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BRINGING EUROPEAN BUILDING POLICY TO LIFE

# Minimum Energy Performance Standards and Trajectories of Progressive Building Renovation: Policy Guideline Summary

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**May 2026**

This project has received funding from the European Union's LIFE programme under grant agreement No.101120194. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or CINEA. Neither the European Union nor CINEA can be held responsible for them.

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**Publication date**
May 2026

**Graphic design**
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|---|---|
| **Project number** | 101120194 |
| **Start date of the project** | October 2023 |
| **Duration of the project** | 33 months |
| **Deliverable number** | 3.3 |
| **Deliverable leader** | e-think energy research |

## About EPBD.wise

EPBD.wise aims to kickstart action to bring to life the recast European Energy Performance of Buildings Directive (EPBD) as part of making EU climate goals a reality. Over the course of three years, project partners worked with public authorities (such as municipalities, energy agencies, etc.) in six European countries: Bulgaria, Greece, Hungary, Poland, Romania and Ukraine. The overarching aim was to ensure the design, implementation and evaluation of key provisions to ensure EU buildings align with climate goals. Starting with investigation of needs and good practices in the six focus countries, EPBD.wise builds replicable models to support the widespread implementation of effective measures across Europe.

For more information, visit the **EPBD.wise website.**

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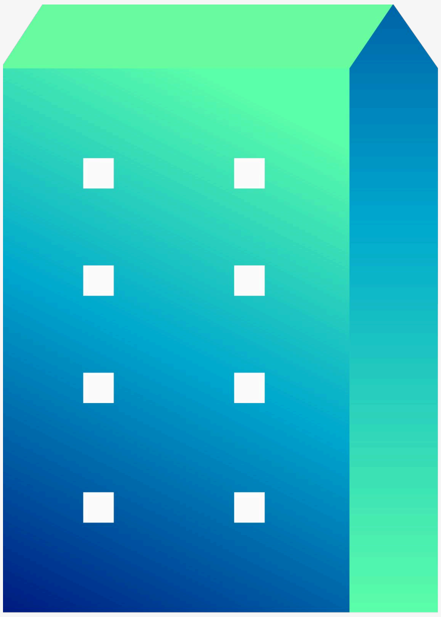

This deliverable examines the replicability of policy recommendations derived for the implementation of Article 9 of the Energy Performance of Buildings Directive (EPBD) across all EU Member States. Building on the policy analysis of Deliverable 3.1 EPBD Article 9 – Minimum Energy Performance Standards (MEPS) and trajectories for progressive renovation [1] and the guidelines developed in Deliverable 3.2 Development of article 9: policy guidelines [2] [3], it broadens the scope from selected focus countries to other EU-27 Member States. The overarching aim is to consolidate project findings into a transferable set of policy tools that national and regional policymakers can use to design and implement minimum energy performance standards (MEPS) and residential renovation trajectories in their specific building stock and regulatory contexts.

The quantitative assessment uses the Invert building stock model to simulate renovation trajectories for all EU Member States under five policy scenarios, ranging from stringent regulatory packages to purely market-based instruments. To ensure transferability, a clustering analysis grouped the 27 Member States into eight clusters based on climate conditions, primary energy factors, and renovation rates. The carbon intensity of electricity supply and the fossil fuel share in building heating emerged as the strongest differentiating factors across Member States. Six representative countries – Ireland, Italy, Czechia, Germany, Lithuania and Croatia – were selected for in-depth scenario comparison.

The scenario modelling yields the two following key findings. For non-residential buildings (Art. 9.1), regulatory standards – particularly when combined with a fossil boiler ban and economic incentives – are an effective instrument for shifting the building stock below the 2030 and 2033 MEPS thresholds. For residential buildings (Art. 9.2), market-based instruments alone tend to be insufficient: mandatory performance standards are necessary not only to meet the 2030 and 2035 interim targets but also for the long-term decarbonisation of the building stock. However, the starting point of Member States in terms of primary energy factors for electricity and district heating, the share of fossil fuels and expected evolution of the total floor area of the building stock strongly frames the results and creates specific challenges and opportunities for meeting targets.

These results point to four policy priorities: investing in robust building stock data as a prerequisite for threshold-setting; designing MEPS as part of an integrated policy package combining binding standards, financial support and enforcement; protecting vulnerable households through targeted financing and adapted governance models; and embedding Article 9 trajectories within National Building Renovation Plans to ensure methodological consistency and long-term coherence. Good practice examples from across the EU confirm that the building blocks for effective implementation are already in place and can be replicated by Member States at earlier stages of transposition.

Taken together, the analytical evidence and good practice examples presented in this deliverable demonstrate that Article 9 implementation is both technically feasible and politically actionable across the full diversity of EU Member States – provided that regulatory ambition is matched by adequate data infrastructure, financial support, and institutional capacity.

# LIST OF ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| **BSO** | Building Stock Observatory |
| **EPBD** | Energy Performance of Buildings Directive |
| **EPC** | Energy Performance Certificate |
| **ETS2** | Emissions Trading System 2 |
| **EU** | European Union |
| **FED** | Final energy demand |
| **GFA** | Gross floor area |
| **JRC** | Joint Research Centre |
| **LTRS** | Long-term renovation strategy |
| **MEPS** | Minimum energy performance standards |
| **NBRP** | National Building Renovation Plan |
| **OSS** | One-stop-shop |
| **PED** | Primary energy demand |
| **PEF** | Primary energy factor |
| **RP** | Renovation Passport |
| **WPB** | Worst-performing buildings |
| **ZEB** | Zero-emission building |

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# 1

# INTRODUCTION

This deliverable examines the replicability of recommendations developed regarding the implementation of Article 9 of the Energy Performance of Buildings Directive (EU) 2018/844 (EPBD) across EU Member States. Article 9 establishes requirements for the energy performance of buildings, aiming to promote transparency and efficiency in building energy use. Building on the policy analysis in Deliverable 3.1 EPBD Article 9 – Minimum Energy Performance Standards (MEPS) and trajectories for progressive renovation [1] and guidelines in Deliverable 3.2 Development of article 9: policy guidelines [2] [3], this report assesses implementation challenges, best practices, and transferability to other Member States. This work supports the project's goal of enhancing EPBD enforcement through cross-border learning and policy harmonisation.

## 1.1 Scope and objectives of the deliverable

This deliverable is related to the final stage of the EPBD.wise project, which builds on the policy guidelines developed in Phase 2. While Phase 2 concentrated on developing tailored guidance for a set of focus countries, Phase 3 broadens the scope to the full EU-27, with the objective of consolidating the project's findings into a comprehensive and transferable set of policy tools.

This deliverable builds on country-specific policy guidelines for the implementation of Article 9 of the EPBD and assesses their transferability across EU Member States. This involves refining the analytical framework considering updated data and stakeholder feedback and ensuring that the guidance produced is sufficiently robust and adaptable to accommodate the diversity of building stock conditions, regulatory contexts and institutional capacities found across Member States.

Article 9 is closely interconnected with National Building Renovation Plans (NBRPs). Across six key dimensions – building stock data, modelling assumptions, scenario design, scenario results, target achievement, and monitoring – the two policy instruments share a common analytical backbone, but they differ in scope and focus (see Table 1).

*Table 1: Distinction of content regarding policy guideline documents for NBRP and Art. 9*

| | Policy guideline NBRP [4] | Policy guideline Article 9 |
|---|---|---|
| **Building stock data** | Data collection and description of building stock data, including the distribution of energy consumption levels | How to derive worst-performing buildings and 16th/26th quantile thresholds for MEPS for non-residential buildings and primary energy demand target reduction for residential buildings |
| **Modelling assumptions and scenario design** | Overall modelling approach, scenario design and scenario framework data (e.g. energy prices) | Specific elements affecting the effectiveness of Art. 9 instrument, such as evolution of primary energy factors |
| **Scenario results** | Overall pathway results, e.g. in terms of final energy demand by energy carrier | Specific results showing Art. 9 target achievement split by residential and non-residential buildings |
| **Checking target achievement** | Overall evaluation of target achievement, including ZEB consistency, RED consistency, fossil fuel phase-out | Art. 9 targets, regarding the renovation of non-residential buildings in compliance with MEPS, and compliance with the trajectories for residential buildings |
| **Stakeholder engagement** | Included | Not included |
| **Monitoring and evaluation** | Monitoring of renovation activities and establishment of a continuous feedback and evaluation mechanism | Focus on compliance with MEPS (non-residential buildings) |

## 1.2 Structure of the deliverable

This deliverable is organised into eight main sections, reflecting the sequential logic from policy framework analysis to quantitative modelling, stakeholder engagement, and actionable recommendations for Article 9 implementation across EU Member States.

**Section 1** introduces the scope and objectives of the deliverable, outlines its structure, and describes the overall methodology and analytical approach underpinning the work.

**Section 2** provides a description of the Article 9 framework as established by the EPBD, covering the key obligations for Member States regarding worst-performing buildings, minimum energy performance standards (MEPS), and national renovation trajectories.

**Section 3** compiles the policy needs and best practice examples gathered across the six EPBD.wise focus countries, summarising the main gaps and challenges identified in the transposition and implementation of Article 9.

**Section 4** presents the quantitative assessment of Article 9-related policies using the Invert/EE-Lab building stock model. It covers the characterisation of national building stocks, the identification of worst-performing buildings, the definition of MEPS thresholds, and the modelling results for both the non-residential and residential sectors under five policy scenarios.

**Section 5** analyses the consistency and interaction of Article 9 with related policy instruments, specifically National Building Renovation Plans (NBRPs), energy performance certificates (EPCs), Renovation Passports, and zero-emission buildings (ZEBs).

**Section 6** draws on good practice examples from frontrunner EU Member States to illustrate replicable regulatory and financial models for implementing Article 9.

**Section 7** synthesises the quantitative results, good practice examples and stakeholder insights into actionable policy guidelines.

## 1.3 Description of the Article 9 framework in accordance with the EPBD

Article 9 of the EPBD [5] focuses on accelerating building renovations to achieve a fully decarbonised building stock by 2050. It introduces MEPS for non-residential buildings and a national trajectory for residential buildings.

