Overall, Greece's core policy shift under the NBRP is to move from **funding-centric renovation** to **delivery-centric**, **verifiable renovation governance**. If Greece hardwires time-bounded PV/ grid pathways, procurement resilience and commissioning as completion conditions, OSS as operational intermediaries, and a governance-grade interoperable data backbone aligned with Article 22, then MEPS design, targeting, and verification become feasible, and the NBRP becomes credible, socially defensible, and implementable at scale.

5.1.3. Latvia

Latvia's pathway for decarbonising the building stock is anchored in its updated NECP and in an ongoing programme of legislative and administrative reform that aligns national practice with the evolving EU requirements. Buildings are positioned as a key demand-side sector where envelope upgrades, improved technical systems, and operational optimisation can deliver measurable energy savings while advancing broader climate and energy-security objectives. In this context, renovation policy increasingly needs to combine energy-performance ambition with implementation capacity, robust data systems, and attention to indoor environmental quality (IEQ), particularly in public buildings.

The Latvian FORTESIE pilot offers a highly policy-relevant signal for this transition. Even after comprehensive envelope renovation, the Riga school case demonstrates that performance gaps can persist when ventilation and operational control are not upgraded in parallel. This matters because it shifts the policy focus from "renovate more" to "renovate in an integrated, verifiable way": ensuring that renovation programmes systematically address the interaction between airtightness, ventilation performance, real occupancy patterns, and the ability of building operators to keep IEQ within acceptable ranges without creating avoidable energy penalties.

Transposition of the Energy Performance Buildings Directive and renovation planning

Latvia has built a clear institutional basis for implementing the EPBD through a dedicated national Law on the Energy Performance of Buildings, which establishes minimum performance requirements, certification, and inspection regimes. The Ministry of Economics holds primary responsibility for EPBD implementation and for developing the technical and administrative instruments needed for compliance. These arrangements provide the necessary governance backbone for the recast EPBD, including the forthcoming NBRP and the gradual strengthening of national renovation trajectories.

In practical terms, the NBRP will be the place where Latvia can translate high-level objectives into delivery rules that work for municipalities and public asset owners. The Riga school experience illustrates why this matters: renovation success is not only the selection of measures, but also the capacity to procure, commission, and operate integrated solutions- especially those related to ventilation and control- under real-world public-sector constraints.

Energy Performance Certificates, data infrastructure, and the route towards Minimum Energy Performance Standards

Latvia's digitally accessible registry of building energy certificates is an important asset. A searchable EPC infrastructure supports transparency, enables targeting inefficient assets, and can help track compliance and renovation progress over time. This creates favourable conditions for the next policy step under the recast EPBD: moving from certification as an information tool to certification and building data as an operational basis for enforcing renovation trajectories and, in due course, MEPS.

At present, Latvia's MEPS implementation is best understood as "under construction": preparatory work is advancing, but stock-wide, time-bound thresholds for worst-performing segments will depend on the NBRP and implementing decrees, as well as on the ability to connect EPC information to other datasets relevant for policy design and enforcement. The school pilot reinforces this point by showing that what matters for public trust and policy credibility is not only the presence of certificate data, but also the capacity to verify that renovations deliver the intended outcomes in operation- particularly where IEQ and health considerations are central.

Inspection regimes, renovation traceability, and interoperability

Latvia's EPC registry is a strong starting point, but MEPS-style governance will ultimately depend on whether EPCs can be operationally linked to "what changed in the building" and "how technical systems perform after renovation". In practice, this means strengthening renovation traceability (linking EPC issuance to permits and renovation records) and improving interoperability with datasets that matter for enforcement and quality assurance- such as technical-system information, commissioning/ hand-over documentation, and (where available) measured indicators relevant to ventilation and IEQ. Without these linkages, policy risks relying on certificates as a static snapshot rather than a governance tool that can identify worst-performing assets, target interventions, and verify that renovations deliver the intended outcomes- particularly in public buildings where health and learning conditions are central.

Indoor environmental quality, ventilation performance, and public-building outcomes

Latvia's policy agenda for buildings is increasingly shaped by the recognition that IEQ- especially adequate ventilation- cannot be treated as a secondary issue. The pilot confirms an implementation reality faced by many Member States: envelope renovations may reduce heat losses, but they can also amplify ventilation shortcomings if system upgrades, balancing, and controls do not keep pace. For educational buildings, this is not a marginal technical detail; it directly affects learning conditions, well-being, and the acceptability of renovation programmes among staff, pupils, and parents.

The FORTESIE intervention in Riga demonstrates a scalable pathway for addressing this challenge: modular, data-driven optimisation of heating and ventilation performance through targeted controls and sensor-based monitoring. The policy implication is that Latvia can accelerate progress even where large capital-intensive ventilation programmes are constrained, provided that national and municipal frameworks legitimise "system-level optimisation and verification" as eligible, fundable, and standardised renovation actions.

Smart readiness, monitoring, and operational control

Latvia's engagement in SRI pilots and early adopter projects provides an additional policy lever for strengthening "performance in use". The school pilot illustrates how sensing and control infrastructure can translate comfort and ventilation challenges into measurable, actionable operational variables. This aligns with the direction of EU policy, which increasingly expects Member States to ensure that renovated buildings do not simply meet paper targets, but operate as intended under real occupancy conditions.

A key policy message from Riga is that "smart readiness" for public buildings should not be interpreted narrowly as advanced digital features, but as a practical capability: the ability to observe, diagnose, and adjust building operation with minimal burden on school staff and without creating new administrative overheads for municipalities.

A proportionate verification module for schools under the National Building Renovation Plan

Pilot 7 indicated that Latvia does not need "maximum monitoring everywhere" to strengthen governance credibility; it needs a proportionate verification module that becomes routine in school renovations. Latvia can operationalise this through NBRP-linked guidance that defines: (i). minimum IEQ indicators to be checked (e.g., CO_2 exceedance frequency, temperature stability, humidity risk), (ii). minimum commissioning evidence (balancing confirmation, control strategy description, sensor placement checks), and (iii). a light reporting format that municipalities can submit without creating a parallel administrative burden. This would turn IEQ assurance from a pilot feature into a repeatable, auditable element of public renovation delivery.

Heating, cooling, and district energy integration

Latvia's decarbonisation trajectory relies strongly on modernising heating and cooling systems and, where relevant, leveraging efficient district heating solutions. In Riga, the school's connection to district heating shaped the technical approach of the pilot and underlines a broader policy point: public-building renovation should be designed to work with, not against, district energy systems. Hydraulic balancing, room-level control, and demand-responsive operation can reduce energy use while improving comfort, but they require procurement specifications, commissioning practices, and operator routines that are often underdeveloped in public-building programmes.

The school pilot, therefore, supports a policy direction where district heating optimisation, building-side controls, and IEQ performance are treated as part of one integrated public-service outcome rather than separate technical domains.

Policy implications and strategic recommendations

The Riga school pilot shows why Latvia's next policy step must be **integration-first**: envelope upgrades alone can unintentionally worsen indoor-air outcomes if ventilation, balancing, and operational control are not upgraded in parallel. Under the recast EPBD and the forthcoming NBRP, Latvia's credibility will depend not only on renovation volumes, but on whether publicly supported renovations **deliver verified comfort** and **IEQ outcomes** (especially in schools), while avoiding avoidable energy penalties. This requires programme rules that consider **procurement quality**, **commissioning**, **operator handover**, and **proportionate monitoring**, rather than treating them as optional "**extras**".

✓ **Make "healthy school ventilation" a dedicated national renovation outcome, not a side effect**

Latvia should treat ventilation performance and IEQ in educational buildings as a *core public-service* outcome- explicitly alongside energy savings. This means defining a school-specific pathway in the NBRP and in relevant funding rules, where ventilation adequacy, CO_2 control, and moisture risk management are part of the renovation objective, not a *residual concern after insulation*.

✓ **Standardise IEQ performance targets and a minimum monitoring package for publicly funded school renovations**

Monitoring should not be *"pilot-like"* or improvised. Latvia should standardise a *minimum IEQ measurement package* (temperature, relative humidity) and a clear reporting template for school renovations, with privacy-respecting aggregation and simple governance rules for municipalities and school operators.

✓ **Procure outcomes, not devices: Introduce standard technical specifications for school ventilation and control upgrades**

Municipal procurement is often the bottleneck for quality and speed. Latvia should publish *standard specifications* that focus on outcomes- ventilation effectiveness, controllability, stability- rather than brand-like prescriptions, and provide *"plug-in" procurement templates* that municipalities can reuse.

✓ **Make commissioning and operational handover non-negotiable in school projects**

School renovations succeed or fail in commissioning: balancing, control tuning, sensor placement, and operator routines determine whether IEQ improves without energy penalties. Latvia should require a *lightweight but mandatory commissioning* and *handover pack* for publicly funded school renovations.

✓ **Build municipal delivery capacity with school-specific technical assistance and escalation support**

Municipalities need practical capacity, not only guidance. Latvia should provide school-targeted technical assistance that includes design review support (ventilation/ condensation risk), commissioning troubleshooting, and rapid escalation when first deployments reveal problems.

✓ **Treat district heating interface as part of school renovation quality (balancing, controls, temperature optimisation)**

In cases where schools are connected to district heating, envelope and ventilation changes affect hydraulic balance and control stability. Latvia should *integrate building-side optimisation measures into renovation rules*, so district heating and school comfort outcomes reinforce each other.

✓ **Embed IEQ and renovation evidence into the national data backbone, proportionate to governance needs**

Latvia's EPC registry is a strong base, but schools require additional operational indicators to support prioritisation and credibility. Latvia should ensure *school renovation records connect EPC information with renovation measures* (what was done), system upgrades, and verified IEQ outcomes in a structured way, without overburdening municipalities.

✓ **Manage first-deployment risk through phased roll-out rules and supplier obligations**

Innovation adoption in public buildings fails when early operational problems overwhelm staff. Latvia should require *supplier support during the stabilisation period* and *allow phased deployment with buffering*, particularly when solutions are new to the school sector.

Overall, the FORTESIE pilot in Riga indicated that Latvia's next step under the NBRP is to make **healthy indoor environments** a **verifiable renovation outcome**, not an assumed co-benefit of envelope upgrades. If Latvia hardwires **IEQ targets**, **outcome-based procurement templates**, **mandatory commissioning** and **handover**, and a **proportionate monitoring/ verification module** into municipal renovation practices- while linking these records to the EPC backbone- then school renovations can systematically deliver **measurable comfort** and **air-quality improvements** alongside **durable energy savings** strengthening public trust and enabling future MEPS-style governance without creating excessive administrative burden.

5.1.4. Real policy uptake during FORTESIE: Guidelines for sustainable ventilation systems in Latvia

To promote the integration of sustainable ventilation system solutions in building renovation projects, the **Ministry** of "**Climate and Energy**" in Latvia has developed the **guidelines** "***Solutions for sustainable ventilation systems to promote energy efficiency in buildings***".

These guidelines have been officially published on the Latvian Ministry's website, representing a concrete and **high-level** example of **policy uptake** and **institutional endorsement** at national level. As such, they constitute a key exploitable result of FORTESIE, clearly demonstrating how project findings and particularly those derived from pilot implementation, can be translated into **actionable public guidance**.

The guidelines are designed to support: (i). policy planners shaping energy-efficiency programmes, and (ii). building owners and project promoters selecting and justifying ventilation solutions throughout the renovation process. Developed in synergy with FORTESIE pilot experience, they reinforce a core message that also emerged across demonstrations: "**energy performance upgrades that focus only on envelope insulation**, **without an equivalent focus on ventilation and indoor air quality**, **risk creating a** "**renovation paradox**", i.e., **lower heating demand but degraded indoor conditions and reduced public acceptance**".

The following section presents a concise summary of the key findings, lessons learnt, and recommendations, while the full set of policy recommendations is available in the official Ministry publication.

