Analysis and evaluation of methodologies, EE indicators and projections for assessing the impacts of EE policies and measures in pilot MSs

Deliverable D5.1

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Content

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Summary

Deliverable D5.1 develops and applies a harmonised methodological framework for assessing energy efficiency developments across EU Member States. Prepared under WP5 of the **streamSAVE+** project, the deliverable supports the implementation and monitoring of the Energy Efficiency Directive (EED), particularly with regard to Article 4 final energy consumption targets and the broader Energy Efficiency First principle. Its central objective is to improve the consistency, transparency, and comparability of both historical and projected energy efficiency assessments.

A key methodological challenge in current EU energy efficiency evaluation lies in the disconnect between ex-post monitoring and ex-ante scenario modelling. Historical efficiency trends are typically assessed using indicator-based approaches such as ODEX, while forward-looking projections contained in National Energy and Climate Plans (NECPs) are developed using modelling frameworks that are not directly comparable to historical indicators. This fragmentation limits policymakers' ability to determine whether projected efficiency improvements are consistent with observed developments and whether planned measures reflect realistic trajectories.

Deliverable D5.1 addresses this gap by applying the ODEX methodology in a unified manner to both historical data and forward-looking projections. By extending ODEX beyond its traditional retrospective role and integrating it into scenario analysis, the deliverable establishes a coherent analytical structure that enables direct comparison between past performance and expected future outcomes. This approach allows the separation of activity, structural, and intensity effects in energy demand trends and facilitates the translation of national projections into harmonised efficiency indicators and estimated energy savings.

To support this methodological integration, a structured data collection template was developed under Task T5.1. The template systematically links sectoral final energy consumption data with underlying activity indicators across industry, transport, households, and services. This integration enhances transparency, enables calculation of implied energy intensities, and strengthens the plausibility and internal consistency of national projections. Eight Member States—Austria, Slovenia, Lithuania, Croatia, Greece, Czech Republic, Belgium, and Portugal—completed the methodological template, providing valuable insights into national modelling practices and indicator systems.

From this broader group, five Member States—Slovenia, Croatia, Lithuania, Belgium, and Greece—were selected for in-depth quantitative assessment based on data completeness and suitability for harmonised ODEX-based analysis. The pilot application translates national projection pathways into comparable trends in final energy consumption, technical ODEX development, and estimated energy savings, while assessing projected alignment with Article 4 targets.

The results show that most assessed Member States are broadly aligned with their 2030 final energy consumption targets under current projections, although compliance margins are often limited. Transport electrification and residential renovation consistently emerge as the dominant structural drivers of long-term energy savings. However, the timing and intensity of projected efficiency improvements differ significantly across countries, highlighting the importance of sustained implementation beyond 2030 to secure long-term reductions in final energy demand.

Overall, Deliverable D5.1 strengthens the analytical foundation of EU energy efficiency monitoring by bridging ex-post and ex-ante assessment frameworks, improving cross-country comparability, and enhancing the transparency of NECP-based projections. By integrating historical evidence and future expectations within a single indicator structure, the deliverable provides a robust and consistent basis for evaluating the credibility and ambition of Member State energy efficiency pathways under the Energy Efficiency Directive framework.

About streamSAVE+

With the ambitious recast of the Energy Efficiency Directive (EED - EU/2023/1791), there is increased pressure on the EU Member States (MS) to introduce new policy measures or enhance existing policies to increase significantly energy savings and reductions. Although a lot has been done to streamline the energy savings calculations (cf. H2020 streamSAVE) and to improve measurement and verification procedures (cf. H2020 ENSMOV), many Member States still need to further improve their approaches to successfully meet their EED targets.

The streamSAVE+ project aims to support Member States in their efforts to achieve their energy efficiency goals and provide highly scalable energy savings in accordance with Articles 4, 5, and 8 of the updated Energy Efficiency Directive (EED recast). The project's main goal is to streamline energy savings calculations. Particularly for actions - the so-called Priority Actions - that still offer substantial savings or for which energy savings can be difficult to evaluate. These actions can cover a variety of sectors, such as electrification in transport, integration of renewable energy sources (RES) for heating and cooling in buildings, and improvements in electric motors driven systems.

Four key activities are envisioned:

1. Development of a knowledge hub: Given the importance of deemed savings approaches in Member States’ EED reporting streamSAVE+ focuses on streamlining bottom-up calculations methodologies of the Priority Actions. streamSAVE+ offers these savings methodologies in a transparent and streamlined way, to also show the comparability of savings.
2. Facilitation of dialogue among MSs to foster knowledge sharing and peer-to-peer cooperation. This involves nine participating countries (AT, BE, BG, CZ, EL, HR, LT, PT, SI), and a broader group of interested participants from six outreach countries (ES, FI, FR, IE, RO, SK).
3. Capacity building: Assistance to participating countries considering their requirements and needs. In-depth support will be given by technology experts, policy experts and country experts.
4. Analysing policies and future trends to establish the data framework and preparation of the policy packages of the participating countries.

More broadly, the project aims at fostering transnational knowledge and dialogue between public authorities, technology experts, and market actors. The key stakeholders will improve their energy savings calculation skills and ensure thus the sustainability and replicability of the streamSAVE+ results towards all European Member States.

1. Introduction

1.1. Background and Objectives

Building upon a diverse body of empirical and theoretical literature, this study advances the hypothesis that *future progress in energy efficiency is best achieved through a systemic and integrated approach that combines technological innovation, targeted policy design, and behavioural change mechanisms*. This hypothesis reflects growing recognition in the academic and policy domains that isolated interventions are insufficient to close the persistent efficiency gap observed across sectors and countries, particularly EU Member States. The European Union acts as a central driver of energy-efficiency progress by setting binding targets, harmonizing policy frameworks, and coordinating measures that guide and support national actions across all member states. According to Mah et al. (2025) six of the ten most energy-efficient countries worldwide are EU member states, underscoring the Union's significant influence in shaping ambitious and effective efficiency policies.

Energy efficiency (EE) is widely recognized as a central pillar of the clean-energy transition and one of the most cost-effective strategies for reducing greenhouse gas emissions, strengthening energy security, and supporting long-term economic resilience as recognised by Filippini et al. (2014), Horowitz & Bertoldi (2015), Cahill et al. (2010) and Boonekamp (2006). Within the European Union (EU), this recognition has been operationalized through the Energy Efficiency Directive and the Energy Efficiency First principle (von Malmborg, 2023a, 2023b), both aimed at accelerating efficiency improvements across major sectors and governance levels (Economidou et al. (2022); Malinauskaite et al. (2019, 2020)).

Despite this strong policy architecture, most Member States continue to exhibit a persistent *efficiency gap*, defined as the difference between technically and economically achievable savings and their more modest real-world uptake as reported by Bukarica & Robić (2013) and Pusnik et al. (2017).

A considerable body of research attributes this gap to behavioural, informational, and institutional barriers. Information asymmetries and bounded rationality limit the adoption of efficient technologies as reported in Bukarica & Tomšić (2017), while behavioural biases and habitual consumption patterns further hinder cost-effective investments (Reuter et al. (2020)). Changing consumption trends driven by digitalisation, and evolving mobility practices add new complexities to demand-side behaviour and the effectiveness of traditional policy interventions as shown in Brugger et al. (2021). Additional challenges emerge at the level of public and commercial buildings where high upfront costs, fragmented regulatory responsibilities, and slow renovation cycles continue to impede progress, as shown in recent assessments of large public buildings by Zhou et al. (2024). These findings resonate with broader concerns of Papantonis et al. (2022) about governance fragmentation and uneven policy implementation across Member States and align with Mandel & Pató (2024) analysis showing that demand-side measures grounded in the Energy Efficiency First principle can effectively compete with supply-side investments.

At the energy-system level, Europe's high import dependency and exposure to volatile global markets further underline the strategic value of reducing demand as reported by Guarascio et al. (2025). At the same time, rebound effects, where efficiency improvements induce additional consumption, continue to undermine expected savings as highlighted by Karakaya et al. (2024). Chu et al. (2024) report that broader economic structures, including the size of the shadow economy and national economic sophistication, also shape energy-intensity trajectories. Recent research further highlights those divergences in local energy planning (Palermo et al. (2024)), inconsistencies in energy performance certification methodologies (Sesana et al. (2024)), and persistent municipal-level barriers (Rivas et al. (2022)). Aforementioned studies collectively point to the need for more coherent multi-level governance. In parallel, studies on behavioural change and prosumerism underscore the importance of integrating sufficiency-oriented strategies into the efficiency agenda (Korsnes et al. (2024)).

Complementary evaluation studies confirm the need for more robust methods to assess whether policies truly deliver measurable energy savings as highlighted by Bertoldi & Mosconi (2020).

Methodological innovation has attempted to keep pace with these complexities. Approaches such as stochastic frontier analysis provide insights into the gap between actual and optimal energy demand (Filippini & Hunt (2012)), while hybrid top-down and bottom-up indicators improve sector-level evaluation (Reuter et al. (2021)). Meta-modelling efforts offer simplified yet comprehensive tools for evaluating efficiency policy impacts across multiple dimensions as reported in Bashmakov et al. (2024). Policy-learning research further demonstrates that iterative feedback and stakeholder interaction shape the effectiveness and longevity of efficiency policies as reported by von Malmborg (2024). Together, these developments underscore a clear message: energy-efficiency outcomes reflect the interaction of technical, behavioural, economic, and institutional dynamics, and thus require evaluation frameworks capable of integrating these dimensions over time.

Over the past two decades, considerable effort has gone into developing accounting frameworks and indicator-based tools for tracking energy-efficiency trends. Ang et al. (2010) review major accounting systems and emphasize the need for more uniform concepts and decomposition structures. At the EU level, indicator work increasingly seeks to connect observed consumption patterns with policy interventions. Horowitz & Bertoldi (2015) for example, propose a harmonized model combining bottom-up indicators with top-down data to estimate realized policy impacts. More recently, decomposition studies have extended this logic across countries and sectors. Trotta (2020) uses ex-post index decomposition to quantify Finland's efficiency-related energy and climate benefits and warns against relying solely on ex-ante engineering estimates that often overstate savings. Jain (2025) applies decomposition to 144 countries, illustrating both the strengths and limitations of ex-post approaches for understanding long-term efficiency trends.

Sector-specific analyses similarly highlight the close link between indicators and policy objectives. Tsemekidi Tzeiranaki et al. (2023) examine tertiary-sector trends in relation to EU climate targets, while Rodriguez et al. (2020) stress that indicators are not neutral but embed assumptions about productivity, decoupling, and policy priorities. Together, these contributions show substantial progress in developing ex-post indicator frameworks but also reveal that they are largely used for retrospective attribution or communication rather than integrated with forward-looking scenario exercises.

Despite progress in measurement and modelling, a major methodological gap remains. Ex-post and ex-ante assessments of energy-efficiency developments are generally conducted using incompatible analytical frameworks grounded in different assumptions, variables, and sectoral boundaries. The ODEX indicator is widely used for retrospective assessment of sectoral efficiency trends, yet it has rarely been extended to forward-looking contexts. Conversely, ex-ante scenario modelling relies on conceptual structures that cannot be directly compared with historically observed ODEX trends. This fragmentation limits policymakers' ability to judge whether projected efficiency pathways are consistent with empirical evidence or whether planned measures reflect realistic trajectories.

The present study addresses this methodological gap by applying the ODEX approach to both historical data and forward-looking policy scenarios. Using a single indicator framework for ex-post and ex-ante assessments creates a coherent basis for comparing past performance with expected future outcomes, enabling policymakers to evaluate whether projected efficiency gains align with observed trends. The novel contribution of this study lies in extending ODEX beyond its conventional retrospective role to serve as a tool for scenario analysis, thereby providing a consistent and transparent framework for assessing long-term policy strategies. By integrating ex-post evidence and ex-ante expectations within one analytical structure, the study strengthens the empirical foundation on which future EU energy-efficiency planning can rely.

Against this background, Deliverable D5.1 develops and applies a harmonised framework that integrates ex-post and ex-ante efficiency assessment within a single indicator structure.

1.2. Scope of Deliverable D5.1

Deliverable D5.1 provides the methodological and data foundation for assessing energy efficiency (EE) developments in a harmonised and comparable way across EU Member States. It is produced within the framework of WP5 of the **streamSAVE+** project and supports the implementation and monitoring requirements of the Energy Efficiency Directive (EED), in particular those related to energy consumption targets (Article 4) and end-use energy savings obligations (Article 8).

The deliverable has three main objectives.

First, it establishes a consistent methodological approach for the ex-post and ex-ante assessment of energy efficiency progress. Building on the ODYSSEE-MURE framework, the deliverable applies the ODEX methodology to distinguish “underlying” efficiency improvements from changes driven by activity growth or structural shifts. This provides a transparent basis for interpreting observed energy trends and for assessing the credibility of projected efficiency trajectories in National Energy and Climate Plans (NECPs).

Second, D5.1 develops a harmonised data framework to support comparable analysis across countries and sectors. The deliverable identifies key EU-wide data sources (NECPs, NECP Progress Reports, Eurostat, ODYSSEE, and JRC-IDEES) and describes the screening, collection, and quality assurance procedures used to compile a structured dataset. A core contribution is the integration of sectoral activity indicators alongside energy consumption data, enabling the calculation of specific energy consumption, decomposition analysis, and plausibility checks of national projections.

Third, the deliverable applies the harmonised framework in a pilot assessment of selected Member States. Using the common template and the ODEX-based approach, national projection pathways are translated into comparable sectoral trends in final energy consumption, technical ODEX development, and estimated energy savings. This pilot application illustrates how differences in national modelling practices, indicator systems, and data availability influence projected efficiency outcomes and the margin of compliance with EED targets.

The scope of D5.1 covers the four main final energy demand sectors—industry, transport, households, and services—reflecting their dominant contribution to final energy consumption and their central role in meeting EU decarbonisation objectives. The deliverable focuses on methodological consistency and transparency rather than on a detailed evaluation of individual policy measures. While bottom-up savings reported under Article 8 are considered as part of the broader indicator landscape, the main analytical emphasis lies on extracting comparable efficiency signals from observed statistics and NECP-based projections through a harmonised top-down approach.

Overall, Deliverable D5.1 provides a coherent methodological baseline, a structured dataset, and a pilot cross-country assessment that together support subsequent tasks in WP5, including deeper peer-to-peer exchange, refinement of modelling approaches, and strengthened consistency between monitoring systems and projection frameworks.

1.3. Pilot Member States Included

As part of WP5, a harmonised data collection template on methodologies, indicators, and projections was developed under Task T5.1 and circulated to participating Member States. The objective was to gather structured and comparable information on national modelling approaches, sectoral energy projections, activity indicators, and monitoring practices related to energy efficiency assessment under the Energy Efficiency Directive (EED). By standardising the reporting structure across countries, the template aimed to improve transparency, support methodological consistency, and facilitate cross-country comparability of projected energy efficiency developments.

The following Member States completed and submitted the template on methodologies, indicators, and projections:

- Austria
- Slovenia
- Lithuania
- Croatia
- Greece
- Czech Republic
- Belgium
- Portugal

The responses provided a comprehensive overview of national practices regarding projection modelling, treatment of activity drivers, calculation of energy intensity indicators, and integration of policy measures into energy demand scenarios. In addition, the submissions allowed identification of differences in sectoral disaggregation levels, projection horizons, baseline assumptions, and data availability constraints. This broader participation enabled a structured review of methodological diversity across Member States and informed the refinement of the harmonised analytical framework applied in this deliverable.

For the in-depth quantitative assessment presented in Chapter 5, a subset of these countries was selected. The selection was based on analytical feasibility criteria, including:

- Completeness and internal consistency of reported sectoral data;
- Availability of sufficiently detailed activity indicators to support ODEX-based decomposition;
- Coverage of projection years aligned with NECP reporting;
- Suitability for harmonised calculation of technical ODEX indices and energy savings.

The Member States included in the harmonised assessment are:

- Slovenia
- Croatia
- Lithuania
- Belgium
- Greece

These five countries provided sufficiently detailed and coherent datasets to enable full implementation of the methodological framework. The assessment includes:

- Analysis of projected final energy consumption trajectories at total and sectoral level;
- Derivation of technical ODEX indices using a harmonised baseline approach;
- Estimation of ex-post (historical) and ex-ante (projected) energy savings;
- Evaluation of projected alignment with Article 4 final energy consumption targets under the EED.

While Austria, Czech Republic, and Portugal actively contributed to the methodological template exercise, the available data did not allow for a complete harmonised quantitative assessment within the scope and timeline of this deliverable. In some cases, limitations were related to sectoral disaggregation, activity data availability, projection horizon differences, or methodological incompatibilities with the ODEX-based approach. Nevertheless, their participation played a crucial role in validating the flexibility of the template design, identifying practical data constraints, and improving the robustness and clarity of the overall framework.

The selected pilot Member States represent a diverse range of economic structures, energy system characteristics, modelling practices, and implementation pathways. Differences across the assessed countries include variation in base years, projection horizons (e.g. up to 2040 or 2050), depth of sectoral detail, and timing profiles of projected efficiency improvements (front-loaded, sustained, delayed, or structurally reoriented transitions). Applying a single harmonised analytical framework across these varied contexts demonstrates both the adaptability and methodological consistency of the ODEX-based approach.

It is important to emphasise that the pilot assessment does not aim to rank, benchmark, or evaluate the performance of individual Member States. Rather, it serves to illustrate how national NECP-based projections can be translated into a consistent analytical structure that separates activity, structural, and efficiency effects. By doing so, the assessment strengthens transparency, supports comparability, and contributes to evidence-based evaluation of projected energy efficiency developments under the Energy Efficiency Directive framework.

2. Data Framework Establishment

Estimating the effects of energy efficiency policies demands access to comprehensive and granular datasets. This requires detailed information on energy consumption differentiated by industrial subsectors, transport modes, specific end uses within the residential sector (e.g. space heating, water heating, and appliances), and relevant subsectors within the services sector. Equally important is the availability of robust activity data per subsector or end use, enabling the calculation of specific energy consumption indicators (e.g. kWh/m² per year for buildings, energy per passenger-kilometre in transport, or energy per unit of industrial output). Only through the systematic pairing of energy and activity data is it possible to isolate efficiency improvements from structural and activity-driven changes in demand. The development of this data foundation was carried out under **Task T5.1 – Establishment of the data framework: identification of relevant sources and methodology alignment**, and corresponds to **Milestone MS9 – Establishment of the data framework** within WP5. Task T5.1 focused on identifying relevant EU and national data sources, aligning sectoral definitions and units, and creating a harmonised data collection template to ensure consistency and comparability across Member States. The milestone marked the completion of a structured, cleaned, and standardised dataset that provides the empirical backbone for subsequent analytical tasks. This chapter therefore describes the main data sources used, as identified under Task T5.1, and outlines the procedures applied for data collection, filtering, harmonisation, and quality assurance. It explains how the data framework established at Milestone MS9 enables reliable cross-country assessment of energy efficiency trends and supports the methodological analysis conducted in subsequent tasks.

2.1. Identification of Relevant Data Sources

The first step in establishing the data framework is the identification of relevant data sources. For this purpose, the main relevant data sources needed for a harmonised top-down assessment of energy savings are hereby selected. The review of available data sources was guided by the following main criteria to meet the objective of harmonised data:

- **Data coverage** for the 27 Member States (or at least several Member States).
- **Official or well-established** data or reporting (i.e. either data reported by national public authorities or statistical offices, or data commonly used in the literature or by the EU institutions).
- **Regular updating** or data including **time series** (about previous and/or future years).
- **Granularity / disaggregation** in line with (or going beyond) the need of the methodology to assess energy savings
- Based on these criteria, five relevant data sources are selected:
- ***National Energy and Climate Plans (NECPs)***, as these are essential strategic planning reports delivered by the European Union's (EU) Member States (MSs) every five years (including scenarios covering at least the next 10 years).
- ***National Energy and Climate Progress Reports (NECPRs)***, as these need to be submitted by MSs every two years and analyse the degree to which the objectives delineated in the NECPs are being achieved (including data about previous years).
- The ***Eurostat repository***, gathering all datasets from the EU's statistical office.
- The ***ODYSSEE database***, being a comprehensive data repository for monitoring energy efficiency indicators and trends in MSs and beyond (including long time series until year n-2), and complementing Eurostat data with more disaggregated or detailed data.
- The ***Joint Research Centre (JRC) Integrated Database of the European Energy System (IDEES)***, being a consistent set of disaggregated data available for all MSs regarding energy, activity, and emissions.

These are summarised in Table 1. Additionally, in the table several characteristics per data source are listed. This summary provides a holistic yet detailed understanding of each relevant data source.

Table 1: Summary of characteristics per data source.

Data source	Type of data and granularity	Geographic level and coverage	Update frequency & last update	Mandatory vs. voluntary	Time lag	Forecasting possibility
***NECP* (part 2)**[1]	Data on activity, energy consumption and energy intensity (overall and per sector; no or limited disaggregation per sub-sector)	National level (all 27 MS)	Every 5 years. Final update was due in June 2024.	Mandatory.	Focus on the next 10 years	Yes. NECPs include scenarios about at least the next ten years (and possibly beyond).
***NECPR* (Annexes *IV*, *XI* and *XVII*)**[2]	Data on energy consumption (no or limited disaggregation), energy savings (per policy measure or policy package; i.e. from bottom-up monitoring), and building renovations.	National level (all 27 MS)	Every 2 years. Latest reporting was due in March 2025.	Mandatory or voluntary (depending on the indicators).	Data typically reported about years n-2 and n-3: successive NECPRs thus provide a time series from 2021 until year n-2 (included) of the latest reporting.	No, NECPRs provide data about progress / achievements in previous years.

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[1] See mandatory template for the NECPs set in the Annex I of the Regulation (EU) 2018/1999 on the Governance of the Energy Union and Climate Action.

[2] See mandatory template for the NECPRs set in the Commission Implementing Regulation (EU) 2022/2299 as regards the structure, format, technical details and process for the integrated national energy and climate progress reports.

***Eurostat*[3]**	Energy consumption and activity data, per sector and with detailed data per energy carrier for the energy sector (but limited disaggregation for the energy consumption data). Also, energy efficiency indicators.	European, national (all 27 MS) level.	Depending on the sector, even quarterly. Last update can generally be considered to be Dec. 2025.	Mandatory.	On average n-2.	Not explicitly available in the repository, however it is possible to forecast with the data available in the repository.
***Odyssee*[4]**	Four sectors: transport, industry, households, and services & agriculture. Within each sector, 4 to 12 subsectors. Data on energy activity, energy consumption, and energy efficiency indicators.	European and national level (all 27 MS).	Yearly. Last update can generally be considered to be Dec. 2025.	Voluntary.	n-2.	Not explicitly available in the repository, however it is possible to forecast with the data available in the repository.
***JRC-IDEES*[5]**	Four sectors: industry, power generation, residential, and transport. Data on	European and national level (all 27 MS).	Biannually, however last update was in 2021.	Voluntary.	n-4	Not explicitly available in the repository, however it is possible to forecast with the

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[3] https://ec.europa.eu/eurostat/data/database

[4] https://www.indicators.odyssee-mure.eu/

[5] https://jeodpp.jrc.ec.europa.eu/ftp/jrc-opendata/JRC-IDEES/JRC-IDEES-2023_v1/

	energy activity and energy consumption.					data available in the repository.

Hereby, various complementary data sources may also be relevant for assessing energy savings will be illustrated. These are not the main data sources to be considered when working with EE indicators and projections. Nonetheless, depending also on the purpose of study and research, these repositories can hold important data additions and can be used by Member States to report in their NECP or NECPR; and also, for general benchmarking and monitoring activities.

- The ***Household Budget Surveys (HBS) or national statistical repositories*** are conducted/updated annually and contain essential data about the residential sector. Additionally, HBS hold data concerning transport and any other common citizen expenditures. The type of data and granularity varies per country, however usually divided among transport, industry, residential, tertiary/services, and agriculture. It can cover also the regional and/or local governance level. The HBS are updated yearly and are mandatory, with forecasting capability depending on the country's statistical data.
- The ***National projections of anthropogenic greenhouse gas emissions – GovReg***[6] is an annual reporting obligation required by Article 18(1)(b) of Implementing Regulation 2020/1208, Annex XXV. Hereby, data about various gas emissions is reported and differentiated per type of land (e.g., “sum afforested land”, “sum deforested land”, etc.); but also, the carbon intensity of the overall economy. Transport parameters are also considered. All data is projected until the year 2055. The report focuses on GHG emissions; however, it is a good exercise to ensure that the data used for these projections is the same used by the Member State in its NECP.
- The ***European Spatial Planning Observation Network (ESPON) repository***[7] holds interesting data supporting EU development policies. Within the environment, climate and energy sector there are 234 indicators available, with certain data available also at the regional and/or local level.
- The ***Danish Energy Catalogues***[8] provide technical data on energy technologies and their costs, environmental impact, and performance. The type of data is spread across eight categories: generation of electricity and district heating; individual heating plants; renewable fuels; carbon capture, transport, and storage; energy storage; industrial process heat; transport of energy; commercial freight and passenger transport. These are available at European and national level and are updated annually; with data up to 2050.
- The ***European building stock observatory*** provides technical data with regards to the performance of the European building stock.
- The ***Mure***[9] repository provides data regarding energy efficiency policies and measures by European country in industry, transport, and buildings.

2.2. Methodology for Data Collection and Screening

2.2.1 Introduction and Objective

Under the scope of Task T5.1, a harmonised data collection template was developed to systematically gather sectoral data on National Energy and Climate Plan (NECP) projections, with particular emphasis on sectoral activity indicators. The purpose of this task was to establish a consistent and transparent database that enables robust modelling, scenario analysis, and policy assessment across countries.

While NECPs provide projections of final energy consumption and greenhouse gas emissions, they often lack a structured and comparable presentation of the underlying activity drivers. In many cases, projected energy demand is reported at an aggregated sectoral level without sufficient explanation of

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[6] https://reportnet.europa.eu/public/countries

[7] https://database.espon.eu/

[8] https://ens.dk/en/analyses-and-statistics/technology-catalogues

[9] https://www.measures.odyssee-mure.eu/

the physical, economic, or demographic assumptions underpinning these trends. This limits the possibility of verifying projections, comparing structural assumptions across countries, or decomposing trends into activity, efficiency, and structural effects.

Task T5.1 therefore focused on bridging this gap by designing a template that systematically links projected energy demand to measurable sectoral activity variables. By explicitly collecting both energy consumption and its underlying drivers, the template ensures that energy trends can be interpreted in structural terms rather than treated as standalone aggregates. This approach improves transparency, facilitates cross-country comparability, and strengthens the analytical basis for subsequent modelling work.

In addition, the template was designed to support several key objectives:

- To enable consistency checks between projected energy demand and macroeconomic or demographic developments;
- To allow derivation of implied energy intensities (e.g. energy per passenger-kilometre, per tonne of output, or per square metre);
- To identify structural shifts, such as modal change in transport or transformation of industrial production;
- To provide a robust empirical foundation for bottom-up and hybrid energy demand models developed in subsequent tasks.

The template covers four key demand sectors:

- Industry
- Transport
- Households
- Services

These sectors were selected due to their dominant contribution to final energy consumption and their central role in achieving national decarbonisation targets. Each sector exhibits distinct structural drivers and policy levers, making it essential to collect sector-specific activity data alongside energy projections.

Each sector is organised in a harmonised format to allow comparability across reporting entities and over time. The structure ensures that both historical statistical data and forward-looking projections are reported in a consistent manner, with clear differentiation between observed trends and model-based expectations. This harmonisation is particularly important for cross-country assessment, as it reduces methodological discrepancies and enhances the reliability of comparative analysis within the broader framework of WP5.

2.2.2 Structure of the Data Collection Template

The template developed under Task T5.1 consists of sector-specific sheets accompanied by general reporting guidance to ensure consistent interpretation and completion across countries. The structure was intentionally designed to be both standardised and flexible: standardised in terms of core variables and reporting logic, and flexible enough to accommodate differences in national data availability and modelling practices.

Each sector sheet contains two core components:

- Final energy consumption data
- Sector-specific activity data

The first component captures total and, where available, disaggregated final energy consumption for the respective sector. The second component records the underlying activity indicators that explain the evolution of energy demand. This dual structure ensures that projected energy consumption can always be interpreted in relation to physical, economic, or demographic drivers.

The template follows a consistent internal logic across all sectors. Energy data are presented first, followed by activity indicators, using harmonised units and clearly specified time horizons. Where possible, subsector breakdowns are aligned with common energy balance classifications to facilitate consistency with official statistics and NECP reporting formats.

The time horizon includes both historical statistical data and forward-looking projections. Historical data are collected for 2020 and 2022 to provide a recent and reliable baseline reflecting post-pandemic energy trends. These years serve as calibration points for assessing the plausibility of projected developments.

Projection years include 2025 and 2030, aligned with NECP reporting obligations and intermediate policy targets. Where available, projections are extended to 2040 and 2050 to capture longer-term decarbonisation pathways and structural transformations. This extended horizon is particularly relevant for analysing deep electrification, industrial transformation, building stock renovation, and long-term modal shifts in transport.

A clear distinction is maintained between statistical observations and projected values throughout the template. Historical data are reported as observed values based on national statistics or official energy balances, while projection data are derived from NECP scenarios or supporting modelling exercises. This separation is essential for:

- Ensuring transparency in trend analysis;
- Identifying discontinuities between realised developments and projected trajectories;
- Avoiding unintentional mixing of observed and model-based data;
- Supporting consistency checks between baseline trends and policy-driven changes.

By structurally separating past data from forward-looking projections, the template enhances analytical clarity and allows subsequent modelling work to explicitly account for structural breaks, policy interventions, or methodological shifts embedded in NECP scenarios.

The figures below present illustrative examples of the filled-in sectoral data collection templates developed under Task T5.1 and applied in Task T5.2. They demonstrate how the harmonised structure was operationalised using national data, integrating statistical information, projections, and activity indicators within a consistent reporting framework.

The examples cover the four main final energy demand sectors: **Industry, Transport, Households, and Services**. Each template follows the same structural logic, clearly separating historical statistical data (2020, 2022) from projection years (2025, 2030, 2040, 2050, where available). Units and data sources are explicitly documented, ensuring transparency and traceability of the reported values.

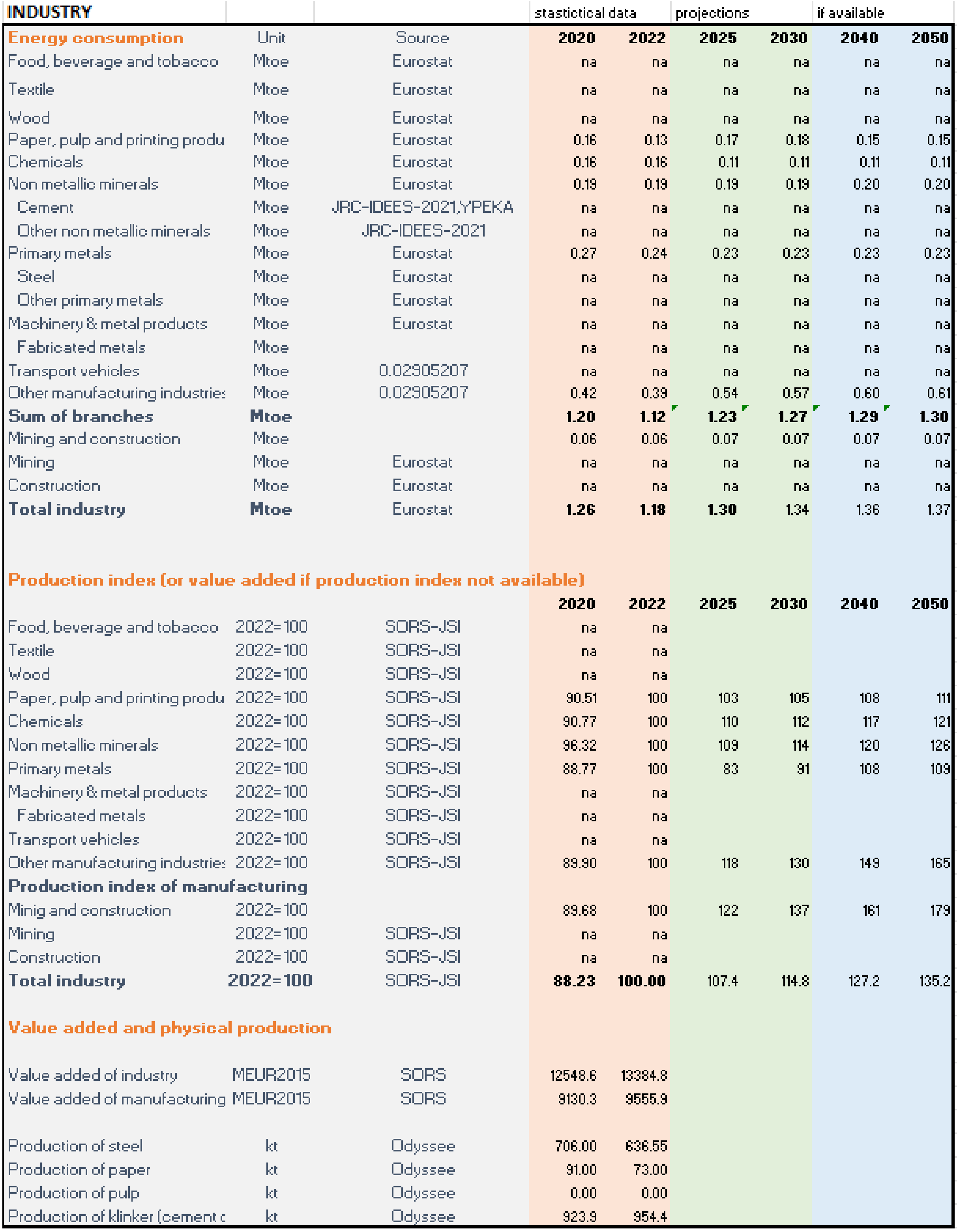
The **Industry template** example illustrates how final energy consumption by industrial branches is combined with production indices, value added, and selected physical production indicators. This structure enables linking energy demand to industrial output dynamics and supports the calculation of energy intensity trends and structural effects.