1. **9(1) Non-Residential Buildings (MEPS):** Member States must renovate **the worst-performing 16% of non-residential buildings by 2030**, rising to **26% by 2033.** They can set energy performance thresholds based on **primary or final energy use** and may define additional energy indicators. Certain buildings, like historical and religious structures, may be exempt under clear criteria.
2. **9(2) Residential Buildings (National Trajectory):** Member States must ensure at least a **16% reduction in average primary energy use by 2030, a 20–22% reduction by 2035,** and further progressive reductions until 2050. This trajectory must align with NBRPs and identify the number of buildings, units or floor areas to be renovated annually, prioritising the worst-performing buildings. Addressing energy poverty is a key aspect, requiring financial and technical support for vulnerable households.

Member States must also implement monitoring and enforcement mechanisms, including penalties, to ensure compliance with the new standards.

New buildings and demolished buildings are counted in the calculations for renovation targets and energy performance improvements.

# 2

# BUILDING STOCK DATA

Reliable building stock data is the foundational prerequisite for Article 9 implementation. Without it, Member States cannot identify worst-performing buildings, set meaningful MEPS thresholds, or monitor policy effectiveness. The EPBD requires NBRPs to present building stock distribution by conditioned floor area and specific energy use – for both residential and non-residential segments – as the basis for deriving the 16th and 26th percentile thresholds for non-residential MEPS.

Four approaches are available, each with trade-offs:

- Archetype-based modelling is widely applicable but risks underestimating real-world performance variance.
- Measured energy consumption data captures actual usage accurately but is harder to obtain where diverse fuel types or data protection constraints apply.
- EPC databases provide standardised data, yet they tend to overrepresent renovated buildings and show inconsistencies with national energy balances.
- Statistical approaches offer a pragmatic fallback where data is scarce but rely on assumptions that may not transfer across contexts.

No single approach is sufficient. Member States should combine multiple data sources to cross-validate results and make their methodological choices explicit – particularly given the implications for how MEPS thresholds are set and how compliance is subsequently assessed.[1]

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[1] For more detail, see D2.3 *Development of NBRP: Policy Guidelines Summary* [6]

The implementation of Article 9 MEPS requires not only a legal and policy analysis but also a quantitative understanding of how the building stock would respond to different regulatory and economic interventions. This chapter presents the modelling approach and scenario design used to simulate renovation trajectories and energy performance improvements across EU Member States, as well as the methodology applied to identify representative countries for the case study analysis. Together, these two elements form the analytical backbone of the EPBD.wise assessment of MEPS implementation pathways.

To derive the transformation of the building stock and model the scenarios, we use the Invert modelling framework. Invert/EE-Lab is a bottom-up building stock simulation model that models the energy demand and renovation dynamics of entire national building stocks over time, simulating scenarios for building decarbonisation and projecting primary energy consumption and $CO_2$ emissions across different renovation pathways. It provides a comprehensive understanding of how energy performance in buildings evolves under different policy scenarios (see below), capturing both economic efficiency and realistic decision-making dynamics.[2]

The Invert/Opt(imisation) model was run under different policy scenarios that simulate different policy pathways for phasing out worst-performing buildings, as shown in Table 2. The scenarios combine varying levels of regulatory stringency, economic instruments and technological ambition to reflect alternative policy approaches. Five main scenarios are assessed:

1. **Regulatory+** scenario representing a strong top-down approach with a ban on fossil boilers and stringent MEPS
2. **Regulatory** scenario with moderate standards, but no fossil ban
3. **Mix** scenario combining high $CO_2$ prices (€300/t) and generous subsidies with partial regulatory measures limited to the non-residential sector
4. **Moderate** having moderate subsidies, limited regulation, and a $CO_2$ price of €75/t
5. **Pure economic** scenario relying solely on market-based instruments such as $CO_2$ pricing and subsidies

Each scenario is defined by specific assumptions on $CO_2$ prices, subsidy budgets, and the presence or absence of regulatory instruments for both the residential and non-residential sectors. This design allows assessment of the interactions between policy tools, their effectiveness in driving renovation and fuel switching, and their overall impact on energy demand, emissions and investment needs in the European building stock.

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[2] For a detailed description of the modelling, see Annex 1 - Invert/EE-Lab and Invert/Opt Model

*Table 2: Overview of policy scenarios used in the modelling*

| Scenario name | $CO_2$ price | Subsidies | Ban fossil-based boilers | Residential | Non-residential |
|---|---|---|---|---|---|
| Regulatory+ | €75/t | Moderate | Yes | MEPS | MEPS |
| Regulatory | €75/t | Moderate | No | MEPS | MEPS |
| Mix | €300/t | High | No | No MEPS | MEPS |
| Moderate | €75/t | Moderate | No | No MEPS | MEPS |
| Pure economic | €300/t | High | No | No MEPS | No MEPS |

# 3

# SELECTION OF REPRESENTATIVE MEMBER STATES

In this section, we explain the approach used to group EU Member States based on various data points, with the aim of understanding how Article 9 implementation could be adapted to different countries. We want to explore whether EU Member States present systematic similarities in terms of building stock characteristics and energy system configurations, and thus whether the policy recommendations emerging from the EPBD.wise case studies may be transferable across clusters of countries. The main goal is to check if factors beyond climate and typical building styles have a significant impact on how countries are grouped, providing insights into broader influences on energy policies. The analysis shows that the efficiency of electricity production and the reliance on fossil fuels were the most important factors shaping these groups.

To achieve this, we use a machine learning technique called clustering, which groups similar items based on their characteristics. Clustering algorithms help identify patterns in data without needing predefined categories. One common type is 'k-means' clustering, which is popular for its simplicity: it divides data into a set number of groups (chosen in advance by the analyst) by repeatedly adjusting group centres to minimise distances within each group. However, for our analysis, we selected 'hierarchical' clustering [7], which builds groups step by step like a family tree, merging the most similar countries progressively without requiring an upfront decision on the number of groups. By using hierarchical clustering, we ensure a data-driven approach to forming groups, where countries are combined based on similarities on six key indicators for each EU Member State:

- Relative change in gross floor area 2020–2050[3]
- Fossil fuels share 2020 – share of fossil fuels in total energy[4]

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3. (GFA_2020 – GFA_2050) / GFA_2020, Data retrieved from Invert/EELab, https://www.invert.at/
4. Source: Invert/EE-Lab model calculations (https://www.invert.at/) based on Eurostat energy balance data

- Heating degree days (HDDs) reference year: 2016 [8]
- Primary energy factor (PEF) for electricity – indicating the energy and carbon intensity of electricity supply[5]
- Deep renovation rate [9]
- Long-term renovation strategy (LTRS) evaluation score [10]

The clustering analysis resulted in eight distinct groups of EU Member States, as shown in Table 3.

*Table 3: Cluster membership of 27 EU Member States resulting from hierarchical clustering analysis (Ward linkage, k = 8)*

| Cluster | Countries |
|---|---|
| 1 | Cyprus, Malta |
| 2 | Italy, Spain |
| 3 | Belgium, Netherlands, Ireland, Luxembourg |
| 4 | Sweden, Austria, Denmark, Finland |
| 5 | Lithuania, Bulgaria, Estonia, Latvia, Croatia, Romania, Slovenia |
| 6 | Greece, Portugal |
| 7 | Poland, Czechia, Hungary, Slovakia |
| 8 | France, Germany |

For the next step, we analysed which indicators have the most influence on forming the clusters. The approaches we applied showed that the PEF for electricity (indicating the carbon intensity of a country's electricity supply) and the share of fossil fuels in buildings' energy use are the strongest drivers. Other factors such as national renovation strategy ambitions and heating degree days (HDDs) also play significant roles, while deep renovation rates and projected floor area reductions have smaller effects (Table 4).

From these eight clusters, six countries were selected for detailed scenario analysis, representing five of the clusters. The six countries were Ireland, Italy, Czechia, Germany, Lithuania and Croatia. The selection was cross-checked against gross floor area, final energy demand, and share of renewable energy.

While we selected these specific countries for analysis, they should also be understood as representing types of similar countries or regions.

- The results for Ireland shown below should be understood as representative for countries with a very high share of direct fossil fuel use (>80%) in the base year (2020), a strong expected growth of building stock, moderate HDDs and PEF of electricity.

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[5] Source: Invert/EE-Lab model calculations (https://www.invert.at/) based on Eurostat energy balance data

- Italy stands for countries with a high direct use of fossil fuels share (~60%), but lower expected growth of floor area, low HDDs, and moderate PEF of electricity. The Italian LTRS was evaluated by JRC relatively positively, indicating good experiences with processes relating to setting up such documents in the past [11]. Estimated historical deep renovation rates in Italy were higher than in other countries [12].
- Czechia represents countries with a moderate share of direct fossil fuels in the base year (~40%), due to a higher share of district heating and biomass, moderate to high HDD, and a very high PEF of electricity.
- Germany illustrates a case with a high share of direct fossil fuel use (>70%) in the base year, moderate HDDs, and relatively high PEF of electricity.
- Lithuania stands for countries with a low share of direct fossil fuel use (~20%) in the base year due to a high share of district heating and biomass, high HDDs, moderate to low PEF of electricity, and a very good evaluation of LTRS indicating a high level of expertise and experience with processes relating to setting up such types of reports.
- Croatia represents countries with a moderate share of fossil fuels (~40%), an expected slight decrease of building stock, and moderate to low HDDs as well as PEF of electricity.