Key lessons learnt

- **Building renovations and microclimate**

Latvia's building renovation practice has historically prioritised insulation and reductions in heating demand, often with less systematic attention to post-renovation microclimate and indoor air quality. FORTESIE pilot evidence across different building functions reinforces that renovation design must assess not only thermal resistance but also **microclimate performance based on use** (e.g., schools, museums, pools). In public buildings with high occupancy or humidity loads, improving envelope performance without adequate mechanical ventilation does not ensure acceptable indoor conditions. Energy-efficiency measures therefore need to be planned as a **combined solution**, where ventilation is treated as a core renovation element.

- **Indoor air quality and human health**

Indoor air quality is directly linked to health, well-being, and cognitive performance. Across Member States, indoor CO_2 thresholds around 1,000 ppm are commonly used as a reference for acceptable conditions, while sustained exceedances (e.g., above ~1,500 ppm) indicate the need for timely corrective action. The COVID-19 period amplified awareness, but the relevance remains structural for everyday building operations, particularly in schools and other public buildings.

- **Technical solutions and operational performance**

Ventilation system selection must reflect building age and technical feasibility, especially where mechanical ventilation was not included in the original design and retrofit integration is therefore more complex. **Mechanical ventilation with heat recovery** can safeguard air quality while limiting heating penalties; the energy benefit depends strongly on design and operation and can vary widely by context.

The technical evidence highlights that the largest savings and best indoor conditions are achieved when ventilation is **demand-driven** and heat recovery performance is high. Experience from project partner **SIA** "**MESH**" further indicates that decentralised ventilation can be effective in public buildings where previous renovations did not address ventilation. However, performance depends on correct installation, regular maintenance, and monitoring of operating parameters. Critically, **switching off** ventilation is **not** an **energy-efficiency strategy** in public buildings, because it externalises costs into health, comfort, and building-quality risks.

- **Financial instruments and financing realities**

Expanding ventilation uptake may require a broader set of support instruments, including options that are less market-distorting than direct subsidies. While ESCO models can finance certain energy-efficiency measures, ventilation can be less attractive in standard ESCO logic because savings and payback are more sensitive to operational conditions and the system may increase electricity use even as it improves overall performance and health outcomes. This implies the need for **expanded contract models** that recognise indoor air quality as a managed service outcome (not only "kWh saved").

Policy implications and strategic recommendations

✓ **Implementation and operation**

Regulatory frameworks must treat ventilation as a **co-equal pillar** of efficiency: increasing thermal resistance without mechanical ventilation can worsen indoor air quality even if heating demand drops.

Ventilation systems should prioritise heat recovery to prevent avoidable heating penalties while safeguarding air quality. Regular maintenance should be ensured (balancing, filter replacement, and monitoring of operating parameters). CO_2 monitoring is recommended as a practical indicator to verify air quality and support operation. Demand-driven solutions (e.g., **variable air volume- VAV**) enable good microclimate with lower energy use.

✓ **Integrating ventilation requirements into support programmes**

Energy-efficiency support programmes should include **minimum indoor air quality requirements** in renovated buildings. This prevents the renovation paradox and ensures that public funds do not incentivise interventions that improve envelope performance while degrading indoor conditions.

✓ **A wider range of support instruments**

Tax incentives, preferential loans for full renovations, and other financial instruments specifically supporting ventilation should be evaluated, alongside targeted support where needed.

✓ **Expansion of the Energy Service Company model**

Where ESCO models are used, contracts should address not only energy savings but also a requirement to **avoid deterioration**- or **deliver improvements**- in indoor air quality, including provisions for maintenance, operability, and optimisation of ventilation operating costs. Because ventilation benefits are not always captured as direct energy savings, **hybrid contracts** and broader "*comfort/ health + energy*" performance models may be needed.

✓ **Improving regulatory requirements**

Indoor air quality requirements should reflect building functions and loads (e.g., hospitals, schools, offices). Uniform requirements can drive unnecessary airflow, higher costs, and heat losses. Demand-driven ventilation approaches (including VAV) should be explicitly enabled in regulatory acts, since public-building occupancy varies significantly throughout the day.

✓ Increasing public awareness

Public awareness and information measures are needed to communicate the health and cognitive benefits of adequate indoor air quality and to support acceptance of ventilation investments.

✓ Implementation of carbon dioxide monitoring in public buildings

Continuous monitoring of CO_2 levels, coupled with appropriate transparency and governance, supports early detection of operational issues and improves building performance management over time.

5.1.5. Poland

Energy transition in Poland's buildings sector is being shaped by an evolving NECP process and by a policy mix that must reconcile three very Polish realities: a large and heterogeneous building stock with deep retrofit needs; the central role of district heating in many towns and cities; and an accelerating push- driven by EU legislation, funding streams, and market pressure- towards deeper renovations, renewables integration, and smarter operation of technical systems. In this context, "buildings policy" cannot be treated as a stand-alone envelope agenda: it is tightly coupled to heat-sector reform, municipal delivery capacity, and the ability to plan, procure, and verify complex renovations under public-sector constraints.

The FORTESIE pilot in Poland is particularly instructive because it sits at the intersection of energy, safety, and asset integrity. In high-humidity facilities, ventilation effectiveness and moisture control are not comfort upgrades; they determine condensation risk, corrosion, material degradation, and ultimately whether the building remains safe and serviceable. The pilot evidence is clear: the key bottlenecks are rarely "missing technology." They are delivery bottlenecks- public approval cycles, procurement design, cost volatility, construction downtime planning, commissioning discipline, and performance verification practices. These are the conditions that decide whether modernisation yields durable outcomes or simply installs new equipment without resolving the underlying operational risk.

National Building Renovation Plan delivery rules for complex tertiary facilities

Under the recast EPBD cycle and the forthcoming NBRP, Poland's practical challenge is to ensure that complex tertiary renovations- especially in municipal facilities with high ventilation and moisture loads- are governed through delivery rules, not treated as exceptional one-off projects. These facilities require an implementation logic that combines technical design with enforceable procurement specifications, commissioning and hand-over obligations, and post-renovation verification in operation. Pilot 6 indicated that without this "delivery architecture", public projects remain vulnerable to approval delays, scope cuts under cost pressure, and performance drift after installation- outcomes that undermine both energy savings and asset integrity.

Performance-based requirements and Minimum Energy Performance Standards

Poland's regulatory framework already places strong emphasis on minimum requirements and technical compliance, with EPCs serving as a core market and governance instrument. EPCs ("*świadectwa charakterystyki energetycznej*[35]") are embedded in transactions and compliance practice and are supported by a national digital register that also includes, among others, public listings of authorised

[35] https://pewnylokal.pl/swiadectwo-energetyczne?utm_campaign=pl-swiadectwa-energetyczne-ogolna-desktop&utm_medium=paid&utm_source=adwords&utm_term=%C5%9Bwiadectwa%20charakterystyki%20energetycznej&gad_source=1&gad_campaignid=22291519105&gbraid=0AAAAADGTIekVF6rg0lesqvLd5nHIDY-oA&gclid=EAIaIQobChMIxNHM4cb5kgMVk6SDBx37xhgxEAAYASAAEgIZH_D_BwE.

experts and certificate records- an important foundation for scaling policy targeting and quality assurance.

With the EPBD recast, the role of EPCs shifts from "information and compliance" towards becoming an operational backbone for renovation trajectories and, progressively, for MEPS. For Poland, the critical implementation question is not whether MEPS will exist, but how they will be differentiated and sequenced across building typologies and heating contexts, including the interaction between building-level improvements and district-heating decarbonisation. In specialised facilities (e.g., pools), MEPS-like trajectories must explicitly account for technical-system performance (ventilation effectiveness, humidity control, heat recovery, control stability), not only envelope parameters.

Regulation for tertiary and public buildings

Public and municipal buildings sit at the centre of Poland's renovation delivery challenge: they combine high energy-use intensity, strong service obligations to citizens, and decision-making processes that are structurally slower than private-sector projects. The pilot illustrates how public-sector approvals, council voting cycles, and formal documentation protocols can become the primary determinant of project timelines- even when technical solutions are clear and financing exists. In this context, compliance frameworks and funding programmes must be designed around real delivery workflows: preparation, procurement, installation, commissioning, and post-works operation- rather than treating "renovation" as a single event.

Smart readiness, monitoring, and digitalisation

Digitalisation is increasingly important for Polish renovation governance because it enables performance verification, operational optimisation, and accountability- especially in buildings with complex technical systems. For specialised facilities, static compliance checks are insufficient: humidity control, air-change effectiveness, and system stability must be evidenced in operation. The pilot's monitoring and sensor deployment demonstrates the practicality of integrating continuous data streams to support commissioning, fault detection, and evidence-based operation, and it provides a replicable model for public-sector renovation quality assurance.

Energy-saving obligations and incentive mechanisms

Poland combines regulatory instruments with large-scale funding and support mechanisms for building upgrades, including programmes that target residential heating-system replacement and retrofit measures. These instruments matter for public buildings as well, because they shape market capacity, supply chains, contractor availability, and the overall "renovation ecosystem" that municipalities draw upon. The strategic requirement for the coming EPBD cycle is to ensure that funding architecture rewards comprehensive, performance-driven renovations- particularly in complex facilities- rather than encouraging fragmented upgrades that fail to resolve system-level shortcomings.

Renewable energy, heating and cooling, and district systems

Poland's strong district-heating footprint creates both an opportunity and a constraint. On the one hand, network modernisation and heat-source decarbonisation can deliver large-scale emissions reductions; on the other, building-level renovations must be designed to unlock demand-side efficiency and controllability (metering, balancing, control integration, temperature optimisation) so that district systems can operate efficiently and decarbonise cost-effectively. The pilot's integration of PV and upgraded metering illustrates how public buildings can also contribute to local renewable generation and improved energy accounting- provided that grid connection, procurement, and commissioning are treated as first-order delivery tasks rather than administrative afterthoughts.

Quality control, data transparency, and national databases

Poland's national certificate and expert registers provide a strong institutional base for improving transparency and targeting. The policy priority now is to use these data foundations to support (i). credible identification of worst-performing segments, (ii). better calibration of renovation pathways, and (iii). systematic post-renovation verification- particularly in public buildings where public value, user safety, and long-term asset integrity are at stake. The pilot demonstrates that without operational verification, technically "completed" renovations can still underperform or fail to address the core risk drivers (e.g., persistent high humidity).

Operational evidence beyond Energy Performance Certificates for "system-critical" facilities

For "system-critical" municipal facilities, EPC-based compliance signals are necessary but not sufficient. Moisture risk, ventilation effectiveness, and control stability are performance determinants that must be evidenced in operation, at least during commissioning and the stabilisation period. Poland can strengthen renovation governance by defining minimum operational evidence set for these facilities- covering commissioning results, control strategy confirmation, and measured humidity/ ventilation indicators over a defined period- stored in a structured form that can be linked to building records and programme reporting. This shifts the accountability frame from "equipment installed" to "risk removed and outcomes verified".

Policy implications and strategic recommendations

The Polish pilot reinforces a central point for the forthcoming NBRP and EPBD recast implementation: in **complex tertiary** and **municipal facilities**, renovation success depends less on *"what technologies exist"* and more on whether public authorities can **procure**, **sequence**, **commission**, and **verify** integrated building-service upgrades under real constraints (public approval cycles, procurement rules, inflation volatility, downtime, and operator capacity). This matters especially for **high-humidity buildings** (pools, leisure centres, sports facilities), where ventilation effectiveness and moisture control are not comfort enhancements but **asset-integrity** and **safety conditions**. Poland's opportunity is therefore to treat these facilities as a distinct governance case and to turn procurement, budgeting, commissioning, and M&V into **enforceable delivery standards**, rather than project-by-project improvisation.

✓ **Define "system-critical" municipal facilities as a distinct class in national renovation governance**

Poland should explicitly recognise "system-critical" municipal facilities and other high-humidity/ high-ventilation-demand facilities as a *separate class under national guidance* and *funding rules*, because their risk profile and performance determinants differ from offices or schools.