The **Transport template** example shows the integration of energy consumption by transport mode with detailed activity indicators, including vehicle stock, passenger transport (passenger-kilometres), freight transport (tonne-kilometres), and vehicle-kilometres travelled. This comprehensive structure allows for decomposition of energy demand changes into activity growth, modal shift, and efficiency improvements.

The **Households template** example presents end-use energy consumption (heating, water heating, cooking, appliances, cooling) alongside structural indicators such as dwelling stock, floor area, population, and degree days. This enables climate-corrected analysis and supports the assessment of energy efficiency improvements at end-use level.

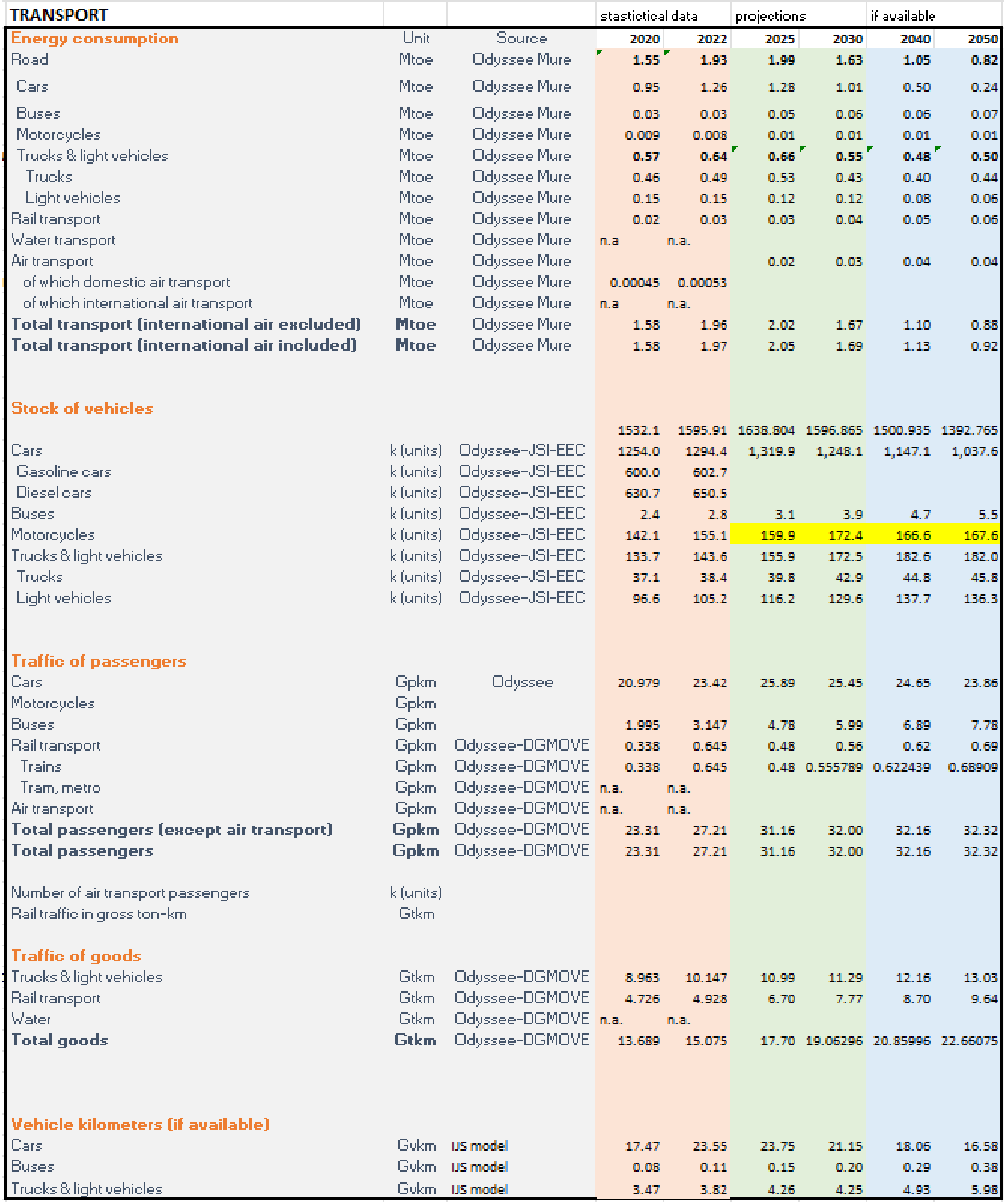
The **Services template** example demonstrates how climate-corrected energy consumption is linked with employment and floor area indicators across subsectors. This facilitates evaluation of tertiary sector energy intensity trends and structural developments.

These filled-in templates illustrate the practical application of the harmonised methodology developed under Task T5.1 and provide the empirical basis for the analytical work conducted in Task T5.2, including ODEX-based monitoring and ex-ante assessment of projected energy efficiency improvements.



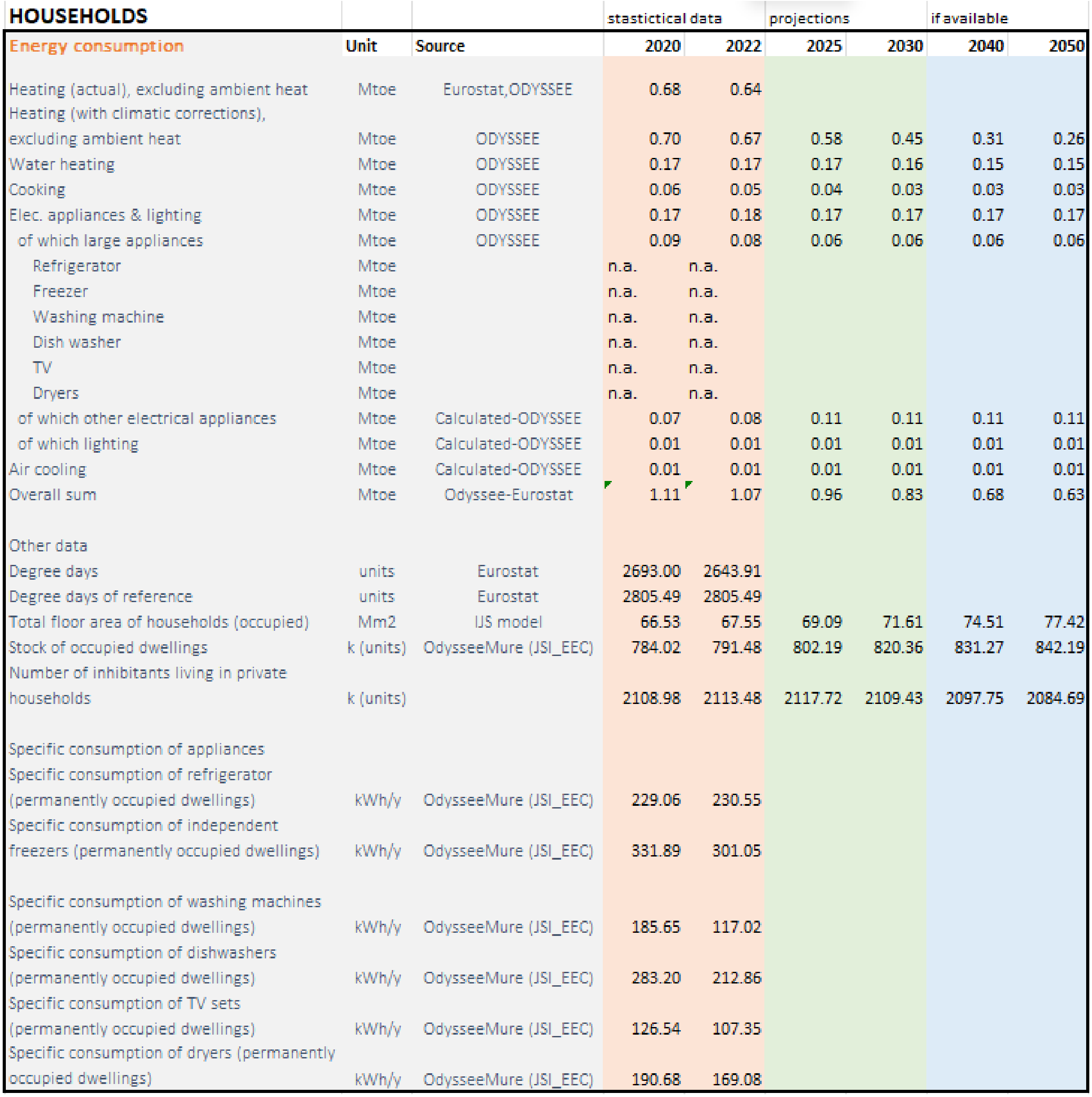
INDUSTRY			stastictical data		projections		if available	
Energy consumption	Unit	Source	**2020**	**2022**	**2025**	**2030**	**2040**	**2050**
Food, beverage and tobacco	Mtoe	Eurostat	na	na	na	na	na	na
Textile	Mtoe	Eurostat	na	na	na	na	na	na
Wood	Mtoe	Eurostat	na	na	na	na	na	na
Paper, pulp and printing produ	Mtoe	Eurostat	0.16	0.13	0.17	0.18	0.15	0.15
Chemicals	Mtoe	Eurostat	0.16	0.16	0.11	0.11	0.11	0.11
Non metallic minerals	Mtoe	Eurostat	0.19	0.19	0.19	0.19	0.20	0.20
Cement	Mtoe	JRC-IDEES-2021,YPEKA	na	na	na	na	na	na
Other non metallic minerals	Mtoe	JRC-IDEES-2021	na	na	na	na	na	na
Primary metals	Mtoe	Eurostat	0.27	0.24	0.23	0.23	0.23	0.23
Steel	Mtoe	Eurostat	na	na	na	na	na	na
Other primary metals	Mtoe	Eurostat	na	na	na	na	na	na
Machinery & metal products	Mtoe	Eurostat	na	na	na	na	na	na
Fabricated metals	Mtoe		na	na	na	na	na	na
Transport vehicles	Mtoe	0.02905207	na	na	na	na	na	na
Other manufacturing industrie	Mtoe	0.02905207	0.42	0.39	0.54	0.57	0.60	0.61
Sum of branches	**Mtoe**		**1.20**	**1.12**	**1.23**	**1.27**	**1.29**	**1.30**
Mining and construction	Mtoe		0.06	0.06	0.07	0.07	0.07	0.07
Mining	Mtoe	Eurostat	na	na	na	na	na	na
Construction	Mtoe	Eurostat	na	na	na	na	na	na
Total industry	**Mtoe**	Eurostat	**1.26**	**1.18**	**1.30**	1.34	1.36	1.37
Production index (or value added if production index not available)								
			2020	**2022**	**2025**	**2030**	**2040**	**2050**
Food, beverage and tobacco	2022=100	SORS-JSI	na	na				
Textile	2022=100	SORS-JSI	na	na				
Wood	2022=100	SORS-JSI	na	na				
Paper, pulp and printing produ	2022=100	SORS-JSI	90.51	100	103	105	108	111
Chemicals	2022=100	SORS-JSI	90.77	100	110	112	117	121
Non metallic minerals	2022=100	SORS-JSI	96.32	100	109	114	120	126
Primary metals	2022=100	SORS-JSI	88.77	100	83	91	108	109
Machinery & metal products	2022=100	SORS-JSI	na	na				
Fabricated metals	2022=100	SORS-JSI	na	na				
Transport vehicles	2022=100	SORS-JSI	na	na				
Other manufacturing industrie	2022=100	SORS-JSI	89.90	100	118	130	149	165
Production index of manufacturing								
Minig and construction	2022=100		89.68	100	122	137	161	179
Mining	2022=100	SORS-JSI	na	na				
Construction	2022=100	SORS-JSI	na	na				
Total industry	**2022=100**	SORS-JSI	**88.23**	**100.00**	107.4	114.8	127.2	135.2
Value added and physical production								
Value added of industry	MEUR2015	SORS	12548.6	13384.8				
Value added of manufacturing	MEUR2015	SORS	9130.3	9555.9				
Production of steel	kt	Odyssee	706.00	636.55				
Production of paper	kt	Odyssee	91.00	73.00				
Production of pulp	kt	Odyssee	0.00	0.00				
Production of klinker (cement c	kt	Odyssee	923.9	954.4				

Figure 1: Example of filled in Template for Industrial sector



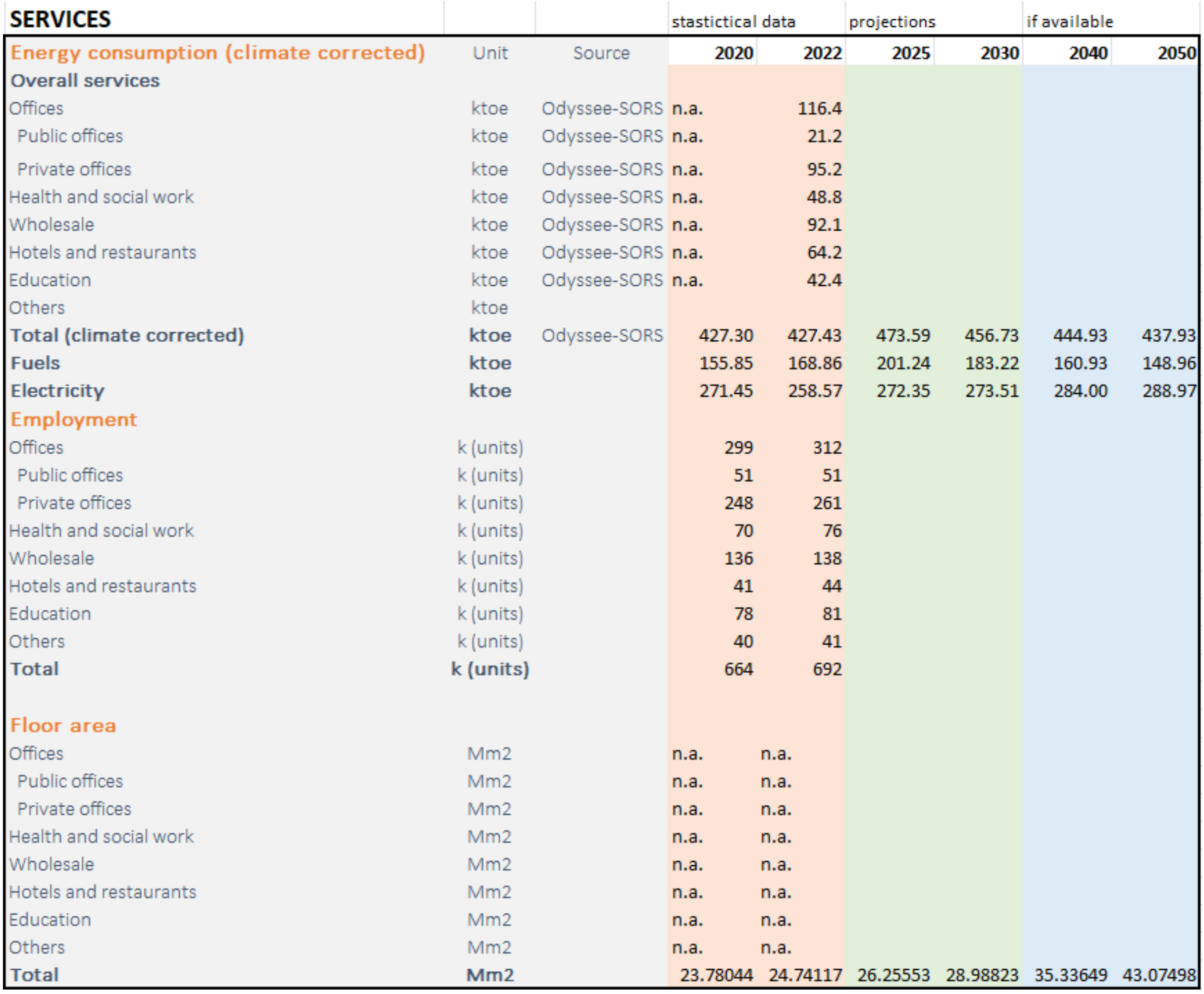
TRANSPORT			stastictical data		projections		if available	
Energy consumption	Unit	Source	**2020**	**2022**	**2025**	**2030**	**2040**	**2050**
Road	Mtoe	Odyssee Mure	**1.55**	**1.93**	**1.99**	**1.63**	**1.05**	**0.82**
Cars	Mtoe	Odyssee Mure	0.95	1.26	1.28	1.01	0.50	0.24
Buses	Mtoe	Odyssee Mure	0.03	0.03	0.05	0.06	0.06	0.07
Motorcycles	Mtoe	Odyssee Mure	0.009	0.008	0.01	0.01	0.01	0.01
Trucks & light vehicles	Mtoe	Odyssee Mure	**0.57**	**0.64**	**0.66**	**0.55**	**0.48**	**0.50**
Trucks	Mtoe	Odyssee Mure	0.46	0.49	0.53	0.43	0.40	0.44
Light vehicles	Mtoe	Odyssee Mure	0.15	0.15	0.12	0.12	0.08	0.06
Rail transport	Mtoe	Odyssee Mure	0.02	0.03	0.03	0.04	0.05	0.06
Water transport	Mtoe	Odyssee Mure	n.a	n.a.				
Air transport	Mtoe	Odyssee Mure			0.02	0.03	0.04	0.04
of which domestic air transport	Mtoe	Odyssee Mure	0.00045	0.00053				
of which international air transport	Mtoe	Odyssee Mure	n.a	n.a.				
Total transport (international air excluded)	**Mtoe**	Odyssee Mure	1.58	1.96	2.02	1.67	1.10	0.88
Total transport (international air included)	**Mtoe**	Odyssee Mure	1.58	1.97	2.05	1.69	1.13	0.92
Stock of vehicles								
			1532.1	1595.91	1638.804	1596.865	1500.935	1392.765
Cars	k (units)	Odyssee-JSI-EEC	1254.0	1294.4	1,319.9	1,248.1	1,147.1	1,037.6
Gasoline cars	k (units)	Odyssee-JSI-EEC	600.0	602.7				
Diesel cars	k (units)	Odyssee-JSI-EEC	630.7	650.5				
Buses	k (units)	Odyssee-JSI-EEC	2.4	2.8	3.1	3.9	4.7	5.5
Motorcycles	k (units)	Odyssee-JSI-EEC	142.1	155.1	159.9	172.4	166.6	167.6
Trucks & light vehicles	k (units)	Odyssee-JSI-EEC	133.7	143.6	155.9	172.5	182.6	182.0
Trucks	k (units)	Odyssee-JSI-EEC	37.1	38.4	39.8	42.9	44.8	45.8
Light vehicles	k (units)	Odyssee-JSI-EEC	96.6	105.2	116.2	129.6	137.7	136.3
Traffic of passengers								
Cars	Gpkm	Odyssee	20.979	23.42	25.89	25.45	24.65	23.86
Motorcycles	Gpkm							
Buses	Gpkm		1.995	3.147	4.78	5.99	6.89	7.78
Rail transport	Gpkm	Odyssee-DGMOVE	0.338	0.645	0.48	0.56	0.62	0.69
Trains	Gpkm	Odyssee-DGMOVE	0.338	0.645	0.48	0.555789	0.622439	0.68909
Tram, metro	Gpkm	Odyssee-DGMOVE	n.a.	n.a.				
Air transport	Gpkm	Odyssee-DGMOVE	n.a.	n.a.				
Total passengers (except air transport)	**Gpkm**	Odyssee-DGMOVE	23.31	27.21	31.16	32.00	32.16	32.32
Total passengers	**Gpkm**	Odyssee-DGMOVE	23.31	27.21	31.16	32.00	32.16	32.32
Number of air transport passengers	k (units)							
Rail traffic in gross ton-km	Gtkm							
Traffic of goods								
Trucks & light vehicles	Gtkm	Odyssee-DGMOVE	8.963	10.147	10.99	11.29	12.16	13.03
Rail transport	Gtkm	Odyssee-DGMOVE	4.726	4.928	6.70	7.77	8.70	9.64
Water	Gtkm	Odyssee-DGMOVE	n.a.	n.a.				
Total goods	**Gtkm**	Odyssee-DGMOVE	13.689	15.075	17.70	19.06296	20.85996	22.66075
Vehicle kilometers (if available)								
Cars	Gvkm	IJS model	17.47	23.55	23.75	21.15	18.06	16.58
Buses	Gvkm	IJS model	0.08	0.11	0.15	0.20	0.29	0.38
Trucks & light vehicles	Gvkm	IJS model	3.47	3.82	4.26	4.25	4.93	5.98

Figure 2: Example of filled in Template for Transport sector



HOUSEHOLDS			stastictical data		projections		if available	
Energy consumption	**Unit**	**Source**	**2020**	**2022**	**2025**	**2030**	**2040**	**2050**
Heating (actual), excluding ambient heat	Mtoe	Eurostat,ODYSSEE	0.68	0.64				
Heating (with climatic corrections), excluding ambient heat	Mtoe	ODYSSEE	0.70	0.67	0.58	0.45	0.31	0.26
Water heating	Mtoe	ODYSSEE	0.17	0.17	0.17	0.16	0.15	0.15
Cooking	Mtoe	ODYSSEE	0.06	0.05	0.04	0.03	0.03	0.03
Elec. appliances & lighting	Mtoe	ODYSSEE	0.17	0.18	0.17	0.17	0.17	0.17
of which large appliances	Mtoe	ODYSSEE	0.09	0.08	0.06	0.06	0.06	0.06
Refrigerator	Mtoe		n.a.	n.a.				
Freezer	Mtoe		n.a.	n.a.				
Washing machine	Mtoe		n.a.	n.a.				
Dish washer	Mtoe		n.a.	n.a.				
TV	Mtoe		n.a.	n.a.				
Dryers	Mtoe		n.a.	n.a.				
of which other electrical appliances	Mtoe	Calculated-ODYSSEE	0.07	0.08	0.11	0.11	0.11	0.11
of which lighting	Mtoe	Calculated-ODYSSEE	0.01	0.01	0.01	0.01	0.01	0.01
Air cooling	Mtoe	Calculated-ODYSSEE	0.01	0.01	0.01	0.01	0.01	0.01
Overall sum	Mtoe	Odyssee-Eurostat	1.11	1.07	0.96	0.83	0.68	0.63
Other data								
Degree days	units	Eurostat	2693.00	2643.91				
Degree days of reference	units	Eurostat	2805.49	2805.49				
Total floor area of households (occupied)	Mm2	IJS model	66.53	67.55	69.09	71.61	74.51	77.42
Stock of occupied dwellings	k (units)	OdysseeMure (JSI_EEC)	784.02	791.48	802.19	820.36	831.27	842.19
Number of inhibitants living in private households	k (units)		2108.98	2113.48	2117.72	2109.43	2097.75	2084.69
Specific consumption of appliances								
Specific consumption of refrigerator (permanently occupied dwellings)	kWh/y	OdysseeMure (JSI_EEC)	229.06	230.55				
Specific consumption of independent freezers (permanently occupied dwellings)	kWh/y	OdysseeMure (JSI_EEC)	331.89	301.05				
Specific consumption of washing machines (permanently occupied dwellings)	kWh/y	OdysseeMure (JSI_EEC)	185.65	117.02				
Specific consumption of dishwashers (permanently occupied dwellings)	kWh/y	OdysseeMure (JSI_EEC)	283.20	212.86				
Specific consumption of TV sets (permanently occupied dwellings)	kWh/y	OdysseeMure (JSI_EEC)	126.54	107.35				
Specific consumption of dryers (permanently occupied dwellings)	kWh/y	OdysseeMure (JSI_EEC)	190.68	169.08				

Figure 3: Example of filled in Template for Households sector



SERVICES			stastictical data		projections		if available	
Energy consumption (climate corrected)	Unit	Source	**2020**	**2022**	**2025**	**2030**	**2040**	**2050**
Overall services								
Offices	ktoe	Odyssee-SORS	n.a.	116.4				
Public offices	ktoe	Odyssee-SORS	n.a.	21.2				
Private offices	ktoe	Odyssee-SORS	n.a.	95.2				
Health and social work	ktoe	Odyssee-SORS	n.a.	48.8				
Wholesale	ktoe	Odyssee-SORS	n.a.	92.1				
Hotels and restaurants	ktoe	Odyssee-SORS	n.a.	64.2				
Education	ktoe	Odyssee-SORS	n.a.	42.4				
Others	ktoe							
Total (climate corrected)	**ktoe**	Odyssee-SORS	427.30	427.43	473.59	456.73	444.93	437.93
Fuels	**ktoe**		155.85	168.86	201.24	183.22	160.93	148.96
Electricity	**ktoe**		271.45	258.57	272.35	273.51	284.00	288.97
Employment								
Offices	k (units)		299	312				
Public offices	k (units)		51	51				
Private offices	k (units)		248	261				
Health and social work	k (units)		70	76				
Wholesale	k (units)		136	138				
Hotels and restaurants	k (units)		41	44				
Education	k (units)		78	81				
Others	k (units)		40	41				
Total	**k (units)**		664	692				
Floor area								
Offices	Mm2		n.a.	n.a.				
Public offices	Mm2		n.a.	n.a.				
Private offices	Mm2		n.a.	n.a.				
Health and social work	Mm2		n.a.	n.a.				
Wholesale	Mm2		n.a.	n.a.				
Hotels and restaurants	Mm2		n.a.	n.a.				
Education	Mm2		n.a.	n.a.				
Others	Mm2		n.a.	n.a.				
Total	**Mm2**		23.78044	24.74117	26.25553	28.98823	35.33649	43.07498

Figure 4: Example of filled in Template for Services sector

2.2.3 Collection of Sectoral Energy Consumption Data

For each sector, total final energy consumption is reported in harmonised units (e.g. Mtoe or equivalent), ensuring comparability across countries and consistency with national energy balances. Where possible, energy consumption is further disaggregated by subsector or end-use in order to capture structural differences and enable more detailed analytical work.

The template is designed to reflect both the structure of official energy statistics and the analytical needs of sectoral modelling. As a result, it allows for the collection of sufficiently granular data to support decomposition analysis, intensity calculations, and validation of projected trends against underlying activity drivers.

In the transport sector, energy consumption is broken down by mode (road, rail, water, air), with road transport further disaggregated into passenger cars, buses, motorcycles, light-duty vehicles, and trucks. This level of detail is essential given the diversity of policy measures affecting the sector, including electrification of passenger cars, efficiency standards for heavy-duty vehicles, and modal shift strategies.

International aviation is reported separately to ensure consistency with energy balances and emissions accounting conventions. This distinction is particularly important because international aviation is often treated differently in national inventories and climate targets. By explicitly separating it, the template enhances transparency and prevents distortions in trend analysis.

Where available, further differentiation by fuel type (e.g. electricity, liquid fuels, biofuels) can be included to capture electrification dynamics and fuel switching, although the minimum requirement focuses on mode-based disaggregation.

In the industry sector, total final energy use is complemented, where possible, by a breakdown into energy-intensive subsectors such as iron and steel, cement, chemicals, or other major industrial branches. This level of detail allows for assessment of structural transformation and industrial decarbonisation dynamics.

Energy-intensive industries are particularly relevant because they account for a disproportionate share of industrial energy demand and emissions. Disaggregating these subsectors enables analysis of:

- Changes in production volumes versus efficiency improvements;
- Electrification and hydrogen uptake;
- Structural shifts in industrial composition;
- The impact of specific decarbonisation technologies (e.g. CCS, alternative fuels).

If detailed physical subsector data are not available, the template allows for reporting at a more aggregated level, while clearly documenting data limitations.

For households and services, total final energy consumption is collected, with additional breakdowns by end-use or subsector where available. In the residential sector, this may include heating, cooling, domestic hot water, cooking, and appliances. In the services sector, disaggregation may follow building categories or economic subsectors.

Such differentiation supports analysis of building-related energy demand, electrification of heating systems, deployment of heat pumps, and efficiency improvements in appliances and equipment. It also allows for linking energy consumption trends to building stock characteristics and renovation rates, where such data are available.

2.2.4 Emphasis on Sectoral Activity Data

A central contribution of Task T5.1 is the systematic integration of sectoral activity data alongside energy consumption figures. While energy projections provide information on expected demand levels, they do not explain the underlying drivers of change. Activity indicators represent the structural determinants of energy demand and are therefore indispensable for modelling, consistency checks, and policy evaluation.

By explicitly linking energy consumption with its corresponding demand drivers, projected trends can be interpreted in terms of changes in economic output, mobility demand, building stock evolution, or demographic development. This structural perspective is essential for distinguishing between:

- Growth in activity levels (e.g. increased transport demand or higher industrial output);
- Changes in sectoral structure (e.g. modal shift in transport or shifts in industrial composition);
- Improvements in energy intensity (e.g. efficiency gains, electrification, or fuel switching).
- **Transport Sector**

In the transport sector, activity data include vehicle stock (thousand units), passenger transport demand (passenger-kilometres), freight transport activity (tonne-kilometres), and, where available, vehicle-kilometres travelled. These indicators are collected with modal breakdowns (road, rail, air, water) and further disaggregation within road transport where possible.

Linking these variables to energy consumption enables calculation of implied energy intensities (e.g. energy per passenger-kilometre or per tonne-kilometre). This facilitates validation of projection consistency and assessment of assumptions related to modal shift, fleet electrification, vehicle efficiency improvements, and mobility patterns.

- **Industry Sector**

In the industry sector, activity indicators include physical production volumes (e.g. tonnes of steel, cement, chemicals) or, where necessary, value added and production indices. The use of physical output data is particularly important in energy-intensive industries, where changes in production volumes can strongly influence total energy demand.

The integration of activity data enables differentiation between structural change and efficiency improvements. A decline in industrial energy use may result from reduced output, technological efficiency gains, fuel switching, or a shift toward less energy-intensive subsectors. Without activity data, such distinctions would not be analytically possible. The template therefore supports assessment of sectoral energy intensity trends and the structural drivers underlying projected decarbonisation pathways.

- **Households Sector**

For households, activity variables include population, number of households, and residential floor area. In some cases, additional indicators such as dwelling types, renovation rates, or heating degree days are available. These variables are crucial for interpreting residential energy demand, as total consumption is strongly influenced by demographic and structural developments.

Combining energy use with floor area or household numbers allows calculation of energy consumption per dwelling or per square metre. This provides insight into the effectiveness of renovation programmes, heating system electrification, and improvements in building energy performance.

- **Services Sector**

In the services sector, activity data may include commercial floor area, employment levels, or sectoral value added. These indicators capture the scale and structure of tertiary activity and allow calculation of energy use per unit of economic output or per square metre of commercial space.

Pairing these variables with energy consumption enables assessment of energy intensity trends and structural developments within the sector. It also helps identify broader dynamics such as digitalisation, changes in service provision, and shifts toward more or less energy-intensive activities.

The Official or well-establish data or reporting integration of activity data significantly strengthens the analytical robustness of the dataset. It enables decomposition of projected energy demand into activity, structural, and intensity effects, enhances transparency of NECP assumptions, and provides a solid foundation for subsequent modelling and policy assessment tasks. By embedding structural drivers directly into the data framework, Task T5.1 ensures that sectoral projections can be interpreted, validated, and compared on a consistent and analytically rigorous basis.

The table below presents a comparative overview of the sectoral activity indicators reported by the assessed Member States, based on the harmonised data collection template developed under Task T5.1 and applied in Task T5.2. Only activity variables explicitly reported by each country are included, ensuring a transparent representation of data availability.

The purpose of this comparison is to evaluate the extent to which structural drivers are systematically incorporated into national datasets used for energy efficiency assessment and projection development. As activity indicators form the analytical basis for ODEX-based decomposition and for distinguishing between activity, structural, and intensity effects, their availability directly influences the robustness and comparability of reported efficiency improvements.

By focusing exclusively on reported activity data, the table highlights cross-country differences in sectoral coverage, level of disaggregation, and reliance on physical, demographic, or economic indicators. These differences have important implications for the methodological consistency of monitoring approaches and for the reliability of ex-ante energy efficiency projections under the Energy Efficiency Directive framework.

Table 2: Cross-Country Comparison of Reported Sectoral Activity Indicators

Sector	**Slovenia – Activity Data Reported**	**Croatia – Activity Data Reported**	**Lithuania – Activity Data Reported**	**Belgium – Activity Data Reported**	**Greece – Activity Data Reported**
Industry	Production index (manufacturing & subsectors); Physical production volumes (steel, paper, pulp, clinker); Value added (industry/manufacturing)	Industrial production index (total/manufacturing); Value added (industry/manufacturing)	Industrial production index (total/manufacturing); Value added (industry/manufacturing)	Industrial production index (manufacturing); Value added (industry/manufacturing)	GDP only
Transport	Vehicle stock (cars – gasoline/diesel, buses, trucks, light vehicles, motorcycles); Passenger transport (pkm by mode); Freight transport (tkm by mode); Vehicle-kilometres (cars, buses, trucks & light vehicles); Air transport (domestic/international)	Vehicle stock (passenger cars, buses, trucks, light-duty vehicles, motorcycles); Passenger transport (pkm by mode); Freight transport (tkm by mode); Air transport (domestic/international)	Vehicle stock (by vehicle type); Passenger transport (pkm by mode); Freight transport (tkm by mode); Air transport (domestic/international)	Vehicle stock (by vehicle type); Passenger transport (pkm by mode); Freight transport (tkm by mode); Air transport (domestic/international)	GDP only
Households	Occupied dwellings; Residential floor area; Population in private households; Degree days (actual/reference); Specific appliance consumption (refrigerators, freezers, washing machines, dishwashers, TVs, dryers)	Number of dwellings; Residential floor area; Population/households; Degree days (actual/reference)	Number of dwellings; Residential floor area; Population/households; Degree days (actual/reference)	Number of dwellings; Residential floor area; Population/households; Degree days (actual/reference)	Population; Number of households
Services	Services sector employment (number of persons)	Services sector employment (number of persons)	Services sector employment (number of persons)	Services sector employment (number of persons)	GDP only

2.2.5 Data Sources, Units, and Documentation

Under Task T5.1, special attention was given to transparency, traceability, and methodological clarity. Given the diversity of national reporting practices and modelling approaches, it was essential to ensure that all collected data could be clearly attributed, interpreted, and verified. The credibility and analytical robustness of the dataset depend not only on the numerical values reported, but also on the transparency of their origin and methodological background.