*Table 4: Key building stock and policy indicators for selected EU Member States under the Renovation+ scenario, 2020–2050*

| **Scenario** | **Renovation+ (MEPS implementation, $CO_2$ price at €75/t, ban on fossil fuel boilers, constant PEF)** | | | | | |
|---|---|---|---|---|---|---|
| **Country** | **Croatia** | **Czechia** | **Germany** | **Ireland** | **Italy** | **Lithuania** |
| Expected growth in gross floor area 2020-2050[6] | -0.06 | +0.06 | +0.05 | +0.27 | 0.00 | -0.03 |
| Fossil fuels share 2020[7] | 0.38 | 0.41 | 0.71 | 0.83 | 0.60 | 0.20 |
| Heating degree days (reference year: 2016) [8] | 2,264.65 | 3,247.67 | 3,009.02 | 2,744.05 | 1,766.12 | 3,829.94 |
| Primary energy factor for electricity[8] | 1.78 | 3.15 | 2.27 | 1.95 | 2.02 | 1.77 |
| Deep renovation rate [9] | 0.10 | 0.10 | 0.10 | 0.10 | 0.30 | 0.20 |
| LTRS evaluation [10] | 3.83 | 3.33 | 3.75 | 3.67 | 4.17 | 4.50 |

In summary, machine learning clustering provides a useful, data-driven lens to identify meaningful groupings among Member States and to spotlight the most influential dimensions (PEF electricity and fossil fuel share) that shape those groupings. While the small sample size and limited indicators mean the groups are not 'fixed rules,' the analysis still delivers actionable insights and a clear rationale for focusing future effort.

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6. GFA_2020 – GFA_2050) / GFA_2020, Data retrieved from Invert/EELab, https://www.invert.at/
7. Source: Invert/EE-Lab model calculations (https://www.invert.at/) based on Eurostat energy balance data
8. Source: Invert/EE-Lab model calculations (https://www.invert.at/) based on Eurostat energy balance data

# 4

# COMPARATIVE SCENARIO RESULTS ACROSS REPRESENTATIVE COUNTRIES

Building on the clustering analysis presented in Section 3, this section compares how Article 9 is implemented across EU Member States. For each representative country, the analysis covers three interconnected dimensions: Section 4.1 describes the identification of worst-performing buildings and the definition of MEPS thresholds, which form the basis for assessing Article 9 compliance. Section 4.2 then presents the scenario results for non-residential buildings under Article 9(1), examining how different policy pathways perform in shifting the energy performance distribution below the 2030 and 2033 MEPS thresholds. Section 4.3 extends the analysis to the residential sector under Article 9(2), focusing on national trajectories for primary energy demand reduction and their consistency with the interim targets set by the EPBD.

## 4.1 Identification of worst-performing buildings and MEPS threshold definition

To compare Member States consistently, we built a common 'archetype-based' modelling framework that can be applied across different national contexts. This framework starts from a core dataset of building stock structure (number of buildings and total floor area by construction period), primarily sourced from the Building Stock Observatory [9] and complemented with national and regional datasets where available.[9]

From this foundation, we derive the key parameters that drive energy performance:

- Building geometry and envelope characteristics (e.g. U-values) from national typologies
- The mix of energy carriers and heating systems per building type
- Indicators of energy performance that inform where the worst-performing buildings are and where renovation potential is greatest

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[9] In case of deviation between BSO and national data, we prioritise national data.

This common approach enables consistent, comparable results across countries, and supports the targeting of renovation strategies and policy interventions.

However, critical gaps remain in the available data, particularly regarding the share of refurbished buildings per construction period and building type, which is often estimated rather than directly measured. Similarly, information on the distribution of different energy carriers across various construction periods is limited, requiring further refinement through estimation techniques and complementary data sources.[10]

## 4.2 Scenario results for non-residential buildings

This section presents the results of the scenario analysis for non-residential buildings, in the context of Article 9(1) of the EPBD, which requires Member States to renovate the 16% worst-performing non-residential buildings by 2030 rising to 26% by 2033. For each country, the distribution of specific primary energy demand (PED) across tertiary sector building categories is assessed under four policy scenarios – Baseline 2020, Regulatory+, Regulatory, and Mix – and examined in relation to the 2033 MEPS threshold. The objective is to illustrate how different combinations of regulatory standards and economic instruments perform in shifting the energy performance distribution of the non-residential stock below the compliance threshold, and to identify the extent to which country-specific conditions influence the effectiveness of each policy pathway.

Figure 1 presents the distribution of specific PED across tertiary sector building categories and its relationship to the 2033 MEPS threshold, under four policy scenarios, for the six representative countries by clusters: Ireland, Italy, Czechia, Germany, Lithuania and Croatia. Results are shown separately for building-use categories including offices, wholesale and retail, hotels and restaurants, health, and education.

The Baseline 2020 distributions reveal considerable variation in energy intensity across building categories and countries, with health and hotels/restaurants consistently showing the highest specific primary energy demand across all six countries. Country-level differences are notable: Czechia and Germany display the widest spread of specific PED values and the highest absolute thresholds, while Italy and Croatia show comparatively lower and more compressed distributions. Ireland and Lithuania stand out for having a relatively large share of buildings clustered just above the threshold, suggesting a substantial renovation need even among moderately performing buildings. Importantly, the clustering analysis highlights that Ireland and Lithuania arrive at this shared outcome through structurally different pathways: Ireland is distinguished by the highest fossil fuel share in the sample (83%), making its building stock acutely sensitive to fuel-switching policies, while Lithuania is characterised by the lowest fossil fuel share (20%) but the highest heating degree days in the sample (3,829), meaning its renovation challenge is primarily heating-demand-driven rather than fuel-mix-driven. This distinction has direct implications for the policy instruments most likely to be effective in each context.

These differences are largely driven by the interplay between the PEF for electricity, the fossil fuel share in heating, and the climatic conditions.[11] For instance, Germany's high thresholds reflect a combination of a cold continental climate (which drives high absolute heating demand), a high fossil fuel share in heating (circa 71%), and a moderately high PEF for electricity (2.27).

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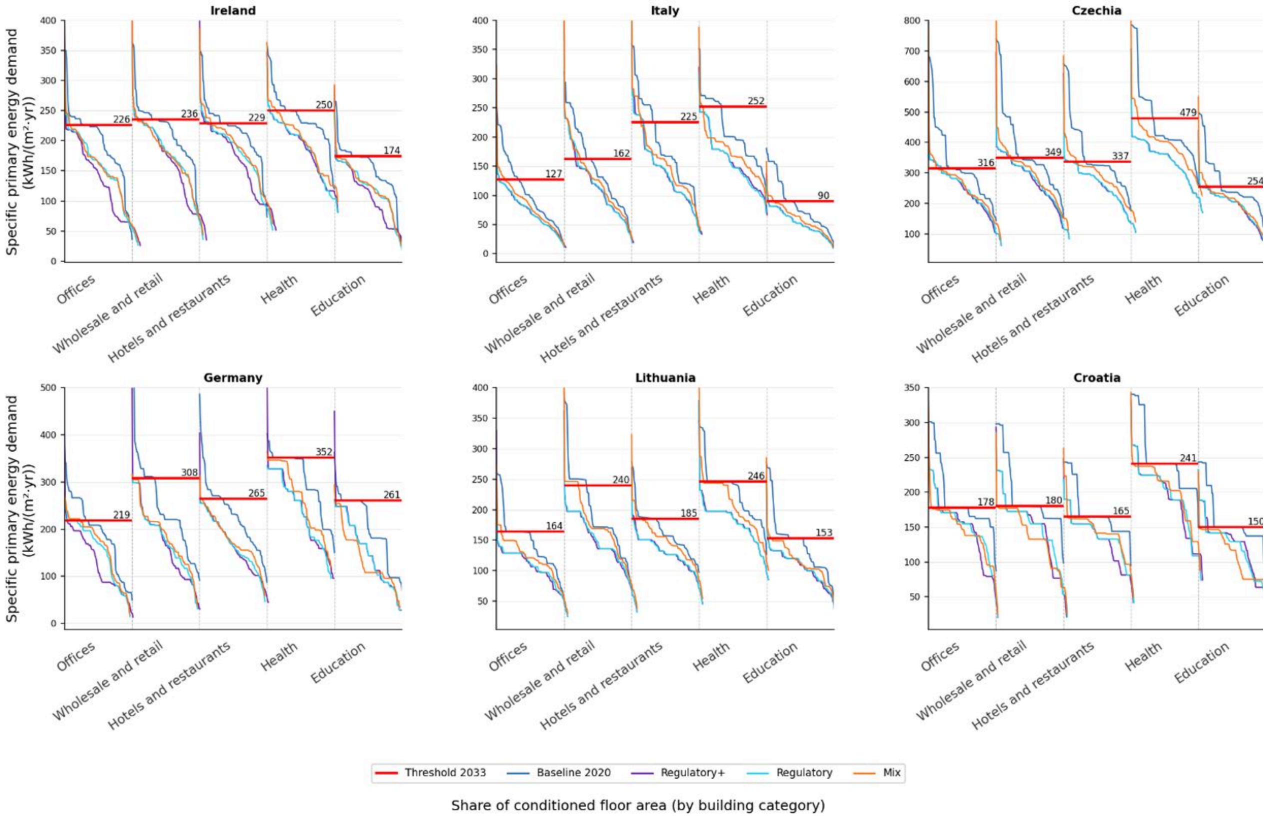
[11] For a more detailed description, see D3.2 *Development of article 9: policy guidelines* [2] [3]

While fossil fuels carry a PEF close to 1.0, the residual electricity and district heating demand is amplified in primary energy terms, and the sheer volume of energy consumed pushes the distribution upward. Italy's lower thresholds, by contrast, reflect its mild Mediterranean climate (which reduces overall heating demand), a moderate PEF for electricity (2.02), and – perhaps counterintuitively – a substantial reliance on fossil fuels for heating (60.5%, third-highest in the sample). Since fossil fuels carry a PEF close to 1.0, buildings that depend heavily on gas heating do not face the same primary energy amplification as those using grid electricity; combined with Italy's lower absolute heating volumes, this compresses the distribution and sets the MEPS threshold at a comparatively lower level. Crucially, the clustering analysis reveals that these country contrasts are not coincidental: Czechia and Germany, despite both sitting at the high-threshold end, are distinguished primarily by Czechia's exceptionally high PEF for electricity (3.15 versus Germany's 2.27) – the single strongest driver identified by the clustering model. This difference helps explain why Czechia displays an even wider PED spread than Germany despite comparable fossil fuel reliance.

For a complete list of values of PEF of electricity and share of fossil fuels, see Annex 2 - PEF and share of fossil fuels.