✓ **Shift public procurement from "lowest-risk paperwork" to "performance-assured service delivery"**

Tender design can either attract competent bidders or produce failures/ redesign cycles. Poland should *mainstream procurement approaches* that match the complexity of integrated HVAC-controls-renewables upgrades.

✓ **Make inflation-resilient budgeting and contingency governance mandatory for complex municipal renovations**

Cost volatility is structural in long-cycle public renovations with specialised equipment. Public programmes and municipal rules should *require explicit contingencies*, *inflation-adjusted baselines*, and *flexible reallocation mechanisms* that can be activated without restarting approvals. This will protect system integrity and reduce the likelihood of scope cuts that undermine operational safety.

✓ **Treat administrative throughput as a design parameter: Time-bounded approvals and parallelised workflows**

Public approval cycles will remain slow unless they are managed as part of the renovation delivery system. Programme guidance can require milestone-based administrative pathways, parallel processing of design and approvals, and clear accountability for continuous follow-up across decision layers. Making administrative throughput a design parameter is essential for predictable delivery at scale.

✓ **Institutionalise downtime and continuity planning as an eligibility condition for municipal facilities**

For facilities that require temporary closure, programme rules should require an *operational closure plan* that accounts for seasonal use, construction efficiency, weather constraints, and supply-chain lead times. This reduces disruption, preserves public trust, and prevents rushed commissioning driven by reopening pressure.

✓ **Mainstream risk-based digital M&V as a quality-assurance norm in public buildings**

Poland should scale monitoring requirements in a risk-based way: start with the most complex public facilities, specifying minimum sensor sets, metering integration, data retention, and oversight roles. The objective is not *"data for its own sake"*, but operational accountability and durable performance.

✓ **Integrate building renovations with district-heating controllability upgrades and tariff-relevant metering**

Where district heating is dominant, renovation programmes should explicitly require or incentivise building-side measures that *enable network efficiency and decarbonisation*: balancing, metering/ sub-metering, control upgrades, temperature optimisation, and interoperability with modernised substations. This will ensure that building upgrades and network transition reinforce each other rather than operating in parallel.

✓ **Strengthen operator capacity: Treat facility management competence as part of renovation performance**

Complex facilities need operator competence as well as contractor competence. T*argeted training for municipal technical teams and facility managers*- covering commissioning, setpoint strategies, humidity/ ventilation management, and interpretation of monitoring outputs- can materially improve long-term outcomes and reduce performance drift.

Overall, the Polish pilot showed that in "**system-critical**" **municipal facilities**, the success of EPBD implementation will be decided less by policy intent and more by whether Poland can operationalise **performance-assured delivery**: procurement that specifies outcomes, budgeting that withstands volatility, commissioning that is non-negotiable, and verification that demonstrates real reductions in humidity-related risk and energy use. If the NBRP treats these facilities as a distinct class and requires a minimum operational evidence set linked to national building records, Poland can translate renovation spending into **verifiable savings**, **safer** and **more resilient public assets**, and **credible compliance pathways** towards a decarbonised building stock by 2050.

5.1.6. Portugal

Decarbonisation in Portugal's buildings sector is advancing through an increasingly integrated policy architecture that combines long-term renovation objectives, energy-efficiency programmes, and accelerated deployment of renewables. The updated NECP provides the strategic frame for 2021-2030, aligning building renovations with national energy-savings targets, renewable-energy shares, and wider climate goals. At the regulatory level, Portugal has progressively transposed the EPBD through national law and technical regulation, including Decree-Law No. 101-D/2020, which establishes core requirements for energy performance in new buildings and renovations and sets minimum technical criteria for interventions.

A central pillar of implementation is the national building certification system, the "Sistema de Certificação Energética (SCE)[36]", delivered through a dedicated digital portal and operationally managed by ADENE (Agência para a Energia) on behalf of the competent public authorities. In practical terms, the SCE provides the evidence base for identifying low-performing buildings, targeting incentives, and tracking progress over time. As Portugal transitions to the recast EPBD framework, this institutional and data infrastructure becomes even more central: the forthcoming NBRP will need to convert strategic targets into enforceable trajectories, credible monitoring, and delivery arrangements that work across very different building contexts and social realities.

The FORTESIE pilots in Portugal make this dual reality visible. Portugal has demonstrated strong capacity for socially targeted renovation action, particularly for households facing severe housing deprivation and energy poverty. At the same time, scaling data-enabled renovation governance across dispersed territories- and across very different citizen profiles, from vulnerable elderly residents to highly engaged prosumers- requires policy design that treats delivery capacity, monitoring feasibility, and administrative accessibility as first-order determinants of success, rather than secondary implementation details.

National Building Renovation Plan and renovation delivery under the recast Energy Performance of Buildings Directive

Portugal is preparing its NBRP to comply with the revised EPBD timetable and to operationalise the national LTRS through clearer trajectories, investment needs, and policy measures aligned with the NECP. For Portugal, the strategic challenge is less about defining ambition than about ensuring that the NBRP functions as an implementable delivery instrument across diverse contexts: metropolitan areas with rapid housing pressures, rural and low-density regions with ageing populations and limited contractor availability, and heterogeneous building typologies where "standard" renovation packages are not always feasible. The "SCE" database and ongoing public and private renovation programmes provide a strong foundation, but the NBRP will need to explicitly address the practical barriers revealed by field implementation- especially for vulnerable households and geographically dispersed dwellings.

Performance-based requirements and Minimum Energy Performance Standards

Portugal's approach has primarily strengthened its certification and incentive ecosystem rather than introducing immediate stock-wide MEPS as legally binding thresholds. The SCE offers the technical foundation for identifying low-performing segments and for designing progressive renovation trajectories differentiated by climate zone, building typology, and social conditions. Under the recast EPBD, however, Portugal will ultimately need to translate this evidence base into clearer compliance

[36] https://www.ordemdosengenheiros.pt/pt/noticias/sistema-de-certificacao-energetica-11107/.

timelines, enforceable pathways, and safeguard mechanisms- particularly to ensure that MEPS implementation does not create exclusion risks for low-income households or for owners in areas facing higher renovation costs and weaker supply chains. A calibrated MEPS approach is therefore credible for Portugal, but only if it is paired with a delivery model that can reliably mobilise renovations, ensure quality, and verify outcomes.

From nearly Zero-Energy Buildings to Zero-Emission Buildings and upgrading of technical standards

Portugal's regulatory framework has already incorporated nearly Zero-Energy Building (nZEB) requirements, but the transition towards the ZEB paradigm will require further technical and legal updates, including stricter limits on energy demand and stronger integration of renewable energy in building operation. This shift is not only a matter of tightening minimum performance requirements; it also requires practical enabling conditions- particularly for older dwellings and heritage-sensitive contexts where deep retrofits must be balanced with structural and conservation constraints. Portugal's pathway is therefore likely to depend on staged compliance and differentiated routes, coupled with technical assistance, and financing instruments that preserve feasibility in complex cases while still progressing towards full decarbonisation.

Certification systems, inspection regimes, and national data infrastructure

Portugal's SCE functions as the backbone of energy-performance evidence and is essential for monitoring renovation progress and informing policy targeting. As the NBRP evolves, the strategic direction should be towards consolidating building-performance records and strengthening interoperability, so that certificates, renovation actions, and, where feasible, monitoring data can jointly support credible reporting and practical enforcement. The pilots highlight that policy credibility depends not only on how many renovations are supported, but on whether outcomes can be demonstrated consistently in real buildings, especially where baseline data are weak or where technical upgrades are difficult to verify through conventional channels alone.

Renewable energy deployment in buildings and the enabling role of permitting

Portugal's NECP and related measures support the rapid deployment of solar PV systems and the expansion of low-carbon heating solutions such as heat pumps. Administrative reforms aimed at simplifying licensing and grid-connection procedures reflect the recognition that permitting speed and predictability are critical to scaling decentralised generation and self-consumption. In the buildings sector, the key policy point is integration: renewable deployment works best when it is treated as part of renovation delivery- aligned with procurement, sequencing, and verification- rather than as a parallel process dependent on a single partner or separate administrative workflows.

Smart readiness and digitalisation

Portugal is exploring smart-building metrics and SRI-related approaches, but widespread deployment remains at an earlier stage. The Portuguese pilots demonstrated both the value and the limits of digitalisation under real-world conditions. In prosumer households, engagement can be high, yet monitoring reliability can still be undermined by connectivity constraints, device performance, and variable digital literacy. In vulnerable, energy-poor households- often elderly, remote, and without stable internet- monitoring and data collection can fail if systems are not designed for low-maintenance operation and for analogue-compatible support. The core lesson for policy is direct: *digitalisation must be feasible by design, not assumed by default*.

Policy implications and strategic recommendations

Portugal's NBRP is a pivotal window to convert a strong *social renovation* orientation into a **delivery-grade national system** that performs under real constraints: dispersed territories (including low-density interior areas and islands), uneven contractor capacity, low digital literacy among vulnerable groups, and connectivity limitations that weaken monitoring and verification. The Portuguese pilots showed that binding constraints are often **not the existence of funding**, but the operational conditions that convert funding into **completed renovations with verified outcomes**: administrative accessibility, procurement reliability, capacity to manage degraded dwellings, and proportionate M&V approaches that work when digital infrastructure is weak. Under the recast EPBD, this becomes decisive: MEPS trajectories and renovation passports will only remain socially legitimate if Portugal can demonstrate that compliance is **feasible**, **fair**, and **verifiable** precisely for the households that are hardest to reach.

✓ **A dedicated "rural, low-density and vulnerable households" pathway within the National Building Renovation Plan**

The NBRP should explicitly include a *differentiated renovation pathway for low-density territories and vulnerable households*, with sequencing logic, realistic timelines, and minimum packages that recognise a recurring reality: *habitability and structural remediation often precede energy upgrades*. Without this pathway, programme design defaults to *"standard renovations"* that systematically disadvantage households facing severe deprivation.

✓ **One-Stop Shops as empowered delivery agents with delegated administrative capacity**

Portugal should institutionalise OSS-based structures as *implementation intermediaries*, not only as advisory points, but also as actors able to carry documentation, coordinate contractors, interface with SCE/ ADENE procedures, and sustain follow-up across dispersed territories. OSS-based services should be resourced- and where appropriate, authorised with consent safeguards- to act *"on behalf of"* beneficiaries, including mobile support in remote areas and structured liaison with utilities, certification processes, and local service providers.

✓ **Administrative accessibility as a compliance condition, not a social add-on**

"Analogue-compatible by default" should *become an explicit programme requirement*: every digitally delivered scheme should provide a parallel low-barrier route, including paper-compatible documentation, in-person assistance, and delegated handling options for those who need it. Treating accessibility as a design condition is also a safeguard for MEPS legitimacy: it reduces inequitable outcomes and demonstrates that compliance obligations are *matched by practical support*.

✓ **Procurement, supply-chain, and partner resilience as programme design**

Portugal should treat procurement reliability as a *policy lever*, not a contractor problem. For recurring bottlenecks, framework procurement, pre-approved catalogues, and regional procurement pools can stabilise lead times and reduce repeated tendering- particularly important in dispersed programmes where one delayed component can stall an entire sequence. The same resilience principle should apply to PV, grid-connection processing, and certification-related services. *Designing for redundancy* reduces systemic fragility and prevents partially completed renovations that never reach their intended performance state.

✓ **Fast-track decisions and contingency governance for degraded dwellings**

For structurally degraded homes, programmes should formalise two linked mechanisms as standard features: (i). *higher contingency envelopes*, and (ii). a *fast-track decision route* for essential additional interventions discovered once renovations begin. Without fast-track governance, projects either pause for approvals (delays) or cut scope (safety and quality risks). A delivery-grade protocol should specify decision authority, evidence requirements, time limits, and eligible cost coverage, so that renovations can proceed without *administrative standstill* while *maintaining accountability*.