Each data entry in the template is therefore accompanied by:

- A clear unit specification; and
- A documented data source.

Units are harmonised across sectors and countries to ensure consistency and comparability. Energy consumption is typically reported in Mtoe or equivalent units aligned with national energy balances. Activity indicators are reported in physically meaningful units, such as passenger-kilometres, tonne-kilometres, tonnes of output, square metres of floor area, or number of vehicles. The consistent use of standardised units facilitates the calculation of energy intensities and prevents misinterpretation arising from implicit unit conversions.

In addition to numerical values, each entry requires explicit identification of its source. Data sources include official NECP documents, annexes and supporting modelling documentation, national energy balances, national statistical offices, transport authorities, and sectoral reports. Where available, references to specific tables, figures, or datasets are recorded to improve traceability.

In cases where projections are derived from modelling assumptions rather than directly published figures, this is clearly indicated. If values are calculated, interpolated, or estimated based on available information, the methodological approach is documented to the extent possible. This ensures that users of the dataset understand whether data represent officially reported figures, modelling outputs, or derived estimates.

Such documentation serves several purposes. First, it enhances transparency by making the origin of each data point explicit. Second, it allows verification and cross-checking of values against original sources. Third, it supports reproducibility, as subsequent analytical work can retrace assumptions and, if necessary, update values when revised NECPs or statistical releases become available.

Standardised units and explicit documentation are therefore not merely administrative features of the template; they are central elements of its methodological design. Together, they ensure comparability across countries, strengthen confidence in the dataset, and provide a reliable empirical basis for modelling, scenario analysis, and policy evaluation conducted in subsequent tasks.

2.2.6 Quality Assurance and Consistency Checks

The template developed under Task T5.1 facilitates multiple layers of validation in order to ensure the reliability, internal coherence, and analytical robustness of the collected dataset. Given that the data are derived from different national sources, modelling frameworks, and reporting formats, systematic quality assurance is essential to guarantee comparability and prevent misinterpretation.

A first level of validation concerns internal numerical consistency. Subsector values are checked to ensure that they sum to reported sector totals wherever disaggregation is provided. Any discrepancies between aggregated and disaggregated values are flagged and clarified, either through correction or through explicit documentation of methodological differences in national reporting. This basic consistency check ensures structural integrity of the dataset.

A second level of validation examines the relationship between energy consumption and activity growth. Because the template systematically collects activity indicators alongside energy data, it is possible to calculate implied energy intensities (e.g. energy per passenger-kilometre, per tonne of industrial output, or per square metre of floor area). These implied intensities are assessed for plausibility over time. Sharp improvements or deteriorations in energy intensity are scrutinised to determine whether they reflect documented policy measures, technological shifts, or structural transformation, or whether they indicate inconsistencies in the underlying data.

A further quality check focuses on the identification of discontinuities between historical and projected values. Since historical data (2020 and 2022) are based on observed statistics and projection data (from 2025 onwards) are derived from NECP scenarios, breaks in trends may occur. While structural breaks may reflect genuine policy-driven transitions, abrupt and unexplained changes often reveal differences in accounting methods, scenario baselines, or modelling assumptions. The template structure makes such breaks visible and supports further investigation.

Cross-referencing projections with macroeconomic and demographic assumptions represents another important validation layer. Energy demand developments are examined in light of projected GDP growth, population trends, industrial output evolution, and transport demand changes. Inconsistencies—such as declining activity combined with rapidly increasing energy consumption, or vice versa are flagged for review. This cross-sectoral perspective strengthens the overall coherence of the dataset.

Particular attention is paid to the transition between the last statistical year (2022) and the first projection year (2025). This period represents the interface between observed data and model-based scenarios. Abrupt changes at this boundary may signal recalibration of modelling frameworks, revised accounting conventions, or implicit assumptions not clearly documented in NECPs. Careful examination of this transition helps ensure that projected trends are analytically defensible and not artefacts of methodological discontinuities.

The presence of activity indicators significantly enhances the robustness of the quality assurance process. By enabling the calculation of implied intensities and structural ratios, the dataset allows unrealistic trends to be detected at an early stage. This structural validation goes beyond simple numerical checks and ensures that energy projections remain consistent with physical, economic, and demographic developments.

2.2.7 Contribution of Task T5.1 to the Overall Analytical Framework

By developing a harmonised data collection template, **Task T5.1 – Establishment of the data framework: identification of relevant sources and methodology alignment** created the structured empirical foundation for subsequent modelling and analytical work within WP5. Rather than relying solely on aggregate NECP projections, Task T5.1 introduced a consistent framework linking projected energy demand to explicit structural and activity-based drivers, thereby improving interpretability, transparency, and analytical depth.

The integration of sectoral activity indicators ensures that energy projections are understood as outcomes of defined assumptions regarding economic growth, mobility demand, industrial production, building stock evolution, and demographic change. This structural anchoring enhances the credibility of scenario analysis and strengthens the evaluation of decarbonisation pathways.

The dataset produced under Task T5.1 supports several core analytical functions within WP5. It enables calibration and validation of sectoral demand models by providing harmonised historical baselines and comparable projection benchmarks. The availability of activity indicators allows modelling not only against total energy consumption but also against underlying drivers such as passenger-kilometres, industrial output, and floor area.

The structured dataset also enables decomposition of projected energy demand into activity, structural, and intensity effects, clarifying whether reductions stem from efficiency improvements, electrification, structural transformation, or changes in demand levels. In addition, the harmonised format facilitates cross-country comparison of structural assumptions, including modal shift trajectories, industrial transformation rates, electrification pathways, and renovation dynamics. This comparative dimension strengthens the analytical coherence of WP5 and supports identification of methodological gaps or inconsistencies.

By linking energy projections to their underlying drivers, Task T5.1 also supports evaluation of policy ambition and internal consistency within NECP frameworks. Projected efficiency gains can be assessed against declared measures and targets, allowing identification of potential misalignments between strategic objectives and quantified outcomes.

Through this structured and harmonised approach, Task T5.1 transforms heterogeneous national projection data into a coherent, comparable, and model-ready dataset. It thus provides the empirical backbone for evidence-based scenario analysis and policy evaluation across the broader WP5 framework

3. Proposed methodology for the ex-post and ex-ante assessment of energy efficiency policies with ODEX

This chapter presents the methodological foundation used to evaluate historical and projected energy efficiency developments within the scope of this study. The objective is to establish a transparent, harmonised, and policy-relevant framework capable of assessing both past performance (ex-post) and anticipated future impacts (ex-ante) of energy efficiency measures in a consistent manner across sectors and countries. The methodological approach applied here builds directly on the data framework and alignment work carried out under **Task T5.1 – Establishment of the data framework: identification of relevant sources and methodology alignment**, which provided the structured and harmonised dataset necessary for consistent cross-country application.

Monitoring energy efficiency progress requires more than observing changes in total energy consumption. Energy demand is influenced by economic growth, structural shifts, demographic developments, and technological improvements. A credible assessment methodology must therefore distinguish between changes driven by increased activity and those resulting from genuine improvements in how efficiently energy is used. Without such differentiation, reductions in energy use may be misinterpreted, and policy impacts may be either overstated or underestimated.

To address this challenge, the proposed approach is based on the ODEX methodology developed within the ODYSSEE-MURE framework. ODEX provides a sector-specific, activity-based indicator of energy efficiency progress that enables the isolation of intensity improvements from structural effects. By linking energy consumption to measurable activity indicators—systematically compiled under Task T5.1—the method captures changes in specific energy use and translates them into interpretable efficiency indices and energy savings values. This makes it particularly suitable for assessing compliance with the Energy Efficiency Directive and for analysing the credibility and ambition of National Energy and Climate Plans.

The methodology is applied in a unified manner to both historical statistical data and forward-looking projections. This dual application ensures comparability between ex-post performance and ex-ante policy ambition, allowing for a structured evaluation of whether projected savings represent a continuation of historical trends, a scaling-up of implementation, or a structural shift in sectoral dynamics.

The following sections first outline the policy relevance and conceptual foundations of the ODEX framework, then describe the simplified methodological logic adopted in this study. While the explanation provided here focuses on clarity and transparency of approach, the full mathematical formulation and technical refinements are documented in the accompanying scientific publication (Pušnik et al., 2025).

3.1. Significance of ODEX Methodology in EE Policy Assessment

The ODEX (ODYSSEE Energy Efficiency Index) as presented in Lapillonne (2020) methodology serves as a standardized, top-down framework for monitoring and evaluating energy efficiency (EE) policies within the European Union. In Energy Efficiency Directive (EU) 2018/2002 (European Parliament and the Council (2018)) and Directive (EU) 2023/1791 (European Parliament and the Council (2023)) stipulate binding energy-saving obligations for Member States (Article 4, 5 and Article 8), noting the necessity of reliable evaluation methods to ensure that efficiency measures deliver tangible benefits. The subsequent European Green Deal (European Commission (2019)) further emphasizes energy efficiency as an essential strategy in the drive toward climate neutrality by 2050. By providing harmonized data and transparent benchmarks, the *ODEX* is recognized within these initiatives for its utility in verifying whether actual efficiency gains align with policy objectives.

In addition, the ODYSSEE-MURE Project established the *ODEX* as an integral component of a broader EU-wide system for policy evaluation and cross-country comparisons. Through this platform, policymakers and stakeholders gain access to in-depth analyses and methodological guidance, ensuring that energy-saving achievements can be tracked. As a result, the *ODEX* serves not only as a diagnostic measure of progress, but also as an instrument for informed decision-making, contributing to the EU's overall endeavour to reduce energy consumption and greenhouse gas emissions.

By isolating technology-driven efficiency gains from structural or behavioural shifts, ODEX offers a robust measure of genuine improvements across industry, transport, residential, and service sectors. ODEX measures total observed efficiency improvements and does not directly distinguish between policy-induced effects and autonomous technological progress, but provides information on total aggregated savings. Unlike conventional energy intensity indicators (e.g., energy consumption per unit of GDP), ODEX focuses on changes in specific energy consumption expressed in physical units, thus providing a more accurate assessment of energy efficiency advancements (Lapillonne (2020)) as energy consumption is more directly dependent on physical production than economic value.

A key strength of ODEX lies in its disaggregation capability, enabling detailed examinations of sub sectoral trends (e.g., residential heating vs. industrial processes). Additionally, the methodology distinguishes between gross (apparent) and technical efficiency gains, allowing analysts to account for non-technical influences on energy use. This distinction underpins a more nuanced interpretation of observed changes and the identification of genuine technological improvements as reported in Lapillonne (2020).

ODEX also enhances cross-country comparability by harmonizing data and methodologies, thereby facilitating benchmarking of EE measures among EU member states. Through its mathematical framework, the index can be converted into aggregated energy savings, supporting monitoring obligations under directives such as the Energy Efficiency Directive (EED). As a result, ODEX provides policymakers with a reliable tool for ex-post evaluation, strategic planning, and ensuring alignment with broader EU decarbonization objectives.

3.2. Methodological Framework for Energy Efficiency Assessment

This section presents the methodological approach used to assess energy efficiency improvements and projected energy savings. The explanation is intentionally provided in simplified terms to clarify the overall logic of the approach. The detailed technical formulation, including equations and methodological refinements, is presented in the scientific paper (Pušnik et al., 2025) (available at: https://link.springer.com/article/10.1007/s12053-025-10399-x) and should be consulted for a comprehensive description of the analytical procedures.

3.2.1 General Approach

The assessment is based on the ODEX methodology, a sectoral energy efficiency indicator developed within the ODYSSEE-MURE framework and widely applied across the European Union for monitoring energy efficiency progress. The method is designed to evaluate how efficiently energy is used in the main final energy consumption sectors: industry, transport, households, and services. By focusing on sector-specific developments, the approach provides a structured and comparable way of tracking efficiency improvements over time.

Rather than examining total energy consumption alone, the approach links energy use to sectoral activity levels. This distinction is essential because energy consumption can change for two fundamentally different reasons. It may increase or decrease due to changes in activity, such as higher industrial production, growing mobility demand, population growth, or expansion of building floor area. Alternatively, energy consumption may change because technologies become more efficient, operational practices improve, or behavioural patterns shift toward lower energy use. The ODEX methodology separates these effects by relating energy consumption to measurable activity indicators, thereby isolating the efficiency component from structural or economic drivers.

This linkage between energy use and activity makes it possible to assess efficiency progress in a more meaningful way than through aggregate indicators such as energy per unit of GDP. While macro-level indicators can reflect economic restructuring or sectoral shifts, they do not necessarily capture improvements in how efficiently energy is used within specific activities. By contrast, ODEX focuses on specific energy use—for example, energy per unit of industrial output, per passenger-kilometre in transport, or per square metre of heated floor area in buildings—thus providing a more direct measure of technical and operational efficiency.

In simple terms, the method answers the question: are we using energy more efficiently, or are observed changes in consumption mainly the result of structural or economic developments? By distinguishing between these effects, the methodology supports a clearer understanding of past performance and future expectations in energy efficiency policy.

3.2.2 Linking Energy Use to Activity

The core of the methodology consists of calculating specific energy use, which represents the amount of energy required per unit of activity. Instead of analysing total consumption in isolation, energy demand is normalised by an appropriate activity indicator that reflects the underlying driver of demand in each sector. Examples include energy used per unit of industrial output, per passenger-kilometre in transport, per tonne-kilometre of freight, per square metre of heated floor area in buildings, or per dwelling in the residential sector.

This approach transforms raw energy data into intensity indicators. These indicators allow a clearer interpretation of whether energy is being used more efficiently over time. If specific energy use declines, it indicates that less energy is required to deliver the same level of activity, which is typically associated with technological improvements, better operational practices, or behavioural changes. Conversely, if specific energy use increases, it may signal efficiency deterioration, structural shifts within subsectors, or data inconsistencies that require further examination.

By observing how these specific energy indicators evolve over time, it becomes possible to track efficiency improvements independently of changes in economic growth, mobility demand, demographic developments, or expansion of the building stock. This distinction is particularly important when assessing policy impacts, as it allows changes in energy demand to be attributed more precisely to efficiency measures rather than to broader macroeconomic trends.

The required data therefore consist of two main components: sectoral energy consumption and corresponding activity indicators. Energy consumption data must be sufficiently disaggregated to reflect sectoral and, where possible, subsectoral developments. Activity data must be selected carefully to ensure that they accurately represent the structural drivers of energy demand within each sector.

To ensure methodological consistency, these data were collected using a harmonised template. The template was designed to standardise reporting formats, units, and sectoral definitions across countries and across time horizons. Historical statistical data were combined with forward-looking projections derived from national modelling exercises and official planning documents. This integration of observed and projected data enables both retrospective assessment of efficiency trends and forward-looking evaluation of anticipated policy impacts.

3.2.3 Construction of the ODEX Index

Once specific energy indicators are calculated for each subsector, they are aggregated into a composite sectoral index. This aggregation follows a weighted approach, where each subsector contributes to the overall index proportionally to its share in total sectoral energy consumption. In practice, energy-intensive activities have a greater influence on the final index than smaller consumers, ensuring that the indicator reflects the real structure of energy demand within the sector.

The purpose of this weighting system is to ensure representativeness. For example, improvements in a large industrial branch or a dominant transport mode will have a stronger impact on the overall sectoral index than changes in smaller subsectors. This approach allows the index to capture the combined effect of efficiency changes across diverse activities while preserving their relative importance.

The resulting sectoral index is normalised to a chosen base year, which is set to a value of 100. Subsequent values indicate relative efficiency changes compared to that base year. If the index declines to 95 in a later year, this corresponds to a 5 percent improvement in energy efficiency relative to the base year. Conversely, an increase above 100 would indicate a deterioration in specific energy use. This index format provides a transparent and intuitive way to interpret efficiency trends and enables consistent comparison across sectors and over time.

In addition to sector-level indices, the methodology allows for the calculation of an aggregate economy-wide index, combining the four main demand sectors. This broader indicator provides a summary view of overall energy efficiency developments while remaining grounded in sector-specific calculations.

To reduce the influence of short-term fluctuations, such as climatic variability, temporary economic shocks, or statistical irregularities, a smoothing procedure is applied. Typically, this involves using a moving average approach, which dampens abrupt year-to-year variations that do not reflect structural efficiency changes. By doing so, the indicator better captures long-term technological progress and sustained behavioural shifts rather than transient anomalies.

Through this structured aggregation and normalisation process, the ODEX index provides a robust and policy-relevant measure of energy efficiency progress.

3.2.4 Estimation of Energy Savings

The ODEX index can be translated into energy savings, thereby converting relative efficiency improvements into absolute energy quantities. In practical terms, energy savings represent the volume of energy that would have been consumed if efficiency levels had remained unchanged compared to the previous year. When the ODEX index declines, this reduction reflects an improvement in specific energy use, which can be expressed as avoided energy consumption.

This transformation from an index value to energy savings makes the results more tangible and policy-relevant. While percentage improvements provide information about the direction and magnitude of efficiency trends, expressing savings in physical units (such as ktoe or Mtoe) allows for direct comparison with energy balances, policy targets, and national energy planning figures.

The calculation follows a top-down logic. Changes in the ODEX index are applied to the observed or projected sectoral energy consumption in order to determine how much energy has been saved due to efficiency improvements. In this way, the method maintains consistency between intensity indicators and aggregate consumption levels.

The analysis includes both ex-post and ex-ante components. The ex-post assessment evaluates historical energy savings based on observed statistical data. This provides insight into how past policies, technological progress, and behavioural changes have contributed to actual efficiency gains.

The ex-ante assessment estimates future savings using projected energy consumption and activity data up to 2030, 2040, and 2050. These projections are derived from national modelling exercises and planning assumptions. By applying the same methodological framework to future data, it becomes possible to assess the expected impact of planned policies and structural changes.

This dual perspective enables a structured comparison between past performance and anticipated policy ambition. It allows policymakers and analysts to evaluate whether projected efficiency improvements are consistent with historical trends, aligned with strategic targets, or indicative of an acceleration or slowdown in energy efficiency progress.

3.2.5 Use of Technical ODEX

When combining historical observations with forward-looking projections, methodological inconsistencies can arise. These may stem from differences in baseline years, revisions of statistical data, variations in modelling assumptions, or structural breaks between observed data and projected values. As a result, specific energy consumption may occasionally increase between two consecutive years, even when no real deterioration in technical efficiency has occurred. Such increases can artificially produce negative energy savings values, which may distort the interpretation of results.

To address this issue, a technical version of the ODEX indicator is applied. The technical ODEX focuses exclusively on underlying efficiency improvements and filters out increases in specific consumption that are not attributable to genuine efficiency decline. In practical terms, when specific energy use rises between two years due to temporary fluctuations, structural adjustments, or data inconsistencies, the methodology prevents this increase from being interpreted as negative technical progress.

This adjustment improves the robustness of the results, particularly when assessing long-term trends and future projections. It ensures that the calculated energy savings reflect structural and technological improvements rather than short-term anomalies or modelling artefacts. By stabilising the index in this way, the technical ODEX provides a more reliable representation of technical efficiency progress and enhances the comparability between ex-post observations and ex-ante projections.

The use of the technical ODEX is especially important in forward-looking analyses, where projections may involve discrete changes in assumptions, sectoral definitions, or activity growth patterns. By neutralising unrealistic reversals in efficiency trends, the approach maintains analytical consistency and strengthens the credibility of the estimated energy savings.

3.2.6 Analytical Value of the Method

The principal strength of this methodology lies in its capacity to distinguish genuine efficiency improvements from changes driven by structural or activity-related factors. In many conventional analyses, reductions in overall energy intensity—such as energy consumption per unit of GDP—are interpreted as evidence of improved efficiency. However, such aggregate indicators often reflect broader economic transformations, including shifts from energy-intensive industries toward services, changes in trade patterns, or variations in economic growth rates. They do not necessarily indicate that technologies have become more efficient or that energy is being used more effectively within specific activities.

By contrast, the ODEX framework is grounded in physical and sector-specific indicators that directly link energy use to measurable activities. This makes it particularly well suited for policy evaluation, as it allows analysts to assess whether implemented measures are delivering tangible improvements in energy performance. The method also enables the decomposition of energy demand trends into activity, structural, and intensity effects, thereby providing a clearer understanding of the underlying drivers of change.

Another important advantage of the approach is its transparency. The calculation is based on clearly defined activity indicators, explicit weighting structures, and standardised procedures. This improves reproducibility and facilitates communication of results to policymakers and stakeholders. Because the methodology operates at the subsector level before aggregation, it also allows for targeted analysis of specific branches or end uses, which is particularly relevant when evaluating sector-specific measures.

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At the same time, the framework is sufficiently flexible to accommodate differences in national data availability and modelling structures. Countries may vary in the level of disaggregation, statistical detail, or modelling sophistication. While such differences can influence the precision of results, the use of a harmonised methodological structure ensures that assumptions, limitations, and data gaps remain transparent and analytically traceable. This enhances comparability while acknowledging practical constraints.

The methodology provides a coherent and policy-relevant framework for evaluating both historical energy efficiency performance and anticipated future developments. It supports evidence-based assessment of energy and climate strategies by linking measurable efficiency improvements to sectoral dynamics.

4. Analysis of Methodologies, Indicators and Projections in Pilot Member States

4.1. Overview of National Methodological Approaches

This chapter provides a structured overview of the national methodological approaches applied by the assessed Member States—Austria, Slovenia, Lithuania, Croatia, Greece, Czech Republic, Belgium and Portugal—to project, calculate, monitor and report energy efficiency improvements. The analysis reflects how countries operationalise the requirements of the Energy Efficiency Directive (EED), in particular Articles 4 and 8, within their National Energy and Climate Plans (NECPs) and national reporting systems.

The assessment was carried out under **Task T5.2 – Analysis and evaluation of methodologies, EE indicators and projections for assessing the impacts of EE policies and measures in pilot MSs**, and directly contributes to the achievement of **Milestone MS10 – Analysis and evaluation of methodologies, EE indicators and projections for assessing the impacts of EE policies and measures in pilot MSs**. It builds upon the foundations established in **Task T5.1 – Establishment of the data framework: identification of relevant sources and methodology alignment**. Under Task T5.1, a harmonised data collection template was developed to compile sectoral energy consumption data, activity indicators, and projection information from key sources such as NECPs, NECP Progress Reports, Eurostat, ODYSSEE, and JRC-IDEES. This task ensured data consistency, standardised units of measurement, and alignment of sectoral definitions, thereby creating a structured and transparent analytical basis for cross-country comparison.

Building on this framework, Task T5.2 extended the work from data preparation to methodological analysis, the results of which are presented in Chapter 5 of this deliverable and formally consolidated under Milestone MS10. The template developed in T5.1 was adapted and circulated to the participating Member States to gather detailed information on national modelling approaches, monitoring systems, energy efficiency indicators, baseline definitions, and projection methodologies. This structured collection process enabled a systematic evaluation of how energy efficiency impacts are quantified ex-post and projected ex-ante across countries. The combined implementation of Tasks T5.1 and T5.2 ensured that the assessment is grounded in harmonised data structures while allowing a comprehensive review of methodological diversity.

Methodologically, the analysis is anchored in the ODEX (Energy Efficiency Index) framework. While ODEX is traditionally used for monitoring historical energy efficiency progress, within Task T5.2 it was also applied for the ex-ante assessment of projected energy policy impacts. By linking energy consumption to sectoral activity drivers—systematically collected under Task T5.1—the ODEX-based approach enables decomposition of energy demand trends into activity, structural, and efficiency effects. This makes it possible to isolate underlying efficiency improvements embedded in national projections and to assess the credibility of reported savings under Articles 4 and 8 of the EED.

Although all assessed countries operate within the same EU regulatory framework, substantial differences emerge in modelling architecture, degree of methodological standardisation, institutional coordination, and integration of data sources. Variations are particularly evident in baseline definitions, treatment of activity drivers, calculation of cumulative savings, and the way policy measures are embedded in projection models. These methodological divergences influence the transparency, robustness, and comparability of reported savings and projected efficiency trajectories.

By combining the harmonised data framework developed under Task T5.1 with the structured methodological review carried out in Task T5.2—and formalised through Milestone MS10—this chapter provides a coherent and comparable analytical assessment. The following sections summarise the current state of monitoring methodologies, indicators used for energy efficiency assessment, and projection approaches in the assessed Member States, highlighting both areas of convergence and structural differences that have implications for EU-level monitoring and policy evaluation.

4.2. Ex-ante Methodologies: Projection and Scenario Frameworks

All assessed Member States develop energy efficiency projections within the framework of their National Energy and Climate Plans (NECPs), structured around scenarios with existing measures (WEM) and with additional measures (WAM). These scenarios form the analytical backbone for assessing compliance with Article 4 of the Energy Efficiency Directive (EED) and are embedded within broader energy, climate and decarbonisation modelling exercises. In practice, energy efficiency improvements are modelled as part of integrated energy system transformations rather than as isolated policy effects.

A number of Member States rely on integrated optimisation-based energy system models. **Greece**, the **Czech Republic**, and **Portugal**, as well as the Walloon region in **Belgium**, use TIMES-based modelling frameworks. These models represent the entire energy system across supply and demand sectors and simulate technology choices over long-time horizons, typically up to 2040 or 2050. The optimisation structure allows the model to identify cost-optimal combinations of technologies under policy constraints such as energy efficiency targets, renewable energy shares or emission reduction pathways. Within this framework, energy efficiency improvements are reflected through changes in building renovation rates, uptake of high-efficiency industrial equipment, electrification of transport, heat pump deployment, and shifts in fuel use. The endogenous representation of technology choice enhances internal consistency between energy demand reduction, electrification and renewable deployment. Because efficiency is embedded within broader system optimisation, isolating the direct impact of individual efficiency measures can be analytically challenging.

Croatia applies the LEAP modelling framework using a bottom-up end-use approach. In this structure, projections begin with estimating future useful energy demand by sector and subsector, based on activity indicators such as population growth, industrial production, floor area or transport demand. Final energy consumption is then derived by applying technology efficiency assumptions and projected fuel shares. Policy measures are incorporated as changes in technology efficiency, penetration rates or fuel switching parameters. The resulting final energy projections are subsequently linked to supply-side modelling tools to ensure coherence with primary energy consumption and energy system constraints. This sequential structure allows for transparent representation of sectoral efficiency assumptions but requires careful calibration to ensure consistency between demand and supply modules.

Lithuania currently uses a comprehensive Excel-based national energy model for NECP projections. The modelling framework combines macroeconomic drivers, sectoral activity projections and policy-specific assumptions to estimate future energy consumption and savings. While the Excel-based system allows flexibility and transparency, the country has identified the need to transition toward more advanced tools such as MESSAGE and MAED to enhance scenario robustness and cross-sector consistency. At present, detailed modelling efforts are most advanced in the transport sector, where alternative modelling tools are being tested and calibrated against the main projection framework.

Slovenia combines energy system optimisation and sectoral demand modelling using reference energy system models. Its projections integrate macroeconomic assumptions, demographic trends, energy price trajectories and EU policy constraints within WEM and WAM scenarios. Buildings and transport play a central role in projected savings trajectories, with modelling assumptions focusing on renovation dynamics, electrification of passenger transport and improvements in industrial energy intensity. The modelling framework ensures alignment between efficiency assumptions and overall energy balance projections.

In **Belgium**, projections are developed at both federal and regional levels. Federal long-term outlooks rely on PRIMES-based modelling, while regions such as Flanders and Wallonia use their own simulation tools, including TIMES-Wal in Wallonia and sector-specific building stock models in Flanders. This reflects Belgium's federal governance structure, in which energy and climate competences are largely decentralised. While this allows modelling to reflect regional specificities, it also introduces complexity in harmonising assumptions and aggregating results at national level.

Across all assessed countries, sectoral modelling structures share common features. The buildings sector is typically modelled through stock-based approaches that account for building typologies, renovation rates, efficiency standards and technology diffusion (e.g., heat pumps, insulation measures). Industrial projections vary in detail: some countries use technology-explicit representations for major industrial processes, while others rely on macro-level energy intensity trends linked to projected output growth. Transport modelling is generally less granular. Most countries rely on assumptions about electric vehicle uptake, biofuel shares, fuel taxation and modal shifts rather than fully dynamic fleet-stock turnover models. As a result, transport efficiency projections are often more sensitive to assumed electrification rates than to detailed vehicle efficiency improvements.

A common structural feature across Member States is that energy efficiency is embedded within broader decarbonisation modelling rather than treated as a stand-alone analytical block. This integrated approach strengthens overall system coherence, ensuring consistency between demand reduction, renewable energy expansion and greenhouse gas mitigation pathways. It also complicates the analytical separation of efficiency-driven savings from structural changes such as electrification, fuel switching or economic transformation. Consequently, while ex-ante projections provide internally consistent energy system pathways, attributing projected reductions exclusively to energy efficiency policies requires careful interpretation.

4.3. Ex-post Methodologies: Calculation of Achieved Energy Savings

Ex-post methodologies across the assessed Member States are primarily shaped by the requirements of Article 8 of the Energy Efficiency Directive (EED), which obliges countries to quantify and report cumulative end-use energy savings from policy measures. As a result, all countries apply bottom-up approaches to calculate policy-driven savings at measure level. Nonetheless, the degree of formalisation, standardisation and digitalisation of these methodologies varies considerably.

A common structural feature is that savings are calculated at the level of individual measures or projects and subsequently aggregated to sectoral and national totals. This bottom-up logic contrasts with ex-ante modelling and places strong emphasis on measurement, verification and documentation.

Croatia represents one of the most formalised systems. It operates under a legally prescribed national catalogue of monitoring, measurement and verification (M&V) methods. This catalogue contains calculation formulae, default parameters and standardised values for typical energy efficiency measures. Savings from both the Energy Efficiency Obligation Scheme (EEOS) and alternative measures are entered into a dedicated national IT platform (SMIV). The platform supports measure attribution by sector, verifies compliance with technical eligibility criteria, and reduces the risk of double counting through centralised tracking. This structured approach enhances traceability and consistency across reporting cycles.

In **Greece**, bottom-up equations developed by the national energy agency are used to quantify delivered energy savings under both the EEOS and alternative policy measures. Savings are attributed to sectors based on end-use consumption and monitored within the NECP implementation framework. While the methodology is structured, verification relies primarily on administrative and statistical data rather than a fully centralised digital platform comparable to Croatia's system.

Lithuania combines several approaches depending on the type of measure. Engineering calculations are widely applied for investment and renovation programmes. In the buildings sector, Energy Performance Certificates (EPCs) are used to estimate savings per square metre before and after renovation. Where feasible, metered savings based on pre- and post-intervention consumption data are used and adjusted for weather conditions. The Lithuanian Energy Agency conducts quality control, including independent checks and alignment with EU methodological guidance. Although methodologies are well defined, they are implemented across multiple administrative databases rather than through a single unified digital tracking system.

Slovenia applies a national catalogue of deemed savings values complemented by engineering calculations for specific measures. Bottom-up results are reconciled with macro-level indicators such as ODEX and national energy balance data to ensure consistency between reported savings and observed energy trends. This hybrid approach strengthens credibility, although the reconciliation process requires careful methodological alignment between bottom-up and top-down datasets.

Portugal relies strongly on sector-specific monitoring systems. In the buildings sector, the Energy Certification System (SCE) provides verified performance data, while the Management System for Intensive Energy Consumption (SGCIE) covers large industrial installations through mandatory audits and reporting. Project-level monitoring is also conducted for measures supported through national and EU funding instruments. By comparison, Portugal does not yet operate a unified cross-sectoral national catalogue covering all types of measures. As a result, methodologies differ between sectors, and harmonisation across measure types remains an identified area for improvement.

The **Czech Republic** applies programme-specific methodologies, often linked to subsidy schemes. Energy savings are typically calculated using building energy performance certificates, energy audits or engineering estimates defined in programme documentation. Aggregation is carried out at ministerial level for national reporting under Article 8. While systems for subsidy tracking are well established, methodological fragmentation can arise due to differences across programmes and funding instruments.

In **Belgium**, ex-post calculation methodologies are less uniformly documented at national level due to the decentralised governance structure. Energy efficiency measures are designed and monitored at regional level, and while bottom-up approaches are applied, publicly available information on baseline definitions, deemed savings values and verification procedures remains limited. This fragmentation can complicate national aggregation and transparency.

In **Austria**, structured bottom-up approaches are used to quantify savings under EED obligations, supported by established administrative procedures and reporting mechanisms. Savings are calculated in accordance with national guidelines aligned with EU requirements, and reporting follows formalised processes under national legislation.

Across all assessed countries, ex-post savings are derived using a combination of:

- deemed savings values for standardised technologies;
- engineering formulae based on technical parameters;
- metered consumption comparisons (before/after implementation);
- EPC-based performance differentials in buildings;
- audit-based verification in industry.

The robustness of savings tracking depends heavily on three structural factors: the existence of a codified national catalogue of calculation methods, the degree of digitalisation of reporting platforms, and the clarity of verification and quality control procedures. Countries with centralised IT systems and legally codified methodologies generally demonstrate stronger traceability and lower risks of double counting. In contrast, systems relying on programme-specific methodologies and fragmented administrative databases may face challenges in harmonisation and consistency.