*Figure 1: Primary energy demand distribution and 2033 MEPS thresholds for the non-residential sector with primary energy factor varying over time and including user behaviour under four policy scenarios (Baseline 2020, Regulatory+, Mix, Regulatory) for the year 2033, shown by building use category*



Across all countries, the **Regulatory+** scenario – combining stringent MEPS with a fossil boiler ban – produces the most pronounced shift of the PED distribution below the 2033 threshold. The **Regulatory** scenario, without a fossil boiler ban, delivers more modest improvements, particularly in the upper tail of the distribution where the most energy-intensive buildings are concentrated. The **Mix** scenario, applying high $CO_2$ prices (€300/t) alongside MEPS for the non-residential sector, achieves broadly comparable results in most countries, and in some building categories even outperforms the Regulatory+ pathway, underscoring the effectiveness of combining economic incentives with regulatory standards.

Overall, the extended six-country comparison reinforces the finding that mandatory performance standards are indispensable for driving compliance with the 2033 MEPS threshold in the tertiary sector, while also highlighting the importance of tailoring policy instrument mixes to national building stock characteristics and baseline performance levels.

## 4.3 Scenario results for residential buildings

This section presents the scenario results for the residential sector, in the context of Article 9(2) of the EPBD, which requires Member States to achieve a 16% reduction in average PED by 2030 and 20–22% by 2035, with further progressive reductions until 2050. Following the same structure as Section 4.2, results are shown for one representative country per cluster. For each country, the trajectory of cumulative PED reduction is assessed under the five policy scenarios, and examined against the EPBD interim targets, under both constant and decreasing PEF assumptions.

### 1

### Targets and national trajectories

Figure 2 presents the cumulative PED reduction trajectories (%) relative to 2020 for the six representative countries across four policy scenarios, under a decreasing PEF assumption. The EPBD Article 9 interim targets, 16% by 2030 and 20–22% by 2035, are marked as reference lines. A clear scenario hierarchy emerges. Under Regulatory+, all six countries are broadly on track for the 2030 milestone, with two groups discernible: Italy and Ireland show the steepest savings trajectories and reach the target with the widest margins; while Germany, Czechia, Lithuania and Croatia follow with narrower but generally sufficient pathways. The Regulatory scenario mirrors this hierarchy at a lower rate of savings, reaching the 2030 target in most countries. The Mix scenario – high $CO_2$ prices but no residential MEPS – meets the 2030 target in several countries but falls short of the 2035 objective in most; the Moderate scenario falls short of both interim targets in all countries, confirming that market-based instruments alone cannot deliver the required renovation pace. In case of building stock growth, like in Ireland, under the Regulatory+ and Regulatory scenarios, the 2030 interim target of 16% remains achievable even for the existing stock, indicating that new construction, while contributing to aggregate savings, is not the sole driver of compliance. Moreover, in countries with strong building stock growth, such as Ireland, the 2030 interim target of 16% remains achievable under the Regulatory+ and Regulatory scenarios even when restricting the analysis to existing buildings, suggesting that new construction contributes to but does not drive compliance.

The cross-country variation is better understood alongside Figure 5, which shows final energy demand by energy carrier across the six countries under five scenarios for 2020, 2030, 2035 and 2050. Countries achieving steeper savings in Figure 2, Italy and Ireland, also show the largest fuel mix shifts in Figure 5: both enter the period with heavily fossil-fuel-dependent building stocks (Italy ~60%, Ireland ~83%), so renovation combined with fuel switching generates proportionally large primary energy reductions. Germany and Czechia start from higher absolute demand baselines; equivalent renovation effort therefore yields more contained proportional savings, consistent with their lower position in Figure 5. Lithuania, despite low fossil fuel dependence (~20%), shows meaningful demand reduction driven by efficiency improvements in its heating-intensive stock – the highest heating degree days among the six countries. These patterns align broadly with the building stock profiles identified in the clustering analysis: Italy and Ireland share the high fossil fuel shares that translate into strong renovation leverage, while Germany and Czechia reflect the heavier heating demands and higher-energy-intensity stocks of their respective cluster groupings.

*Figure 2: Cumulative specific PED reduction (%) relative to 2020 with dynamic primary energy factor under four policy scenarios (Regulatory+, Regulatory, Mix and Moderate), with EPBD Article 9 interim targets of 16% (2030) and 20–22% (2035) indicated as reference.*

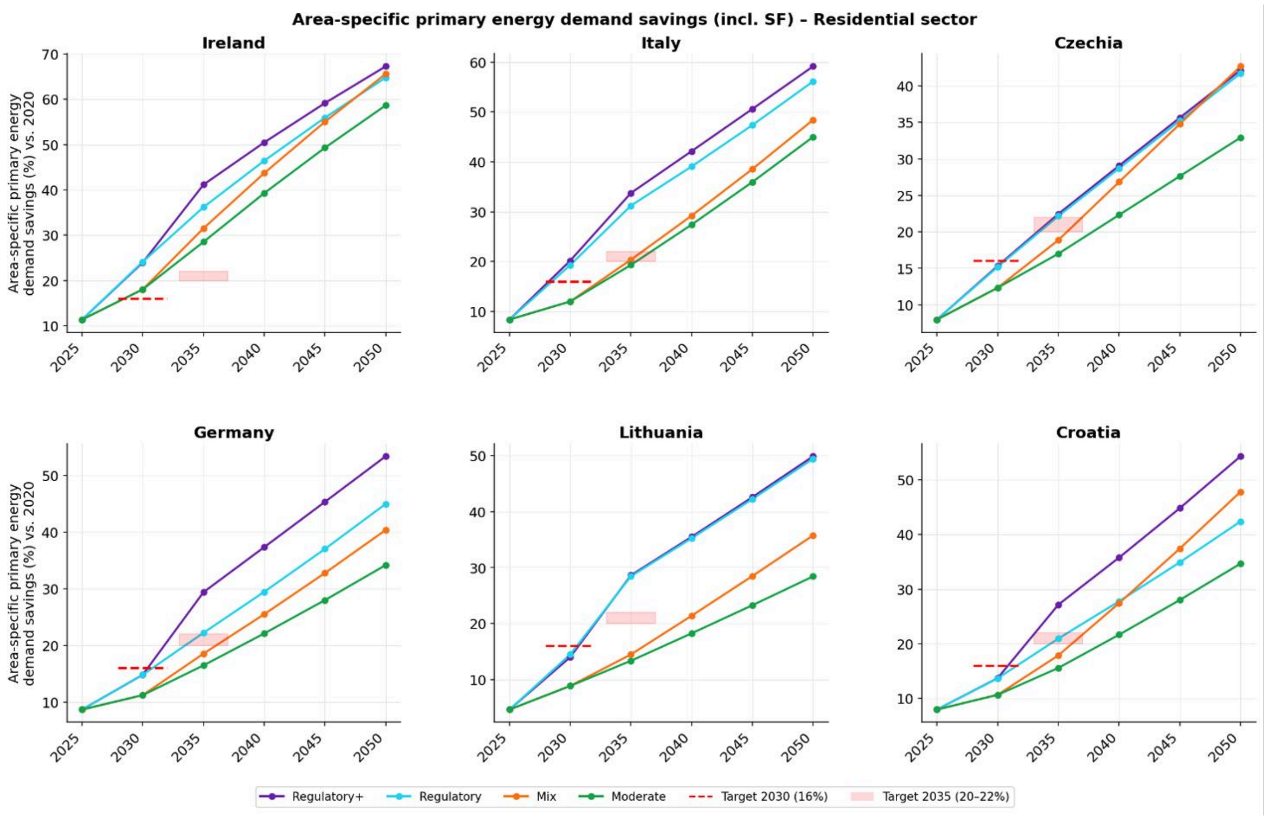
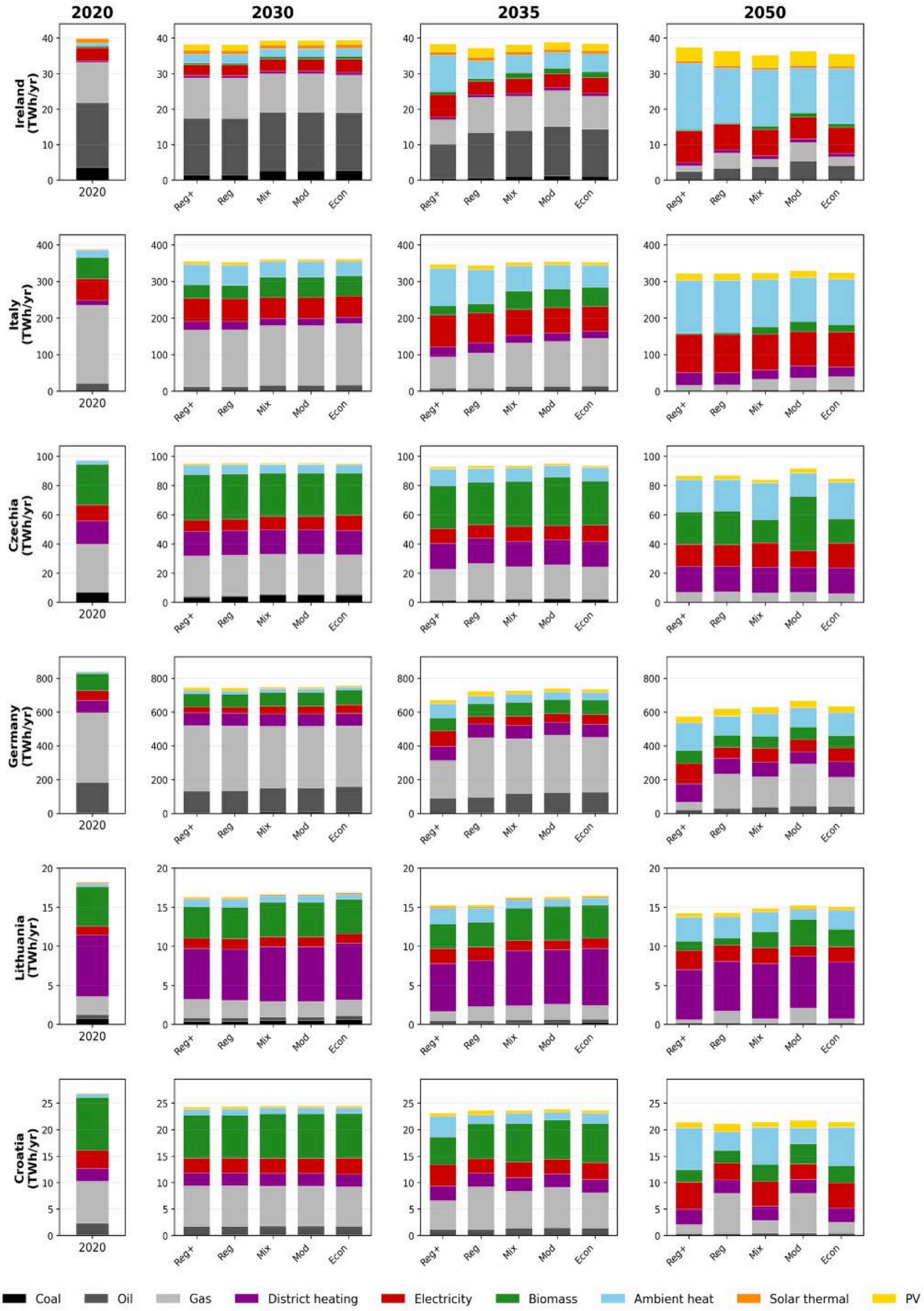