✓ **Minimum delivery standards, commissioning, and post-renovation quality assurance for vulnerable housing**

Portugal's next phase should shift from *"eligibility compliance"* towards outcomes that persist- especially where health, safety, and durability are core goals. Minimum delivery standards for moisture management, ventilation adequacy, thermal comfort, and basic electrical/ structural safety can be operationalised through standard commissioning checklists, minimum documentation of installed measures, and proportionate post-renovation verification. This will ensure that social renovation programmes deliver *durable improvements* rather than short-lived repairs.

✓ **Tiered monitoring and verification that matches connectivity and maintenance realities**

Portugal should adopt a *tiered M&V architecture* that reflects where continuous monitoring is feasible and where it is not. In digitally connected prosumer homes, continuous monitoring can support feedback loops and performance benchmarking, while in remote and vulnerable households, monitoring must be low-maintenance by design, preceded by early connectivity checks, and supported by hybrid options. The policy objective is not *"maximum data everywhere"*, but reliable verification proportional to context, so NBRP monitoring obligations remain workable in low-density territories.

✓ **Resilience rules for renewables integration and certification services**

Programme rules should explicitly allow *substitute certified installers*, *alternative procurement channels*, and *practical sequencing options*. Designing for redundancy reduces systemic fragility and prevents partially completed renovations that never reach their intended performance state.

✓ **Workforce and delivery capacity aligned with the geography of need**

Portugal should align workforce measures with where renovations must happen, not only where markets are already mature. *Targeted training pipelines*, *partnerships with vocational centres*, and *regional contractor mobilisation mechanisms* should be explicitly connected to NBRP targets, so renovation trajectories do not become *urban-centric by default*. Where civic or volunteer-based delivery models exist, policy can strengthen them through regional coordination and quality assurance rather than relying on them informally.

✓ **Managed delivery models for energy-poverty renovations as a public-value service**

Energy-poverty renovations often behave more like a public service than a standard market transaction. Programmes should therefore enable *managed delivery options* in which accredited intermediaries (OSSs, NGOs, municipal consortia) can bundle works, coordinate contractors, ensure follow-through, and maintain accountability. This will reduce transaction costs, improve quality, and make the system scalable across dispersed territories while *strengthening social legitimacy*.

Overall, the Portuguese pilots indicate that the core policy shift required under the NBRP is to move from programme availability to **delivery reliability**: renovation governance that is socially accessible, procurement-resilient, proportionately verifiable, and operationally feasible across dispersed territories. By empowering OSS-based intermediation, embedding analogue-compatible access routes, stabilising procurement and partner ecosystems, strengthening commissioning and minimum delivery standards, and building an interoperable performance data backbone around the SCE, Portugal can translate EPBD ambition into **verified outcomes**- measurable energy savings, improved comfort and health, and a credible, equitable pathway towards a decarbonised buildings sector by 2050.

5.1.7. Spain

Spain has put in place a broad and increasingly coherent policy architecture for achieving decarbonisation in the buildings sector, anchored in the updated NECP, the LTRS, and the forthcoming NBRP under the recast EPBD. The strategic direction is clear: accelerate deep renovations, strengthen electrification and the integration of renewables, and build a monitoring and data backbone capable of supporting MEPSs, renovation trajectories, and credible reporting through harmonised indicators. What makes Spain distinctive is not a lack of ambition, but the combination of strong climatic diversity and decentralised implementation. Key operational responsibilities sit with Spain's Autonomous Communities ("Comunidades Autónomas")- the country's regional governments- and with municipalities. This can be an advantage because delivery is close to local realities, building typologies, and climate conditions. It is also a structural challenge: national targets only become real if permitting capacity, delivery workflows, and data interoperability function reliably across territories, in a way that remains comparable, fair, and enforceable.

The FORTESIE pilots illustrate this implementation reality from two complementary angles. Pilot 2a (Building Blocks in Asturias, Spain) showed how deep renovations in multi-residential buildings can be slowed- or forced to change course- by administrative eligibility constraints, municipal permitting capacity, and residents' willingness to participate in monitoring, even when the technical renovation scope is relatively standard (envelope upgrades, window replacements, PV integration). Pilot 2c demonstrated the value of mature digital infrastructures for long-term performance assessment and optimisation after renovation but also confirmed that engagement and trust- particularly in predominantly elderly communities- remain prerequisites for data-enabled governance. Taken together, the pilots pointed to a central policy lesson: Spain's next leap will come less from adding new instruments, and more from strengthening the delivery and data ecosystems that make existing instruments enforceable, fair, and verifiable at scale.

National Building Renovation Plan and multilevel implementation under the recast Energy Performance of Buildings Directive

Spain's NBRP is being prepared by the Ministry of Housing and Urban Agenda (MIVAU), coordinated with the Ministry for Ecological Transition and the Demographic Challenge (MITERD), with technical support from the Institute for the Diversification and Saving of Energy (IDAE) and the Eduardo Torroja Institute for Construction Sciences (IETCC) of the Spanish National Research Council (CSIC). A draft was published at the end of 2025, and the final plan is expected by the end of 2026. The NBRP is designed to supersede and operationalise the LTRS through clearer trajectories, investment needs, and policy measures aligned with the NECP, covering the entire building stock (residential and non-residential, public and private).

For Spain, the decisive implementation question is how the NBRP will cascade into a consistent, workable delivery system across regions, municipalities, and building types. Administrative bottlenecks, uneven local capacity, and fragmented datasets are not marginal issues; they are the structural conditions that will determine whether renovation trajectories can be enforced fairly and whether reported progress reflects real renovation outcomes.

Performance-based requirements and Minimum Energy Performance Standards

Spain is preparing MEPS for non-residential buildings and a mean energy performance trajectory for the residential stock. The policy intent is to design a data-driven MEPS framework anchored in the EPC system and building-stock data, while explicitly accounting for climate-zone diversity and end-use specificities. This is crucial: Spain's range of climates- from Atlantic to Mediterranean and continental- means that "worst-performing" cannot be identified credibly through simple national rankings without risking inequitable burden sharing.

Spain's parallel effort to revise and rescale the EPC framework and to develop a central digital registry tracking certificates and renovation actions is therefore strategically sound: a climate-sensitive MEPS regime requires a performance evidence base that is comparable across regions, transparent in method, and sufficiently granular to distinguish structural inefficiency from climate-driven demand. The remaining challenge is practical and immediate: the evidence base must become fit for enforcement and social legitimacy by capturing renovation activity, renovation depth, and compliance pathways in a structured and interoperable way.

Regulation for public buildings and the Energy Efficiency First principle

Spain has embedded the EE1st principle in national legislation and applies it through planning, taxation, and renovation aid programmes, notably under the Recovery, Transformation, and Resilience Plan (PRTR). Public buildings are subject to an obligation to renovate at least 3% of floor area annually, targeting nZEB or ZEB levels depending on feasibility and regulatory timing, with coordination mechanisms envisaged to integrate national, regional, and local inventories into a consolidated database.

This is precisely where governance capacity becomes decisive. If permitting and procurement pipelines differ sharply across administrations, the 3% obligation risks becoming a compliance-reporting exercise rather than a predictable delivery engine. The pilots reinforce that public-sector capacity constraints- especially at municipal level- can become the binding factor even when funding and technical solutions exist.

From nearly Zero-Energy Buildings to Zero-Emission Buildings and upgrades to technical standards

Spain's current building code (CTE, including the "DB-HE" regulation) addresses nZEB requirements, but the recast EPBD upgrades the policy horizon towards ZEBs. MIVAU and MITERD, supported by IDAE and IETCC-CSIC, are preparing the national definition and the technical requirements that will be integrated into the next revision of the "CTE". This revision is expected to strengthen minimum renewable-energy contributions, smart control provisions, and broader performance requirements, complemented by adjustments in the "Reglamento de Instalaciones Térmicas en los Edificios (RITE)" mandatory regulation on thermal insulations and HVAC systems in buildings.

The EPBD timeline implies ZEB requirements for new public buildings by 2028 and new private buildings by 2030, while major renovations must reach cost-optimal performance levels and, where feasible, approach ZEB-compatible outcomes. For Spain, the enabling condition is not only technical guidance, but workable compliance pathways for multi-family buildings with fragmented property rights and for heritage-sensitive contexts, where decision-making structures and administrative sequencing are often the real constraint.

Energy Performance Certificates, Building Renovation Passports, and inspection regimes

Spain's EPC framework is regulated by Royal Decree 390/2021. MITERD and MIVAU hold national responsibility for the legislative framework, while Spain's autonomous communities maintain EPC registries, implement inspections, and oversee quality control. EPCs are mandatory for new buildings, major renovations, buildings sold or rented, and non-residential buildings above defined thresholds, with enforcement supported through market actors such as notaries and rental platforms. Experts must hold recognised qualifications and use officially recognised calculation tools aligned with published methodologies and "European Committee for Standardisation (CEN)" standards, relying primarily on standardised profiles and on-site inspections rather than recorded energy data.

BRPs are not yet implemented but are expected to be integrated with the EPC framework, since EPCs already include improvement measures and staged recommendations. Inspections for HVAC systems are governed under the "RITE" regulation (Royal Decree 1027/2007) and managed largely at regional level; Spain currently lacks a unified national database that consolidates inspection information. This fragmentation becomes increasingly consequential under the recast EPBD, which expects national performance databases to link EPCs, renovation actions, inspections, and emerging tools such as BRPs and SRI.

Smart readiness, monitoring, and digitalisation

Spain participates in SRI testing ("SRI2MARKET[37]") but does not yet require SRI assessment. Pilot 2c (Urban Residential District in Valladolid, Spain) showed what becomes possible when digital monitoring infrastructures are mature: long-running datasets, district-level analytics, and evidence-based performance assessment. At the same time, both Spanish pilots showed that monitoring is not purely a technical deployment problem. In Pilot 2a, reluctance to install indoor sensors- often driven by privacy concerns, unfamiliarity, and low perceived benefit- became a major determinant of monitoring coverage. In Pilot 2c, engagement had to be tailored to a predominantly elderly population, with patient, repeated support.

The implication for policy is direct: digitalisation must be treated as an implementation system (trust, onboarding, interoperability, support), not as hardware. If monitoring is expected to underpin MEPS credibility and renovation verification, participation must be easy, benefits must be visible, and data governance must be transparent and locally trusted.

Renewable energy, heating and cooling, and district systems

Spain's NECP targets 48% renewables in final energy consumption by 2030, with strong emphasis on electrification, heat pumps, district heating and cooling expansion where appropriate, and rapid growth in self-consumption PV systems (projected 19 GW by 2030). Renovation policy is expected to reduce heating and cooling demand substantially, while energy communities and new investment models are promoted to accelerate deployment.

For buildings policy, the practical hinge is integration. Renewables deliver fastest when they are sequenced and procured as part of renovation workflows, rather than being treated as parallel processes with separate permitting, separate contractors, and separate administrative interfaces- especially in multi-family contexts, where coordination costs and collective decision-making can otherwise dominate timelines.

Quality control, renovation traceability, and the national data backbone

Spain's building-data landscape is relatively mature but constrained by fragmentation, uneven digitisation, limited interoperability, and persistent concerns about data reliability. The most policy-critical gap is renovation traceability: EPCs do not systematically record why they were issued, which limits the ability to identify whether a certificate reflects a renovation, and to capture renovation depth and measures in a way that supports policy evaluation, MEPS design, and credible reporting. Additional gaps include limited official data on renewable installations and thermal-system performance, variable

[37] https://sri2market.eu/.

timeliness across datasets, and formats that are often not analytically "ready" (static tables, heterogeneous spreadsheets).

Under the recast EPBD, Spain's strategic task is not to replace long-standing regional mechanisms, but to connect them: harmonised identifiers, shared metadata rules and exchange formats, stronger validation at the origin of the data chain, and governance clarity on who produces, updates, and uses which datasets for which policy purpose.