While all countries comply with the bottom-up logic required under Article 8 EED, the level of methodological maturity and integration varies significantly, influencing transparency, comparability and long-term credibility of reported energy savings.

4.4. Baselines, Additionality and Double Counting

The definition of baselines and the treatment of additionality and double counting are central to the credibility of reported energy savings under Article 8 EED. While all assessed Member States operate within the common framework of Annex V of the Directive, practical implementation varies in structure, transparency and methodological sophistication.

Baseline definitions differ both conceptually and operationally. In **Greece** and **Croatia**, baselines are generally linked to the most recent available national energy balance year. This approach ensures consistency with official statistics and national reporting but may be less sensitive to project-level consumption patterns unless additional adjustments are applied.

In **Lithuania** and **Portugal**, baselines are typically defined at the level of individual measures. They are derived from pre-implementation consumption averages or sector-specific historical data. This allows for more precise attribution of savings to specific interventions but requires detailed data collection and consistent methodological application.

In the **Czech Republic**, project-level baselines commonly use a two- or three-year pre-implementation consumption average. This helps reduce volatility caused by abnormal years (e.g. weather fluctuations) and strengthens the statistical robustness of savings estimates.

In **Slovenia**, baselines are aligned with the EED obligation period and reference consumption prior to implementation of measures. For Article 8 reporting, savings are calculated using nationally defined deemed values and engineering methods, with baselines defined consistently within the framework of the national catalogue. Slovenia also reconciles bottom-up savings with macro-level indicators such as national energy balances and ODEX-type indices, which provides an additional consistency check between reported savings and observed energy trends.

In **Belgium**, baseline methodologies are less uniformly documented at national level due to the decentralised governance structure. Since energy efficiency competences are largely regional, baseline definitions and calculation practices may differ between Flanders, Wallonia and Brussels-Capital. While this allows regional tailoring, it complicates aggregation and methodological transparency at federal level.

Across all countries, additionality — meaning that reported savings must exceed what would have occurred in the absence of the measure — is formally addressed in line with Annex V principles. Additionality is typically defined relative to EU minimum standards, national regulatory requirements, or business-as-usual market developments.

Croatia addresses double counting risks through its central IT-based reporting platform, which distinguishes clearly between savings from the Energy Efficiency Obligation Scheme (EEOS) and alternative measures. This structured tracking system reduces overlap risk and strengthens traceability.

Lithuania applies national overlap-adjustment rules and quality control procedures to prevent double counting across funding schemes and policy instruments. Independent checks are integrated into the monitoring framework.

In **Slovenia**, additionality and double counting are managed through the application of EU minimum standards and cross-checking across schemes. Savings are attributed to sectors and measures within a coordinated reporting structure, reducing overlap risk between financial instruments and obligation-based measures.

In **Greece**, compliance with additionality and overlap requirements is ensured through institutional oversight by the NECP monitoring team and the national energy agency. Verification relies on administrative coordination and bottom-up calculation protocols.

Portugal explicitly recognises the methodological challenges posed by bundled renovation measures, behavioural interventions and cross-sectoral policies. Internal validation and cross-checking procedures are applied, but the absence of a unified national deemed-savings catalogue increases complexity in overlap management.

In the **Czech Republic**, double counting is primarily addressed through subsidy management systems that assign unique project identifiers. While this prevents duplication within funding schemes, the increasing number of parallel programmes in some sectors heightens coordination demands.

Despite structured mechanisms across countries, common challenges remain. The coexistence of EU funds, national subsidy schemes, regulatory standards and obligation mechanisms increases the risk of overlap if coordination mechanisms are not fully harmonised. Long-standing support programmes and evolving efficiency standards make it progressively more difficult to define a clear counterfactual baseline. Behavioural and cross-cutting measures are particularly difficult to assess due to uncertainties in baseline assumptions and rebound effects.

While formal compliance with Annex V requirements is evident in **Slovenia**, **Croatia**, **Lithuania**, **Greece**, **Portugal**, **Czech Republic**, **Belgium** and **Austria**, the methodological robustness of baseline setting and additionality assessment varies. Countries with codified catalogues and digital tracking systems demonstrate stronger institutional control, whereas decentralised or programme-specific approaches require enhanced coordination to ensure transparency and consistency under the revised EED framework.

4.5. Analysis of Energy Efficiency Indicators Used

Energy efficiency indicators are the operational bridge between policy design, modelling assumptions and measurable progress toward national and EU targets. Based on the national templates, all assessed Member States, **Austria, Slovenia, Lithuania, Croatia, Greece, Czech Republic, Belgium and Portugal** use a combination of aggregate energy indicators, policy-driven savings metrics and sectoral performance indicators. However, the structure, integration and analytical depth of these indicator systems differ significantly.

This section examines how indicators are used to monitor compliance with Article 4 (energy consumption targets) and Article 8 (end-use savings obligations), how they interact with modelling frameworks, and how effectively they capture genuine efficiency improvements as opposed to structural or economic effects.

4.5.1 Aggregate Consumption Indicators: PEC and FEC

Primary Energy Consumption (PEC) and Final Energy Consumption (FEC) constitute the central quantitative benchmarks for energy efficiency monitoring in all assessed Member States. Derived from national energy balances compiled by statistical offices and energy authorities, these indicators form the formal reference for assessing compliance with Article 4 of the Energy Efficiency Directive (EED). They are reported annually within national energy statistics and incorporated into biennial NECP progress reports and Energy Union governance submissions.

PEC measures the total energy demand of an economy, including transformation losses in electricity and heat generation, distribution losses and own consumption of the energy sector. It therefore captures the efficiency of both the supply and demand sides of the energy system. FEC, by contrast, measures energy delivered to end users in buildings, industry, transport, agriculture and services. It reflects direct consumption by final consumers and is more closely associated with behavioural and technological changes in end-use sectors.

Together, PEC and FEC provide a high-level picture of the trajectory of national energy demand. Their strength lies in their consistency, comparability across Member States and direct linkage to EU-level targets. Because they are rooted in harmonised statistical methodologies (Eurostat energy balances), they provide a stable and transparent monitoring framework for evaluating overall energy system performance.

From an analytical perspective, PEC and FEC are composite indicators influenced by multiple structural drivers beyond energy efficiency policy. Economic growth is one of the most significant determinants. An expanding economy, particularly one characterised by energy-intensive industrial production or increased mobility demand, may drive up energy consumption even if technical efficiency improves. Conversely, structural shifts from heavy industry to service-oriented sectors may reduce energy consumption independently of explicit efficiency measures.

Weather variability also affects annual energy consumption, particularly in the buildings sector. Cold winters or heatwaves can lead to significant fluctuations in heating and cooling demand. While some countries apply climate corrections in analytical assessments, headline PEC and FEC values typically reflect actual observed consumption and therefore embed climatic effects.

Electrification trends further complicate interpretation. Increased electrification of transport or heating may reduce primary energy consumption if electricity is generated efficiently and increasingly from renewable sources. At the same time, final electricity consumption may increase, even though overall system efficiency improves. This dynamic means that changes in PEC and FEC may move in different directions depending on the structure of energy supply.

Fuel switching between fossil fuels and renewables can also affect PEC independently of end-use efficiency improvements. Renewable electricity generation often carries lower primary energy accounting factors, leading to reductions in PEC even without direct efficiency gains in end-use sectors.

Demographic changes, including population growth, urbanisation or changes in household size, additionally influence final consumption patterns.

For these reasons, reductions in PEC or FEC cannot automatically be interpreted as pure efficiency improvements. Conversely, rising energy consumption does not necessarily imply policy failure if economic output or service demand grows at a faster rate and energy intensity declines.

The way countries contextualise PEC and FEC therefore matters. In **Belgium**, monitoring appears to rely primarily on aggregate consumption trends as headline indicators, with more limited use of complementary efficiency indices. This places greater interpretative weight on macro-level trends. In contrast, **Slovenia, Croatia, Greece and Portugal** supplement PEC and FEC with structural efficiency indicators such as ODEX and sectoral intensity metrics. This layered approach allows these countries to better disentangle structural effects from underlying technical efficiency improvements.

In summary, PEC and FEC remain indispensable for compliance assessment under Article 4 EED due to their harmonised and legally binding character. Their analytical value depends on how effectively they are complemented by additional indicators capable of isolating efficiency trends from broader economic and structural dynamics.

4.5.2 Article 8 Cumulative Savings Indicators

All assessed Member States report cumulative end-use energy savings under Article 8 of the Energy Efficiency Directive (EED). These savings represent the quantified impact of implemented policy measures, including building renovation subsidies, energy efficiency obligation schemes (EEOS), industrial optimisation programmes, transport incentives, public sector efficiency measures and fiscal instruments.

Conceptually, Article 8 savings differ fundamentally from aggregate consumption indicators such as PEC and FEC. While PEC and FEC reflect overall system-wide energy demand, Article 8 savings are calculated bottom-up and measure-specific. They quantify the reduction in energy consumption attributable to a defined intervention relative to a specified baseline. This makes Article 8 indicators directly linked to policy implementation and therefore more suitable for evaluating programme performance and regulatory compliance.

The indicator measures cumulative annual savings over the obligation period, meaning that each year's new savings are added to the savings achieved in previous years, adjusted for the lifetime of measures. As a result, the trajectory of cumulative savings reflects both the volume of new interventions and the persistence of earlier measures.

In **Croatia, Slovenia and Lithuania**, bottom-up savings from individual measures are aggregated through relatively structured monitoring systems. These systems often provide sectoral disaggregation (e.g. residential buildings, services, industry, transport and public sector) and allow tracking of savings by measure type. The aggregation process typically distinguishes between savings generated under an Energy Efficiency Obligation Scheme and those arising from alternative measures financed through public funds. This structured tracking improves traceability and facilitates reporting to the European Commission.

In **Portugal**, Article 8 reporting is closely linked to sector-specific monitoring frameworks. Building-related savings are derived largely from the Energy Certification System (SCE), which enables estimation of pre- and post-renovation performance. Industrial savings are monitored through the Management System for Intensive Energy Consumption (SGCIE), which requires energy audits and performance reporting. Savings from other sectors are compiled from programme-level monitoring systems and funding instruments.

The **Czech Republic** aggregates savings across multiple subsidy programmes, public funding mechanisms and voluntary agreements. Project-level savings are calculated using predefined methodologies embedded within programme rules and then consolidated at national level for reporting purposes. The approach provides flexibility but may result in methodological variation across programmes.

In **Greece**, savings are reported from both the Energy Efficiency Obligation Scheme and alternative measures. Institutional monitoring mechanisms ensure aggregation across sectors, with bottom-up equations used to calculate delivered savings. Sectoral attribution is typically based on end-use consumption categories.

Although Article 8 savings provide a direct and policy-relevant link between implemented measures and quantified outcomes, their robustness and comparability depend heavily on underlying methodological assumptions. Several core parameters shape the magnitude and structure of reported savings.

Measure lifetimes play a decisive role in determining cumulative savings. Since Article 8 reporting is based on cumulative annual savings over the obligation period, the assumed technical lifetime of a measure defines how long annual savings are credited. Longer lifetimes mechanically increase cumulative savings, even if the number of new measures implemented each year remains unchanged. Differences in lifetime assumptions across Member States therefore have a substantial impact on reported totals.

Deemed savings values are frequently applied to standardised measures such as boiler replacements, insulation upgrades or lighting retrofits. These values are based on default technical parameters (e.g. efficiency improvement, operating hours, load factors). Variations in default assumptions across countries — reflecting climatic conditions, usage patterns or national standards — directly influence reported savings, even for similar physical interventions.

Baseline definitions determine the counterfactual scenario against which savings are calculated. Some countries use regulatory minimum standards as the baseline, while others rely on historical consumption averages or typical market practice. These methodological choices can significantly alter calculated savings volumes, particularly in sectors where standards evolve rapidly.

Climate corrections are sometimes applied to adjust savings for weather-related variability, especially in heating- and cooling-related measures. Inconsistent application of climate normalisation affects year-to-year comparability and cross-country alignment.

Attribution rules govern how savings are allocated across sectors and how overlaps between funding instruments are handled. Differences in how Member States distinguish between obligation schemes and alternative measures, or how they prevent double counting across programmes, can alter both sectoral distributions and total savings figures.

Because of these methodological differences, cross-country comparability of Article 8 savings is inherently limited. Two Member States implementing similar renovation programmes may report different savings outcomes due to variations in lifetime assumptions, baseline treatment or default performance parameters. Furthermore, Article 8 savings do not automatically translate into proportional reductions in macro-level final energy consumption, since broader economic dynamics, electrification and structural change also influence energy demand.

Despite these limitations, Article 8 cumulative savings remain one of the most policy-relevant indicators in the EU energy efficiency framework. They provide transparency regarding the scale of intervention, allow monitoring of annual progress within the obligation period, and offer insight into the relative contribution of different sectors to national efficiency efforts.

To strengthen the analytical robustness of the framework, greater harmonisation of key methodological parameters particularly lifetimes, baseline treatment and default savings values, would enhance comparability across Member States while preserving the flexibility needed to reflect national specificities and sectoral characteristics.

4.5.3 ODEX and Underlying Efficiency Trend Indicators

To overcome the analytical limitations of aggregate consumption indicators such as PEC and FEC, several Member States apply ODEX-type indices or equivalent decomposition methods to measure underlying energy efficiency trends. ODEX, developed within the ODYSSEE-MURE framework, is designed to isolate technical efficiency improvements from structural and activity-related effects. By adjusting for changes in sectoral composition and activity levels, it provides a clearer picture of genuine efficiency progress.

Unlike simple energy intensity indicators (e.g. energy per unit of GDP), ODEX decomposes trends by sector and end-use. It tracks changes in specific energy consumption per activity unit — such as kWh per square metre in buildings, energy per tonne of industrial output, or fuel consumption per vehicle-kilometre — and aggregates these into a composite index. This structure enables a more robust distinction between:

- Technical efficiency improvements
- Structural economic shifts
- Changes in activity demand

Slovenia, Croatia, Greece and Portugal explicitly use ODEX or equivalent indicators to monitor long-term efficiency trends across households, industry, transport and services. In these countries, ODEX serves as a complementary analytical layer alongside Article 8 savings and aggregate energy consumption indicators. It is particularly valuable for verifying whether bottom-up reported savings are reflected in observable efficiency improvements at sector level.

In **Lithuania**, although ODEX is not always highlighted as a central monitoring tool, sectoral intensity indicators are used to track developments in buildings, transport and industry. These functionally serve a similar purpose by monitoring energy use per activity indicator, even if not aggregated into a formal ODEX composite index.

The **Czech Republic** applies sectoral energy intensity indicators and modelling-based decomposition analysis within its analytical framework. While not always formally labelled as ODEX, similar principles are applied through modelling outputs and statistical analysis to distinguish structural from efficiency effects.

In **Austria**, efficiency monitoring combines bottom-up savings tracking with energy intensity indicators derived from national statistics and EU reporting structures. The approach includes structural analysis of energy demand but does not always rely on a centralised ODEX composite index.

In **Belgium**, systematic use of ODEX-type indicators appears more limited at national aggregation level. Monitoring relies more heavily on primary and final energy consumption trends, supported by modelling outputs. While regional analyses may include decomposition elements, the absence of a consistently applied national efficiency index reduces analytical transparency in distinguishing structural and technical drivers of change.

The relevance of ODEX-type indicators becomes particularly important in countries experiencing structural economic transformation or strong electrification dynamics. For example:

- A shift from heavy industry to services may reduce overall energy intensity without technical efficiency gains.
- Rapid electrification of transport may increase final electricity consumption while improving system efficiency.
- Growing mobility demand may offset vehicle efficiency improvements.

Without decomposition analysis, such dynamics may be misinterpreted as either policy success or failure.

The integration of ODEX or sectoral intensity indicators alongside bottom-up Article 8 savings strengthens methodological robustness in several ways. First, it enables cross-validation between reported savings and observed efficiency trends. Second, it provides explanatory power when aggregate consumption does not evolve as projected. Third, it supports more evidence-based policy adjustments by identifying sectors where efficiency progress is lagging.

ODEX and decomposition approaches also depend heavily on the availability and quality of disaggregated activity data. Transport and services sectors often present data gaps across multiple countries. Where activity statistics are incomplete or inconsistent, the reliability of efficiency indices is reduced.

Countries such as **Slovenia, Croatia, Greece and Portugal**, which systematically integrate ODEX-type indicators into their monitoring frameworks, demonstrate stronger analytical capacity to distinguish between structural change and technical efficiency improvements. Countries relying primarily on aggregate consumption trends, including **Belgium,** have a more limited ability to isolate efficiency-specific effects.

For improved comparability and analytical coherence across the EU, broader and more harmonised application of decomposition-based efficiency indicators would strengthen the interpretative value of national reporting under the EED framework.

4.5.4 Sectoral Intensity and Performance Indicators

Beyond aggregate consumption metrics and cumulative Article 8 savings, most Member States apply sector-specific intensity and performance indicators to track efficiency developments within key areas of final energy use. These indicators provide greater analytical granularity and help identify where efficiency improvements are occurring — and where structural or behavioural effects may dominate.

Buildings Sector

In the buildings sector, the most widely used indicator is energy consumption per square metre (kWh/m²). This metric adjusts for changes in total floor area and enables monitoring of improvements in building envelope performance, heating systems and overall energy management.

Countries with well-developed Energy Performance Certificate (EPC) registries — including **Slovenia, Portugal, Croatia and the Czech Republic** — are able to monitor building performance more systematically. EPC databases allow tracking of pre- and post-renovation performance, distribution of buildings across efficiency classes and average energy demand trends by building type. Renovation rates, average EPC class improvements and heating system replacement statistics (e.g. boiler-to-heat-pump transitions) are frequently used as complementary indicators.

In **Slovenia**, strong EPC coverage and subsidy monitoring systems enable relatively robust tracking of residential building performance improvements, supporting reconciliation between reported Article 8 savings and observed efficiency trends.

Although these indicators strengthen sectoral transparency, comparability across countries remains limited due to differences in climate conditions, EPC methodologies and building typologies.

Industry Sector

In industry, sectoral intensity indicators typically measure energy consumption per unit of physical output (e.g. per tonne of product) or per unit of economic output (e.g. energy per gross value added). These metrics allow separation of technical efficiency improvements from changes in production volume and structural shifts in industrial composition.

Data quality is generally stronger for large energy-intensive installations subject to EU ETS reporting, mandatory audits or energy management requirements. Countries such as **Portugal, Lithuania, Croatia and Slovenia** benefit from structured reporting obligations for large industrial consumers, which improve the reliability of energy intensity statistics.

In **Slovenia**, industrial efficiency monitoring is supported by EU ETS reporting and mandatory energy audits for large enterprises. Energy intensity indicators are complemented by ODEX-type analysis, allowing partial distinction between technical efficiency improvements and structural changes in industrial output.

In all Member States, monitoring efficiency in small and medium-sized enterprises (SMEs) remains less granular. SME energy use is often captured only in aggregate statistical categories, making it difficult to isolate efficiency improvements from broader economic dynamics.

Transport Sector

Transport presents one of the most challenging sectors for efficiency monitoring. Common indicators include energy consumption per passenger-kilometre, per tonne-kilometre, average fuel consumption per vehicle and electrification shares of vehicle fleets.

Most Member States rely primarily on aggregate fuel sales data and vehicle registration statistics rather than detailed fleet turnover or real-world consumption data. As a result, efficiency trends are often inferred from modelling assumptions and technological penetration rates rather than directly measured.

As electrification accelerates, interpretative complexity increases. A rising share of electric vehicles may reduce energy use per kilometre in final energy terms while simultaneously increasing electricity consumption. Distinguishing between genuine efficiency improvements and shifts in energy carrier therefore becomes analytically demanding.

Countries such as **Slovenia, Croatia and Portugal** attempt to combine transport intensity indicators with modelling-based scenario assumptions, but detailed vehicle-level efficiency tracking remains limited across most Member States.

Agriculture and Public Sector

Agriculture is generally less developed in terms of efficiency indicators. Energy consumption is typically monitored in aggregate form, with limited disaggregation by equipment type or production process. As a result, technical efficiency improvements in agricultural machinery or irrigation systems are rarely captured through detailed performance metrics.

The public sector shows greater variation. Some countries operate dedicated monitoring systems for public buildings, allowing tracking of energy consumption trends and renovation progress. Where such systems exist including in **Slovenia and Croatia,** they provide clearer visibility of public-sector efficiency performance and support targeted policy evaluation.

4.5.5 Implementation and Activity Indicators

Implementation data

In addition to quantified energy savings expressed in ktoe or GWh, several Member States complement their monitoring frameworks with implementation and activity indicators that measure the physical uptake of policy measures. These indicators provide a tangible link between financial support schemes, regulatory instruments and observable technical transformation in end-use sectors.

Across the assessed countries — **Austria, Slovenia, Lithuania, Croatia, Greece, Czech Republic, Belgium and Portugal** — implementation indicators are used to varying degrees and with different levels of systematisation.

In **Lithuania**, implementation metrics are explicitly embedded within programme monitoring structures. Renovated floor area, building upgrades, transport electrification measures and industrial interventions are systematically tracked and linked to reported savings. This creates relatively strong transparency between physical outputs and bottom-up calculated energy savings.

Portugal similarly relies on implementation data from the Energy Certification System (SCE) for buildings and the Management System for Intensive Energy Consumption (SGCIE) for industry. Renovated floor area, audit implementation rates and installed efficiency technologies are used to support savings calculations and programme evaluation.

In **Slovenia**, subsidy schemes administered by the Eco Fund and related institutions generate detailed data on implemented measures, including heating system replacements, insulation measures and renewable heating installations. These physical outputs are connected to national savings calculations and allow cross-checking between reported Article 8 savings and observed implementation trends.

Croatia uses its national IT monitoring platform to register implemented measures under both obligation schemes and alternative measures. The system captures measure-level implementation data, which strengthens traceability and allows aggregation by sector and technology type.

In the **Czech Republic**, implementation indicators are typically embedded within subsidy programmes. Building renovation projects, industrial upgrades and public sector interventions are tracked through programme management systems. While these indicators are robust at programme level, they are less harmonised across instruments.

In **Greece**, implementation tracking is linked to the Energy Efficiency Obligation Scheme and national support programmes, including building renovation initiatives. Physical outputs are monitored, but aggregation and public transparency of activity-level data are more limited compared to countries with centralised IT systems.

In **Austria**, energy efficiency programmes also collect implementation data, particularly in buildings and industry, although reporting structures are distributed across institutions and programmes.

In **Belgium**, the decentralised governance structure means implementation indicators are often tracked at regional level (Flanders, Wallonia, Brussels-Capital). While regional monitoring may be detailed, aggregation at federal level is more complex and methodological consistency varies.

Across Member States, commonly monitored implementation indicators include:

- Number of renovated dwellings
- Renovated floor area
- Number of heating systems replaced
- Installed heat pump capacity
- Number of industrial energy audits completed
- Uptake of energy management systems
- Number of electric vehicles registered
- Installed renewable heating capacity

These indicators play an important analytical role. They allow assessment of policy delivery speed, evaluation of cost-effectiveness, identification of implementation bottlenecks and support for ex-post programme evaluation. Importantly, they also provide an intuitive narrative dimension to energy efficiency monitoring by translating abstract energy savings into observable transformation.

Implementation indicators are typically programme-specific and lack harmonisation across Member States. Definitions of what constitutes a "renovation", how floor area is calculated, or which vehicle categories are counted differ substantially. As a result, while these indicators are highly valuable for national policy management, they are less suitable for EU-level benchmarking without further methodological alignment.

Activity data

A significant cross-cutting challenge concerns access to detailed activity data. In several Member States, modelling experts and national authorities consider disaggregated activity data, such as industrial production data at subsector level, building-level consumption datasets or detailed vehicle usage statistics, to be confidential or commercially sensitive. This presents a major obstacle when attempting to reconcile implementation data, bottom-up savings and macro-level consumption trends. Limited access to granular activity data reduces the precision of decomposition analysis and complicates peer-to-peer methodological exchange.

This confidentiality issue is particularly acute in industry and transport. Company-level consumption and production data are often protected under statistical secrecy rules, while detailed mobility data may be held by private operators. Even where data exist, institutional fragmentation may restrict access for modelling or evaluation purposes.

Implementation and activity indicators significantly strengthen national monitoring frameworks across all assessed Member States. Countries with centralised IT platforms and structured programme reporting, such as **Croatia, Lithuania, Slovenia and Portugal,** demonstrate stronger traceability between policy actions and reported savings. In more decentralised systems, notably **Belgium,** aggregation and harmonisation present additional challenges.

Against this background, understanding which institutions are responsible for preparing NECP projections becomes particularly relevant. Institutional responsibility often determines who has access to activity data, how confidentiality constraints are managed, and how effectively modelling, monitoring and reporting systems are integrated.

The following graph presents the results of a targeted stakeholder poll conducted in connection with the **streamSAVE+ project workshop Data for energy savings calculations: insights from key databases**

at EU and national level, that took place on 24 February 2026. The workshop brought together stakeholders from the energy efficiency field, including representatives of ministries, national energy and environmental agencies, research institutions and other organisations involved in data management, modelling and policy implementation.

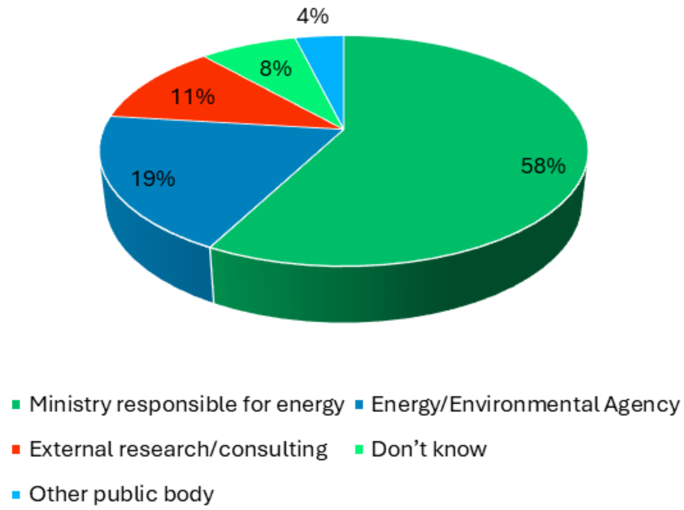

Figure 5: Institutional Responsibility for the Preparation of NECP Projections (N=26)

The poll was distributed to workshop participants to gather structured information on institutional responsibilities, data sources and methodological practices related to NECP projections and energy efficiency monitoring. In particular, it aimed to identify which institutions are primarily responsible for the preparation of NECP projections across participating countries.

By mapping governance arrangements, the graph provides additional context for interpreting the data access, coordination and methodological challenges described above. The findings reflect stakeholder-reported practices and perspectives from experts directly engaged in national processes and should therefore be understood as practitioner-based insights collected within the framework of the **streamSAVE+** project activities.

The graph shows that in the majority of participating countries, **ministries are directly involved in the preparation of NECP projections**, often in combination with national energy or environmental agencies. Only a smaller share of countries relies exclusively on external research institutes or consulting organisations.

This institutional distribution has important implications for the availability and accessibility of activity data.

First, where ministries are centrally involved, access to official statistical datasets is generally stronger. This does not automatically resolve the issue of **granular activity data availability**, particularly when detailed industrial, building-level or transport data are subject to confidentiality constraints. Even within government structures, access to highly disaggregated data may be restricted due to statistical secrecy rules or data protection regulations.

Second, the involvement of national energy or environmental agencies suggests that technical expertise and data handling capacity are present in many countries. Nevertheless, agencies often depend on external data providers (e.g. statistical offices, transport authorities or private operators), which can limit direct access to detailed datasets required for decomposition analysis and validation of modelling outputs.

Third, in countries where external research institutes are involved, access to detailed activity data may be further constrained. External experts typically rely on formal data-sharing agreements and may face additional limitations when attempting to use confidential micro-level datasets. This can restrict the depth of modelling exercises and the reconciliation between bottom-up savings and macro-level consumption trends.

The graph above highlights that **institutional responsibility alone does not guarantee full access to granular activity data**. Even where preparation of NECP projections is centrally coordinated, confidentiality constraints, fragmented data ownership and limited interoperability between institutions remain significant barriers.

The findings therefore reinforce the cross-cutting challenge identified earlier: improving structured access to disaggregated activity data — while respecting confidentiality requirements — is essential for strengthening modelling robustness, enhancing reconciliation between indicators and improving the overall credibility of energy efficiency monitoring under the revised EED framework.

For future improvement under the revised EED framework, enhancing transparency of implementation metrics, improving access to disaggregated activity data (while respecting confidentiality constraints), and developing a limited set of harmonised core implementation indicators at EU level would substantially improve comparability and analytical robustness across Member States.

4.5.6 Consistency Between Indicators

A central analytical challenge across all assessed Member States, **Austria, Slovenia, Lithuania, Croatia, Greece, Czech Republic, Belgium and Portugal,** is the reconciliation of different indicator layers within national energy efficiency frameworks. Monitoring systems operate simultaneously on multiple levels: bottom-up savings reported under Article 8, structural efficiency indices (such as ODEX or sectoral intensity indicators), aggregate energy balance indicators (PEC and FEC), and ex-ante modelling projections under WEM/WAM scenarios. Ensuring coherence across these dimensions is methodologically demanding.

In theory, cumulative bottom-up savings should gradually translate into observable reductions in final energy consumption. If significant annual savings are reported from building renovation programmes, industrial efficiency measures or transport electrification, these impacts should be reflected in sectoral and national energy balance data. In practice the relationship between bottom-up savings and aggregate consumption trends is neither direct nor proportional.

Across Member States, several structural factors complicate reconciliation:

- Economic growth may offset efficiency gains by increasing overall activity levels.
- Structural shifts in GDP composition (e.g. decline of heavy industry, growth in services) can alter energy demand independently of technical efficiency.
- Electrification may reduce primary energy consumption while increasing final electricity use.
- Weather variability introduces volatility, especially in heating-related consumption.
- Rebound effects may partially offset technical efficiency improvements.

Countries that integrate bottom-up savings with structural efficiency indicators are better positioned to interpret these dynamics. **Slovenia and Croatia**, for example, combine Article 8 savings tracking with ODEX-type analysis and sectoral intensity indicators, providing a more robust analytical basis for cross-validation.

Portugal also applies a layered monitoring approach, linking building certification data, industrial audit reporting and energy balance statistics. This improves the ability to assess whether reported savings correspond with observed consumption trends.

In **Lithuania**, bottom-up savings are complemented by sectoral intensity indicators and modelling-based analysis. While reconciliation is performed, the transition toward more advanced modelling tools is expected to further strengthen consistency between projection assumptions and observed trends.

The **Czech Republic** relies on programme-level bottom-up savings combined with modelling outputs from TIMES-CZ and related tools. Reconciliation occurs through comparison of projected and observed consumption trajectories, although methodological fragmentation across subsidy programmes can complicate full alignment.

In **Greece**, savings under Article 8 are monitored institutionally and linked to modelling projections produced by the TIMES framework. The absence of detailed activity data in some sectors limits the depth of decomposition analysis, making reconciliation more dependent on modelling assumptions than on empirical structural indicators.

In **Austria**, reconciliation relies on structured bottom-up reporting combined with national energy statistics and intensity indicators. While alignment with EU reporting requirements is ensured, integration between modelling and detailed sectoral performance tracking varies across sectors.

In **Belgium**, reconciliation is further complicated by the decentralised governance structure. Federal and regional modelling systems coexist, and monitoring responsibilities are distributed. While regional analyses may include decomposition elements, aggregation at national level requires coordination across jurisdictions, making systematic reconciliation more complex.

Another important dimension concerns the link between ex-ante modelling assumptions and measurable implementation indicators. In some Member States, including **Slovenia, Croatia, Lithuania and Portugal,** modelling assumptions about renovation rates, technology uptake or electrification are partially reflected in tracked implementation metrics such as renovated floor area or registered electric vehicles. This strengthens feedback loops between projections and real-world developments.

In contrast, where modelling assumptions are embedded in optimisation frameworks without direct linkage to measurable physical indicators, explaining deviations between projected and observed trends becomes more difficult. This partial disconnect is more visible in systems where modelling and monitoring institutions operate separately or where detailed activity data are not readily accessible.

Data availability remains a cross-cutting constraint. In several Member States, disaggregated industrial production data, detailed building-level consumption data or fleet-level mobility statistics are considered confidential or commercially sensitive. This restricts the ability of modelling experts and analysts to perform detailed decomposition and validation exercises, limiting the precision of reconciliation between bottom-up and top-down indicators.

Reconciliation between indicator types is not only a methodological exercise but a core element of credibility under the revised EED framework. Countries that integrate bottom-up savings, structural efficiency indices, sectoral performance indicators and modelling projections within a coherent analytical structure, such as **Slovenia, Croatia and Portugal,** demonstrate stronger interpretative capacity. Countries facing institutional fragmentation or data constraints, such as **Belgium and, in certain sectors, Greece and Austria,** encounter additional complexity in ensuring full consistency.

Strengthening integration across indicator types, improving transparency of modelling assumptions, and enhancing access to disaggregated activity data will be essential for improving robustness, comparability and policy feedback across all assessed Member States.

4.5.7 Analytical Implications

Sectoral intensity and performance indicators significantly enhance the interpretative strength of national energy efficiency frameworks. They allow policymakers to:

- Identify sectors where efficiency gains are accelerating or stagnating

- Assess alignment between bottom-up savings and observed performance trends
- Evaluate effectiveness of targeted support schemes
- Detect structural effects that may distort aggregate consumption indicators

Buildings and large industry are generally the most robustly monitored sectors due to regulatory reporting requirements and certification systems. Transport, SMEs and agriculture remain more challenging due to fragmented data and reliance on modelling assumptions.