*Figure 3: Final energy demand by energy carrier across six exemplary countries and five scenarios for 2020, 2030, 2035 and 2050 (TWh/year). The 2020 column shows a single bar representing the base year energy mix; subsequent columns show results under five policy scenarios.*



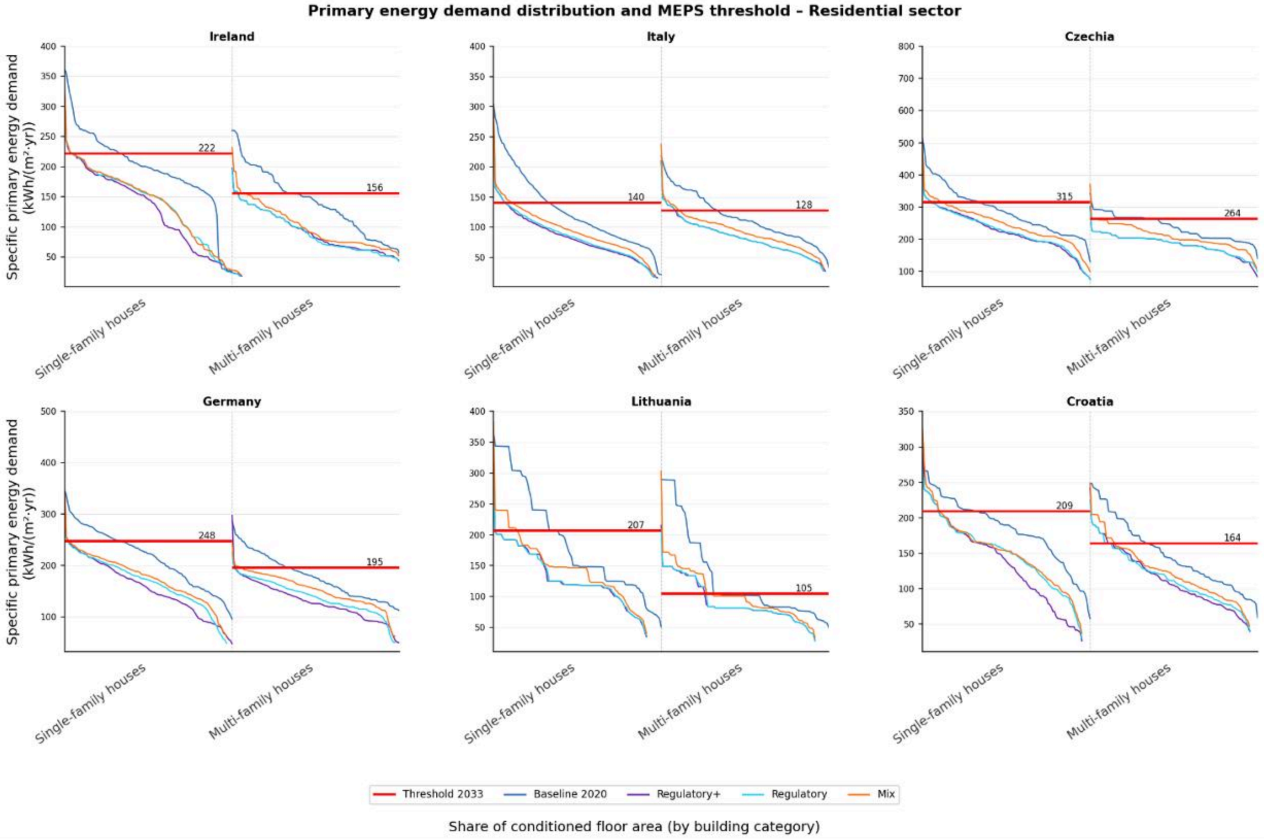
## 2 Sub-target 9.2 – Contribution of worst-performing buildings to primary energy demand reduction

Article 9(2) of the EPBD requires Member States not only to achieve the aggregate PED reduction trajectory, but also to ensure that the worst-performing buildings contribute meaningfully to that reduction – preventing targets from being met exclusively through incremental improvements across the broader stock.

Figure 4 presents the PED distribution and MEPS thresholds for the residential sector, disaggregated by building type (single-family and multi-family houses) and accounting for user behaviour and time-varying primary energy factors. The 2020 baseline reveals a wide spread of specific energy demand across all six countries, with the upper tail of the distribution – predominantly single-family houses – sitting well above the 2033 MEPS threshold. Country-level differences are pronounced and reflect the structural characteristics identified in the clustering analysis. Czechia and Germany display the widest spreads and highest absolute thresholds, driven by cold continental climates and high absolute heating demand – amplified in Czechia's case by the highest PEF for electricity in the sample (3.15 versus Germany's 2.27). Ireland and Lithuania stand out for having a comparatively large share of buildings clustered just above the threshold, though through structurally different pathways: Ireland's challenge is largely fuel-mix-driven, given its exceptionally high fossil fuel share in heating (83%), while Lithuania's is heating-demand-driven, with the highest heating degree days among the six countries. Italy and Croatia show more compressed distributions and comparatively lower thresholds, consistent with their milder climates and lower absolute heating volumes.

The **Regulatory+** and **Regulatory** scenarios consistently shift this distribution downward over time, bringing a larger share of the stock below the threshold across all countries, though a residual tail of hard-to-renovate buildings persists. The **Mix** scenario, which relies on high $CO_2$ pricing rather than MEPS, delivers comparatively weaker distributional effects in the residential sector, in contrast to its stronger performance in the non-residential sector, underlining the limited reach of purely economic instruments in driving deep renovation of residential buildings. The Moderate scenario is not shown separately, as its results closely mirror those of the Mix scenario; this convergence is largely explained by the limited increase in ETS carbon prices between 2030 and 2033, which reduces the effective difference between the two pricing assumptions over this period.

*Figure 4: Primary energy demand distribution and 2033 MEPS thresholds for the residential sector under Baseline 2020 and three policy scenarios (Regulatory+, Mix, Regulatory) for the year 2033, shown by building type (single-family and multi-family houses)*



These distributional shifts translate directly into the worst-performing buildings' contribution to aggregate PED reduction shown in Figure 5, which presents results for all six representative countries under the Mix scenario, normalised to the 2020 base year. Across all countries, the remainder (blue) – the share of PED persisting after renovation – declines progressively from 2020 to 2035, with worst-performing buildings (pink) accounting for a consistent and growing share of the total reduction over time. By 2030, the remainder in most countries sits just above the target line (0.84, corresponding to 16% savings), suggesting that the Mix scenario alone narrowly falls short of the Article 9(2) interim target – consistent with the limited distributional shift seen in Figure 4 under this scenario. By 2035, however, the remainder approaches or falls within the target band (0.78–0.80) in several countries – most notably Ireland and Lithuania – indicating progressive alignment with the Article 9(2) requirements. The contribution of other renovations (green) remains small throughout, confirming that worst-performing buildings are the primary driver of PED reduction. Country-level differences are modest: Croatia and Germany show a comparatively larger green component by 2035, while Ireland and Czechia exhibit a more contained total reduction, consistent with their higher baseline PED levels.

*Figure 5: Share of base year (2020) area-specific primary energy demand (PED) for the residential sector under the Mix scenario, including user behaviour.*