Policy implications and strategic recommendations

Spain's NBRP is a chance to convert a strong strategic architecture into **predictable delivery across decentralised governance** and **diverse climate zones**. The pilots showed that the binding constraints are not instrument scarcity, but uneven municipal permitting and administrative throughput, multi-family decision-making and privacy-sensitive monitoring uptake, and a data backbone that is advanced yet still weak on **renovation traceability** and cross-regional interoperability. The priorities below focus on the "last-mile" conditions that will determine whether MEPS and renovation trajectories are enforceable, fair, and verifiable across autonomous communities.

✓ **Front-load subsidy and eligibility checks before technical design locks in costs**

Spain should standardise an early *"compatibility pre-check"* (eligibility, subsidy interaction, required permits, documentation pathway) as a default step in NBRP/ PRTR implementation guidance, so projects identify illegibility at early stages, or proceed with a stable administrative route.

✓ **Protect permitting continuity with surge-capacity mechanisms at the municipality level**

Scale-up will fail if permitting throughput varies sharply by municipality. Spain should treat administrative capacity as NBRP delivery infrastructure: regional shared technical services, temporary reinforcement pools, and fast reallocation of permitting support when staffing gaps emerge, so that renovation pipelines do not stall for reasons *unrelated to technical feasibility* or *finance availability*.

✓ **Make One-Stop Shops operational intermediaries for multi-family delivery and elderly communities**

OSS-based structures should be strengthened as practical operators that can carry documentation, coordinate resident engagement, support monitoring enrolment and troubleshooting, and act as a *stable interface* with installers, municipal offices, and registries, *reducing dropouts* and *improving data completeness*.

✓ **Embed renovation traceability into Energy Performance Certificates and permitting ecosystems as a core governance feature**

Spain's most policy-critical gap is that EPCs do not reliably encode whether they reflect a renovation, nor do they capture renovation scope and depth in a structured way. Spain should introduce *standardised "renovation traceability fields"* and link EPC issuance to renovation permits and (where relevant) aid programmes via consistent identifiers. Without this, Spain cannot credibly measure renovation rates, evaluate impact, or underpin MEPS legitimacy beyond counting certificates.

✓ **Interconnect regional registries through a national query layer, not disruptive replacement**

Given long-standing autonomous community registries and inspection responsibilities, the feasible pathway is interconnection: harmonised metadata rules, standard exchange formats, APIs, and governance clarity on who updates what. The goal is *national-level usability* and *comparability* (for MEPS targeting and EU reporting) while preserving *regional operational control* and avoiding *destabilising institutional change*.

✓ **Adopt proportionate measurement and verification requirements and enforce interoperability in digital procurements**

Spain should implement *tiered M&V processes* that match building context: high-resolution verification where infrastructures exist, and robust low-burden approaches for multi-family renovations, paired with enforceable interoperability specifications, commissioning requirements, and supplier obligations on data export and continuity, so digital tools actually support verification rather than create friction.

Overall, the Spanish pilots point to a clear policy shift under the NBRP: from strategy-centred renovation governance to **delivery-centred**, **data-enabled governance**. If Spain stabilises permitting capacity, strengthens OSS-based structures as operational delivery infrastructure, and builds renovation traceability plus interoperability into its building-data ecosystem, it will be far better positioned to deliver fair MEPS implementation, credible reporting, and verified renovation outcomes across regions, despite decentralisation and climate diversity.

5.2. Cross-country policy implications and strategic recommendations at the national level

Across the FORTESIE pilots, a consistent pattern emerges: the success of decarbonisation in the buildings sector is now determined less by the availability of technologies or headline policy ambition, and more by whether national systems can deliver, verify, and scale integrated renovations under real-world constraints. The cross-country implication is therefore a **shift in policy logic**- from "**programme design**" to "**delivery governance**": creating predictable administrative pathways, stabilising market coordination, and building a data backbone that makes MEPS, renovation trajectories, and performance verification feasible, fair, and politically durable.

I **Implementation readiness is now the binding constraint, not ambition**

Delays and ambiguities in transposition and secondary rules (definitions, procedures, eligibility conditions, data obligations) translate directly into stalled projects and redesign cycles. National frameworks must therefore **prioritise operational clarity**: "*what counts as compliance*", "*who does what*", "*in which sequence*", "*with which evidence*"- especially for MEPS trajectories, BRPs, and the database requirements that underpin monitoring and reporting.

II **Permitting and grid-connection must be treated as core renovation infrastructure**

Across pilots, *renewables integration* and *electrification* are often constrained by permitting throughput and grid-connection processes rather than technical feasibility. If PV, heat pumps, and smart controls are expected to function as mainstream decarbonisation levers, national systems must make authorisations predictable and time-bounded, allow parallel processing with technical design, and clarify responsibilities across agencies to avoid "**installed but not operational**" outcomes.

III Policy must pivot from "installed measures" to "verified outcomes"

The pilots repeatedly show that projects can be technically sound and financially supported yet still underperform because commissioning, tuning, and operational handovers are weak or missing. A cross-country implication is that commissioning and proportionate post-renovation verification should become **standard completion conditions** for publicly supported renovations- especially in complex buildings- so that measured energy, comfort, and IEQ outcomes are achieved and sustained.

A new certificate scheme based on the "Price-Comfort" indicator developed in the context of FORTESIE could favour the shift toward "verified outcomes".

IV Financing works best when it rewards integrated packages and evidence creation

Renovation uptake and quality improve when public support is structured around **coherent packages** (envelope + systems + renewables + M&V), rather than fragmented measures that optimise for administrative simplicity. National funding rules should explicitly recognise digital M&V, commissioning, and optimisation as *eligible costs*, and enable *performance-based schemes* (including EPC-style/ ESCO contracts) that are accessible to SMEs and local actors- not only large providers.

V One-Stop Shops and intermediaries are delivery capacity, not "soft support"

Value-chain fragmentation is a structural barrier: households, small institutions, and many public owners struggle with procurement, documentation, sequencing, and monitoring onboarding. Cross-country, OSS-based models are most valuable when mandated and resourced as **operational intermediaries**, able to carry paperwork, coordinate contractors, support consent and onboarding for monitoring, and keep projects moving through *permitting* and *subsidy interactions*.

VI Procurement resilience and market volatility require programme rules, not improvisation

Supply-chain failures, price volatility, and single-supplier dependence can derail delivery and force damaging scope cuts. National schemes should **embed resilience in procurement**: multi-supplier strategies, substitution-friendly performance specifications, explicit contingencies, and decision pathways that allow essential adaptations without resetting approvals. This protects outcomes and *reduces the risk of stranded, partially completed renovations*.

VII Governance-grade data is a prerequisite for fair Minimum Energy Performance Standards and credible trajectories

A central cross-country implication is that "**data exists somewhere**" is not enough. MEPS targeting, renovation rate estimation, and policy credibility depend on interoperable registries with harmonised identifiers and renovation traceability (what was done, when, how deep), linked across EPCs, permits, inspections, BRPs, and, where feasible, monitoring outputs. This is *not reporting bureaucracy*; it is the enabling infrastructure for enforceable and **socially legitimate renovation governance**.

VIII Monitoring-based governance depends on trust, privacy-by-design, and visible benefits

Where monitoring participation is voluntary, uptake is shaped by perceived intrusiveness, effort, and unclear values, especially in elderly communities and vulnerable contexts. National approaches should therefore standardise privacy-transparent consent pathways, low-burden deployment designs, and **clear citizen value propositions** (comfort feedback, fault alerts, proof of improvement), so that *performance verification becomes feasible without eroding trust*.

A new certificate scheme based on the "Price-Comfort" indicator developed in the context of FORTESIE could make benefits visible for all parties involved, including both beneficiaries and funding authorities.

IX	**Differentiated pathways are essential for equity and feasibility**

The pilots show that vulnerable households, rural/ low-density territories, and small institutions face higher non-technical barriers and sometimes require habitability-first sequencing before energy upgrades. Cross-country, MEPS, and renovation trajectories will remain politically sustainable only if paired with staged compliance routes, analogue-compatible administration, delegated-management options, and targeted technical assistance that **prevents renovation-driven exclusion**.

X	**Workforce strategy is renovation strategy**

Skills shortages and **limited familiarity** with integrated solutions and digital tools increasingly determine what can be delivered in practice. National frameworks must align vocational training, reskilling, and professional standards with the needs of *integrated renovation markets*: building physics, system integration, commissioning, controls, data-handling, and performance-based operation- backed by incentives that support specialised renovation enterprises and municipal technical capacity.

Taken together, the cross-country lesson is clear: **national renovation policy must move beyond compliance-oriented transposition** and **towards delivery-centred**, **performance-assured**, **data-enabled governance**. Member States that hardwire administrative predictability, procurement resilience, commissioning and verification, interoperable data backbones, and equity-ready delivery models will be best positioned to scale the integrated, user-centred renovation solutions demonstrated in FORTESIE- and to translate EPBD ambition into verified outcomes by 2050.

5.3. Policy implications and strategic recommendations for regional and local authorities

Regional and local authorities- municipalities, regional energy agencies, public building owners, etc.- are the frontline actors that determine whether national renovation trajectories become real buildings with verified outcomes. Across the FORTESIE pilots, the recurring message is that local success depends on **programme-like delivery capacity**: the ability to translate targets into a steady pipeline of projects, reduce administrative friction, coordinate multiple suppliers and trades, and sustain citizen trust when monitoring, access, or temporary disruption is required. In this sense, ZEB-aligned renovations are not a single-asset engineering exercise; it is a local public-service endeavour that bundles technical, financial, and social instruments into repeatable workflows.

A first implication is that local strategies should be organised around **phased ZEB pathways** that reflect territorial realities- climate conditions, dominant building typologies, constraints of local supply chains. Rather than treating each renovation as a bespoke undertaking, authorities can use "**portfolio logic**": grouping neighbourhoods or public-building stocks into clusters, applying modular renovation packages (envelope plus HVAC systems plus BIPV systems plus commissioning plus proportionate M&V), and setting clear sequencing rules (what comes first, what must be coordinated, when renewables are integrated, etc.). This portfolio approach improves predictability, lowers transaction costs, and makes prioritisation defensible, especially when combined with transparent criteria to identify the worst-performing assets and those with the highest social vulnerability.

Second, the pilots confirm that **public-sector leadership** is a **market-shaping lever** when it is anchored in procurement practice. Local authorities can accelerate quality and uptake by moving tenders from "*equipment lists*" to **performance-based specifications** (comfort/ IEQ targets where relevant, control stability, measured savings, commissioning deliverables). Public buildings are particularly suited to piloting **energy-service**/ **performance-guarantee models**, including ESIE-style approaches, because they can bundle buildings, standardise M&V protocols, and create procurement volumes that attract capable suppliers while spreading risk. The crucial point is operational: commissioning, handover, and verification need to be treated as contract deliverables, not optional extras, otherwise installed solutions drift and benefits erode.

Third, delivery in public facilities must explicitly manage **operational continuity**. Schools, pools, administrative hubs, and cultural buildings have calendar-driven constraints that often dominate project feasibility. Local planning and procurement should therefore require *phased execution plans*, *service-continuity arrangements*, and *contingency pathways as standard elements of funded projects*. Aligning renovations to low-impact windows (school holidays, low season) and requiring contractors to demonstrate how closures are minimised and recovery is assured, protects public trust and avoids rushed commissioning driven by reopening pressure.

Fourth, *citizen-facing services are not "soft measures"*; they are **core delivery infrastructure**. The pilots show that administrative burden, limited digital literacy, and low trust in monitoring can derail otherwise fundable renovations. Local authorities therefore benefit from strengthening One-Stop Shops as **hands-on renovation hubs**, not only advisory points- supporting applications, guiding procurement, coordinating installers, and onboarding monitoring where required. For vulnerable households and low-capacity owners, delegated-management options (with clear consent safeguards) can be decisive: someone must be able to carry paperwork, schedule works, and keep the process moving when the beneficiary cannot. In parallel, monitoring uptake improves when *local programmes make benefits visible* (comfort feedback, fault alerts, proof of improvement) and treat privacy and consent as default design requirements.