Countries that integrate sectoral performance indicators with ODEX-type indices and bottom-up Article 8 savings such as **Slovenia and Croatia,** demonstrate stronger analytical coherence across their monitoring systems. This may partially reflect differences in system scale and institutional complexity. In contrast, where sectoral indicators are limited or weakly integrated, interpreting deviations between projected and observed energy trends becomes more difficult.

Strengthening sectoral data granularity, improving integration between modelling and monitoring, and enhancing harmonisation of performance indicators would improve analytical consistency and support more transparent evaluation of energy efficiency progress under the revised EED framework.

4.5.8 Comparative Assessment

Overall, the assessed Member States **Austria, Slovenia, Lithuania, Croatia, Greece, Czech Republic, Belgium and Portugal,** demonstrate compliance with the mandatory indicator requirements under the Energy Efficiency Directive (EED). All report primary and final energy consumption, provide cumulative Article 8 savings, and operate some form of sectoral monitoring framework. From a formal compliance perspective, national systems are therefore aligned with EU reporting obligations.

Nevertheless, the sophistication, coherence and analytical integration of indicator frameworks differ substantially across countries.

Countries such as **Slovenia, Croatia and Portugal** display relatively structured and multi-layered monitoring systems. They combine bottom-up savings tracking, sectoral performance indicators, and in several cases ODEX-type decomposition analysis. This layered structure allows cross-validation between policy-driven savings and observable efficiency trends, strengthening credibility and interpretability. In these systems, implementation indicators (e.g. renovation rates, heating system replacement, electrification uptake) are increasingly linked to modelling assumptions and monitoring outputs, improving transparency.

Lithuania also demonstrates structured bottom-up tracking and sectoral monitoring, although further integration between modelling tools and observed performance indicators remains under development. The planned transition toward more advanced modelling frameworks is expected to enhance coherence between projections and monitoring.

The **Czech Republic and Austria** operate structured reporting systems aligned with EED requirements, but their indicator frameworks are more programme-driven and less systematically integrated across analytical layers. While sectoral intensity indicators and modelling tools are used, reconciliation across bottom-up savings, modelling assumptions and macro-level trends is more fragmented.

In **Greece**, bottom-up savings and modelling projections are formally aligned under the NECP framework, but limitations in detailed sectoral activity data constrain deeper decomposition analysis. This reduces the ability to validate efficiency trends independently of modelling outputs.

Belgium faces additional complexity due to its decentralised governance structure. Monitoring responsibilities are distributed across federal and regional levels, and while compliance indicators are reported, systematic integration of bottom-up tracking, decomposition analysis and modelling assumptions at national level is less consolidated. This fragmentation can limit transparency and comparability.

Across the assessed Member States, several common areas for strengthening indicator frameworks emerge.

First, transport efficiency monitoring remains comparatively weak. Most countries rely heavily on aggregate fuel sales data and electrification shares rather than on detailed fleet-level performance indicators. As transport becomes a central driver of projected savings, improving data granularity and real-world performance tracking will be essential.

Second, harmonisation of lifetime assumptions, baseline definitions and deemed savings values in Article 8 reporting would significantly improve cross-country comparability. Current methodological differences make it difficult to interpret reported savings volumes across Member States.

Third, integration between ex-ante modelling projections and ex-post monitoring indicators remains uneven. In several countries, modelling assumptions regarding renovation rates, technology uptake or industrial efficiency improvements are not fully aligned with measurable implementation indicators. Strengthening this link would improve policy feedback and reduce discrepancies between projected and observed outcomes.

Fourth, transparency of calculation methodologies varies. Publicly accessible documentation of default values, correction factors and attribution rules are not always comprehensive, limiting external scrutiny and peer comparison.

Fifth, cross-sector reconciliation between bottom-up savings, sectoral intensity indicators and aggregate consumption trends is not yet systematically embedded in all national systems. Where such reconciliation is applied for example through combined use of ODEX and bottom-up tracking interpretative robustness is stronger.

In conclusion, while all assessed Member States fulfil formal reporting obligations under the EED, the analytical depth and robustness of their energy efficiency indicator systems vary. Countries with integrated, multi-layered indicator frameworks demonstrate stronger capacity to interpret trends, validate policy impacts and adjust strategies. Strengthening methodological harmonisation, improving transport data, enhancing transparency and reinforcing reconciliation mechanisms will be essential under the revised EED framework to ensure credible monitoring, more effective policy evaluation and improved comparability across Member States.

The differences observed across Member States do not reflect compliance gaps, but rather varying degrees of methodological maturity and institutional integration.

4.6. Key Challenges Identified in Pilot Member States

The national templates submitted by **Austria, Slovenia, Lithuania, Croatia, Greece, Czech Republic, Belgium and Portugal** confirm that all pilot countries have established operational systems for projecting, monitoring and reporting energy efficiency in line with the Energy Efficiency Directive (EED).

At the same time, the templates clearly identify a number of structural, methodological and institutional challenges that affect the robustness, integration and transparency of national frameworks.

The challenges identified do not concern non-compliance with the Energy Efficiency Directive, but rather relate to structural and methodological aspects of implementation.

These include data availability and granularity, methodological harmonisation, modelling sophistication, interoperability between statistical and modelling systems, and coordination across national institutions. Such challenges reflect the increasing analytical and governance complexity associated with energy efficiency monitoring and projection under the revised EED framework.

The overview presented below is based on issues explicitly raised in the national templates collected under **Task T5.2 – Analysis and evaluation of methodologies, EE indicators and projections for assessing the impacts of EE policies and measures in pilot MSs**.

These findings provide a structured diagnostic of methodological and data-related constraints and will directly inform the peer-to-peer capacity support activities implemented under **Task T5.3 – P2P capacity support on improving MS's reporting on policy impacts and projections**.

Slovenia

In Slovenia, the reported challenges are primarily related to **data granularity and sectoral coverage** within the national energy efficiency monitoring framework. While the buildings sector is supported by relatively comprehensive EPC-based datasets and an established catalogue of deemed savings values, data availability in other sectors is more limited. In particular, the tertiary (services) sector is monitored with less detailed activity data, which reduces the precision of sector-specific efficiency analysis. Similarly, the agriculture sector is covered at a more aggregated level, constraining the ability to assess technical efficiency trends and measure-specific impacts in detail.

Another identified challenge concerns the **reconciliation between bottom-up energy savings calculations and top-down energy balance indicators**. Although both approaches are systematically applied in Slovenia, further efforts are required to ensure consistent assumptions, alignment of methodologies and coherence between reported cumulative savings under Article 8 and observed developments in final energy consumption. Strengthening this analytical linkage remains an ongoing task.

In the transport sector, monitoring relies predominantly on aggregate fuel consumption statistics. The limited availability of detailed vehicle-level performance data and disaggregated mobility information represents a challenge in terms of analytical depth. Improved access to such data would enhance the robustness of transport-sector efficiency evaluation and strengthen overall monitoring consistency.

Croatia

In Croatia, one of the reported challenges concerns the **consistent application of the monitoring, measurement and verification (M&V) framework across implementing bodies**. Although a legally defined system and a central IT platform for tracking savings are in place, ensuring uniform methodological application remains demanding. As the diversity and number of measures increase, maintaining harmonised baseline definitions, measure lifetimes and standardised savings values becomes more complex.

The template also highlights the need to strengthen the **integration between the LEAP projection model and ex-post monitoring results**. While projections and reporting are formally aligned, a deeper analytical linkage between modelling assumptions and realised savings would enhance overall coherence and improve the policy feedback cycle.

In addition, **transport data limitations** are identified as a constraint. Limited availability of detailed vehicle efficiency data and modal split information restricts the ability to conduct more precise and sector-specific assessments of transport efficiency developments.

Lithuania

In Lithuania, a key reported challenge concerns the **current structure of the Excel-based national projection model**. While the model is functional and transparent, it lacks the optimisation capabilities and cross-sector integration of more advanced modelling tools. The template indicates that ongoing efforts to transition toward more sophisticated modelling frameworks are intended to improve scenario robustness, internal consistency and long-term analytical capacity.

Another identified challenge relates to **data availability and granularity**, particularly in the industry and services sectors. Activity data for smaller enterprises are less detailed, limiting the precision of sectoral efficiency analysis. Lithuania also highlights the need to further develop and harmonise **national standardised savings values** and to ensure the robust implementation of **overlap adjustment rules under Article 8 reporting**, in order to strengthen methodological consistency and prevent double counting.

In the transport sector, **limited data detail** is reported as a constraint. Improved information on vehicle efficiency and real-world usage patterns would enhance the accuracy and analytical depth of transport efficiency monitoring.

Greece

In Greece, the template highlights **constraints in data availability and granularity**, particularly regarding detailed activity data across end-use sectors. While TIMES-based modelling provides a structured framework for projections, limited empirical activity data restrict deeper decomposition analysis and reduce the ability to independently validate modelling outputs against observed sectoral developments.

Greece also identifies the need to **expand and refine bottom-up methodologies**, including the development of additional standard savings approaches. Furthermore, **capacity constraints in data collection and methodological development** are acknowledged, affecting both the depth and the sectoral coverage of monitoring systems.

The **transport and services sectors** are explicitly identified as areas where monitoring data are more limited. This reduces analytical precision and constrains more detailed assessment of efficiency trends in these sectors.

Czech Republic

In the Czech Republic, a central reported challenge is **methodological fragmentation across subsidy programmes**. Bottom-up savings are calculated under multiple instruments, each applying programme-specific calculation rules. While this approach ensures internal consistency within individual programmes, the harmonisation of baseline definitions, lifetimes and other key parameters across instruments remains incomplete, limiting overall methodological coherence.

The template also identifies **data limitations in the transport sector** and reduced granularity for smaller enterprises in industry. In addition, there is a need to strengthen the **integration between modelling outputs and programme-level monitoring systems**, in order to improve consistency between ex-ante projections and realised savings reported under Article 8.

Portugal

In Portugal, a key reported challenge concerns the **methodological complexity of quantifying savings from bundled renovation measures and behavioural interventions**. The template identifies the **absence of a unified cross-sectoral bottom-up savings catalogue** as a structural limitation, as sectoral monitoring systems operate under different methodological approaches, which complicates harmonisation and aggregation.

Portugal also reports challenges related to the **interoperability between sectoral monitoring systems** and the **reconciliation of modelling projections with observed consumption trends**. Strengthening alignment between ex-ante modelling assumptions and ex-post monitoring results is identified as an area for further improvement.

In addition, **limited data granularity in the transport sector and among SMEs** is acknowledged as a constraint, with improved data detail expected to enhance overall analytical capacity and precision in efficiency assessments.

Belgium

In Belgium, the main reported challenges are linked to the **federal governance structure**, under which energy efficiency competences are largely decentralised. The division of responsibilities between federal and regional authorities (Flanders, Wallonia and Brussels-Capital Region) complicates the **methodological harmonisation and aggregation of results at national level**. Each region may apply its own monitoring approaches, modelling tools and calculation methodologies, which requires additional coordination efforts when compiling national reports under the EED framework.

The template indicates that effective **coordination across jurisdictions** is necessary to ensure consistent application of savings calculation methodologies, baseline definitions and reporting procedures. Differences in modelling assumptions, data sources or standardised savings values across regions can create discrepancies that must be reconciled before national aggregation.

Aggregating regional savings and projections into a coherent national framework therefore remains administratively and analytically complex. Where methodologies or modelling tools differ between regions, additional validation and alignment processes are required to ensure comparability and avoid inconsistencies. This multi-level governance structure increases the importance of structured coordination mechanisms to maintain transparency, consistency and credibility at national level.

Austria

In Austria, the reported challenges relate primarily to the **integration of distributed administrative systems** involved in energy efficiency monitoring and reporting. While reporting obligations under the EED are fulfilled and established methodologies are in place, improving harmonisation between modelling frameworks, monitoring systems and sectoral data collection processes remains an ongoing effort. Ensuring consistent data flows and methodological alignment across institutions is identified as a key area for further refinement.

The template also highlights the need to strengthen **transport monitoring beyond aggregate fuel indicators**, as more detailed data would improve the precision of sectoral efficiency assessments. In addition, improving **data coverage for SMEs in industry** is recognised as a priority, given that monitoring systems are generally more robust for large energy consumers.

Finally, enhancing the **linkage between modelling assumptions and observable implementation data** is described as an area for development, with the aim of improving consistency between ex-ante projections and ex-post reported results.

Table 3 provides a structured overview of the key challenges explicitly identified in the national templates of the pilot Member States **Austria, Slovenia, Lithuania, Croatia, Greece, Czech Republic, Belgium and Portugal**. The table organises the reported challenges into four analytical categories: data granularity, methodological consistency, integration between modelling and monitoring systems, and institutional or structural constraints.

The purpose of the table is not to rank countries, but to present in a comparable format the types of limitations each Member State has reported in relation to its energy efficiency projection, monitoring and reporting framework. The challenges listed reflect practical implementation issues rather than regulatory non-compliance. In all cases, reporting obligations under the EED are fulfilled; however, countries identify areas where further methodological refinement, improved data availability or stronger coordination would enhance analytical robustness and transparency.

The categorisation highlights recurring cross-cutting themes particularly data gaps in transport and SMEs, methodological harmonisation challenges in Article 8 reporting, and the need to strengthen alignment between ex-ante modelling projections and ex-post monitoring results. At the same time, it also illustrates country-specific constraints, such as federal coordination in **Belgium**, modelling transition in **Lithuania**, or reconciliation between bottom-up and top-down indicators in **Slovenia**.

This comparative presentation supports identification of common areas for technical support and methodological development under the revised EED framework.

Table 3: Key Challenges Identified in Pilot Member States.

Country	Data Granularity Issues	Methodological Challenges	Modelling & Monitoring Integration	Institutional / Structural Challenges
Slovenia	Limited detail in services and agriculture; transport relies on aggregate fuel data	Reconciliation between bottom-up savings and top-down energy balance indicators	Need to strengthen consistency between savings reporting and observed final energy consumption	–
Croatia	Limited transport data (vehicle efficiency, modal split)	Maintaining harmonised baselines, lifetimes and standardised values across diverse measures	Strengthening integration between LEAP model projections and ex-post monitoring	Ensuring consistent application of M&V framework across implementing bodies
Lithuania	Limited SME data in industry and services; limited transport detail	Further development and harmonisation of standardised savings values; robust overlap adjustment under Article 8	Limitations of Excel-based model; transition toward more advanced modelling tools	–
Greece	Limited activity data across sectors; weaker data in transport and services	Need to expand and refine bottom-up methodologies and standard savings approaches	Limited ability to validate modelling outputs due to data constraints	Capacity constraints in data collection and methodological development
Czech Republic	Limited transport data; reduced SME data granularity	Fragmentation of methodologies across subsidy programmes; incomplete harmonisation of baselines and lifetimes	Need to strengthen linkage between modelling outputs and programme-level monitoring	–
Portugal	Limited transport and SME data	Complexity in quantifying bundled and behavioural measures; absence of unified bottom-up catalogue	Need to improve reconciliation between modelling projections and observed trends	Interoperability challenges between sectoral monitoring systems
Belgium	– (primarily structural)	Differences in methodologies across regions	Aggregation of regional modelling outputs into national framework	Federal governance structure complicates harmonisation and coordination
Austria	Limited transport detail; reduced SME data coverage	Ongoing harmonisation between modelling and monitoring methodologies	Need to strengthen linkage between modelling assumptions and implementation data	Coordination across distributed administrative systems

5. Assessment of Projections and Energy Efficiency analysis in Pilot Member States

This chapter presents the results of the harmonised assessment of NECP-based energy projections and implied energy efficiency improvements in the pilot Member States. The analysis builds directly on **Task T5.1 – Establishment of the data framework**, which developed the harmonised template for collecting sectoral energy and activity data, and on **Task T5.2 – Analysis and evaluation of methodologies, EE indicators and projections**, which assessed national modelling approaches and projection structures. It operationalises the analytical objectives defined under **Milestone MS10 – Analysis and evaluation of methodologies, EE indicators and projections for assessing the impacts of EE policies and measures in pilot MSs**, by translating methodological review and aligned datasets into a structured comparative assessment.

Using the common data foundation and methodological alignment achieved under Tasks T5.1 and T5.2, the chapter applies the approach described in Chapter 3 ("Proposed methodology for the ex-post and ex-ante assessment of energy efficiency policies with ODEX") to convert national projection pathways into comparable sectoral trends in final energy consumption, technical ODEX development, and estimated energy savings. The objective is to provide a consistent evidence base for evaluating projected efficiency progress under the Energy Efficiency Directive, in particular the extent to which national trajectories align with Article 4 targets and reflect credible implementation dynamics over time.

The assessment is structured along three complementary analytical layers. First, projected final energy consumption is examined at total and sectoral level to identify the overall trajectory, timing of structural change, and relative contribution of each demand sector. Second, technical ODEX indices are derived to provide a harmonised representation of sectoral efficiency gains, allowing comparison of the pace and depth of efficiency improvements embedded in national projections. Third, these index developments are converted into energy savings, enabling analysis of the magnitude and timing of implied savings and comparison between historical (ex-post) performance and projected (ex-ante) ambition.

A key added value of this chapter, enabled by the structured data collection under Task T5.1, the methodological review under Task T5.2, and consolidated through Milestone MS10, is the cross-country comparability achieved through the application of a common analytical framework. While national projections are produced using different modelling tools, assumptions, and sectoral structures, applying the same ODEX-based methodology allows the underlying efficiency signal to be extracted and compared on a consistent basis. At the same time, the analysis recognises that the robustness of results depends on the level of activity data availability and sectoral disaggregation provided by each country, as identified during Task T5.2. Where detailed activity indicators are limited, the assessment necessarily relies more on aggregated trends and modelled structural assumptions.

The chapter is organised by country sections, each presenting sectoral consumption trends, the evolution of the technical ODEX index, and the associated energy savings profile over the available projection horizon. This is followed by a comparative synthesis highlighting common structural patterns, differences in timing and sectoral drivers, and the margins of compliance with the 2030 Article 4 target. The final sections consolidate the main findings and draw cross-cutting conclusions on the credibility, ambition, and structural coherence of projected energy efficiency pathways across the assessed Member States, thereby giving practical effect to the analytical framework established under Tasks T5.1 and T5.2 and the objectives of Milestone MS10.

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5.1. Slovenia – Energy Efficiency Analysis (2022–2050)

5.1.1 Evolution of Final Energy Consumption

Overall Trajectory

Slovenia's final energy consumption over 2022–2050 (excluding ambient heat) follows a non-linear but clearly declining long-term pathway. Consumption increases slightly from approximately **4,730 ktoe in 2022** to around **4,769 ktoe in 2025**, reflecting short-term dynamics in sectoral activity.

After 2025, a downward trend becomes evident. By **2030**, final energy consumption decreases to approximately **4,316 ktoe**, aligning closely with the 2030 target. The most significant structural reduction occurs during the **2030–2040 period**, when consumption drops sharply to about **3,628 ktoe**, marking the main transformation phase.

The decline continues toward **2050**, reaching approximately **3,361 ktoe**, though at a more moderate pace compared to the 2030–2040 interval. This suggests that the strongest structural adjustments occur before 2040, while post-2040 reductions reflect the gradual maturation of technical efficiency potential.

The graph below illustrates a slight short-term increase followed by sustained and structurally significant reductions, with the most pronounced transformation taking place between 2030 and 2040.

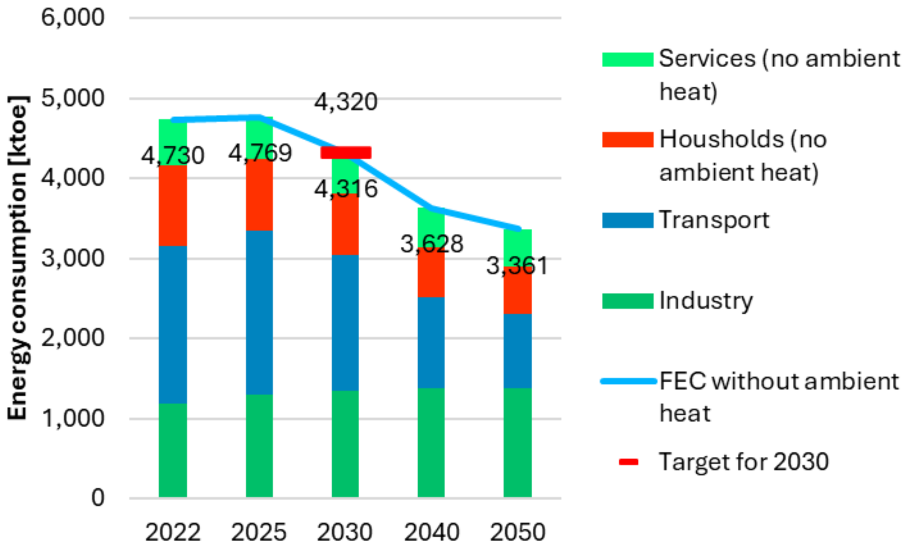

Figure 6: Total final energy consumption per sector for Slovenia up to 2050

The projected 2030 level aligns with Slovenia's target under Article 4 of the Energy Efficiency Directive. However, sustained compliance depends on consistent policy implementation, particularly in transport electrification and residential heating.

Reductions are primarily driven by **transport** and **households**, while industry and services adjust more gradually.

Sectoral Developments

Industry

Industrial energy consumption increases over the projection horizon. From approximately **1,181 ktoe in 2022**, final energy demand rises in 2030 and continues increasing through 2040 and 2050. This indicates that growth in industrial activity outweighs efficiency gains over time.

At the same time, energy savings expand progressively, reaching around **120 ktoe in 2030**, **164 ktoe in 2040**, and **217 ktoe in 2050**. These figures demonstrate ongoing improvements from process modernization, enhanced energy management, and progressive electrification. However, the magnitude of savings is not sufficient to reverse overall consumption growth.

The graph below shows that efficiency gains moderate industrial demand but do not lead to absolute reductions. Compared to other sectors, industrial improvements remain incremental, with activity growth continuing to drive a gradual increase in final energy consumption through 2050.

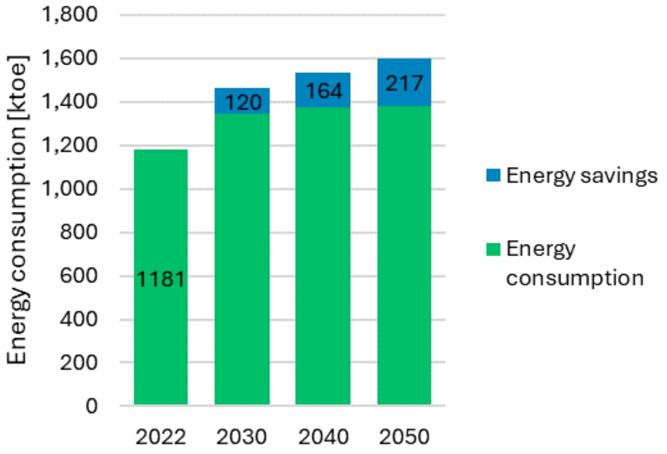

Figure 7: Total final energy consumption in Industry in Slovenia up to 2050

Transport

The transport sector exhibits the most pronounced structural transformation over the projection horizon. From approximately **1,977 ktoe in 2022**, energy consumption declines progressively after 2030, reaching significantly lower levels by 2040 and further decreasing toward 2050. At the same time, cumulative energy savings increase sharply, reaching around **520 ktoe in 2030**, **1,113 ktoe in 2040**, and **1,365 ktoe in 2050**. This reflects accelerated electrification of passenger vehicles, improvements in freight efficiency, and gradual structural shifts in mobility patterns. The most substantial reductions in consumption occur during the **2030–2040 period**, marking the core transformation phase. By 2050, transport accounts for the largest share of total energy savings, confirming its central role in the overall efficiency pathway.

The graph below shows a decisive and sustained transport transition, with efficiency gains more than offsetting activity growth and driving significant long-term reductions in final energy consumption.

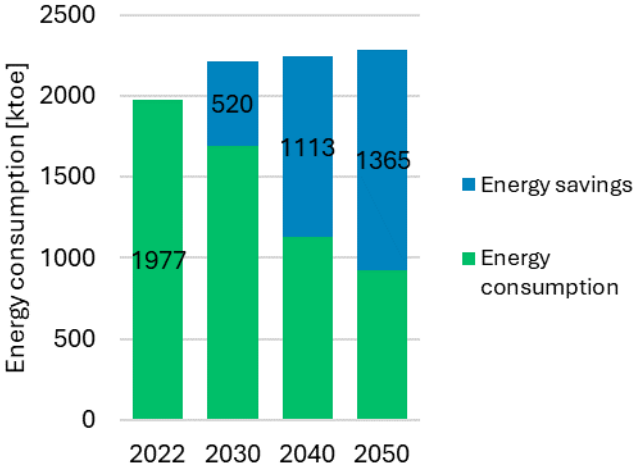

Figure 8: Total final energy consumption in Transport sector in Slovenia up to 2050

Households

Residential energy use declines steadily throughout the projection period. From approximately **1,000 ktoe in 2022**, final energy consumption decreases significantly by 2030 and continues falling through 2040 and 2050. The reduction is continuous rather than abrupt, indicating a sustained transformation of the sector. At the same time, cumulative energy savings increase progressively, reaching around **293 ktoe in 2030**, **461 ktoe in 2040**, and **530 ktoe in 2050**. These savings reflect large-scale building renovation, stricter insulation standards, widespread deployment of heat pumps, and modernization of heating systems. The most pronounced reductions occur between 2022 and 2040, while post-2040 improvements continue at a slightly more moderate pace as the technical renovation potential gradually matures.

The residential sector demonstrates a consistent and structurally significant decline in final energy consumption, driven primarily by improvements in space heating efficiency and heating system transformation.

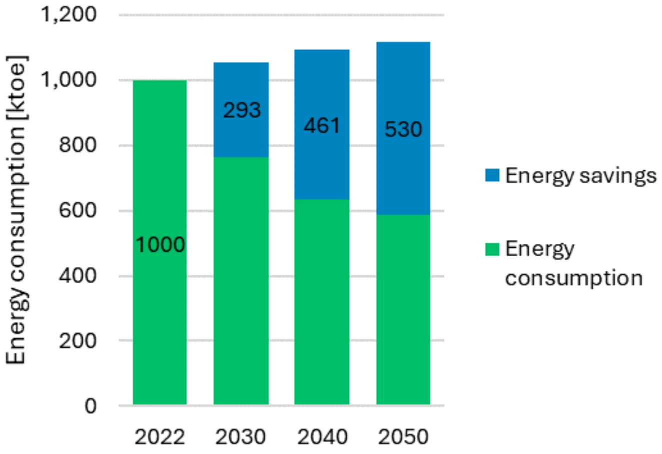

Figure 9: Total final energy consumption in Households in Slovenia up to 2050

Services

Energy use in the services sector declines moderately over the projection horizon, despite continued growth in commercial activity. From approximately **572 ktoe in 2022**, final energy consumption decreases by 2030 and continues to fall slightly toward 2040. By 2050, consumption remains broadly stable compared to 2040, indicating that reductions taper off in the later period.

At the same time, cumulative energy savings increase progressively, reaching around **44 ktoe in 2030**, **156 ktoe in 2040**, and **260 ktoe in 2050**. These improvements reflect stronger building standards, more efficient HVAC systems, and upgraded lighting technologies.

The graph below indicates that efficiency gains largely offset activity-driven demand growth, resulting in a modest but sustained downward trajectory in final energy consumption, with stabilization occurring as technical efficiency potential matures toward 2050.

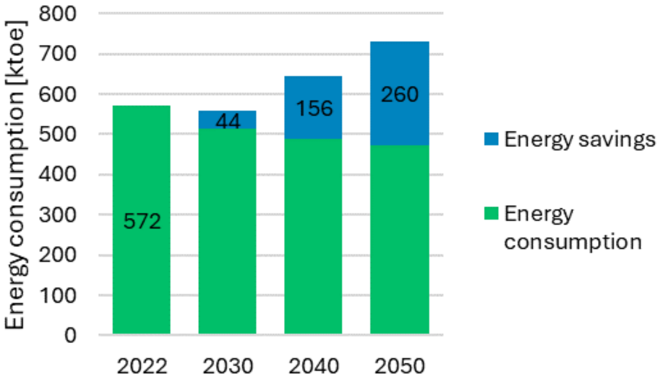

Figure 10: Total final energy consumption in Services in Slovenia up to 2050

5.1.2 Technical ODEX Development and Efficiency Gains

Using 2022 as the baseline (ODEX = 100), the projected technical ODEX evolution is as follows:

Table 4: Projected technical ODEX evolution for Slovenia up to 2050

Sector	2025	2030	2040	2050
Industry	93	91	89	85
Transport	93	76	49	38
Households	88	74	59	53
Services	100	91	73	59

By 2050, cumulative technical efficiency improvements relative to 2022 reach:

- **Transport:** 69%
- **Households:** 53%
- **Services:** 45%

- **Industry:** 18%

Transport is the dominant driver of efficiency gains, particularly during 2030–2040, the peak transformation phase. Household improvements are substantial but moderate after 2040. Industry shows steady yet comparatively modest gains throughout the period.

5.1.3 Energy Savings Dynamics

Cumulative Savings

Cumulative energy savings increase steadily over the projection horizon, with a pronounced acceleration after 2030.

- **2022–2025 – Initial Phase:**
  By **2025**, cumulative savings reach approximately **375 ktoe**, reflecting early efficiency improvements across all sectors, with transport and households already contributing noticeably.
- **2025–2030 – Rapid Expansion:**
  Savings rise sharply to around **977 ktoe by 2030**, more than doubling compared to 2025. Transport becomes the dominant driver during this period, supported by growing residential contributions.
- **2030–2040 – Structural Transformation Phase:**
  The most significant increase occurs between 2030 and 2040, when cumulative savings surge to approximately **1,894 ktoe**. Transport clearly accounts for the largest share of savings, while households provide substantial additional reductions and industry and services contribute steadily.
- **2040–2050 – Continued Growth with Moderation:**
  By **2050**, cumulative savings reach approximately **2,372 ktoe**. Growth continues, though at a somewhat moderated pace compared to the 2030–2040 decade.

Cumulative savings expand progressively across all sectors, with transport emerging as the principal driver of long-term savings, supported by significant contributions from households and more gradual improvements in industry and services.

Average Annual Savings

Projected average annual savings for 2023–2030 are approximately twice the historical average observed during 2015–2022. The strongest acceleration occurs in transport and households.

Annual savings peak during 2031–2040 due to large-scale electrification of the vehicle fleet. After 2040, annual savings moderate as fleet transformation and renovation programs mature.

The projections imply a substantial acceleration of implementation compared to historical performance.

5.1.4 Ex-post vs. Ex-ante Comparison

During **2015–2022 (ex-post)**, average annual energy savings amounted to approximately **70 ktoe**. Savings were moderate and relatively balanced across sectors, with households and industry contributing significantly, while transport played a limited role due to slower electrification and gradual fleet turnover.

In the projected period **2023–2025 (ex-ante)**, annual savings increase sharply to around **125 ktoe**, representing an increase of nearly **80% compared to historical performance**. This marks the first major acceleration phase. The increase is driven primarily by intensified residential renovation and a strong expansion of transport electrification.

During **2026–2030**, annual savings remain high at approximately **120 ktoe**, slightly below the 2023–2025 peak but still well above historical levels. In this phase, **households are the dominant contributor**, reflecting large-scale building renovation and heating system modernization.

In **2031–2040**, annual savings decline to around **92 ktoe**, but remain about **30% higher than the historical average**. During this period, **transport becomes increasingly dominant**, while residential savings moderate as earlier renovation efforts mature.

After **2040**, annual savings decrease significantly to approximately **48 ktoe**, falling below historical levels. This reflects technical saturation of cost-effective measures rather than a weakening of policy ambition.

Slovenia's projected pathway shows a strong front-loaded acceleration (2023–2030), followed by gradual moderation.

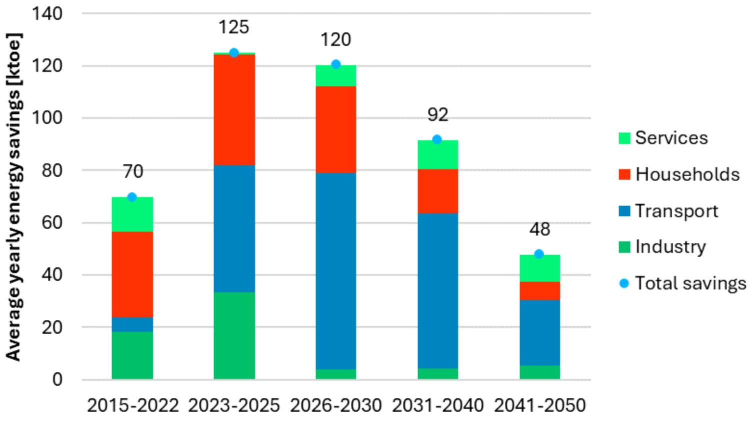

Figure 11: Average yearly sector-specific energy savings and total energy savings in Slovenia; ex-post for period 2015–2022 and ex-ante for the period 2023–2050

Final energy consumption was evaluated under two scenarios: one including projected energy efficiency improvements and one without them.

Without additional efficiency measures, final energy consumption would be approximately:

- **19% higher in 2030**,
- **48% higher in 2040**,
- **67% higher in 2050**.

The strongest acceleration in energy savings occurs in the period 2023–2025 and remains elevated through 2030. During this medium-term transformation phase, households are the dominant driver, reflecting large-scale residential renovation and heating system upgrades. After 2030, transport becomes increasingly important as electrification expands and efficiency gains deepen. Beyond 2040, annual savings decline due to the gradual saturation of cost-effective technical potential. Overall, large-scale residential renovation and transport electrification emerge as the structurally decisive policy pillars of the transition.