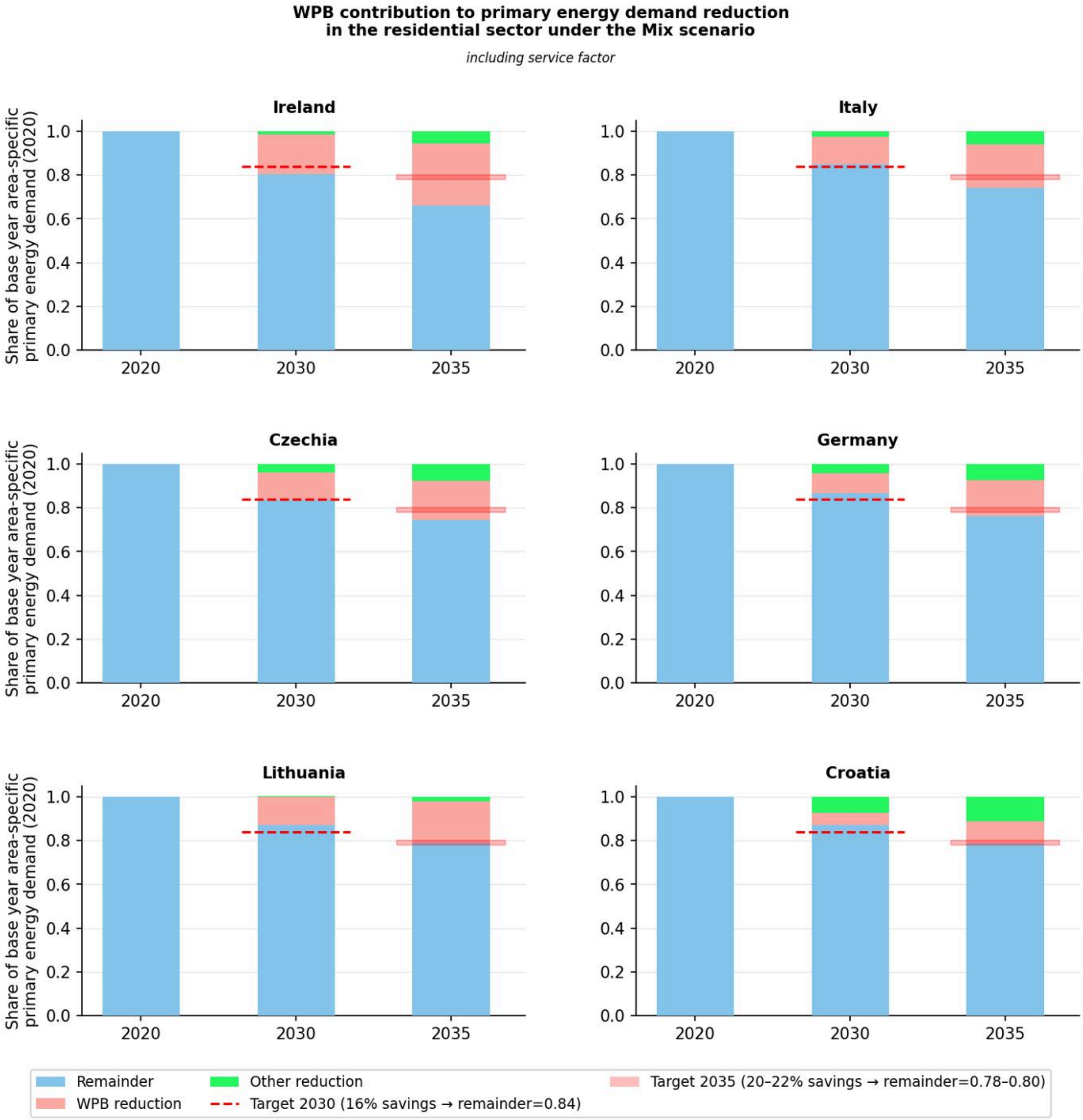


*Table 5: Area-specific worst-performing buildings (WPBs) contribution to primary energy demand reduction in the residential sector under the Mix scenario, including service factor. Cases where the target for WPBs is not achieved are coloured in red.*[12]

| Country | Scenario | WPB contribution to primary energy demand reduction | |
|---|---|---|---|
| | | in 2030 (%) | in 2035 (%) |
| Croatia | Mix | 5.44 | 9.9 |
| Czechia | Mix | 12.5 | 17.84 |
| Germany | Mix | 9 | 16.27 |
| Ireland | Mix | 18.19 | 28.34 |
| Ireland | Pure economic | 18.19 | 28.34 |
| Ireland | Moderate | 18.19 | 26.77 |
| Italy | Regulatory+ | 30.25 | 42.46 |
| Italy | Regulatory | 29.85 | 41.46 |
| Italy | Mix | 12.47 | 19.78 |
| Italy | Pure economic | 12.47 | 19.78 |
| Italy | Moderate | 12.47 | 18.92 |
| Lithuania | Regulatory+ | 23.66 | 38.06 |
| Lithuania | Regulatory | 24.84 | 38.5 |
| Lithuania | Mix | 13.38 | 18.85 |
| Lithuania | Pure economic | 13.38 | 18.85 |
| Lithuania | Moderate | 13.38 | 17.75 |

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[12] Based on a 55% contribution share for the residential sector, targets are considered met where values reach ≥ 8.8% by 2030 and ≥ 11% by 2035.

# 5

# SYNERGIES WITH OTHER EPBD INSTRUMENTS

Article 9 does not operate in isolation but is deeply interconnected with three complementary EPBD instruments: the National Building Renovation Plan (NBRP), the energy performance certificate (EPC) system, and Renovation Passports (RPs).

- The NBRP provides the strategic framework within which Article 9 targets must be planned, quantified and monitored. Member States are required to embed MEPS thresholds and residential trajectory milestones directly into their NBRPs, ensuring that Article 9's quantitative obligations are anchored in a transparent, long-term national strategy. Synchronising Article 9 trajectory development with the first draft NBRP, which was due by December 2025, is strongly recommended.
- The EPC system underpins Article 9 both as a data source and as a compliance tool. EPCs identify the worst-performing buildings subject to MEPS, verify post-renovation compliance, and provide the statistical basis for monitoring residential trajectories. The mandatory recalibration of EPC classes by 2026 – aligning class G with the worst-performing stock – will further strengthen this function and ensure comparability across Member States.
- RPs translate Article 9's aggregate targets into building-level renovation roadmaps, guiding owners through staged interventions that cumulatively meet deep renovation requirements. When issued jointly with EPCs and referenced explicitly in NBRPs, RPs create a coherent micro-to-macro link between individual renovation pathways and national decarbonisation trajectories.
- The ZEB standard should be understood as the long-term destination toward which both MEPS thresholds and national residential trajectories are directionally oriented. While ZEB alignment was not explicitly modelled in this analysis, Member States should keep this horizon in view when designing their Article 9 implementation frameworks.

# 6

# GOOD PRACTICE EXAMPLES FROM EU MEMBER STATES

Several EU Member States have already developed regulatory frameworks and financial instruments that anticipate or closely align with the requirements of Article 9 of the EPBD.[13]

**Trigger-point obligations**

Linking renovation requirements to property transactions is one of the most effective ways to capture renovation moments that would otherwise not occur. Flanders (Belgium) operationalised this through the Renovation Pact (2014), which made minimum energy performance requirements mandatory at the point of sale or change of ownership, including roof insulation and double-glazing requirements, enforced through a penalty points system [13]. Similarly, Brussels Capital Region requires residential building owners to implement five mandatory energy performance measures progressively between 2030 and 2050, identified through the EPC at the point of assessment [14].

**Phased bans on worst-performing buildings**

Several Member States have introduced time-bound phase-out trajectories for the lowest EPC classes, providing long-term regulatory certainty for property owners and investors. France has established the most comprehensive timeline: under the Climate and Resilience Act (2021), class G buildings must be renovated by 2025, class F by 2028, and all buildings must reach at least EPC D by 2034 [15]. The Netherlands applied a sector-specific version of this approach for offices, rendering the use of buildings rated energy class D or lower illegal from 2023, with a further requirement to reach label A by 2030 – affecting approximately 62,000 offices [16].

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[13] For a more detailed description see D3.1 *EPBD Article 9 – Minimum Energy Performance Standards (MEPS) and trajectories for progressive renovation: Policy needs and analysis of good practice examples* [1]

### Sector-specific standards for non-residential buildings

Beyond the office sector, France's 2019 Tertiary Sector Decree (Décret Tertiaire) requires reductions in final energy consumption of 40% by 2030, 50% by 2040, and 60% by 2050 for commercial buildings over 1,000 m² [15]. Flanders extended its ownership-triggered renovation obligation to tertiary buildings from 2021, requiring deep renovation within five years of a full change of ownership for non-energy-efficient properties [13].

### Enforcement mechanisms

Strong enforcement is a consistent feature of effective MEPS frameworks. England and Wales impose financial penalties of up to £4,000 (approx. €4,600) for non-compliant residential landlords and up to £150,000 (approx. €172,000) for non-residential properties under the Energy Efficiency (Private Rented Property) Regulations [17]. The Netherlands goes further, with non-compliant offices facing penalties up to forced closure [16]. Flanders uses a penalty points system that excludes non-compliant homes from the rental market entirely [13].

### Financial support and one-stop-shop services

Regulatory obligations are consistently paired with financial instruments and advisory services. Flanders offers green bonds and energy loans of up to €15,000 over ten years [13]. Scotland provides interest-free loans of up to £38,500 (approx. €44,000) through Home Energy Scotland, combined with free nationwide advisory services, government grants for low-income households, and area-based local authority schemes for hard-to-reach properties [18]. The Netherlands combines tax incentives and green loans with preferential interest rates, backed by technical advisory services from the Netherlands Enterprise Agency (RVO) [16].

# 7

# POLICY GUIDELINES AND RECOMMENDATIONS

The guidelines presented below synthesise the quantitative scenario results (Chapter 4), the good practice examples from frontrunner Member States (Chapter 6), and the insights gathered during stakeholder roundtables with national experts. They are organised around four inter-related dimensions: data infrastructure, regulatory design, social equity, and policy coherence.

## 1 Invest in building stock data

Robust MEPS implementation is impossible without reliable, comprehensive building stock data. Stakeholder discussions carried out within EPBD.wise pointed to critical gaps: in Croatia, only 9% of buildings hold an EPC, making statistically representative identification of the worst-performing buildings on the basis of EPCs extremely difficult, if not impossible. Polish experts highlighted two compounding problems. First, inconsistencies in primary energy factor methodology, particularly the transition from non-renewable to total PEF, can significantly shift worst-performing buildings thresholds and distort progress reporting. Second, and less commonly discussed, EPC quality itself is a growing concern: in Poland, a share of EPCs are generated automatically, without on-site assessment, reducing their reliability as a basis for threshold calibration. In other countries, such as Ireland, the EPC database, covering roughly 60% of the residential stock, is skewed toward new and recently renovated buildings and is therefore not representative of the full stock.

The modelling results in Chapter 4.2 reinforce these concerns: the identification of worst-performing buildings and the calibration of MEPS thresholds are highly sensitive to the quality and completeness of the underlying building stock data.

That it is especially true for the non-residential sector, where reliable categorisation by typology remains scarce across most Member States. Where EPC databases are incomplete or unreliable, a hybrid approach is a workable alternative, as it combines archetype-based modelling with national energy statistics, building registries, construction permit data, satellite imagery, and datasets such as the EU Building Stock Observatory. In Portugal, for instance, EPC building characteristics are combined with national building stock statistics to derive non-residential MEPS thresholds, as no single integrated source covers all typologies.