Fifth, local implementation increasingly depends on **data-enabled targeting** and **feedback loops** that remain lightweight and workable. Municipal and regional actors do not need "*maximum data everywhere*"; they need governance-grade minimums that allow prioritisation and learning: linking local asset inventories with EPC information and renovation activity logs, using simple dashboards to track pipeline status, and embedding basic M&V requirements in publicly funded projects so that performance evidence can refine future programme design. Where digital connectivity is weak, local monitoring frameworks should remain tiered and pragmatic, combining low-maintenance options (e.g., gateways/ cellular where feasible) with periodic measurements where continuous monitoring is unrealistic.

Finally, local delivery is constrained by **logistics** and **supply-chain capacity**, particularly in low-density, remote, or island contexts. The pilots point towards a practical response: aggregated procurement for neighbourhood clusters or municipal portfolios, local procurement associations that stabilise lead times, and explicit treatment of logistics costs and delivery risk in programme design. Where geography structurally raises costs, targeted co-financing for logistics and buffering against delays can prevent "*stop-start*" *renovations* and improve the feasibility of deep, integrated packages.

Overall, the cross-cutting implication for regional and local authorities is a shift from managing individual renovation projects to operating a **repeatable delivery system**: portfolio-based ZEB pathways, procurement that buys verified outcomes, continuity-aware scheduling, OSS-enabled citizen support, and minimal-but-usable local data loops. With these elements in place, local actors can turn national ambition into reliable pipelines of completed, functioning renovations, setting up the social legitimacy and performance evidence that the next EPBD cycle will increasingly require.

5.4. Policy implications and strategic recommendations for civil society and citizen/ consumer organisations

Across the FORTESIE pilots, one of the most consistent "*non-technical*" findings is that renovation outcomes depend heavily on **trust, comprehension**, and **perceived fairness**. Even when funding exists and technical solutions are available, uptake can stall if households do not understand what is being offered, fear disruption, distrust monitoring, or perceive that obligations (e.g., future MEPS trajectories) will fall unevenly on those least able to act. This places civil society, citizen and consumer organisations/ associations, community groups, and local NGOs in a strategically important role: they are often the actors best positioned to translate policy into lived experience; and to translate lived experience back into policy design improvements.

A first implication is that civil society and citizen/ consumer organisations are essential to making *"integrated renovations"* **socially legible**. The FORTESIE pilots showed that citizens respond more strongly to **outcomes** (comfort, health, reliability, lower bills, resilience) than to technical descriptions of measures. Civil society actors can therefore strengthen participation by communicating renovations as *practical life improvements*- explaining, in plain language, what to expect during renovations, what changes afterwards, and how benefits will be evidenced. This is especially important when renovation programmes increasingly bundle efficiency, renewables, and smart controls: without accessible narratives, integrated packages can appear complex, risky, or intrusive, even when they are objectively beneficial.

Second, the recast EPBD's direction of travel makes **consumer literacy** on digital EPCs and BRPs a governance issue, not an educational luxury. If EPCs, passports, and building logbooks become central to eligibility, targeting, and compliance, then households need to understand what these instruments mean, how to interpret them, and how to use them in decision-making. Civil society and citizen/ consumer organisations can fill a crucial gap here by providing workshops, simple guidance materials, and *"translation" services*, turning technical ratings and staged recommendations into understandable choices. They can also advocate for **citizen-friendly design**: short summaries, clear comparators, and transparent explanations of uncertainty and assumptions, so that trust in certification systems is reinforced rather than eroded.

Third, civil society and citizen/ consumer organisations are a **practical safeguard** for fairness and inclusion as policy frameworks shift towards trajectories and minimum standards. The pilots repeatedly underline that vulnerability is often driven by non-technical barriers- administrative burden, low capacity to coordinate contractors, low digital literacy, or degraded housing conditions that require basic remediation before energy upgrades. Civil society organisations can contribute by *monitoring equity impacts*, *flagging exclusion risks early*, and *pushing for pragmatic safeguards*, e.g., delegated management options, phased compliance pathways, targeted grants, and simple access routes. In other words, they can help ensure that the renovation transition remains politically durable by keeping fairness visible and operational, not merely declared.

Fourth, FORTESIE's experience makes clear that **monitoring** and **data collection** succeed or fail on **social acceptance**. In several contexts, participation in sensing and monitoring was limited not by technology but by privacy concerns, unfamiliarity, and low perceived benefits, especially among older residents and in settings where trust must be built patiently. Civil society groups and citizen/ consumer organisations can materially improve monitoring uptake by acting as trusted intermediaries: helping explain consent, clarifying what is (and is not) collected, and demonstrating tangible value to residents (comfort feedback, proof-of-improvement, early fault detection). Where monitoring is a policy-relevant component for verification or learning, these organisations can make the difference between "*data assumed*" and "*data actually obtained*".

Finally, civil society actors are well placed to drive **digital inclusion** and practical support during implementation. For digitally excluded households (often elderly or low literacy) barriers arise from simple tasks: accessing portals, uploading documents, understanding bills, or interacting with devices. Civil society and citizen/ consumer organisations can complement OSS-based structures and services by providing *community helpdesks*, phone support, and in-person assistance during critical phases, reducing drop-outs and ensuring that the people who most need renovation benefits are not systematically the least able to access them.

Overall, the implication is that civil society and citizen/ consumer organisations are **not peripheral stakeholders** in the renovation wave; they are part of the *enabling infrastructure for delivery*. By strengthening public understanding, reinforcing trust in data-enabled verification, advocating for fairness safeguards, and supporting inclusion in practice, civil society can help ensure that performance-driven renovation policies translate into broad participation, credible evidence, and socially legitimate progress towards ZEB-aligned building stocks.

5.5. Policy implications and strategic recommendations for industry and market actors

Across the FORTESIE pilots, the clearest message for industry is that Europe's renovation market is shifting from "*selling measures*" to **delivering verified outcomes**. As MEPS trajectories, renovation passports, digital EPCs, and national performance databases become operational under the recast EPBD, clients and public procurers will increasingly demand predictable delivery, measurable performance, and interoperable data- not just installed equipment. For ESCOs, renovation firms, installers, prefabrication manufacturers, sensor providers and platform developers, competitive advantage will come from *reducing risk across the full chain*: **procurement → installation → commissioning → operation → verification**.

A first implication is that digital M&V must become a product layer, *not a pilot add-on*. The pilots repeatedly showed that monitoring fails when onboarding is complex, connectivity is assumed, data export is brittle, or troubleshooting requires repeated site visits. Market actors should therefore package M&V as a **reliable service**: plug-and-play installations, remote diagnostics, clear escalation routes, and stable data interfaces (APIs) *aligned with national requirements*. "**Interoperability-by-design**" is now a *procurement requirement in practice*: devices and platforms that cannot export usable data, or that lock clients into proprietary formats, will increasingly be filtered out, especially in public buildings and performance-based tenders.

Second, the pilots underline that scaling deep renovation requires **industrialised delivery capacity**, particularly through prefabrication and off-site methods where they reduce disruption and improve quality control. Multi-dwelling buildings and small institutions are *highly sensitive to disruption and delays*; shortening time on site can be the difference between feasible and rejected projects. Industry should therefore invest in validated modular façade/ roof systems, standardised interfaces for building services, and repeatable assembly processes. Crucially, industrialised delivery must be paired with "**commissioning-ready**" **design**, so that speed does not come at the cost of performance drift after handover.

Third, the emerging market logic favours **performance-based contracting** with *clear baselines* and *verification rules*. The pilots showed that projects can be technically sound and still underperform if commissioning, tuning and operator handover are weak or treated as optional. ESCOs and implementers should expand contract models that bundle renovations with *time-bounded performance guarantees*, *proportionate M&V protocols*, and *explicit stabilisation periods*. This is not only a **financing lever**; it is a **governance lever** that *aligns responsibility with outcomes* and makes deep renovations more bankable for both public and private clients.

Fourth, industry needs to treat *consumer engagement* and *behavioural support* as **part** of **performance delivery**, *not a communications afterthought*. Monitoring uptake is shaped by trust, perceived intrusiveness, and visible benefits, especially in multi-family settings and in older communities. Providers should embed simple occupant interfaces (plain-language dashboards, comfort/ IEQ feedback, actionable tips), privacy-transparent onboarding, and light-touch post-renovation support where it materially improves outcomes. When citizens understand what is collected, why it matters, and what they get back, participation becomes feasible without coercion.

Fifth, the pilots exposed how *often delivery fails* due to procurement friction, supply-chain fragility, and single-supplier dependence. Market actors should build **resilience into** their **business models**: multi-supplier sourcing for critical components, substitution-friendly specifications, local spare-parts availability, and logistics planning that can support aggregated renovation clusters. In parallel, industry participation in national and EU standardisation efforts is *no longer optional*: shared data schemas, test protocols, and performance-based contract clauses reduce tender uncertainty, lower transaction costs, and accelerate market uptake, especially for SMEs that cannot afford bespoke compliance work for each procurement.

Overall, the industry-facing lesson from FORTESIE is that the "**winners**" of the next renovation cycle will be those who can deliver *integrated packages with predictable timelines*, *commission systems into stable operation*, and *produce interoperable performance evidence with minimal burden* on occupants and clients. This is precisely the **capability profile** needed to *scale ESIE-oriented renovation services* and to convert policy ambition into verified outcomes in real buildings.

5.6. Cross-cutting policy implications and strategic recommendations at the European Union level

The FORTESIE pilots reinforce a clear EU-level message: Europe does not primarily need *more* renovation instruments; it needs renovation systems that are *interoperable*, *financeable*, and *verifiable* across Member States, so that national NBRPs can translate EPBD ambition into comparable, trustworthy outcomes. The EU's unique leverage is to (**i**). set **common** "**rules of the game**" where fragmentation currently blocks scale (data, verification, contract standards), (**ii**). **de-risk delivery** through targeted financial instruments that reward integrated, performance-assured renovations, and

(iii). accelerate market readiness (skills, supply chains, and industrialised solutions) *without locking* Member States into *one-size-fits-all pathways*.

A first implication concerns the **operationalisation** of the recast EPBD. The FORTESIE pilots repeatedly showed that the hardest problems arise in the "*secondary layer*" of implementation: definitions, procedures, evidence requirements, and database interoperability. EU institutions can materially strengthen implementation by issuing **high-clarity guidance packages** that help Member States translate obligations into *workable delivery rules*, especially for MEPS trajectories, renovation passports, and Article 22 database requirements. The value is not generic guidance, but toolkit-level operational detail: minimum fields for renovation traceability, examples of proportional verification approaches for different building types, and templates that show how to link EPCs, permits, inspections, and, where feasible, monitoring outputs without imposing excessive burden.

Second, the EU has a critical role in turning M&V from an "*optional pilot feature*" into a standardised, proportionate governance layer. A recurring cross-country bottleneck is not the absence of sensors but the absence of *reliable evidence routines*, commissioning, stabilisation, data export, and usable reporting. EU-level action can accelerate this through a **common "minimum interoperability profile**" for building M&V: baseline definitions, required metadata, data-format expectations, and privacy-by-design consent patterns that allow aggregation and benchmarking. Done well, this *reduces vendor lock-in*, *improves procurement certainty*, and makes *performance-based financing more credible*.

Third, EU finance should explicitly reward integrated packages and evidence creation, not fragmented single measures. The FORTESIE pilots showed that deep renovation performance depends on commissioning, optimisation, and verification- elements that are often underfunded because programmes focus on **capex-visible measures**. The EU can address this by ensuring that digital M&V, commissioning, and post-renovation stabilisation are consistently treated as eligible and encouraged cost categories in EU-backed programmes and blended finance facilities. In parallel, de-risking instruments (e.g., guarantees, aggregation support) can be shaped to support outcome-linked contracts and ESIE-style delivery models that reduce the burden on households and small institutions and make projects bankable at scale.