5.1.5 Overall Assessment

Slovenia's projected efficiency pathway demonstrates a clearly front-loaded transition, with annual savings increasing by nearly 80% compared to historical levels in the 2023–2030 period.

The household sector serves as the principal driver during the renovation-intensive phase up to 2030. Transport becomes more important after 2030, while industry and services contribute steady but smaller gains.

Although annual savings moderate after 2030 and decline further after 2040, the cumulative impact of early acceleration secures substantial structural reductions. Achieving Slovenia's medium- and long-term objectives therefore depends primarily on successfully delivering the early renovation wave and sustaining transport electrification through 2040.

5.2. Croatia – Energy Efficiency Analysis (2022–2050)

5.2.1 Evolution of Final Energy Consumption

Overall Trajectory

Croatia's final energy consumption over 2022–2050 follows a steadily declining pathway. Total consumption decreases from approximately **6,684 ktoe in 2022** to around **6,358 ktoe in 2025**, indicating an early but moderate reduction. By **2030**, final energy consumption declines further to about **5,747 ktoe**, marking a more substantial step down compared to 2022 levels. The most pronounced reduction occurs during the **2030–2040 period**, when consumption drops sharply to approximately **4,579 ktoe**, reflecting the main structural transformation phase.

After 2040, the decline continues, though at a slightly moderated pace, reaching roughly **3,865 ktoe by 2050**. This continued decrease indicates sustained efficiency gains and structural adjustments across sectors, even as the most significant transformation occurs before 2040.

The graph below shows a gradual initial decline followed by an accelerated reduction after 2030, with continued but somewhat smoother decreases toward 2050 as technical efficiency potential progressively matures.

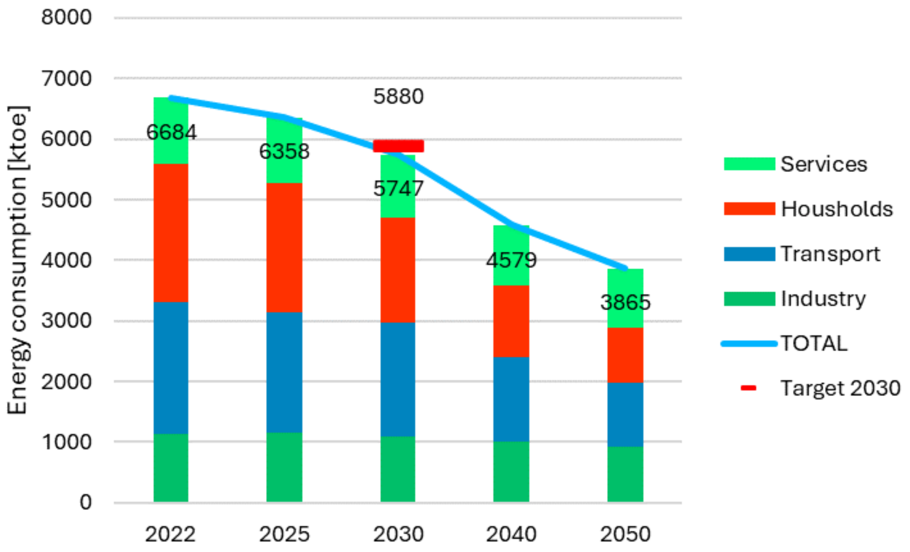

Figure 12: Total final energy consumption per sector for Croatia up to 2050

The projected 2030 level aligns with Croatia's target under Article 4 of the Energy Efficiency Directive. However, maintaining compliance depends on continuous policy implementation, particularly in the residential and transport sectors.

Reductions are primarily driven by households and transport, while industry and services contribute more gradually.

Sectoral Developments

Industry

Industrial final energy consumption declines progressively over the projection period. From approximately **1,134 ktoe in 2022**, consumption decreases by 2030 and continues to fall through 2040 and 2050, reaching its lowest level at the end of the projection horizon.

At the same time, cumulative energy savings increase significantly, reaching around **188 ktoe in 2030**, **292 ktoe in 2040**, and **567 ktoe in 2050**. These improvements reflect modernization of production processes, enhanced energy management systems, electrification of selected activities, and structural adjustments within manufacturing.

Although economic output may continue to grow, improvements in specific energy consumption are sufficient to generate net reductions in final energy demand. Compared to other sectors, industrial improvements are steady and structurally significant, particularly in the long term, with savings increasing markedly toward 2050.

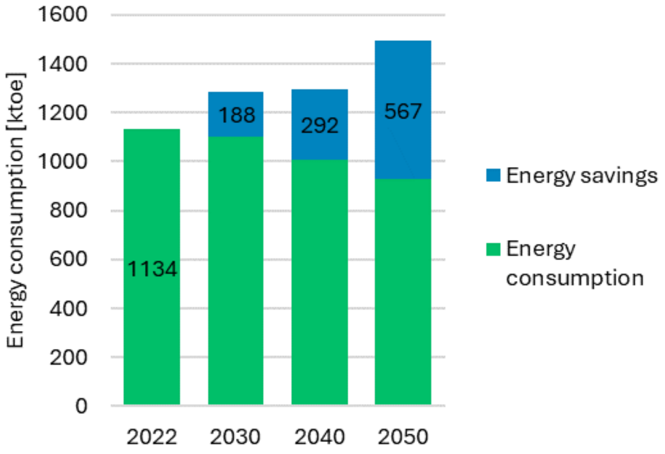

Figure 13: Total final energy consumption in Industry in Croatia up to 2050

Transport

Transport energy consumption declines progressively throughout the projection period. From approximately **2,178 ktoe in 2022**, final energy demand decreases significantly by 2030 and continues falling through 2040 and 2050, reaching roughly half of its initial level by the end of the horizon.

The most substantial reductions occur between **2030 and 2040**, marking the core transformation phase. During this period, cumulative energy savings increase sharply, reaching around **272 ktoe in 2030**, **739 ktoe in 2040**, and **1,111 ktoe in 2050**.

This trend reflects accelerated electrification of passenger vehicles, improved vehicle efficiency, gradual fleet turnover, and efficiency gains in freight transport. By 2050, transport contributes one of the largest shares to overall cumulative energy savings, confirming its central role in the long-term decarbonization pathway.

The graph below illustrates a decisive structural transition in the transport sector, with sustained reductions in final energy consumption driven by electrification and efficiency improvements.

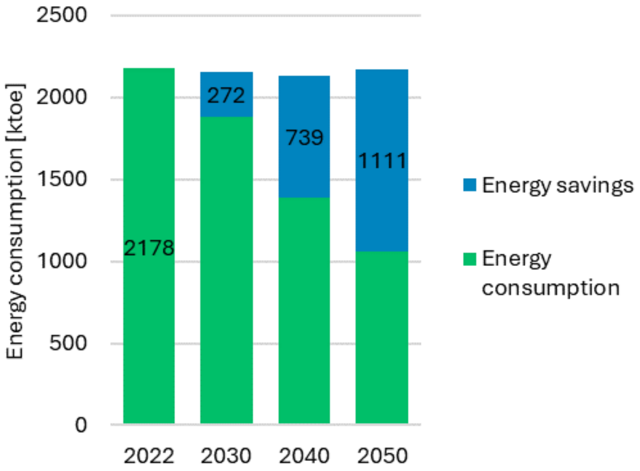

Figure 14: Total final energy consumption in Transport sector in Croatia up to 2050

Households

The residential sector exhibits the strongest absolute reduction in final energy consumption over the projection horizon. From approximately **2,286 ktoe in 2022**, energy demand declines significantly by 2030 and continues to fall sharply through 2040 and 2050, reaching well below half of its initial level by mid-century.

Cumulative energy savings increase substantially, reaching around **411 ktoe in 2030**, **986 ktoe in 2040**, and **1,350 ktoe in 2050**. These reductions are primarily driven by large-scale building renovation, modernization of heating systems, widespread deployment of heat pumps, and improved insulation standards.

Efficiency improvements in appliances and lighting provide additional contributions. While reductions continue after 2040, the pace becomes slightly more moderate as the most accessible renovation potential is progressively realized.

The graph below confirms that the residential sector plays a central role in driving long-term energy demand reductions, with sustained structural improvements through 2050.

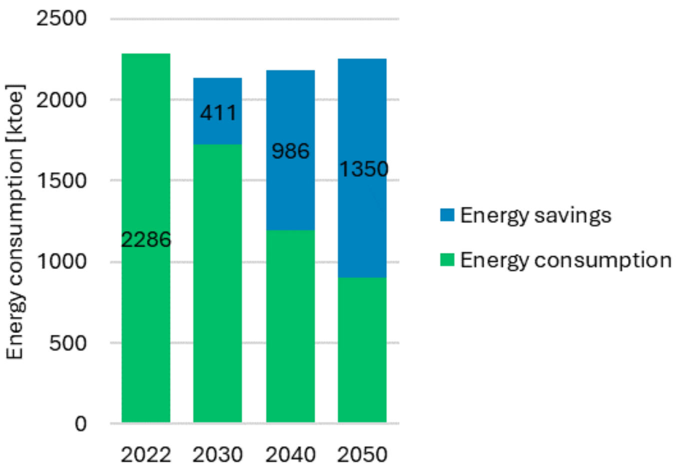

Figure 15: Total final energy consumption in Households in Croatia up to 2050

Services

Energy consumption in the services sector declines moderately over the projection horizon, despite continued growth in floor area and activity. From approximately **1,087 ktoe in 2022**, final energy demand decreases by 2030 and continues to fall slightly toward 2040. By 2050, consumption remains broadly stable compared to 2040 levels, indicating that reductions slow in the later period.

At the same time, cumulative energy savings increase progressively, reaching around **125 ktoe in 2030**, **285 ktoe in 2040**, and **374 ktoe in 2050**. These gains reflect improvements in HVAC systems, lighting technologies, and energy management practices.

Efficiency improvements largely offset activity growth, resulting in a modest but sustained net reduction in final energy consumption, with stabilization occurring as technical efficiency potential gradually matures toward 2050.

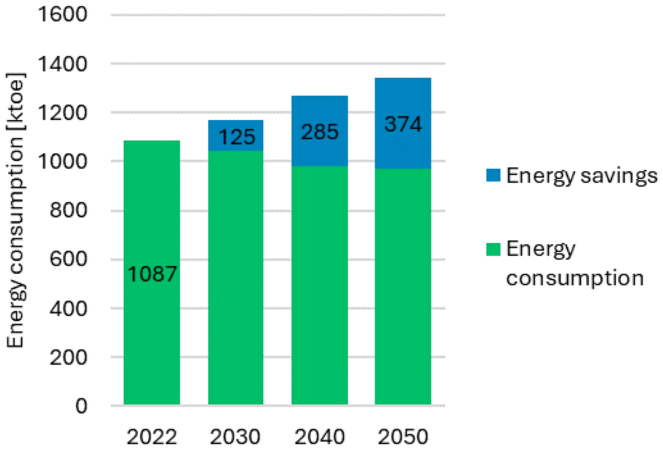

Figure 16: Total final energy consumption in Services in Croatia up to 2050

5.2.2 Technical ODEX Development and Efficiency Gains

Using 2022 as the baseline (ODEX = 100), the projected technical ODEX evolution is as follows:

Table 5: Projected technical ODEX evolution for Croatia up to 2050

Sector	2025	2030	2040	2050
Industry	89	85	77	60
Transport	92	87	65	48
Households	99	81	55	39
Services	97	86	70	62

By 2050, cumulative technical efficiency improvements relative to 2022 reach:

- **Transport:** 51%
- **Households:** 59%
- **Services:** 34%
- **Industry:** 50%

The household sector exhibits the strongest relative improvement, particularly after 2030, reflecting intensified renovation and heating modernization. Transport shows substantial progress after 2030 due to electrification. Industrial improvements advance steadily across the entire period.

5.2.3 Energy Savings Dynamics

Cumulative Savings

Cumulative energy savings increase steadily over the projection horizon, with a clear acceleration after 2030:

- **2022–2025 – Initial Phase:**

By **2025**, cumulative savings reach approximately **358 ktoe**, reflecting early efficiency measures across all sectors, with contributions from industry, transport, and households.

- **2025–2030 – Moderate Expansion:**
  Savings increase to around **996 ktoe by 2030**, marking a significant step-up compared to 2025. Households and transport play increasingly important roles during this period.
- **2030–2040 – Structural Acceleration:**
  The strongest growth occurs between 2030 and 2040, when cumulative savings rise sharply to approximately **2,302 ktoe**. Households become the dominant contributor, supported by substantial gains in transport and steady industrial improvements.
- **2040–2050 – Continued Growth:**
  By **2050**, cumulative savings reach approximately **3,402 ktoe**. Growth continues at a strong pace, with households maintaining the largest share, transport contributing significantly, and industry and services providing steady additional savings.

Cumulative savings expand progressively across all sectors, with the main structural acceleration occurring between 2030 and 2040 and households and transport representing the principal drivers of long-term savings.

Average Annual Savings

Projected average annual savings for 2023–2030 are approximately twice the historical average observed during 2015–2022. The most pronounced acceleration occurs in the residential sector.

Annual savings remain elevated during 2031–2040, particularly in households and transport. After 2040, annual savings moderate slightly as major efficiency opportunities have already been implemented.

The projections indicate the necessity of accelerated implementation compared to historical performance.

5.2.4 Ex-post vs. Ex-ante Comparison

During 2015–2022 (ex-post), average annual energy savings amounted to approximately 52 ktoe. Savings were moderate, with industry and households providing the largest shares. Transport contributed only marginally due to limited electrification and gradual fleet turnover.

In the projected period 2023–2025 (ex-ante), annual savings increase sharply to around 119 ktoe, more than double the historical level (+129%). Transport becomes a major contributor due to accelerated electrification, while households also expand their role through renovation measures.

During 2026–2030, annual savings increase further to approximately 128 ktoe, and in 2031–2040 they reach about 131 ktoe, marking the peak structural transformation phase. This represents an increase of roughly 150% compared to historical performance. The household sector becomes the dominant contributor during this period, supported by sustained renovation and heating modernization. Transport remains structurally important.

Even in 2041–2050, annual savings remain high at around 110 ktoe, still more than double the historical average. Unlike a front-loaded transition, Croatia's pathway shows sustained elevated savings over the long term, rather than a sharp post-2030 decline.

This comparison confirms that Croatia’s efficiency strategy relies on maintaining significantly higher implementation levels than historically observed, not only temporarily but throughout the projection horizon.

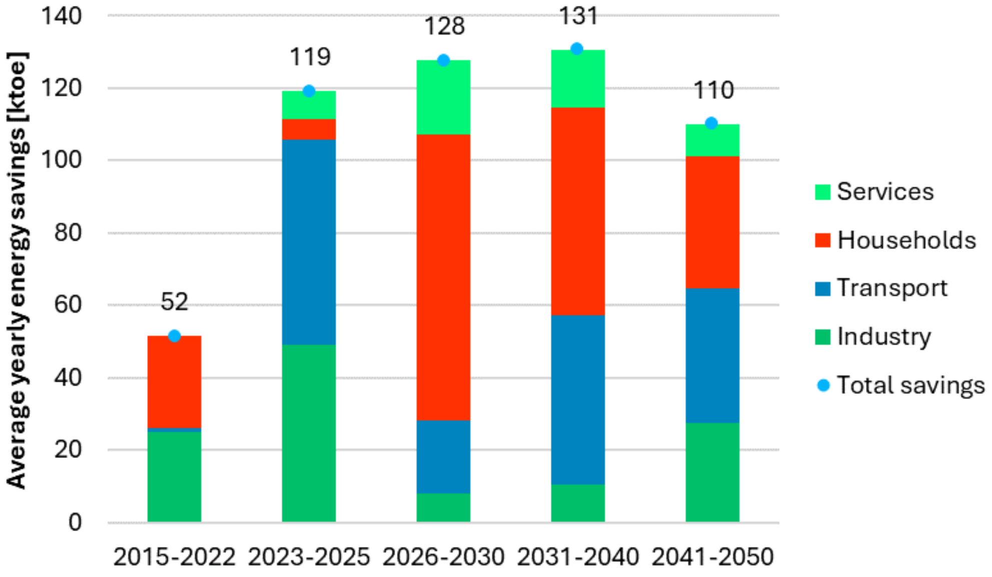

Figure 17: Average yearly sector-specific energy savings and total energy savings in Croatia; ex-post for period 2015–2022 and ex-ante for the period 2023–2050

Final energy consumption was evaluated under two scenarios: one including projected energy efficiency improvements and one without them.

Without additional efficiency measures, final energy consumption would be approximately:

- **17% higher in 2030**,
- **50% higher in 2040**,
- **88% higher in 2050**.

The sustained high level of annual savings (above 110 ktoe from 2023 onward) explains the widening gap between the efficiency and counterfactual scenarios. Unlike a temporary acceleration, Croatia’s pathway reflects a structurally higher efficiency trajectory maintained across decades.

After 2023, annual energy savings more than double compared to the historical period and remain structurally elevated throughout the projection horizon. The transformation is particularly household-driven during 2026–2040, reflecting intensified building renovation and heating system modernization. Transport provides strong and sustained contributions, especially as electrification expands, while industry and services continue to deliver steady, though comparatively smaller, improvements. Overall, residential renovation and heating modernization emerge as the primary structural drivers of Croatia’s efficiency pathway, supported by transport electrification and incremental industrial gains.

5.2.5 Overall Assessment

Croatia’s projected pathway demonstrates a structurally sustained acceleration of energy efficiency efforts, with annual savings more than doubling compared to the historical period and remaining elevated through 2050.

The household sector serves as the principal driver of long-term savings, supported by strong contributions from transport. Industry and services provide steady incremental gains.

Unlike a short-term transformation spike, Croatia’s efficiency transition is characterized by long-term stability at a high level of implementation, which is essential for achieving national and EU climate and energy objectives.

5.3. Lithuania – Energy Efficiency Analysis (2022–2040)

5.3.1 Evolution of Final Energy Consumption

Note: Lithuania’s National Energy and Climate Plan (NECP) provides projections only up to 2040. Therefore, the following assessment is limited to the 2022–2040 period and does not extend to 2050.

Overall Trajectory

Lithuania’s final energy consumption over 2022–2040 follows a gradual declining trajectory, though the reduction is not immediate. Total consumption remains broadly stable between **2022 (5,294 ktoe)** and **2025 (5,268 ktoe)**, indicating only marginal change in the short term. A clearer downward trend emerges after 2025. By **2030**, total final energy consumption decreases to approximately **5,177 ktoe**, and further declines to around **4,887 ktoe by 2040**. The most pronounced reduction therefore occurs during the **2030–2040 period**, marking the main structural adjustment phase. Sectorally, the decline is primarily driven by reductions in transport and household energy use after 2025, while industry remains relatively stable and services show moderate variation. The graph below indicates a gradual rather than accelerated transition, with the most significant structural reductions materializing after 2030.

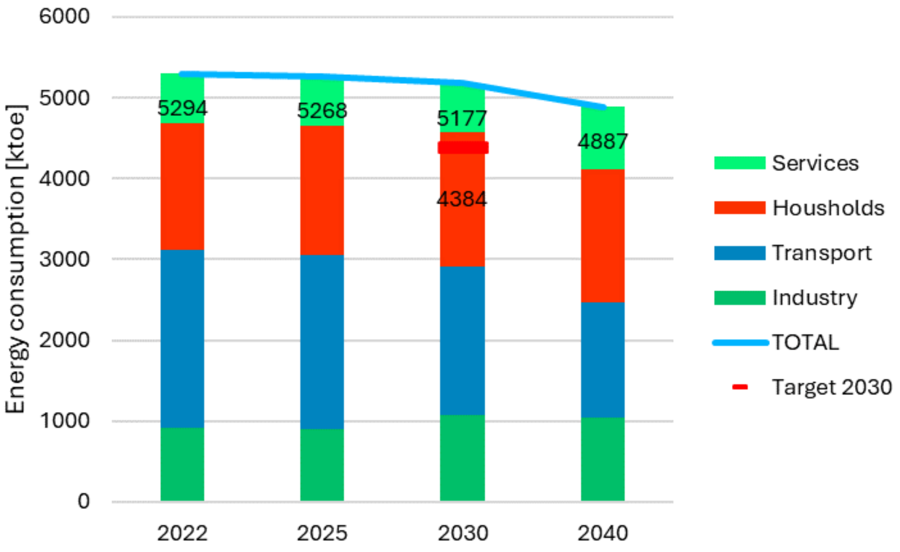

Figure 18: Total final energy consumption per sector for Lithuania up to 2040

The projected 2030 consumption level for Lithuania does **not** reach the target set under Article 4 of the Energy Efficiency Directive. While the gap remains relatively limited, projected final energy consumption in 2030 is still slightly above the binding target. This indicates that additional measures or strengthened implementation will be required to ensure full compliance, particularly in transport electrification and residential heating, where further acceleration could help close the remaining gap.

Overall reductions toward 2040 are driven primarily by transport, supported by structural improvements in industry and steady gains in services.

Sectoral Developments

Industry

Industrial final energy consumption increases between 2022 and 2030, rising from approximately **909 ktoe in 2022** to a higher level in 2030. This suggests that growth in industrial activity outweighs early efficiency gains during the first part of the projection period.

By 2040, consumption declines slightly compared to 2030 but remains above 2022 levels, indicating that efficiency improvements moderate demand growth rather than produce absolute reductions.

Cumulative energy savings increase progressively, reaching around **87 ktoe in 2030** and **124 ktoe in 2040**. These improvements reflect modernization of production processes, electrification of selected activities, enhanced energy management systems, and structural adjustments within manufacturing.

Industrial efficiency gains are steady but moderate relative to other sectors, containing demand growth rather than driving strong net reductions in final energy consumption.

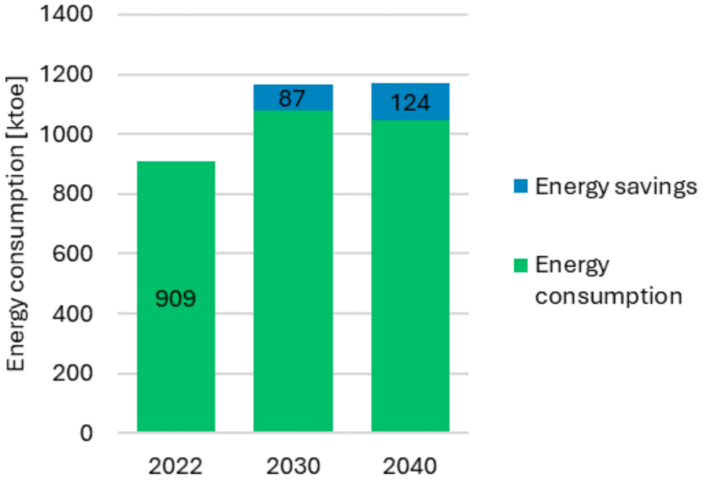

Figure 19: Total final energy consumption in Industry in Lithuania up to 2040

Transport

Transport energy consumption decreases significantly across the projection period. From approximately **2,214 ktoe in 2022**, final energy demand falls sharply by 2030 and declines further by 2040, reaching substantially lower levels compared to the base year.

The most pronounced reductions occur between **2022 and 2030**, with continued strong declines through 2040. At the same time, cumulative energy savings increase rapidly, reaching around **732 ktoe in 2030** and **1,368 ktoe in 2040**.

This development reflects accelerated electrification of passenger vehicles, improvements in vehicle efficiency, freight transport gains, and structural changes in mobility patterns. By 2040, transport clearly represents one of the dominant contributors to total energy savings.

The graph below indicates a decisive structural transformation in the transport sector, with sustained and substantial reductions in final energy consumption.

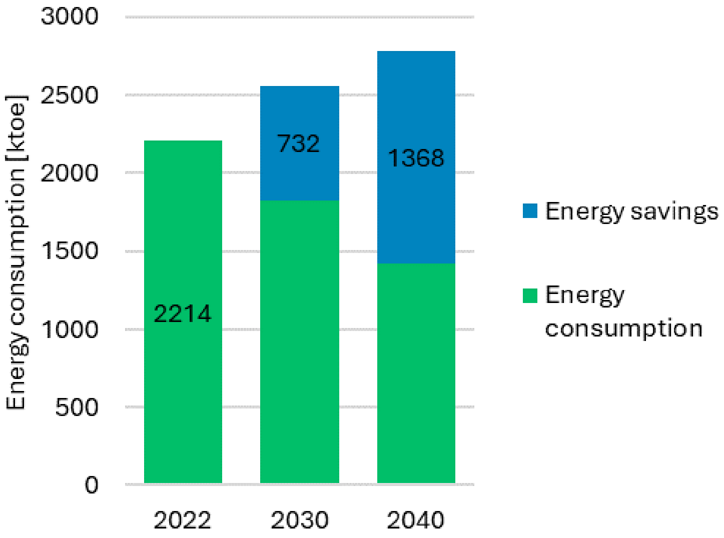

Figure 20: Total final energy consumption in Transport sector in Lithuania up to 2040

Households

Residential energy consumption in Lithuania remains relatively stable over the projection horizon, with a slight increase from approximately 1,559 ktoe in 2022 to a somewhat higher level in 2030, followed by broadly stable consumption toward 2040.

This indicates that efficiency improvements in space heating, building renovation, and heating system modernization are largely offset by underlying activity drivers such as increased floor area, comfort levels, or demographic factors.

While measures such as building renovation, insulation improvements, modernization of district heating systems, and gradual heat pump penetration contribute to efficiency gains, these improvements do not translate into an absolute reduction in final residential energy consumption by 2040. Instead, they help contain growth and stabilize demand.

The residential sector does not achieve substantial absolute consumption reductions in this projection period, suggesting that further acceleration of renovation and heating system transformation would be required to generate stronger demand-side reductions.

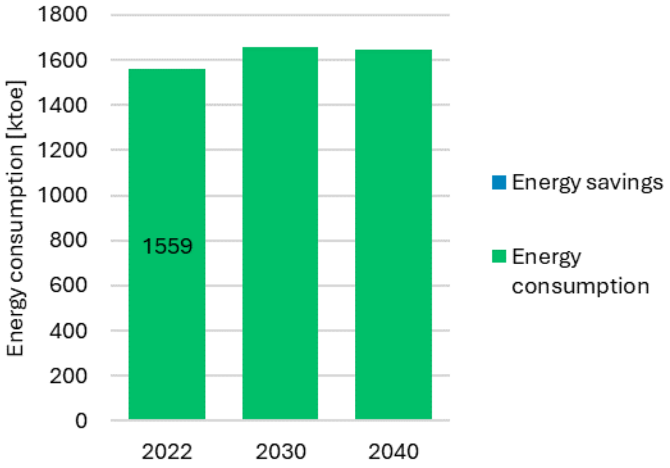

Figure 21: Total final energy consumption in Households in Lithuania up to 2040

Services

Energy use in the services sector increases steadily over the projection horizon. Final energy consumption rises from approximately 613 ktoe in 2022 to a higher level in 2030 and increases further by 2040. Although efficiency improvements—reflected in the growing volume of energy savings—contribute to moderating demand growth, they do not fully offset the expansion of commercial floor area and service activity. Improvements in HVAC systems, lighting technologies, and building standards generate measurable savings, but these gains primarily contain growth rather than produce absolute reductions. As a result, the services sector shows a gradual increase in final energy consumption despite ongoing efficiency measures. The graph below indicates that activity growth outweighs efficiency improvements in this sector, suggesting that stronger or more accelerated efficiency interventions would be required to achieve net consumption reductions.

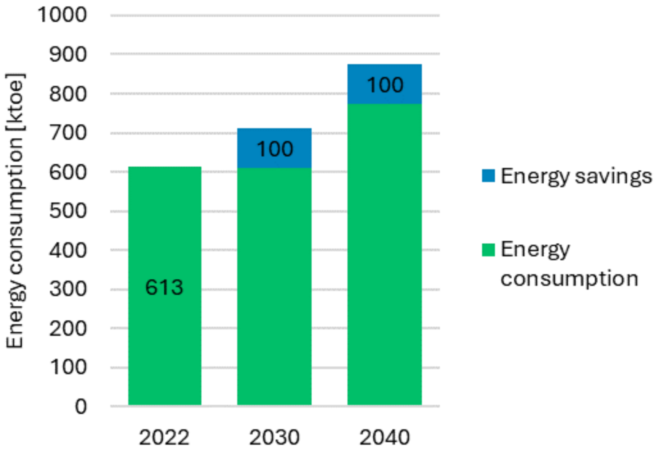

Figure 22: Total final energy consumption in Services in Lithuania up to 2040

5.3.2 Technical ODEX Development and Efficiency Gains

Using 2022 as the baseline (ODEX = 100), the projected technical ODEX evolution is as follows:

Table 6: Projected technical ODEX evolution for Lithuania up to 2040

Sector	2025	2030	2040
Industry	91	91	88
Transport	90	71	49
Households	100	100	100
Services	92	85	85

By 2040, cumulative technical efficiency improvements relative to 2022 reach:

- **Transport:** 62%
- **Households:** 0%
- **Services:** 16%
- **Industry:** 14%

Transport and households exhibit the strongest relative improvements, particularly during the 2030–2040 transformation phase. Industrial and service-sector gains progress steadily but remain comparatively moderate.

5.3.3 Energy Savings Dynamics

Cumulative Savings

Cumulative energy savings increase progressively over the projection period to 2040, following a strongly upward trajectory.

- **2022–2025 – Initial Implementation Phase:**
  By **2025**, cumulative savings reach approximately **389 ktoe**, reflecting early efficiency measures, with transport already emerging as the main contributor.
- **2025–2030 – Rapid Acceleration:**
  Savings more than double to around **920 ktoe by 2030**, driven predominantly by transport efficiency improvements and electrification, while industry and services provide smaller additional contributions.
- **2030–2040 – Structural Expansion Phase:**
  The most pronounced increase occurs during this decade, with cumulative savings rising to approximately **1,592 ktoe by 2040**. Transport clearly accounts for the largest share of savings, while industry, households, and services contribute comparatively modest amounts.

Cumulative energy savings are heavily concentrated in the transport sector, while other sectors play a supporting but secondary role. The main structural acceleration occurs between 2025 and 2040, driven primarily by transport electrification.

Average Annual Savings

Projected average annual savings during 2023–2030 are significantly higher than historical averages observed during 2015–2022, consistent with the structural gap identified in the policy impact assessment. The avoided final energy consumption of approximately 17% by 2030 (compared to a scenario without efficiency measures) illustrates the scale of acceleration required relative to past performance. The strongest increase in annual savings occurs in the residential sector, supported by transport electrification.

During 2031–2040, annual savings remain elevated and contribute to a widening divergence between the efficiency scenario and the counterfactual pathway. By 2040, final energy consumption would be approximately 40% higher in the absence of efficiency measures, underscoring the cumulative impact of sustained annual savings. Compared to historical performance, this period represents a structural and policy-driven acceleration in energy efficiency improvements, particularly in building renovation and transport electrification.

5.3.4 Ex-post vs. Ex-ante Comparison

During 2015–2022 (ex-post), average annual energy savings amounted to 107 ktoe. Savings were largely driven by industry and households, while transport contributed only marginally due to limited electrification and gradual fleet turnover.

In the projected period 2023–2025 (ex-ante), annual savings increase to approximately 130 ktoe, representing an increase of about 21% compared to the historical period. This phase marks the beginning of accelerated implementation. Unlike the historical period, transport becomes the dominant contributor, while industrial savings decline relative to the past.

During 2026–2030, average annual savings remain elevated at around 106 ktoe, broadly comparable to historical levels but with a fundamentally different structure. Transport clearly dominates total savings, while contributions from industry and households become more limited.

In 2031–2040, annual savings decline significantly to approximately 67 ktoe, reflecting a slowdown in implementation and partial saturation of cost-effective measures. Savings in this period are driven almost entirely by transport, with minimal contributions from other sectors.

The comparison shows that Lithuania's transformation is not characterized by a continuous scaling-up of total annual savings, but rather by a structural shift in sectoral contributions, with transport becoming the central driver of projected efficiency gains after 2023.

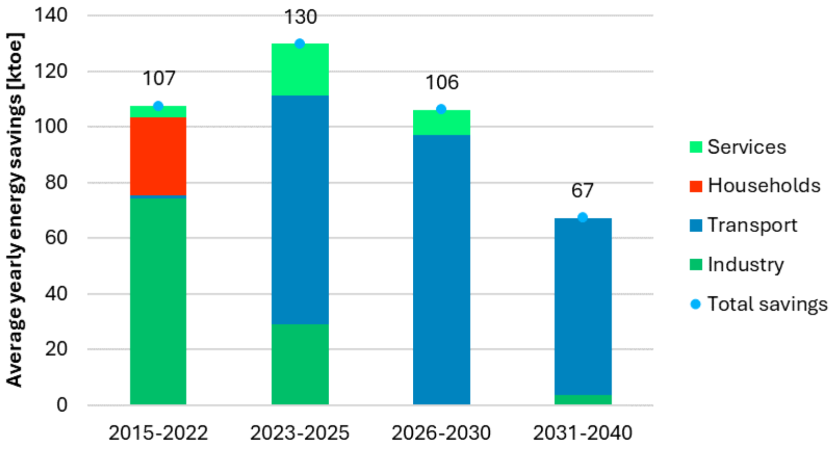

Figure 23: Average yearly sector-specific energy savings and total energy savings in Lithuania; ex-post for period 2015–2022 and ex-ante for the period 2023–2040

Final energy consumption was assessed under two scenarios: one including projected energy efficiency improvements and one without them.

Without additional efficiency measures, final energy consumption would be approximately:

- **18% higher in 2030**,
- **33% higher in 2040**.

Although projected annual savings do not dramatically exceed historical levels (except in 2023–2025), the **cumulative impact of sustained transport-driven savings** leads to a widening divergence between the efficiency and counterfactual scenarios over time.