### What works

- **Portugal** has built a multi-purpose EPC system with a centralised database of over 2.5 million certificates, unique building identifiers, and approximately 300 variables per building, which is used to estimate renovation investment needs and underpin financial instruments. This model illustrates how an EPC database can evolve from a compliance registry into a multi-purpose planning tool. Member States with limited EPC coverage should prioritise expanding the database – including non-residential buildings – and integrating it with national building registers [19].
- **France's** IMOPE database (Indice de Modernisation et d'Occupation du Parc Existant Urbain), [20] which has been developed since 2016, integrates more than 100 data sources at address level across 21 million addresses, covering technical, energy, social and urban dimensions of the entire national building stock. Freely accessible via the national open data platform, it supports housing and renovation policy implementation at all territorial scales – from identifying energy poverty hotspots to targeting worst-performing buildings for renovation.

### Recommendation

*Establish or upgrade national building databases to include at minimum indicators such as construction year, floor area, energy carriers used, EPC class, and renovation status. This should be a prerequisite for defining MEPS thresholds and monitoring Article 9 trajectories. Implement quality assurance mechanisms for EPC calculations to prevent automated or low-quality certificates from undermining threshold reliability. For non-residential buildings, develop structured typological databases covering the categories required by the EPBD. Where EPC coverage is insufficient, adopt hybrid methodologies combining multiple data sources and clearly document the assumptions underpinning threshold definitions.*

*Where EPC coverage is insufficient or unreliable, the identification of worst-performing buildings requires a broader data strategy. Hybrid methodologies combining EPC data with archetype-based modelling, national energy statistics, building registries, construction permit data and satellite imagery should be adopted and clearly documented. In countries where no sufficient address-level database is available, proxies for identifying worst-performing buildings – such as construction period, renovation status and heating system type – offer a workable interim solution, provided their limitations are explicitly acknowledged in MEPS threshold definitions and progress reporting.*

## 2 Combine mandatory standards with financial support

The scenario analysis in Chapters 4.2 and 4.3 provides clear evidence that across all six representative countries and both the residential and non-residential sectors, for many countries purely market-based approaches are insufficient to drive compliance with the 2030 and 2033 MEPS thresholds in existing buildings[14]. The Regulatory+ scenario, combining stringent performance standards with a fossil boiler ban, consistently produces the most pronounced shift of PED distributions below MEPS thresholds. This finding holds across climatically and structurally diverse Member States.

However, regulatory frameworks alone are equally insufficient if financial support is intermittent or unpredictable. Renovation programmes which appear, are scaled back, or disappear between political cycles undermine the sustained market mobilisation that MEPS require. The Polish Clean Air Programme [21] demonstrated what continuity can achieve: at its peak, it supported the replacement of 100,000 coal boilers per year, with banks shifting from being passive lenders to proactively approaching households about renovation financing. This behavioural shift in the financial sector only occurs when programme rules are stable and predictable over multi-year horizons. Several stakeholders highlighted that the current geopolitical context and energy price volatility make it all the more critical to bridge the financing gap. That can be achieved by creating financing instruments that go beyond national budget allocations, including ETS2 revenues, green mortgages, and EU structural funds.

### What works

- **Flanders (Belgium)** enforces renovation obligations triggered at the point of sale, backed by a penalty system that excludes non-compliant homes from the rental market [22]. Financial support through the Flanders Energy Company (Fluvius) lowers the barrier for owner-occupiers [23]. This ‘trigger point’ model, linking MEPS to property transactions, is particularly effective because it captures renovation moments that would otherwise not occur.
- **France** operates a rental prohibition on the worst-performing buildings (EPC classes G and F) with clear, pre-announced timelines: class G buildings may no longer be rented from 2025 or class F from 2028, with all rental properties required to achieve at least EPC class D by 2034, with penalties for non-compliance [15]. The 2021 MaPrimeRénov’ scheme [24] provides income-graduated subsidies, complementing the regulatory framework. This combination of a credible regulatory timeline with means-tested financial support is a replicable model for Member States designing residential trajectories under Article 9(2).
- **Scotland** combines a minimum EPC class D standard for rented properties with Home Energy Scotland, a nationwide one-stop-shop offering free advice and interest-free loans of up to £38,500 (approx. €44,000) [18]. The one-stop-shop model dramatically reduces transaction costs for households. That approach is directly relevant to Member States where financial barriers alone do not explain low renovation rates; advisory and administrative complexity play an equally significant role.

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[14] When also considering new building construction, this result might change in countries with high expected growth of the building stock. From the six countries selected for this report, this is the case for Ireland.

- **The Netherlands** implemented a sector-specific, hard-deadline approach for offices: EPC class C by 2023, with the use of non-compliant offices rendered illegal [16]. This created a clear market signal well in advance of the deadline, mobilising private investment. By 2030, approximately 62,000 offices will require mandatory renovation. This model is directly applicable under Article 9(1) for non-residential buildings.

**Recommendation**

*Design Article 9 implementation as a policy package combining: (i) binding MEPS with clear and pre-announced compliance deadlines; (ii) stable, multi-year financial support programmes with graduated instruments for different household types, direct subsidies for vulnerable households, bank guarantee schemes and green loans for others; (iii) one-stop-shop services reducing administrative friction and providing accessible (non-technical) guidance to building owners, ideally providing additional guidance on staged renovation through Renovation Passports; (iv) enforcement mechanisms including penalties and market restrictions for non-compliant buildings; and (v) ESCO or on-bill financing models adapted to the legal reality of multi-owner buildings, particularly in Central and Eastern European contexts. Programme continuity across political cycles should be treated as a design requirement, not an aspiration.*

## 3 Address the worst-performing buildings in the frame of vulnerable households

A recurring concern is that the worst-performing buildings are disproportionately owned or occupied by lower-income households. This creates a paradox: the buildings most urgently requiring renovation are the hardest to reach through standard market-facing instruments. It will depend on the level of ETS2 revenues and how they are allocated, whether they will be able to cover the full financing gap. Irish stakeholders raised a related point: in the context of an acute housing crisis and very high electricity prices, mandatory MEPS for the residential sector is not currently considered politically feasible. Social and housing market conditions place real limits on the policy instruments available in some Member States. Consequently, Article 9 implementation frameworks must be designed with this in mind. Energy poverty and renovation accessibility are not technical problems alone; they require social policy instruments running in parallel with regulatory ones.

**What works**

- **Greece** has introduced a subsidy programme for vulnerable households that covers up to 100% of renovation costs, conditional on household income, which experts reported has shown strong uptake [25].
- On the data side, **Warsaw (Poland)** offers a replicable model for translating administrative registry data into actionable renovation prioritisation [26]. Working under the C40 Cities framework, the Institute for Structural Research (IBS) developed a composite intervention index for Warsaw's 1,886 municipal buildings, of which 77% are in poor or insufficient technical condition and 8% of the city's population resides in them. Rather than conducting costly dedicated surveys, the approach combined existing administrative datasets – including building technical condition records, heating source data from the Central Emission Evidence of Buildings, social welfare allowances from local welfare centres, and demographic registers – to score buildings

across four equally weighted criteria: technical condition, environmental performance, social vulnerability, and operational feasibility. The resulting ranking, implemented as an interactive dashboard for city officers, enabled prioritisation of 65% of the municipal stock and directly informed the sequencing of renovation investments to balance environmental and social goals.

**Recommendation**

*Develop dedicated renovation support tracks for vulnerable households and multi-family buildings, including full-cost coverage for the lowest income brackets; adapted legal frameworks for collective renovation decisions in condominiums; ESCO or on-bill financing models to remove upfront cost barriers; and composite prioritisation tools integrating energy and social data to sequence renovation investments. Renovation Passports (as described in D4.3, Development of Renovation Passports: Policy Guideline Summary. Preparing the ground for replication in other EU MS [27]) offer a practical instrument to translate financing pathways into building-level renovation roadmaps, lowering entry thresholds especially for households with limited renovation experience. In Member States where mandatory residential MEPS face significant social or housing market constraints, the trajectory under Article 9② may need to rely more heavily on targeted financial incentives and staged obligations, with regulatory requirements phased in as market and social conditions allow.*

## 4

## Embed Article 9 within NBRPs: renovation roadmaps, monitoring, and policy coherence

Article 9 does not operate in isolation. The NBRP is the overarching strategic instrument that should anchor all renovation-related obligations within a single coherent national framework. In practice, this means four things: setting a credible renovation roadmap with milestones, monitoring progress robustly, synchronising Article 9 with other national climate instruments, and building the administrative capacity to deliver.

The scenario results in Chapter 3.3 illustrate why methodological rigour matters. The choice between a constant and a dynamic PEF path substantially affects reported progress under Article 9(2). Under a dynamic path, where PEFs evolve in line with grid decarbonisation, Article 9(2) targets are achieved earlier and under a wider range of scenarios than under constant-path assumptions. This means that NBRP design should explicitly account for expected PEF evolution as an integral part of the trajectory modelling, not just as a sensitivity parameter. Another example is the possible impact of new building construction for Article 9(2) target achievement. The case of Ireland (see Chapter 4.3) shows that the assumption of a strong expected growth of new building construction can significantly affect target achievement. Since the focus of Article 9(2) still should be on building renovation, a separate consideration of targets with and without new building construction is recommended. Without harmonised and documented assumptions embedded in the NBRP, trajectory reporting risks becoming internally inconsistent across planning cycles. This challenge was also raised in stakeholder discussions, noting that methodological choices – which the EPBD guidance allows but does not prescribe – can significantly shift reported savings figures.

This risk is familiar from the predecessor instrument. The JRC assessment of the 2020 LTRS found that reporting on implementation progress was the single most poorly addressed requirement: only 8 out of 29 Member States provided sufficient detail on the implementation of their previous strategy [28]. The JRC concluded that Member States systematically underestimated monitoring and evaluation as a policy instrument, seeing it rather as a compliance formality.