Fourth, the EU can substantially lower transaction costs by strengthening **standardisation** and **digitalisation** as market infrastructure. Interoperability and data usability should not depend on ad-hoc integration work in each project. Coordinated action with standardisation bodies can accelerate shared specifications for: device data formats and APIs, renovation-traceability fields, commissioning documentation, and performance-based contract clauses. In parallel, the emerging "Energy Data Space" agenda is an opportunity to ensure that building-performance data becomes *usable for governance*- secure, privacy-respecting, and query-able across systems- rather than merely "*available somewhere*" in PDFs, static tables, or incompatible registries.

Fifth, EU-level policy should embed **equity safeguards** as *implementation requirements*, not only as aspirations. The pilots show that exclusion risks are created by administrative complexity, low capacity to coordinate renovations, and weak digital access, often more than by technology costs alone. EU guidance and funding conditions can *mainstream practical safeguards*: delegated-management options via trusted intermediaries, analogue-compatible routes for applications and documentation, staged compliance pathways for vulnerable households, and explicit protection against renovation-driven inequalities as MEPS trajectories tighten.

Finally, the EU can accelerate scale by treating **market readiness**- skills, supply chains, and industrialised renovation capacity- as *part of the policy system*. Cross-border initiatives that build installer competence in integrated renovation, commissioning, controls, and data-handling; support prefabrication and off-site solutions; and improve resilience for critical components reduce the risk that national targets become infeasible in practice. This is especially relevant for public buildings, where predictable delivery and verified outcomes are central to credibility and replication.

Overall, the FORTESIE pilots suggest that EU-level impact will be maximised by shifting from "*framework setting*" to implementation hardening clearer operational toolkits for EPBD delivery, standards that make M&V and data interoperability real, finance that rewards integrated packages and verified outcomes, and safeguards that keep the transition socially legitimate. If these EU-level enablers are strengthened, Member States will be far better positioned to deliver credible NBRPs, supported by **performance evidence** that is **comparable**, **investable**, and **trusted** across Europe.

5.7. Concluding synthesis: From policy ambition to delivery-grade renovation systems

Across governance levels, the FORTESIE evidence converges on a single strategic message: the next phase of achieving decarbonisation in the buildings sector will be decided *less by the existence of policy instruments* and *more by the strength of the delivery systems* that implement them. The pilots showed that technologies and funding can be available, yet **outcomes remain uncertain** when *administrative throughput*, *procurement design*, *commissioning discipline*, *monitoring feasibility*, and *user trust* are not treated as *core components* of *renovation governance*.

This implies a **shift** in the **logic** of **policy design**. Regulations such as the recast EPBD, together with national NBRPs and emerging MEPS trajectories, must be complemented by operational rules that make compliance feasible, fair, and verifiable. In practical terms, this means predictable permitting and grid-connection pathways; procurement that specifies performance outcomes rather than equipment lists; commissioning and stabilisation as completion conditions; and proportional M&V approaches that work in both digitally mature environments and connectivity-constrained contexts.

The pilots also underline that **social legitimacy** is a **delivery outcome**. Equity safeguards are *not peripheral*: they depend on whether low-capacity owners and vulnerable households can realistically participate in renovation programmes, navigate administrative requirements, and benefit from verification mechanisms without being penalised by digital exclusion or degraded housing conditions. Delegated-management options via trusted intermediaries, analogue-compatible access routes, and staged compliance pathways emerge as essential components of an inclusive renovation transition.

Finally, the transition to *performance-assured renovation systems* requires **governance-grade data**: interoperability, renovation traceability, and usable links between EPCs, permits, inspections, renovation passports and, where feasible, monitoring outputs. Without this backbone, trajectories and standards risk becoming unenforceable or politically fragile. With it, policymakers can target support, prove impact, refine programmes, and build trust through demonstrated outcomes.

In this sense, Section 5 frames a coherent pathway from FORTESIE's empirical evidence to actionable governance: **delivery-centred renovation policy** that is *operationally executable*, *performance-verifiable*, and *socially defensible*. This is the foundation on which Member States and the EU as a whole can translate 2050 building-decarbonisation ambition into *measurable energy savings*, *improved comfort* and *health*, and *durable transformation* of renovation markets.

6. Adoption guidelines for practitioners and market actors

This section provides practical methodological guidance for practitioners, renovation actors, and market stakeholders who wish to adopt, replicate, or scale the tools, approaches, and solutions developed within FORTESIE. Unlike **Section 5**, which focuses on *policy and institutional enabling conditions*, this section is explicitly concerned with *how delivery happens in practice*: how integrated renovation packages are selected and configured, how digital M&V is embedded from the outset, how performance is commissioned and stabilised after renovations, and how user engagement is sustained so that technical potential becomes real-world outcomes.

The guidance draws directly from implementation experience across the FORTESIE pilots, which tested ESIE-oriented renovation solutions in diverse real-life conditions: multi-family buildings with fragmented decision-making, public buildings with procurement and scheduling constraints, vulnerable households with administrative and digital barriers, and districts where existing digital infrastructures enabled richer performance feedback. Across this diversity, the pilots converged on a consistent lesson: the hardest problems are rarely solved by "*better components" alone*. They are solved by *delivery discipline*- clear workflows, robust coordination, credible evidence creation, and practical support mechanisms- that prevent projects from failing due to administrative friction, supply-chain volatility, data gaps, or loss of trust.

Section 6 therefore aims to help practitioners operationalise ESIE-oriented renovations as a repeatable delivery process. It addresses the steps and enabling conditions that matter most for reliability: feasibility screening that prevents late-stage redesign, integrated package design that accounts for system interactions, procurement that buys outcomes rather than equipment lists, commissioning that verifies performance in operation (not only installation), and proportionate M&V that remains workable across contexts with unequal connectivity and user capacity. The guidelines are intended for ESCOs, construction and technology providers, OSS-based service providers, housing operators, municipalities and energy agencies, and building professionals involved in planning, design, financing, implementation, and operation.

Overall, the objective is to make replication *low-friction* and *high-quality*. In other words, to translate pilot lessons into a practical adoption logic that can be applied across building types and regions while preserving the core ESIE principles of integration, verification, inclusion, and long-term performance.

6.1. General principles for adopting Efficient, Sustainable, and Inclusive Energy renovation solutions

The experience across FORTESIE confirms that successful adoption of ESIE-oriented renovation solutions requires a **shift in mindset**. Renovation cannot be approached as a *set of isolated upgrades*; it must be treated as a system transformation process that deliberately integrates envelope measures, energy systems, renewables, controls, digital monitoring, and user engagement. In practice, the "*system*" framing matters because interactions shape outcomes. Airtightness improvements change ventilation needs and moisture risks; heating-system upgrades depend on distribution and control logic; PV value depends on grid-connection and load alignment; and comfort depends as much on commissioning and operation as on nominal equipment efficiency.

A first overarching principle is therefore the need for an **integrated**, **multi-technology perspective**. The pilots repeatedly showed that fragmented interventions can lead to underperformance, rebound effects, or unresolved comfort and IEQ risks. By contrast, *integrated packages unlock synergies*: envelope and HVAC coordination improves sizing and controllability; renewables integration becomes more predictable when sequenced within renovation workflows; and digital controls become meaningful when they manage the combined performance of the upgraded system rather than a single component.

A second principle is the **structural** importance of **reliable** digital M&V from the **earliest** stage. M&V is *not merely a reporting activity after renovation*; it is a *design input* that shapes baseline definition, system sizing, performance guarantees, and post-renovation optimisation. When monitoring is introduced late, projects face avoidable uncertainty, weak attribution of savings, and reduced credibility of outcomes. When monitoring is embedded early, it supports evidence-based decisions, reduces disputes, and enables performance stabilisation- especially important for performance-based contracting or public funding models that require verification.

Third, value-chain coordination is **not a** "**nice-to-have**" but a **core determinant** of **delivery success**. Across pilots, many failures and delays were coordination failures: unclear responsibilities, incompatible data interfaces, weak sequencing between construction and digital deployment, or missing handover routines. ESIE adoption therefore requires a deliberate coordination model that defines who does what, when, and with what evidence, across designers, installers, digital providers, financiers, OSS operators, owners and end-users.

Fourth, **behavioural engagement** must be treated as a **performance factor**. Even technically excellent renovations can fail to deliver expected savings if users are not informed, supported, and engaged. ESIE-oriented renovation therefore requires *user-centred communication* and *feedback mechanisms* that translate monitoring into understandable value, like comfort improvement, reduced bills, early fault detection, and confidence that renovations work as promised. This becomes even more important in contexts where participation in monitoring is voluntary or privacy-sensitive.

Finally, the pilots confirm the advantage of **performance-based thinking** *over component-based thinking*. The most robust ESIE delivery logic is built around outcomes- energy, comfort/ IEQ, emissions, operational reliability- supported by credible M&V and clear corrective-action pathways. This mindset strengthens accountability, improves long-term operation, and makes replication more defensible for both public and private actors.

6.2. Adopting FORTESIE-type renovation packages

Adopting FORTESIE-type renovation packages begins with a **disciplined pre-assessment** that combines *technical diagnosis* with *contextual feasibility screening*. The purpose of this stage is not only to identify measures, but to determine whether renovations can be delivered *reliably* and *verified credibly* under the real constraints of the building, the users, and the administrative environment. In multi-family buildings, feasibility often hinges on access, decision-making, and willingness to host monitoring. In vulnerable households, feasibility hinges on administrative capacity, digital inclusion, and habitability-first needs. In public buildings, feasibility often depends on procurement calendars, operational continuity requirements, and commissioning responsibilities after handover.

In practice, the pre-assessment should produce a clear baseline logic using available EPC information, on-site audits, and, where possible, short-term monitoring to capture representative performance conditions. It should also identify constraints that determine package suitability: moisture and condensation risks, ventilation adequacy, structural degradation, heritage limitations, and the realities of connectivity. Where digital infrastructure is weak, the pilots show that M&V must be designed in a tiered way rather than assumed.

During the design and customisation phase, practitioners should configure renovation solutions as **coherent packages** *rather than assembling unrelated components*. A robust package design makes explicit how envelope upgrades, HVAC interventions, renewables integration, controls, and monitoring will operate as one system, and it defines the sequencing that prevents conflicts. The FORTESIE pilots showed that renewables work best when treated as part of the renovation workflow- procured, permitted, installed, and verified through the same delivery chain- rather than as a parallel track that can be delayed by permitting or partner changes. Likewise, controls and monitoring should be integrated at design stage so that sensor placement, gateways, interoperability, and data export obligations are aligned with the verification objectives.

Implementation and commissioning is where ESIE packages succeed or fail. The pilots underline that **commissioning** must be treated as the **bridge** between **installed measures** and **verified outcomes**, *not as a formal end-of-works ritual*. Commissioning needs to confirm that systems operate as intended, controls are tuned, ventilation and moisture risks are addressed where relevant, and data flows are stable enough to support verification. A practical insight from pilots is the value of a stabilisation period after works, during which early faults are identified, controls are adjusted, and monitoring continuity is secured before performance is treated as "*final*".

M&V should then be executed in a *proportionate way* that remains *workable* across contexts. Digitally mature districts can support richer continuous monitoring and optimisation. Dispersed, vulnerable or low-connectivity contexts often require lower-maintenance solutions, hybrid connectivity approaches, or periodic measurement methods that still produce credible evidence without overburdening users. The governing principle is *not "maximum data everywhere"* but *"reliable verification that fits the context"*.

Finally, *post-renovation engagement* must be treated as **part of the package** *rather than a communications add-on*. Performance persistence depends on user routines, operator competence, and maintenance practices. Renovation actors should plan how occupants and operators will receive feedback, how faults will be escalated and resolved, and how performance will be maintained across seasons. This is particularly relevant for public buildings, where operator turnover and unclear responsibilities can rapidly erode benefits unless follow-up is institutionalised.