During the historical period, energy savings were driven primarily by industry, which accounted for the largest share of annual improvements. In contrast, the projected pathway shows a clear structural shift: transport electrification becomes the dominant source of savings from 2023 onward. Residential savings continue to contribute, but their role gradually declines after 2025 compared to the stronger expansion phase. As a result, transport electrification emerges as the structurally decisive policy pillar in the medium term, while residential renovation and industrial modernization provide more modest and supportive contributions.

5.3.5 Overall Assessment

Up to 2040, Lithuania's projected pathway demonstrates a structural reorientation of efficiency efforts, with transport replacing industry as the primary driver of annual energy savings.

While total annual savings after 2025 do not significantly exceed historical levels—and even decline after 2030—the cumulative impact of sustained transport electrification remains critical for meeting national targets.

Maintaining alignment with EU and national objectives therefore depends less on expanding total annual savings and more on successfully delivering the transport transition, supported by continued but secondary contributions from households and industry.

5.4. Belgium – Energy Efficiency Analysis (2022–2050)

5.4.1 Evolution of Final Energy Consumption

Note: Belgium uses **2020 as the base year** for its projections. Therefore, all projected efficiency improvements and ODEX developments are referenced to 2020 (ODEX2020 = 100), rather than 2022 as in some other country assessments.

Overall Trajectory

Belgium's final energy consumption over 2020–2050 follows a non-linear trajectory. Consumption increases between 2020 and 2025, reaching a peak around **30,903 ktoe** in 2025. Thereafter, final energy demand begins to decline, falling to approximately **28,081 ktoe in 2030**, and decreasing more substantially to around **23,759 ktoe by 2040**. A further, more moderate reduction occurs toward 2050, when consumption reaches approximately **22,808 ktoe**.

This pattern indicates that the main structural decline takes place after 2025, with the most pronounced reductions occurring in the 2030–2040 period. The post-2025 decline reflects the combined effects of strengthened energy efficiency measures, electrification—particularly in transport—fuel substitution, and broader structural adjustments embedded in Belgium's national energy and climate strategy.

The graph shows an initial rise in energy demand followed by a sustained and structurally significant decline after 2025, with the strongest reduction phase occurring between 2030 and 2040.

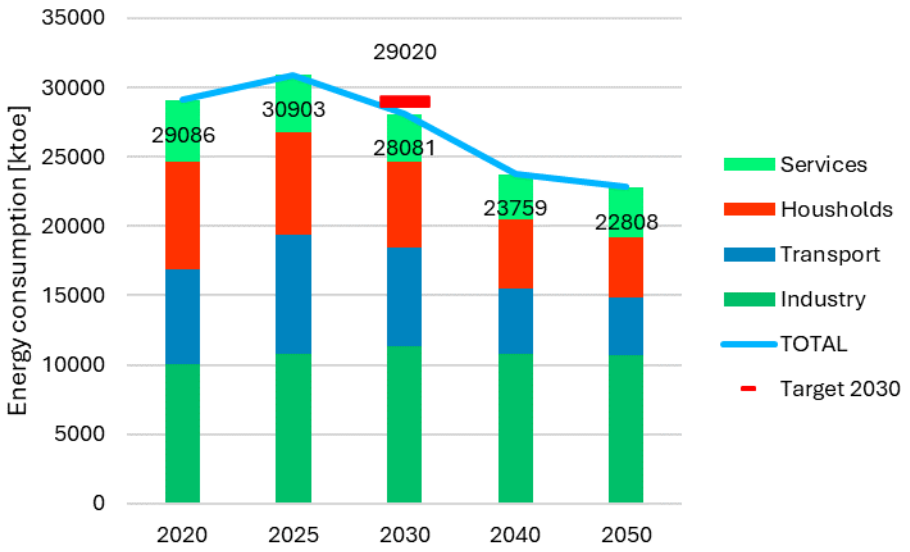

Figure 24: Total final energy consumption per sector for Belgium up to 2050

The projected 2030 final energy consumption level is broadly aligned with Belgium's commitments under Article 4 of the Energy Efficiency Directive. However, the relatively limited buffer between projected consumption and the target highlights the need for full and timely implementation of planned measures.

Overall reductions are primarily driven by transport and households, while industry and services contribute steady but more gradual improvements.

Sectoral Developments

Industry

Industrial final energy consumption declines moderately toward 2030 and continues decreasing gradually thereafter. Improvements stem from process optimization, enhanced energy management systems, electrification of selected processes, and gradual fuel switching. Despite these gains, energy-intensive industries continue to represent a significant share of final demand. Efficiency improvements progress steadily but are moderated by longer investment cycles and technological constraints.

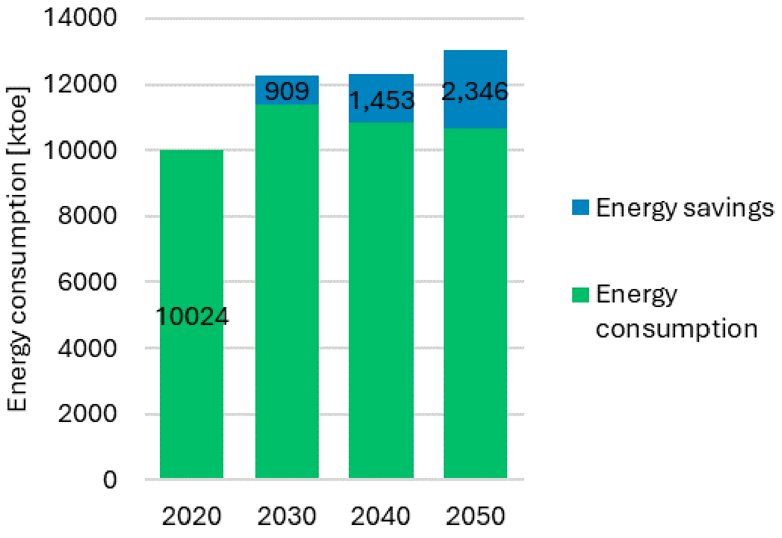

Figure 25: Total final energy consumption in Industry in Belgium up to 2050

Transport

Transport exhibits the most pronounced structural transformation. After 2025, energy consumption declines substantially, with the strongest reductions occurring between 2030 and 2040. Accelerated electrification of passenger vehicles, improvements in vehicle efficiency, and gradual modal adjustments drive this trend. By 2050, transport accounts for the largest share of cumulative energy savings.

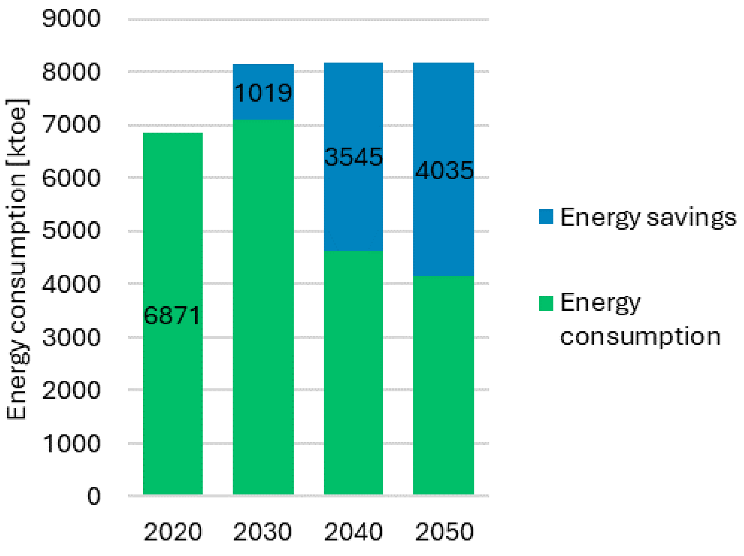

Figure 26: Total final energy consumption in Transport sector in Belgium up to 2050

Households

The residential sector shows a steady decline throughout the projection horizon. Reduced heating demand due to large-scale building renovation, increased heat pump penetration, and improvements in appliance efficiency are the main drivers. Efficiency gains are particularly strong in the earlier phases of the transition.

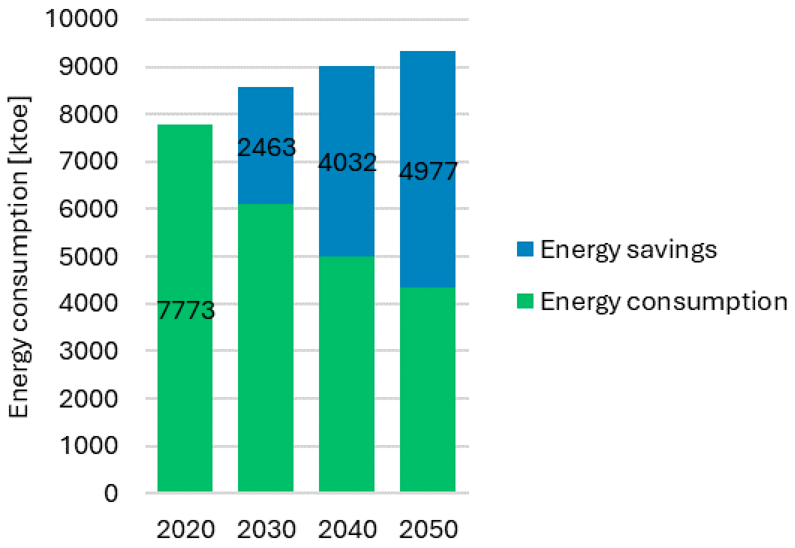

Figure 27: Total final energy consumption in Households in Belgium up to 2050

Services

Energy consumption in services decreases moderately despite ongoing growth in commercial floor area. Improvements in HVAC systems, lighting technologies, and building standards offset increased activity levels, resulting in gradual net reductions.

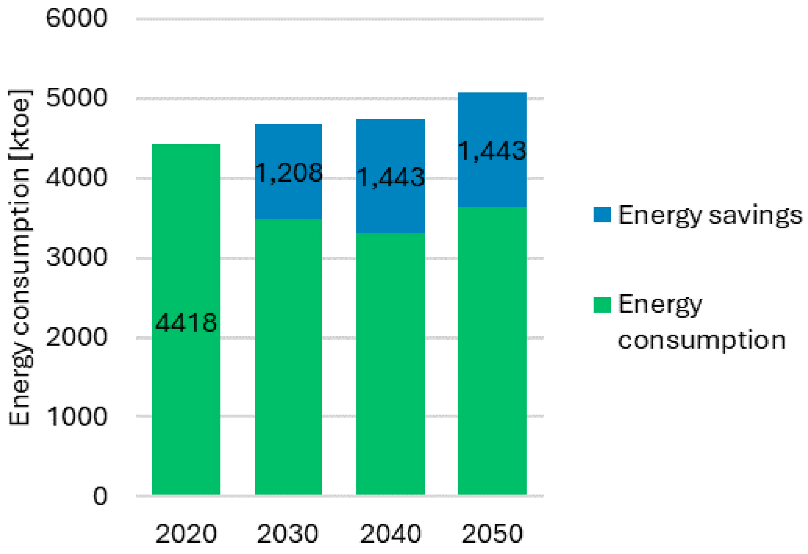

Figure 28: Total final energy consumption in Services in Belgium up to 2050

5.4.2 Technical ODEX Development and Efficiency Gains

Using 2020 as the baseline (ODEX = 100), the projected technical ODEX evolution is as follows:

Table 7: Projected technical ODEX evolution for Belgium up to 2050

Sector	2025	2030	2040	2050
Industry	97	92	88	81
Transport	98	88	57	51
Households	89	71	54	44
Services	90	74	69	69

By 2050, cumulative technical efficiency improvements relative to 2020 reach:

- **Transport:** 59%
- **Households:** 64%
- **Services:** 33%
- **Industry:** 23%

Transport displays the strongest relative improvement, particularly after 2030 when electrification becomes the dominant driver. Household efficiency gains are significant and partly front-loaded, while industrial and service-sector improvements progress more gradually.

5.4.3 Energy Savings Dynamics

Cumulative Savings

Cumulative energy savings rise sharply over the projection period, following a strongly accelerating trajectory.

- **2020–2025 – Initial Build-Up Phase:**
  By **2025**, cumulative savings reach approximately **1,848 ktoe**, reflecting early efficiency gains across all sectors, with households already making a significant contribution.
- **2025–2030 – Rapid Acceleration:**
  Savings increase markedly to around **5,598 ktoe by 2030**, more than tripling compared to 2025. This phase reflects intensified implementation of building renovation and transport efficiency measures.
- **2030–2040 – Structural Transformation Phase:**
  The most pronounced expansion occurs during this decade, with cumulative savings rising to approximately **10,474 ktoe by 2040**. Both households and transport contribute substantially, while industrial savings also increase steadily.
- **2040–2050 – Continued Expansion with Slight Moderation:**
  By **2050**, cumulative savings reach approximately **12,801 ktoe**. Growth continues, though at a somewhat moderated pace compared to the rapid expansion between 2030 and 2040.

By 2050, **households and transport account for the largest shares of cumulative savings**, with industry contributing steadily and services providing a smaller but consistent share.

Average Annual Savings

During the historical period 2010–2019, average annual energy savings amounted to 258 ktoe per year, representing the baseline level of implementation.

In 2020–2025, annual savings increase to approximately 370 ktoe, which is about 43% higher than the historical average. This reflects a clear intensification of policy efforts, particularly in building renovation, early transport electrification, and industrial efficiency measures.

The period 2026–2030 marks the peak of implementation, with annual savings reaching approximately 750 ktoe. This represents an increase of roughly 190% compared to the historical period (nearly three times higher than 2010–2019 levels). This sharp escalation is driven by large-scale residential renovation, strong industrial efficiency improvements, and rapid expansion of transport electrification.

In 2031–2040, annual savings decline to around 488 ktoe, but remain approximately 89% higher than the historical average. Although lower than the 2026–2030 peak, this period still reflects a structurally elevated level of implementation, with transport becoming the dominant contributor.

By 2041–2050, annual savings decrease to approximately 233 ktoe, which is about 10% below the historical average. This moderation reflects technical saturation, as most cost-effective efficiency measures have already been implemented.

Overall, the data indicate that achieving projected energy targets requires a temporary but very substantial scaling-up of efforts, especially during 2026–2030, followed by sustained but gradually moderating implementation.

5.4.4 Ex-post vs. Ex-ante Comparison

During the historical period **2010–2019 (ex-post)**, average annual savings were **258 ktoe**, with relatively balanced sectoral contributions and limited structural transformation.

In contrast, the projected period **2020–2025 (ex-ante)** increases annual savings to **370 ktoe**, representing a **43% increase** over historical performance. This marks the beginning of accelerated implementation.

The most significant divergence occurs in **2026–2030**, when annual savings surge to **750 ktoe,** an increase of approximately **190% compared to the historical average**. This phase represents the core structural transformation window, characterized by large-scale residential renovation, intensified industrial efficiency improvements, and rapid transport electrification.

During **2031–2040**, annual savings decrease to **488 ktoe**, but remain **almost 90% higher than historical levels**. While lower than the peak period, savings remain structurally elevated, with transport accounting for a larger share of total gains.

After **2040**, annual savings fall to **233 ktoe**, slightly below historical averages. This reflects the diminishing availability of cost-effective technical potential after the major transformation phases.

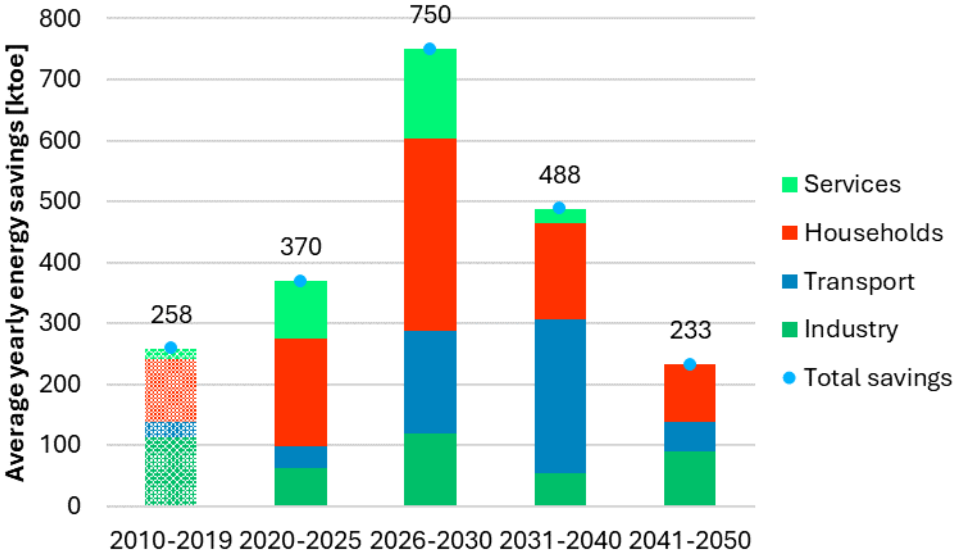

Figure 29: Average yearly sector-specific energy savings and total energy savings in Belgium; ex-post for period 2010–2019 and ex-ante for the period 2020–2050

Overall, the ex-post versus ex-ante comparison shows that projected targets depend on a dramatic temporary scaling-up of efforts particularly during 2026–2030 followed by sustained high implementation through 2040. The transformation is therefore highly front-loaded and policy-intensive compared to historical performance.

From a consumption perspective, without additional efficiency measures, final energy consumption would be approximately:

- **20% higher in 2030**,
- **44% higher in 2040**,
- **56% higher in 2050**.

The widening gap between the efficiency scenario and the counterfactual scenario reflects the cumulative impact of sustained annual savings during the high-effort period.

Transport electrification, large-scale building renovation, and industrial modernization are the primary policy pillars driving this divergence. Without sustained implementation at levels significantly above historical performance, final energy consumption would remain substantially above target-consistent trajectories.

The policy impact assessment confirms that projected outcomes rely on a front-loaded, policy-intensive acceleration phase, followed by structural consolidation through 2040.

5.4.5 Overall Assessment

Belgium's projected efficiency pathway is characterized by a strongly front-loaded acceleration phase, with implementation efforts peaking in 2026–2030 at nearly three times the historical level. Transport and households deliver the largest contributions during the transformation period, while industry and services provide steady incremental gains. Sustaining elevated efforts through 2040 is critical to securing the long-term structural reductions.

5.5. Greece – Energy Efficiency Analysis (2022–2050)

5.5.1 Evolution of Final Energy Consumption

Note: This case is presented to illustrate how the results appear when detailed sectoral activity data were not available. Consequently, the analysis relies more heavily on aggregated indicators and modelled efficiency trends rather than detailed bottom-up sectoral decomposition. The results therefore reflect structural patterns and relative sectoral dynamics rather than highly granular activity-driven effects.

Overall Trajectory

Greece's final energy consumption over 2022–2050 follows a non-linear trajectory. Consumption increases from approximately **14,968 ktoe in 2022** to a peak of about **16,444 ktoe in 2025**, reflecting short-term growth in sectoral activity—particularly in transport and households.

After 2025, a sustained downward trend emerges. By **2030**, final energy consumption declines to approximately **15,588 ktoe**, aligning closely with the 2030 target. The most pronounced reduction occurs during the **2030–2040 period**, when total consumption falls sharply to around **13,932 ktoe**, marking the main structural transformation phase.

The decline continues toward **2050**, reaching approximately **12,983 ktoe**, though at a more moderate pace compared to the 2030–2040 interval. This suggests that the strongest structural adjustments occur before 2040, while reductions after 2040 reflect continued efficiency gains and gradual maturation of electrification and renovation measures.

The graph below indicates an initial increase in demand followed by a sustained and structurally significant decline, with the most substantial reductions taking place between 2030 and 2040.

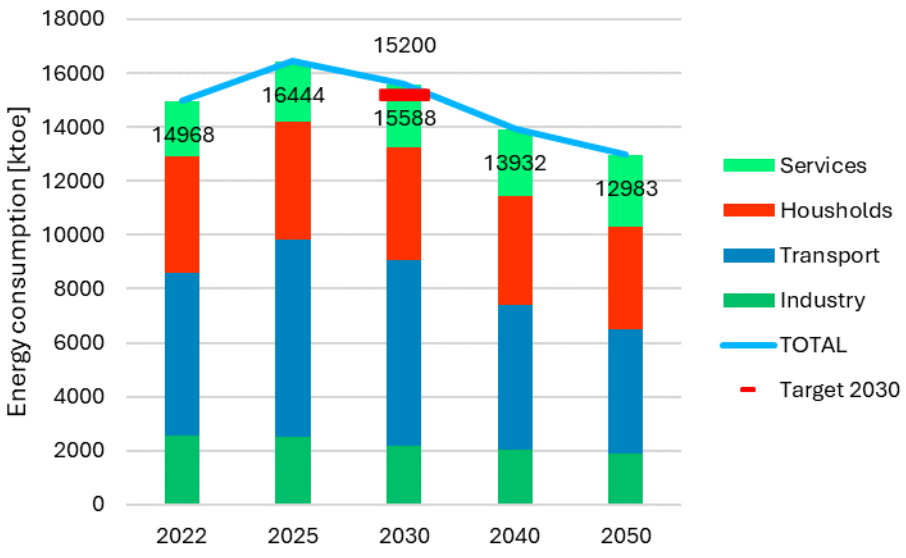

Figure 30: Total final energy consumption per sector for Greece up to 2050

The projected 2030 consumption level is broadly aligned with Greece's target under Article 4 of the Energy Efficiency Directive. However, maintaining compliance requires sustained policy implementation and investment continuity.

Overall reductions are driven primarily by transport and residential heating, supported by gradual structural improvements in industry.

Sectoral Developments

Industry

Industrial final energy consumption declines moderately toward 2030 and continues decreasing gradually toward 2050. Improvements are driven by modernization of production processes, enhanced energy management systems, electrification of selected activities, and gradual fuel substitution. Energy-intensive sectors exhibit incremental efficiency gains rather than abrupt structural shifts.

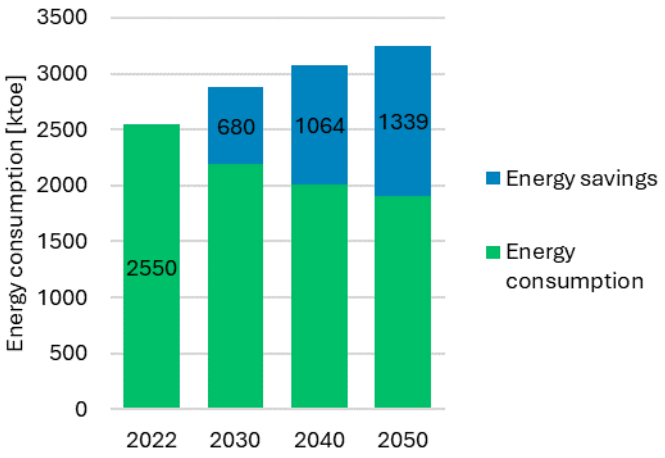

Figure 31: Total final energy consumption in Industry in Greece up to 2050

Transport

Transport energy consumption increases between 2022 and 2030, rising from approximately **6,020 ktoe in 2022** to a higher level in 2030. This suggests that growth in transport activity outweighs early efficiency gains during the initial phase of the projection.

After 2030, a clear downward trend emerges. The most significant reduction occurs during the **2030–2040 period**, when consumption declines substantially, reflecting accelerated electrification of passenger vehicles, improved vehicle efficiency, and structural changes in the transport system. By **2050**, transport energy consumption decreases further, reaching a significantly lower level than in 2030.

At the same time, cumulative energy savings increase markedly, reaching approximately **2,055 ktoe by 2040** and **3,294 ktoe by 2050**, indicating that electrification and efficiency improvements become increasingly impactful in the later stages of the transition.

The graph below shows an initial growth phase followed by a pronounced structural decline after 2030, with transport emerging as one of the largest contributors to cumulative energy savings by mid-century.

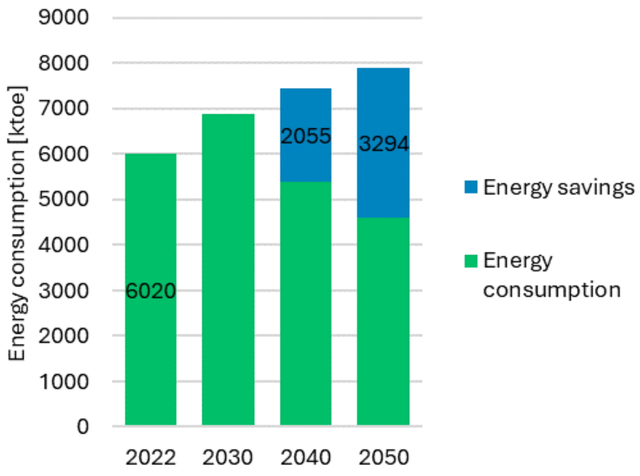

Figure 32: Total final energy consumption in Transport sector in Greece up to 2050

Households

Residential energy consumption declines gradually over the projection period. From 2022 to 2030, consumption decreases slightly, followed by a continued but moderate reduction toward 2040 and 2050. The overall decline is steady rather than steep.

The reduction reflects improvements in building envelope performance, ongoing renovation programmes, gradual deployment of heat pumps, and modernization of heating systems. However, the pace of decline suggests that efficiency gains primarily moderate demand rather than trigger sharp structural reductions.

Efficiency improvements in appliances and cooling systems contribute additional savings, but the graph indicates that residential energy demand decreases incrementally over time rather than substantially.

The residential sector shows a progressive but moderate downward trend in energy consumption through 2050.

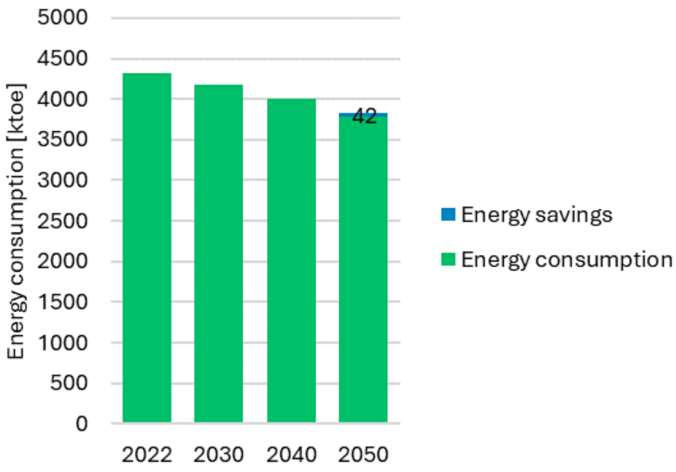

Figure 33: Total final energy consumption in Households in Greece up to 2050

Services

Energy consumption in the services sector increases progressively over the projection horizon. Final energy demand rises from approximately **2,078 ktoe in 2022** to higher levels in 2030, 2040, and 2050, indicating sustained growth in commercial activity and floor area.

Although efficiency improvements are reflected in the growing volume of energy savings (reaching around **24 ktoe in 2030**, **56 ktoe in 2040**, and **74 ktoe in 2050**), these gains are not sufficient to offset the underlying increase in activity. Instead, efficiency measures moderate the growth in demand rather than produce absolute reductions.

Improvements in HVAC systems, lighting technologies, and building standards contribute to incremental savings, but the graph clearly shows that activity-driven demand outweighs these efficiency gains. The services sector exhibits a gradual upward trend in energy consumption through 2050, with efficiency improvements containing—but not reversing—demand growth.

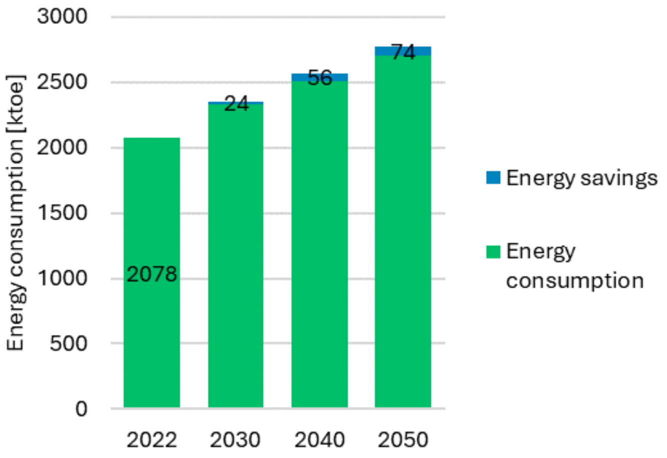

Figure 34: Total final energy consumption in Services in Greece up to 2050

5.5.2 Technical ODEX Development and Efficiency Gains

Using 2022 as the baseline (ODEX = 100), the projected technical ODEX evolution is as follows:

Table 8: Projected technical ODEX evolution for Greece up to 2050

Sector	**2025**	**2030**	**2040**	**2050**
Industry	91	76	64	56
Transport	100	100	72	57
Households	100	100	100	99
Services	100	99	98	97

By 2050, cumulative technical efficiency improvements relative to 2022 reach:

- **Transport:** 55%
- **Households:** 1%
- **Services:** 4%
- **Industry:** 53%

Transport and industry display the strongest relative improvements, particularly during the 2030–2040 transformation phase.

5.5.3 Energy Savings Dynamics

Cumulative Savings

Cumulative energy savings increase progressively across the projection horizon, but the growth pattern is strongly back-loaded rather than evenly distributed.

- **2022–2025 – Initial Phase:**
  Savings are relatively limited, reaching around **263 ktoe by 2025**, with contributions primarily from industry and early efficiency measures.
- **2025–2030 – Gradual Acceleration:**
  By **2030**, cumulative savings rise to approximately **703 ktoe**, reflecting expanding implementation of efficiency measures, though the overall impact remains moderate compared to later periods.
- **2030–2040 – Major Transformation Phase:**
  The most pronounced increase occurs during this period, with cumulative savings surging to around **3,175 ktoe by 2040**. This sharp acceleration reflects large-scale structural changes, particularly in the transport sector.
- **2040–2050 – Continued Expansion:**
  Savings continue to grow significantly, reaching approximately **4,749 ktoe by 2050**, although the rate of increase moderates slightly compared to the 2030–2040 surge.

By 2050, **transport accounts for the dominant share of cumulative savings**, while industry provides a steady and growing contribution. Households and services contribute comparatively smaller shares in this modelled profile.

Average Annual Savings

During the historical period **2015–2022**, average annual energy savings amounted to approximately **240 ktoe**, driven largely by industry and transport.

In the early projected period **2023–2025**, annual savings decline sharply to around **88 ktoe**, remaining at a similar level during **2026–2030**. This represents a significant reduction compared to historical performance. In these years, savings are primarily driven by industry, while transport and households contribute more modestly.

A major structural shift occurs during **2031–2040**, when annual savings increase substantially to approximately **247 ktoe**, slightly exceeding the historical average. This peak is driven predominantly by transport electrification. After **2040**, annual savings moderate to approximately **157 ktoe**, reflecting gradual saturation of technical efficiency potential, while remaining above the 2023–2030 levels.

It should be noted that these results are based on aggregated modelling assumptions, as no detailed sectoral activity data were available for the calculation. Consequently, the distribution of savings across sectors reflects modelled efficiency trends rather than a full bottom-up decomposition of activity and structural effects.

Greece's trajectory is characterized by a **delayed acceleration**, with the most significant gains concentrated in the 2031–2040 period.

5.5.4 Ex-post vs. Ex-ante Comparison

During **2015–2022 (ex-post)**, annual savings were relatively high at **240 ktoe**, supported mainly by industrial and transport improvements.

In contrast, projected savings for **2023–2030 (ex-ante)** decline significantly to around **88 ktoe per year**, indicating a temporary slowdown compared to historical performance. Sectorally, industry dominates savings during this period.

The decisive transformation occurs during **2031–2040**, when annual savings rise sharply to **247 ktoe**, surpassing historical levels. This phase represents the core structural transition window, driven largely by transport electrification.

After **2040**, annual savings decrease to **157 ktoe**, remaining below the transformation peak but above early projection levels.

Given the absence of detailed sectoral activity data, the comparison between ex-post and ex-ante results reflects modeled efficiency dynamics rather than fully disaggregated structural shifts. Nevertheless, the pattern clearly indicates that Greece's efficiency gains are concentrated in the post-2030 period.

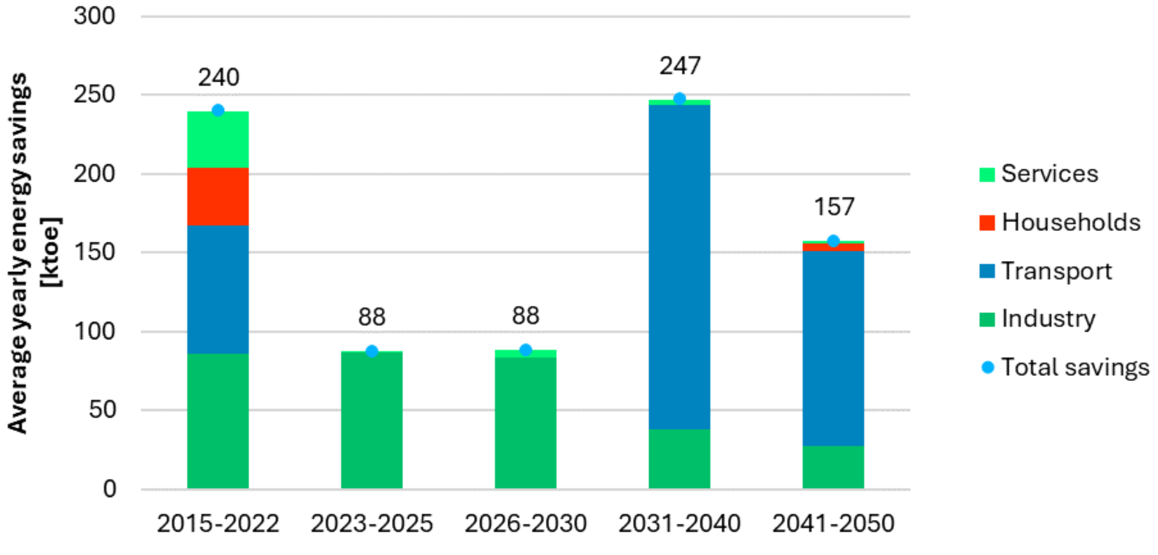

Figure 35: Average yearly sector-specific energy savings and total energy savings in Greece; ex-post for period 2015–2022 and ex-ante for the period 2023–2050

Final energy consumption was evaluated under two scenarios: one including projected technical efficiency improvements and one without them.