### What works

- **Finland** provides the most replicable model for milestone-based renovation roadmaps. Its LTRS – rated highest among all EU strategies for this element by the JRC – sets quantified renovation targets for 2030, 2040 and 2050, disaggregated by building type and renovation depth (low, medium, deep) and broken down by income class. Milestones were developed through scenario modelling and then validated through stakeholder rounds, creating an explicit feedback loop between analytical work and governance. Investment costs are quantified per scenario, enabling realistic financing planning.
- **Lithuania** complements the Finnish model by showing how milestones specific to worst-performing buildings can be embedded within a broader renovation roadmap. Its strategy specifies indicative milestones for 2030, 2040 and 2050 across energy savings, $CO_2$ reductions, renovated floor area, and number of worst-performing buildings addressed, broken down by building type.
- **Spain** demonstrates how renovation planning can be explicitly synchronised with wider climate and energy planning instruments. The Spanish LTRS was designed as a direct complement to the National Energy and Climate Plan, filling gaps rather than duplicating content, and includes a detailed matrix of progress indicators covering the residential sector, tertiary sector and public buildings separately. It is also one of only eight Member States that adequately reported on the implementation of its previous strategy.
- **Denmark** illustrates the value of structured implementation tracking at low administrative cost. Its LTRS includes a dedicated implementation annex documenting the status of all measures from the previous strategy – what was planned, what was delivered, and what remained outstanding. Denmark also developed a default value catalogue for energy savings, allowing programme administrators to calculate renovation outcomes using simple multiplication rather than complex modelling, significantly reducing transaction costs in routine monitoring.

### Recommendation

*Article 9 trajectories should be embedded within NBRPs from the outset, with explicit and consistent methodological assumptions on PEF documented and made transparent. Article 9(2) target achievement should be calculated with and without new building construction to avoid distortion through the effect of new buildings. Milestone-setting should be scenario-informed and disaggregated by building type, renovation depth, and sector, following the Finnish and Lithuanian models. NBRPs should include a dedicated implementation annex reporting progress against the previous planning cycle, as in Denmark. The Article 9 framework should be explicitly cross-referenced with the National Energy and Climate Plan and other national strategic documents to avoid duplication and ensure coherence, following the Spanish model. EPC databases, Renovation Passports and digital building logbooks should be systematically connected to national monitoring frameworks to improve the granularity and reliability of progress reporting.*

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# ANNEX

## Annex 1 – Invert/Opt Model

The figure illustrates the model's structure, showing the interaction between building stock characterisation, policy inputs, investment decision modules and output indicators. The discrete choice module determines renovation and heating system decisions based on economic factors, policy incentives and behavioural parameters. Technology diffusion constraints ensure realistic deployment rates for new technologies.

**Invert/Opt** is a derived model version specifically designed to calculate cost-optimal renovation scenarios. Unlike the simulation-based Invert/EE-Lab, Invert/Opt uses optimisation algorithms to identify the most cost-effective combination of technology options for both heat savings (envelope measures) and heat supply (heating systems) across different time periods.

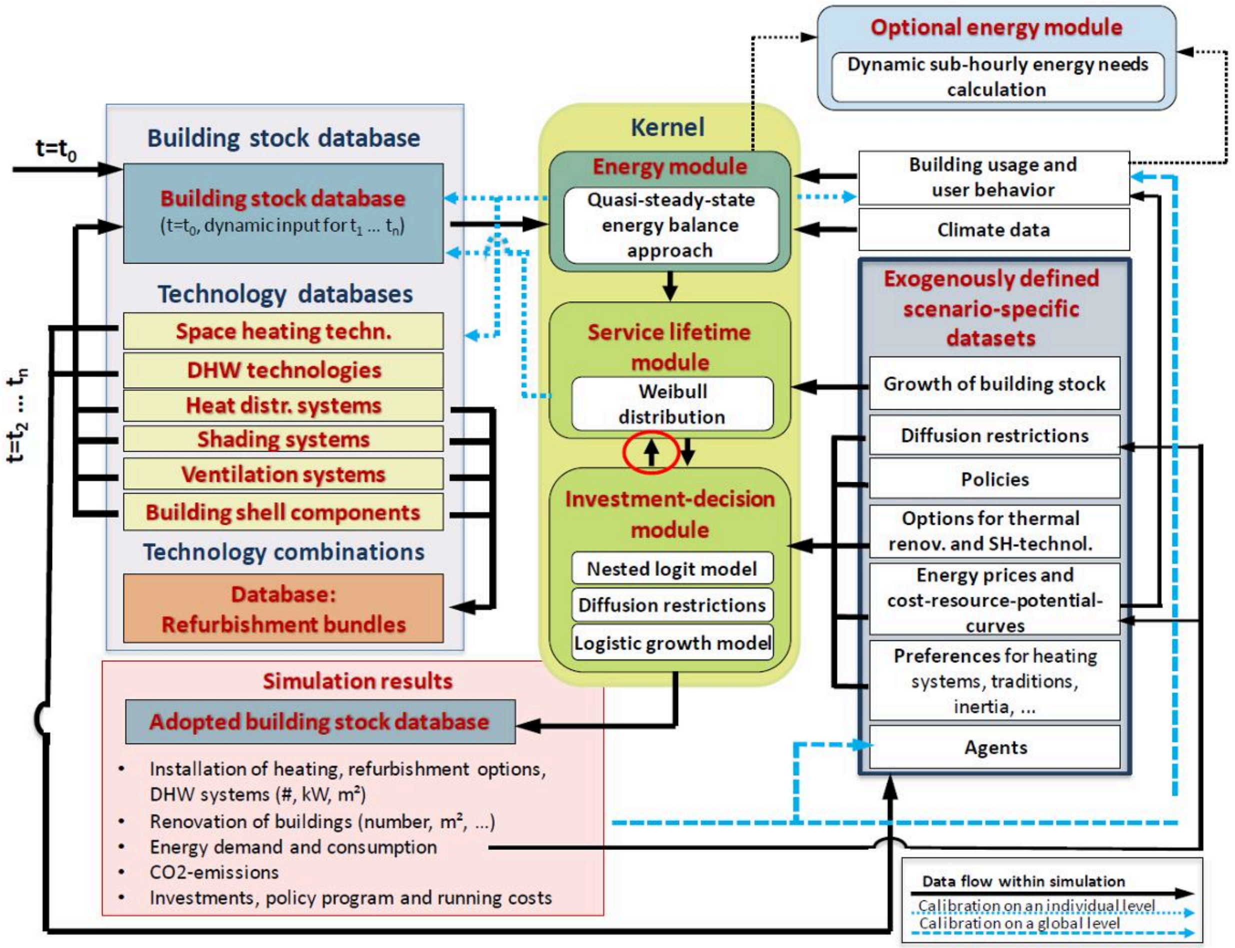
Key features of Invert/Opt include:

- Cost-optimality calculation: Identifies renovation measures that minimise total costs (investment + operating) while meeting energy or emission targets
- High disaggregation: Varies by country from several hundred to several thousand building segments, split across multiple climate regions
- Diffusion constraints: Accounts for limited availability of tradeable biomass, energy infrastructure constraints, and suitable roof areas for solar technologies
- Technology mix outputs: Produces diverse technology portfolios even in optimisation mode, reflecting real-world constraints.

The model calculates cost-optimality for:

- Building envelope retrofitting (insulation of walls, roofs, floors; window replacement)
- Heating and hot water supply system replacement
- Integration of renewable energy technologies (solar thermal, heat pumps, biomass)

*Figure 6: Overview of the structure of Invert/EE-Lab and Invert/Opt*



# Annex 2 – PEF and share of fossil fuels

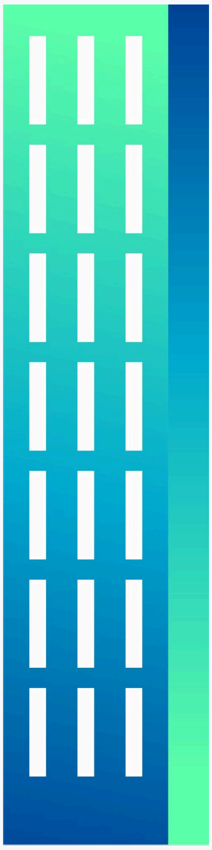
## PEF electricity

| Rank | Country | PEF electricity |
|---|---|---|
| **1** | **Bulgaria** | **3.2662** |
| **2** | Czechia | **3.1537** |
| **3** | **Estonia** | **2.9272** |
| **4** | **Cyprus** | **2.8701** |
| **5** | **France** | **2.8679** |
| 6 | Slovakia | 2.8626 |
| 7 | Hungary | 2.8428 |
| 8 | Poland (updated) | 2.7041 |
| 9 | Romania (updated) | 2.5157 |
| 10 | Malta | 2.3310 |
| 11 | Germany | 2.2677 |
| 12 | Spain | 2.1870 |
| 13 | Finland | 2.0229 |
| 14 | Italy | 2.0205 |
| 15 | Ireland | 1.9540 |
| 16 | Portugal | 1.8502 |
| 17 | Sweden | 1.8005 |
| 18 | Croatia | 1.7830 |
| 19 | Lithuania | 1.7666 |
| 20 | Luxembourg | 1.7300 |
| 21 | Latvia | 1.6663 |
| 22 | Denmark | 1.5422 |
| 23 | Austria | 1.4705 |

## Fossil fuel share in heating final energy demand, 2020

| Rank | Country | Fossil fuel share |
|---|---|---|
| **1** | **Ireland** | **83.1%** |
| **2** | **Belgium** | **82.2%** |
| **3** | **Luxembourg** | **74.5%** |
| **4** | **Germany** | **70.8%** |
| **5** | **Italy** | **60.5%** |
| 6 | Ukraine | 55.8% |
| 7 | Hungary | 55.5% |
| 8 | Slovakia | 53.2% |
| 9 | Spain | 51.8% |
| 10 | France | 50.9% |
| 11 | Poland (updated) | 47.4% |
| 12 | Romania (updated) | 42.1% |
| 13 | Czechia | 40.9% |
| 14 | Austria | 39.7% |
| 15 | Croatia | 38.2% |
| 16 | Portugal | 36.5% |
| 17 | Cyprus | 26.3% |
| 18 | Bulgaria | 20.5% |
| 19 | Denmark | 19.9% |
| 20 | Lithuania | 19.7% |
| 21 | Latvia | 17.6% |
| 22 | Estonia | 12.1% |
| 23 | Finland | 9.2% |
| 24 | Sweden | 7.2% |
| 25 | Malta | 4.8% |

# THE EPBD.WISE CONSORTIUM



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