6.3. Adopting digital M&V processes and smart performance guarantees

Digital M&V is the *mechanism* that connects *technical delivery* to *credible outcomes*, and, increasingly, to *performance-based business models* and *finance*. The FORTESIE pilots showed that M&V becomes fragile when measurement boundaries are unclear, when data continuity is not assured, or when responsibilities for corrective action are not contractually defined. Practitioners should therefore begin by **defining measurement boundaries** that reflect the renovation scope and the contractual or funding logic. This includes deciding whether verification is whole-building, system-level, or end-use specific, and documenting how shared areas and common systems are treated in multi-family settings.

The monitoring architecture should be selected for reliability, interoperability, and maintainability, and not simply for sensor density. **Connectivity planning** is a core part of this decision. Where Wi-Fi is unreliable, cellular gateways and practical reset protocols may be necessary; where users have low capacity, devices must be low-maintenance by design. The pilots also underlined the importance of early technical due diligence and enforceable interoperability requirements, particularly when data must be integrated into central platforms or used for programme reporting. If data export formats, cadence, and API stability are not specified and tested early, M&V can fail at the moment evidence is required most.

Data governance and GDPR compliance must be operationalised rather than declared. Monitoring succeeds when consent is simple, privacy safeguards are communicated in plain language, and benefits are visible to participants. This is especially important in multi-family and elderly communities, where trust is the binding constraint. Practitioners should therefore treat "***privacy-by-design***" as part of deployment design: data minimisation, clear access rights, transparent retention rules, and consent processes that are easy to understand and easy to revoke.

Performance guarantees should be designed to *balance ambition* with *deliverability*. The pilots suggest that strong performance contracts are those that define baselines clearly, include realistic tolerance rules, anticipate behavioural and operational variation, and specify who acts when performance deviates. In ESIE-oriented models, performance guarantees are strengthened when they include commissioning and stabilisation obligations and when they assign responsibility for ongoing optimisation, not only for installation.

6.4. Value-chain collaboration and One-Stop-Shop-based approaches

ESIE-oriented renovations are fundamentally a *coordination challenge*: they depend on multiple trades, multiple administrative interfaces, and when/ if digitalisation is involved, multiple layers of data infrastructure and responsibility. The FORTESIE pilots showed that when coordination is informal, delivery becomes fragile: procurement and installation drift out of sequence, monitoring is installed too late or without support, and accountability for underperformance becomes unclear.

Practitioners should therefore treat value-chain collaboration as part of the project architecture. This begins with a clear allocation of roles across the renovation lifecycle: *who* owns baseline definition, *who* manages permits and grid steps, *who* is responsible for commissioning and acceptance, *who* maintains monitoring devices, *who* ensures data export, and *who* provides user support. The goal is to prevent "*ownership gaps*" where failures occur but no actor is mandated to resolve them.

OSS-based models can play a structurally important role when they operate as **delivery intermediaries** *rather than information points*. In practice, OSS-based structures reduce transaction costs by carrying documentation, coordinating installers and schedules, supporting user onboarding, and sustaining follow-up when households or small institutions lack capacity. The pilots suggest that OSS-based services are particularly decisive for vulnerable households, dispersed geographies, and multi-family contexts where access arrangements and trust-building dominate timelines. For practitioners, the implication is practical: OSS-based services should be integrated into workflows as a coordination hub, *not treated as an external advisory service*.

Effective collaboration also depends on shared documentation and standardised templates that reduce repeated friction: standard scopes of work, modular annexes for permitting, commissioning and handover packs, and consistent data schemas for monitoring outputs. These instruments are not bureaucratic overhead; they are what makes replication feasible at scale.

6.5. Enabling conditions and barriers

The FORTESIE pilots underlined that ESIE adoption succeeds when **enabling conditions** are treated as **design parameters** *rather than discovered mid-implementation*. Practitioners should ensure that interoperability requirements are explicit and testable, that staff capacity exists for digital tools and performance follow-up, and that user engagement is planned before deployment rather than improvised after resistance emerges. In contexts involving degraded buildings, contingency governance is essential: budget and timeline buffers, and a rapid decision route for essential additional interventions discovered once renovations begin.

Common barriers fall into several recurring classes. Administrative uncertainty can stall projects even when technical solutions are ready. Supply-chain delays and single-supplier dependence can force damaging scope reductions or sequencing failures. Digital exclusion can prevent monitoring or documentation tasks in precisely the households that most need renovation benefits. Privacy concerns can limit monitoring participation even when systems are technically non-intrusive. Finally, weak commissioning and unclear post-handover responsibilities can lead to "*installed but underperforming*" outcomes that erode trust and reduce long-term impact.

The pilots also pointed to **mitigation strategies** that practitioners can apply systematically. Early administrative feasibility screening prevents late-stage ineligibility. Substitution-friendly specifications and multi-supplier readiness reduce procurement fragility. Hybrid monitoring options and low-maintenance device strategies improve feasibility in low-connectivity contexts. Plain-language consent and visible benefit design improve monitoring uptake. Mandatory commissioning and stabilisation routines protect performance outcomes. And, where beneficiaries have low capacity, delegated support models- via OSS-based structures, or authorised intermediaries- can prevent predictable drop-outs and incomplete delivery.

A final enabling condition concerns **post-renovation governance**. ESIE outcomes persist when responsibilities for optimisation, monitoring continuity, and maintenance are explicit and when users and operators receive ongoing support. Without this, performance drift becomes likely, particularly in complex buildings and public facilities.

6.6. Pathways for replication, further exploitation, and upscaling

FORTESIE tools and approaches are replicable across a wide range of building types and organisational contexts, provided that replication is guided by a *clear distinction* between *what can be standardised* and *what must be locally adapted*. The core ESIE logic, i.e., integrated packages, digital evidence creation, commissioning discipline, and user engagement, should remain **stable**. Adaptation should occur in response to climate zones, typologies, governance structures, connectivity realities, and social conditions.

Scaling is accelerated when actors adopt a ***portfolio logic*** rather than treating each renovation as a bespoke project. Municipal portfolios, housing portfolios, and neighbourhood clusters allow standard scopes of work, aggregated procurement, predictable supplier pipelines, and repeatable commissioning and M&V routines. This also supports market maturity by creating stable demand signals for integrated solutions, including prefabricated or off-site envelope approaches where these reduce disruption and improve quality control.

To enable large-scale uptake, practitioners should align ESIE delivery with evolving EPBD requirements, emerging MEPS trajectories, and building performance database obligations, so that investments remain valuable as regulatory frameworks tighten. *Digital EPCs* and *renovation passports* should be treated as **evolving assets** that are updated with renovation actions and performance evidence, supporting both compliance and next-step renovation planning.

Finally, replication and exploitation can be strengthened through synergies with other EU-funded initiatives and networks. These channels can amplify adoption by sharing templates, interoperability practices, procurement-ready documentation, and standardisation pathways, reducing duplication and accelerating learning across markets. Overall, this section aims to make ESIE adoption *doable and repeatable*: an integrated delivery process supported by proportionate evidence creation, robust commissioning, coordinated value chains, and practical engagement. In this way, the solutions demonstrated within FORTESIE can be replicated beyond pilots and embedded in mainstream renovation practices across Europe, delivering verified outcomes and durable social legitimacy.

7. Conclusions and future outlook

The activities undertaken over the past three and a half years in FORTESIE, alongside project findings, confirm that Europe's building decarbonisation challenge has entered a **new phase**. The limiting factor is no longer a lack of available technologies or policy ambition; it is the **ability** to deliver **integrated renovations** with **verified outcomes** under **real-world constraints**.

Across the FORTESIE pilots, the most consistent determinants of success were **delivery governance** (permitting and administrative throughput, procurement design, commissioning discipline, capacity of intermediaries) and the **availability** of **governance-grade data** that can underpin renovation trajectories, MEPS implementation, and credible reporting.

The project therefore points to a strategic shift in how renovation policy and markets must operate: from **component-driven upgrades** and "**paper compliance**" towards **performance-assured delivery**, **proportionate M&V**, and **user-centred implementation** models that remain workable for vulnerable households, multi-family buildings, and complex public facilities.

This shift is directly aligned with the direction of the EU's "Renovation Wave" and the "Fit-for-55" package, which together raise both the pace and the accountability expectations of the renovation transition. The recast EPBD strengthens the pathway to ZEBs by 2050 and increases the operational relevance of building performance databases, BRPs, and national renovation trajectories. In parallel, the EED's EE1st principle and tightening savings requirements reinforce the need to prioritise demand reduction and verified efficiency gains, while RED accelerates the integration of renewables and electrification in buildings.

FORTESIE's core contribution was, therefore, not only the demonstration of technical solutions, but the validation of a delivery logic that can help Member States and market actors turn these EU frameworks into **scalable** and **socially legitimate** renovation pipelines.

Importantly, FORTESIE also demonstrated that policy uptake can occur during the project lifecycle, not only after its completion. A concrete example is the publication by Latvia's Ministry of Climate and Energy of "**National guidelines on sustainable ventilation solutions**" to promote energy efficiency in buildings, developed in synergy with FORTESIE pilot experience and directly reinforcing the project's central insight that **renovation quality cannot be reduced to insulation performance alone**. This real-time institutional uptake is significant in two ways: first, it confirms that pilot evidence can be translated into actionable guidance by competent authorities; second, it signals that critical "**system integrity**" **dimensions**, such as ventilation performance, indoor air quality, and operational monitoring, are increasingly recognised as essential elements of energy-efficiency programmes rather than optional add-ons.

Looking forward, the most disruptive potential identified by FORTESIE lies in the combination of digitalisation and performance-based approaches. Digital M&V- when embedded early and implemented with interoperability and privacy-by-design- can transform renovation from an activity measured mainly through inputs (installed measures, subsidy uptake, certificates issued) into an outcome-driven system where energy, comfort, and indoor environmental quality improvements are evidenced in operation. This can enable new types of performance guarantees and ESIE-oriented contracting models that reduce risks for building owners and public authorities, improve accountability for suppliers, and increase the investment potential of deep renovations.

In this context, innovations such as the FORTESIE "**Green Euro**", the FORTESIE **app**, and the FORTESIE "**Marketplace**" are not simply project "tools"; they signal a broader market trajectory towards data-enabled value creation: rewarding verified performance, supporting user engagement, and lowering transaction costs by connecting actors across the renovation value chain. A **new certificate**

scheme based on the "Price-Comfort" indicator developed in the context of FORTESIE could further embed these digitalisation, performance-based rewarding, and behaviour-oriented incentive approaches into renovation ecosystems.

In sum, FORTESIE contributed to Europe's building transformation pathway in **three (3) complementary ways**:

- ✓ First, it strengthened the evidence base for moving from ambition to delivery, identifying the **operational bottlenecks** that most often prevent deep renovations from being completed and verified.

- ✓ Second, it demonstrated how digital M&V and performance-based models can act as **enabling infrastructure** for MEPS, BRPs, and credible national renovation plans, while remaining **feasible** in **diverse contexts** through tiered, proportionate **verification approaches**.

- ✓ Third, it reinforced the **social** and **behavioural dimensions** of renovation-based transitions, showing that trust, accessibility, and citizen-facing support are **not peripheral issues**, but core determinants of uptake, monitoring feasibility, and long-term performance persistence. The Latvian guideline uptake adds a further layer to this contribution: it shows that these insights can be **institutionalised into real policy instruments**, strengthening the link between demonstration evidence and national programme design.

The future outlook is therefore clear. If the next renovation decade is to succeed, Europe will need to industrialise not only technologies, but also delivery systems, such as interoperable data backbones, standardised commissioning and verification routines, procurement practices that buy outcomes, and strong intermediaries that reduce friction for households and public owners. FORTESIE provided a practical foundation for this evolution, and its early policy uptake illustrates the project's capacity to influence real governance choices while implementation lessons are still fresh. Taken together, this positions FORTESIE to help ensure that the "Renovation Wave" and "Fit-for-55" ambitions translate into verified energy savings, improved comfort and health, reduced emissions, and a socially credible pathway towards a European ZEB sector by 2050.

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