Without additional efficiency measures, final energy consumption would be approximately:

- **16–18% higher in 2030**,
- **38–42% higher in 2040**,
- **60–65% higher in 2050**.

Although annual savings are lower in 2023–2030 compared to the historical period, the strong acceleration during **2031–2040** drives a widening divergence between the efficiency and counterfactual scenarios.

Greece experiences a temporary slowdown in energy savings after 2022, followed by a pronounced acceleration after 2030 driven primarily by transport electrification. After 2040, annual savings moderate, reflecting the gradual saturation of technical efficiency potential rather than a weakening of policy ambition. It should be emphasized that, due to the lack of detailed sectoral activity data, the savings profile is based on modelled structural assumptions rather than a fully disaggregated sector-by-sector activity breakdown. Overall, transport electrification emerges as the decisive long-term policy pillar, while industrial and residential improvements provide steadier but comparatively smaller contributions over time.

5.5.5 Overall Assessment

Greece's projected efficiency pathway is characterized by a temporary slowdown in savings after 2022, followed by a delayed but strong acceleration in the period 2031–2040 driven predominantly by transport electrification. While annual savings moderate again after 2040 due to the gradual saturation of technical potential, they remain structurally significant.

Unlike a steady upward trajectory, Greece's transformation is concentrated in the post-2030 period. Transport emerges as the decisive long-term driver of savings, while industry and residential improvements provide more stable but comparatively smaller contributions over time.

It should be noted that, due to the absence of detailed sectoral activity data, the results reflect modelled structural trends rather than a fully disaggregated activity-based decomposition. Nevertheless, the overall pattern clearly indicates that achieving Greece's medium- and long-term energy and climate objectives depends critically on successfully delivering the transport electrification phase after 2030, supported by continued but incremental gains in other sectors.

5.6. Comparison Between NECP Reported Savings and Harmonised Methodology Results

Slovenia's final energy consumption follows a clear downward trajectory from 2022 to 2050, driven by progressively increasing cumulative energy savings.

In 2022, final energy consumption is approximately **4,700 ktoe**. By 2030, cumulative energy savings reach around **977 ktoe**, reducing final consumption to a level that is **slightly below the 2030 target under Article 4 of the Energy Efficiency Directive (EED)**. As shown in the graph, projected consumption remains marginally beneath the red reference line, confirming that Slovenia is **in line with its 2030 binding obligation**, provided planned measures are fully implemented.

After 2030, efficiency gains intensify further. By 2040, cumulative energy savings increase to approximately **1,894 ktoe**, significantly lowering final energy demand compared to 2022 levels. By 2050, cumulative savings reach around **2,372 ktoe**, bringing final consumption down to roughly **3,300 ktoe**.

The graph below illustrates that energy efficiency improvements are the central driver of Slovenia's long-term demand reduction. Achieving consumption slightly below the 2030 EED target represents a key compliance milestone, while continued savings beyond 2030 ensure sustained progress toward long-term national and EU climate objectives.

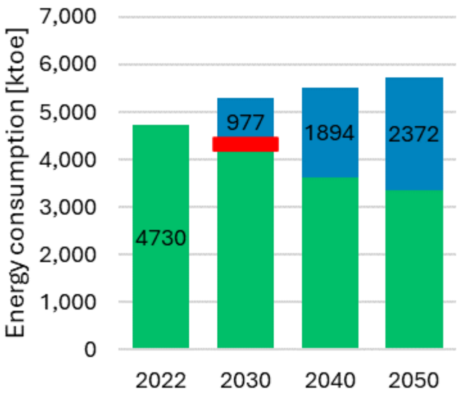

Figure 36: Final Energy Use, Article 4 target for 2030 and assessed savings for Slovenia

Croatia's final energy consumption shows a clear declining trajectory from 2022 to 2050, driven by steadily increasing cumulative energy savings.

In 2022, final energy consumption is approximately **6,700 ktoe**. By 2030, cumulative energy savings reach around **996 ktoe**, reducing final consumption to a level that is **slightly below the 2030 target under Article 4 of the Energy Efficiency Directive (EED)**. As illustrated in the graph, projected consumption in 2030 remains marginally beneath the red reference line, confirming that Croatia is **in line with its 2030 binding obligation**, assuming full implementation of planned measures.

After 2030, efficiency gains intensify significantly. By 2040, cumulative energy savings increase to approximately **2,302 ktoe**, resulting in a substantial structural reduction in final energy demand compared to 2022 levels. By 2050, cumulative savings reach around **3,402 ktoe**, lowering final energy consumption to roughly **3,900 ktoe**.

The graph below demonstrates that energy efficiency improvements are the principal driver of long-term demand reduction in Croatia. Achieving consumption slightly below the 2030 EED target represents a key compliance milestone, while continued savings beyond 2030 secure sustained alignment with national and EU climate and energy objectives through mid-century.

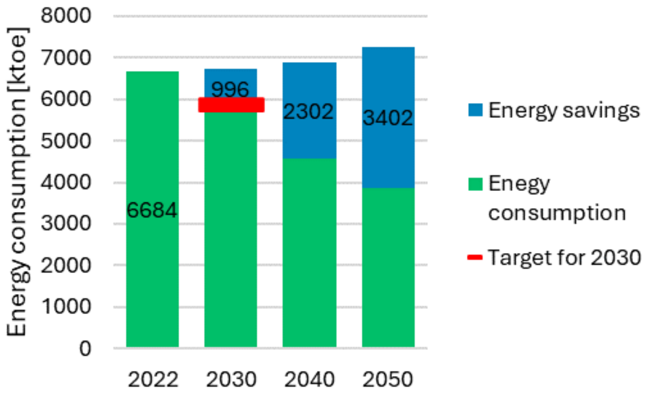

Figure 37: Final Energy Use, Article 4 target for 2030 and assessed savings for Croatia

Lithuania's final energy consumption shows a moderate decline from 2022 to 2040, supported by increasing cumulative energy savings.

In 2022, final energy consumption is approximately **5,300 ktoe**. By 2030, cumulative energy savings reach around **920 ktoe**, contributing to a reduction in final energy demand. However, as illustrated in the graph, projected final energy consumption in 2030 remains **slightly above the Article 4 target under the Energy Efficiency Directive (EED)** (red reference line). This indicates that additional measures or stronger implementation would be required to fully ensure compliance with Lithuania's 2030 binding obligation.

By 2040, cumulative energy savings increase further to approximately **1,592 ktoe**, resulting in a continued structural reduction in final energy demand compared to 2022 levels. Although consumption remains above the 2030 target level, the trend reflects sustained efficiency improvements over time.

The graph below demonstrates that energy efficiency policies are progressively reducing Lithuania's final energy consumption, but enhanced efforts may be necessary to close the remaining gap to the 2030 EED target while maintaining alignment with medium-term energy and climate objectives.

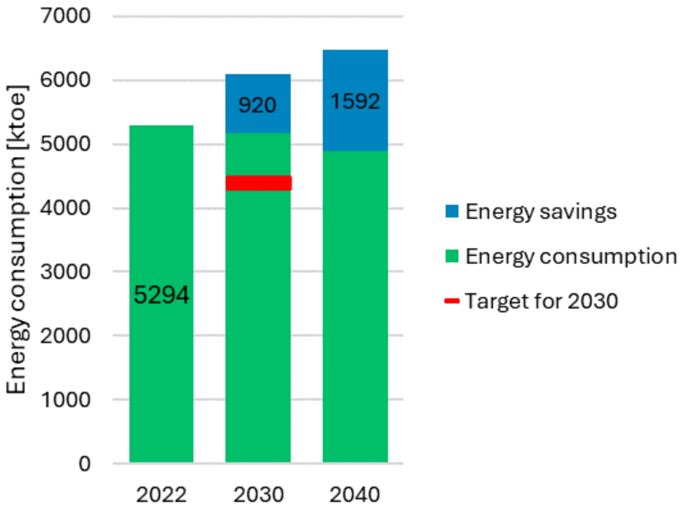

Figure 38: Final Energy Use, Article 4 target for 2030 and assessed savings for Lithuania

Belgium's final energy consumption follows a clear declining trajectory from 2020 to 2050, supported by steadily increasing cumulative energy savings.

In **2020**, final energy consumption is approximately **29,000 ktoe**. By **2030**, cumulative energy savings reach around **5,598 ktoe**, contributing to a measurable reduction in final energy demand. As illustrated in the graph, projected final energy consumption in 2030 remains **slightly below the Article 4 target under the Energy Efficiency Directive (EED)** (red reference line), indicating that Belgium is **in line with its 2030 binding obligation**, provided full implementation of planned measures is achieved.

After 2030, the transformation accelerates. By **2040**, cumulative energy savings increase to approximately **10,474 ktoe**, leading to a substantial structural reduction in final energy demand. By **2050**, cumulative savings reach around **12,801 ktoe**, further lowering final energy consumption compared to 2020 levels.

The graph below demonstrates that energy efficiency improvements are the primary driver of Belgium's long-term reduction in final energy consumption. Achieving consumption slightly below the 2030 EED target represents a key compliance milestone, while the continued growth in savings toward 2040 and 2050 ensures sustained alignment with national and EU energy and climate objectives.

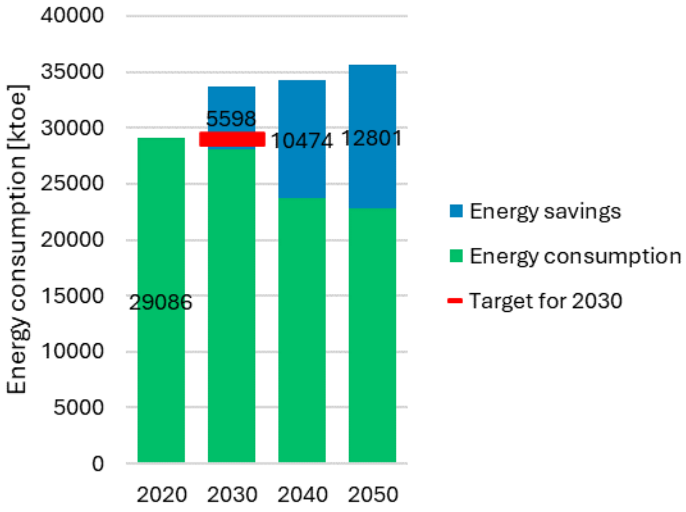

Figure 39: Final Energy Use, Article 4 target for 2030 and assessed savings for Belgium

Greece's final energy consumption shows a gradual declining trajectory from 2022 to 2050, supported by increasing cumulative energy savings. It should be noted that detailed sectoral activity data were not available for this assessment; therefore, the results reflect modeled structural assumptions rather than a fully disaggregated bottom-up activity-based calculation.

In **2022**, final energy consumption is approximately **15,000 ktoe**. By **2030**, cumulative energy savings reach around **703 ktoe**, contributing to a modest reduction in final energy demand. As illustrated in the graph, projected final energy consumption in 2030 remains **slightly above the Article 4 target under the Energy Efficiency Directive (EED)** (red reference line). This indicates that additional measures or stronger implementation would be required to fully ensure compliance with Greece's 2030 binding obligation.

After 2030, efficiency gains accelerate. By **2040**, cumulative energy savings increase significantly to approximately **3,175 ktoe**, leading to a substantial reduction in final energy demand compared to 2022 levels. By **2050**, cumulative savings reach around **4,749 ktoe**, further lowering final energy consumption and reinforcing long-term structural improvements.

The graph below demonstrates that while Greece experiences a relatively modest reduction by 2030, the main transformation occurs after 2030, driven by expanding efficiency measures. Due to the absence of detailed activity data, the savings profile represents modelled structural trends, but it clearly indicates that sustained post-2030 efficiency improvements are crucial for aligning Greece with medium- and long-term national and EU energy and climate objectives.

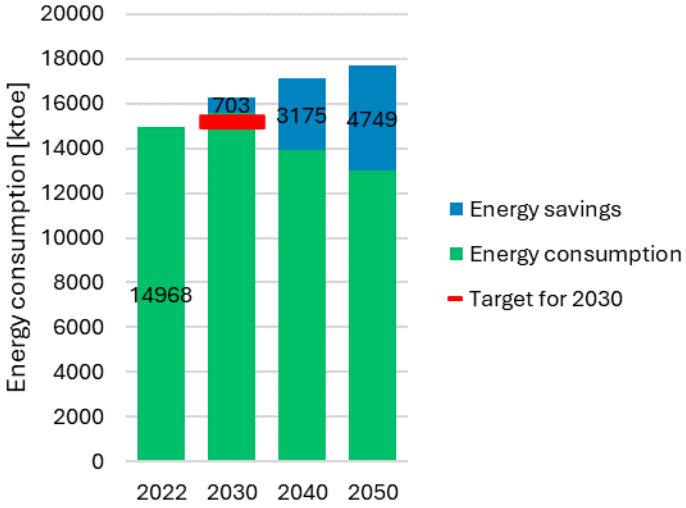

Figure 40: Final Energy Use, Article 4 target for 2030 and assessed savings for Greece

The comparison of final energy consumption trajectories across Slovenia, Croatia, Lithuania, Belgium and Greece reveals both common structural patterns and differences in the margin of compliance with Article 4 of the Energy Efficiency Directive (EED).

Across all assessed countries, cumulative energy savings increase steadily over time, leading to a structural decline in final energy consumption toward 2040 and 2050. In all cases, energy efficiency improvements represent the primary driver of long-term demand reduction.

Regarding the 2030 Article 4 target:

- **Slovenia, Croatia, Belgium and Greece** are projected to achieve final energy consumption levels **at or slightly below their 2030 targets**, indicating formal compliance under current policy assumptions, provided full implementation is maintained.
- **Lithuania** remains **slightly above its 2030 target**, suggesting that additional measures or strengthened implementation efforts would be required to fully close the gap.

In several cases, the compliance margin in 2030 is relatively narrow, underlining the importance of consistent policy delivery and monitoring.

Beyond 2030, cumulative savings increase significantly in all countries, demonstrating that the main structural transformation often intensifies in the 2030–2040 period. This pattern is particularly pronounced in Belgium and Greece, where savings accelerate strongly after 2030, reinforcing long-term demand reduction.

Methodological aspects also influence interpretation. In particular, the Greek case illustrates how the absence of detailed sectoral activity data affects the granularity of results, relying more heavily on modelled structural assumptions rather than bottom-up activity-based decomposition.

The harmonised assessment shows that most assessed Member States are on track to meet their 2030 Article 4 obligations under current projections, while long-term alignment with EU climate and energy objectives depends on sustaining and scaling efficiency improvements beyond 2030.

5.7. Synthesis of Findings

5.7.1 Overall Structural Patterns Across Member States

The comparative assessment of Slovenia, Croatia, Lithuania, Belgium, and Greece reveals a set of common structural dynamics in projected energy efficiency pathways, alongside important country-specific differences in timing, sectoral drivers, and margins of compliance with Article 4 of the Energy Efficiency Directive (EED).

Across all assessed Member States, final energy consumption follows a declining long-term trajectory, supported by progressively increasing cumulative energy savings. In all cases, energy efficiency improvements constitute the principal driver of demand reduction toward 2030 and beyond. The most significant structural transformation generally occurs during the 2030–2040 period, when cumulative savings accelerate markedly and final energy demand declines more steeply.

However, the timing and intensity of acceleration differ considerably:

- **Front-loaded acceleration** is most visible in Belgium and Slovenia, where annual savings increase sharply before or around 2030 and peak during the core transformation phase.
- **Sustained high implementation** characterizes Croatia, where savings more than double compared to historical levels and remain structurally elevated through 2050.
- **Sectoral reorientation without strong scaling-up** is observed in Lithuania, where transport replaces industry as the main driver of savings, but total annual savings after 2025 do not significantly exceed historical levels.
- **Delayed acceleration** defines the Greek pathway, with relatively modest savings before 2030 followed by a pronounced expansion during 2031–2040, primarily driven by transport electrification.

Despite these differences, the structural role of cumulative savings is consistent: without projected efficiency measures, final energy consumption would be substantially higher in all countries by 2030, 2040, and 2050, with divergence widening over time.

5.7.2 Compliance with the 2030 Article 4 Target

The harmonised assessment indicates that most assessed Member States are broadly aligned with their 2030 final energy consumption targets under Article 4 of the EED, assuming full and timely implementation of planned measures.

- **Slovenia, Croatia, Belgium and Greece** are projected to reach final energy consumption levels at or slightly below their 2030 targets, though in several cases the margin of compliance is relatively narrow.
- **Lithuania** remains slightly above its 2030 target under current projections, indicating that additional measures or strengthened implementation would be required to ensure full compliance.

The narrow compliance margins observed in several cases highlight the importance of implementation credibility. Even small deviations in policy delivery, particularly in residential renovation or transport electrification, could shift projected consumption above target-consistent levels.

5.7.3 Sectoral Drivers of Transformation

Across all assessed countries, two sectors consistently emerge as structurally decisive:

Transport

Transport electrification is the dominant long-term driver of efficiency gains in most Member States. In Slovenia, Croatia, Lithuania, Belgium, and Greece, the largest cumulative savings by 2040 or 2050 originate from transport.

The 2030–2040 decade represents the core transformation phase in nearly all cases, reflecting large-scale electrification of passenger vehicles, improvements in freight efficiency, and gradual structural changes in mobility patterns. Even in countries where early savings are moderate (e.g., Greece), transport becomes the decisive contributor in the post-2030 period.

Residential Sector

Residential energy efficiency, particularly building renovation and heating system modernization, plays a central role in Slovenia, Croatia, and Belgium, where it drives strong early or sustained savings.

In contrast:

- Lithuania’s residential sector shows limited absolute reductions and largely stabilizes consumption rather than reducing it significantly.
- Greece demonstrates moderate residential improvements that contain demand rather than drive deep structural decline.

Where residential renovation is intensive and sustained (e.g., Croatia and Belgium), it substantially strengthens both 2030 compliance and long-term structural reductions.

Industry and Services

Industry generally contributes steady but comparatively moderate gains, with improvements driven by process optimization, electrification of selected processes, and energy management systems. In some cases (e.g., Lithuania), efficiency improvements primarily moderate growth rather than reduce absolute consumption.

The services sector typically exhibits moderate improvements that offset activity growth but rarely become the primary driver of savings. In several cases, service-sector energy use stabilizes rather than declines sharply.

5.7.4 Ex-post vs. Ex-ante Dynamics

A central cross-cutting finding of the assessment is the clear divergence between historical energy savings performance (ex-post) and projected savings under current National Energy and Climate Plans (ex-ante). While all countries project continued improvements in energy efficiency, the scale, timing, and structural composition of savings differ markedly from past trends.

Belgium and Croatia: Structural Scaling-Up of Implementation

In **Belgium**, historical average annual savings (2010–2019) amounted to approximately 258 ktoe per year. Under the projected pathway, annual savings increase to around 370 ktoe in 2020–2025 and surge to approximately 750 ktoe in 2026–2030—nearly three times the historical level. Even after the peak transformation window, annual savings remain structurally elevated through 2040 before moderating post-2040 due to technical saturation.

This pattern demonstrates that Belgium’s compliance and long-term trajectory rely on a temporary but very substantial acceleration phase, followed by sustained high implementation levels. The transformation is therefore highly front-loaded and policy-intensive relative to historical performance.

Similarly, **Croatia** shows a strong structural scaling-up. Historical savings (2015–2022) averaged approximately 52 ktoe annually. In contrast, projected annual savings more than double to roughly 119–131 ktoe during 2023–2040 and remain above 110 ktoe even in 2041–2050. Unlike Belgium’s sharp peak, Croatia’s pathway is characterized by sustained elevated savings across decades rather than a single concentrated surge.

In both countries, achieving projected final energy reductions depends on maintaining implementation levels significantly above historical norms. The widening gap between efficiency and counterfactual scenarios illustrates the cumulative impact of sustained acceleration.

Slovenia: Front-Loaded Acceleration with Gradual Moderation

In **Slovenia**, the divergence between ex-post and ex-ante dynamics is characterized by a strong early acceleration. Historical average annual savings (2015–2022) were approximately 70 ktoe. Under the projected pathway, annual savings increase to around 125 ktoe in 2023–2025—an increase of nearly 80%—and remain elevated during 2026–2030.

After 2030, annual savings gradually moderate and decline further after 2040 as cost-effective technical potential becomes saturated. Although annual savings decrease in later decades, the cumulative impact of the early acceleration secures substantial structural reductions in final energy consumption.

Slovenia therefore illustrates a pathway in which early policy intensity is decisive: the credibility of 2030 compliance depends heavily on successfully delivering the front-loaded renovation wave and early transport electrification, while long-term reductions rely on the accumulated effect of early gains.

Lithuania: Structural Recomposition Rather than Volume Expansion

In **Lithuania**, the divergence between ex-post and ex-ante results is less pronounced in terms of total annual savings volume. Historical annual savings (2015–2022) averaged around 107 ktoe. Projected savings increase modestly to approximately 130 ktoe in 2023–2025, then stabilize or decline to around 106 ktoe in 2026–2030 and 67 ktoe in 2031–2040.

Lithuania's transformation is therefore not characterized by a sustained scaling-up of total annual savings. Instead, the key structural change lies in the **sectoral composition** of savings. Historically, industry and households dominated savings. Under the projected pathway, transport becomes the central driver from 2023 onward, reflecting accelerated electrification.

Thus, Lithuania's compliance pathway depends less on expanding total annual savings and more on successfully executing a sectoral pivot toward transport electrification.

Greece: Model-Based Back-Loaded Acceleration under Data Constraints

The Greek case differs not only in its timing profile but also in its **methodological basis**. No detailed sectoral activity data were available for Greece. Consequently, the savings profile relies more heavily on aggregated modelling assumptions and structural efficiency trends rather than on a fully disaggregated bottom-up activity decomposition. This limitation affects the granularity of sectoral interpretation but does not alter the overall structural pattern.

During 2015–2022, Greece recorded relatively high historical average annual savings of approximately 240 ktoe. In contrast, projected savings for 2023–2030 decline sharply to around 88 ktoe per year, representing a temporary slowdown relative to historical performance.

A decisive structural shift occurs during 2031–2040, when annual savings increase to approximately 247 ktoe, slightly exceeding historical levels. This acceleration is driven predominantly by transport electrification. After 2040, annual savings moderate again but remain above early-projection levels.

Greece therefore exhibits a **back-loaded efficiency pathway**, with the main transformation phase concentrated after 2030. Given the absence of detailed activity data, the distribution of savings across sectors reflects modelled structural dynamics rather than a precise activity-based breakdown. Nevertheless, the results clearly indicate that Greece's long-term compliance and demand reduction depend critically on the successful implementation of post-2030 transport electrification measures.

Cross-Country Implications

The comparison shows that compliance with Article 4 and long-term alignment with EU objectives cannot be assessed solely on projected total savings volumes. Instead, three dimensions are decisive:

1. **Timing of acceleration** – front-loaded (Slovenia, Belgium), sustained (Croatia), structurally reoriented (Lithuania), or back-loaded (Greece).
2. **Sectoral distribution** – particularly the central role of transport electrification across all countries and the varying contribution of residential renovation.
3. **Persistence and credibility of implementation** – maintaining elevated savings levels over time rather than relying on short-lived peaks.

In conclusion, the divergence between ex-post and ex-ante dynamics highlights that projected compliance pathways are highly policy-contingent. Achieving 2030 targets and securing structural reductions toward 2040 and 2050 depends not only on aggregate savings levels, but on delivering well-timed, sectorally coherent, and consistently implemented efficiency measures over the entire projection horizon.

6. Recommendations for Harmonising Methodologies and Indicators

This chapter introduces the activities carried out under **Task T5.4 – Recommendations for informed decision-making on EE policies** within WP5. It builds directly on the outcomes of **Task T5.1 (Establishment of the data framework)**, **Task T5.2 (Analysis and evaluation of methodologies, EE indicators and projections)**, and **Task T5.3 (Peer-to-peer capacity support on reporting improvements)**.

While Tasks T5.1–T5.3 focused on developing the analytical framework, assessing national methodologies, and supporting pilot Member States, Task T5.4 consolidates these findings into strategic recommendations. The purpose of this chapter is therefore to translate the technical and empirical insights gained throughout WP5 into policy-oriented guidance aimed at strengthening methodological coherence, transparency, and comparability of energy efficiency assessment across Member States.

6.1. Strengthening the Analytical Backbone of EU Energy Efficiency Governance

The analysis presented in Deliverable D5.1 confirms that, despite a common legislative framework under the Energy Efficiency Directive (EED), significant methodological diversity persists across Member States. Differences in sectoral coverage, baseline definitions, modelling assumptions, activity data reporting, and savings calculation procedures limit the comparability of national efficiency pathways and complicate EU-level monitoring.

While national flexibility in modelling and planning is both legitimate and necessary, greater methodological coherence is essential to ensure that projected efficiency improvements are credible, transparent, and comparable. Harmonisation in this context does not imply standardising national models or centralising analytical processes. Rather, it entails establishing shared reference principles, compatible indicator structures, and minimum reporting standards that strengthen collective oversight while preserving subsidiarity.

Based on the empirical findings of the pilot assessment, this chapter outlines strategic recommendations aimed at reinforcing the analytical integrity of EU energy efficiency governance.

6.2. Bridging the Gap Between Monitoring and Projections

A key structural weakness identified in D5.1 is the disconnect between ex-post monitoring and ex-ante scenario modelling. Historical efficiency developments are typically evaluated using indicator-based approaches such as ODEX, whereas forward-looking projections in National Energy and Climate Plans (NECPs) are derived from modelling frameworks that often rely on different definitions, structural assumptions, and sectoral boundaries.

This separation limits the ability to determine whether projected efficiency improvements represent a continuation of observed trends or a structural shift requiring intensified policy action.

To strengthen policy credibility and ensure internal coherence, Member States should progressively align monitoring and projection frameworks. This includes maintaining consistent sector definitions across historical and projected data, ensuring that projected energy demand can be translated into comparable intensity indicators, and explicitly linking future efficiency improvements to historical trajectories.

Extending established indicator systems, such as ODEX, into forward-looking contexts— as demonstrated in this deliverable — provides a practical pathway toward integrating retrospective and prospective analysis within a single analytical structure. Institutionalising such alignment at EU level would significantly enhance the robustness of future NECP assessments.

6.3. Embedding Structural Drivers Through Systematic Activity Reporting

The pilot assessment highlights the central role of activity data in distinguishing genuine efficiency improvements from changes driven by economic growth or structural transformation. Without systematic reporting of activity indicators, it becomes difficult to assess whether energy demand reductions stem from technological progress, behavioural change, structural shifts, or cyclical fluctuations.

To enhance transparency and analytical depth, future NECP submissions and progress reports should systematically include core activity indicators alongside final energy consumption projections. In transport, this entails reporting passenger and freight activity by mode and vehicle stock by propulsion type. In industry, sector-specific production data or output indices are necessary, particularly for energy-intensive branches. In buildings, floor area, number of dwellings, and demographic indicators are essential. For services, structural indicators such as employment and commercial floor area provide the basis for meaningful intensity assessment.

Integrating such variables strengthens the capacity to validate projections, improves cross-country comparability, and supports application of the Energy Efficiency First principle by clarifying the drivers of demand evolution.

6.4. Enhancing Consistency in Baselines and Reporting Horizons

Differences in base years, reference periods, and projection horizons reduce the interpretability of EU-wide efficiency comparisons. While national planning cycles vary, clearer alignment in reporting conventions would substantially improve transparency.

A strategic step forward would involve agreeing on common reference years for EU-level efficiency indicator reporting, ensuring systematic inclusion of key target years (2030, and where feasible 2040 and 2050), and clearly documenting any structural recalibrations between historical data and projection baselines. Greater consistency in energy balance conventions and price-year assumptions would further strengthen comparability without constraining national modelling autonomy.

6.5. Improving Transparency of Modelling Assumptions

The credibility of projected energy efficiency improvements depends not only on the magnitude of reported savings, but on the transparency and robustness of the assumptions underpinning them. Quantitative results presented in NECPs often summarise complex modelling exercises, yet without clear documentation of core parameters and structural drivers, it becomes difficult to assess whether projected efficiency gains are realistic, internally consistent, and aligned with declared policy measures.

The pilot assessment conducted in Deliverable D5.1 indicates that, in several cases, projections provide limited explanation of how specific policies translate into measurable reductions in energy intensity. For example, electrification targets may be stated without clarifying assumed penetration rates by subsector; renovation ambitions may be presented without specifying annual renovation depth and performance standards; modal shift strategies may be described without quantifying expected changes in passenger- or tonne-kilometre shares. Similarly, assumptions regarding industrial process innovation, fuel switching, hydrogen uptake, or carbon capture deployment are not always explicitly linked to projected energy demand trajectories.

To strengthen analytical credibility and comparability across Member States, greater transparency in modelling documentation is recommended. This should include:

- Explicit electrification rates by sector and end use, including assumed technology diffusion paths and efficiency performance of new equipment;

- Detailed renovation assumptions, including annual renovation rates, depth of renovation, building typologies affected, and expected energy performance improvements;
- Industrial transformation pathways, including process efficiency improvements, structural shifts in production, and assumptions regarding new technologies;
- Quantified modal shift assumptions in transport, including changes in passenger and freight shares across modes;
- Treatment of behavioural effects and potential rebound impacts, where relevant to overall demand projections;
- Clear distinction between autonomous efficiency improvements and policy-induced effects.

Providing this level of detail enhances traceability between policy design and projected outcomes. It allows external reviewers, EU institutions, and peer Member States to better understand the logic of national projections and to identify whether projected savings are grounded in measurable structural changes or embedded in aggregated modelling parameters.

Improved documentation also facilitates cross-country learning. Transparent reporting of modelling assumptions enables identification of best practices in integrating electrification strategies, building renovation policies, industrial decarbonisation pathways, or demand-side measures. It contributes to the development of a shared methodological knowledge base across the Union.

Finally, clarity in assumptions reduces the risk of implicit overestimation of savings. When modelling inputs are not fully specified, there is a possibility that intensity improvements are embedded in baseline recalibrations or structural shifts without explicit policy linkage. Systematic documentation strengthens accountability and ensures that projected energy efficiency trajectories are consistent with both technical feasibility and declared implementation capacity.

Enhancing transparency of modelling assumptions should therefore be considered a strategic priority in future NECP updates and EED reporting cycles. It represents a relatively low-cost but high-impact improvement that can significantly strengthen the credibility, comparability, and policy relevance of EU energy efficiency projections.

6.6. Aligning Savings Calculation Approaches

Under the EED, Member States are required to report achieved and projected energy savings. However, approaches to converting efficiency improvements into savings vary considerably, particularly with regard to baseline definitions and counterfactual scenarios.

The harmonised ODEX-based savings methodology applied in D5.1 demonstrates that a consistent baseline logic can enhance comparability and strengthen alignment between top-down indicator monitoring and bottom-up policy reporting. To improve reporting credibility, Member States should clearly define baseline years and counterfactual assumptions, apply transparent formulas for translating intensity reductions into savings, and explicitly distinguish technical efficiency effects from structural demand changes.

Greater alignment between monitoring indicators and savings reporting would enhance the integrity of Article 4 and Article 8 assessments and reduce fragmentation in EU efficiency governance.

6.7. Strengthening Sectoral Detail and Data Coordination

The robustness and credibility of energy efficiency assessment are closely linked to the level of sectoral detail available in national datasets. Disaggregated data enable identification of structural shifts, differentiation between subsectoral dynamics, and calculation of meaningful intensity indicators. Where sectoral reporting remains highly aggregated or where activity indicators are incomplete, the analytical depth of efficiency assessment is significantly reduced. In such cases, it becomes difficult to distinguish between structural transformation, cyclical developments, and genuine technological progress.

The pilot assessment conducted in Deliverable D5.1 illustrates those limitations in subsector breakdowns, particularly in transport and energy-intensive industries, constrain the application of decomposition analysis and weaken the interpretability of projected savings. For example, without detailed modal data in transport, it is not possible to robustly assess the impact of electrification, modal shift, or efficiency improvements in heavy-duty vehicles. Similarly, aggregated industrial energy data without branch-level production indicators limit the ability to evaluate structural change versus process efficiency improvements.

Strengthening sectoral disaggregation should therefore be considered a priority in future reporting cycles. In transport, this includes consistent reporting by mode and vehicle category, as well as differentiation by propulsion system where feasible. In industry, enhanced coverage of energy-intensive subsectors—such as iron and steel, cement, chemicals, and pulp and paper—would significantly improve the capacity to assess decarbonisation pathways and structural transformation. In buildings, greater detail on end uses and building typologies would support more accurate evaluation of renovation impacts and electrification trends.

Importantly, improving sectoral detail does not necessarily imply creating entirely new reporting obligations. Many of the required data already exist within national statistical systems or sectoral agencies but are not systematically integrated into energy modelling and NECP reporting frameworks. Enhanced coordination between national statistical offices, energy agencies, and modelling institutions would facilitate more consistent use of existing data and reduce fragmentation across reporting streams.

At EU level, improved interoperability between key data platforms—Eurostat, ODYSSEE, JRC-IDEES, and NECP reporting structures—would further strengthen coherence. Aligning classifications, sector definitions, and data formats across these repositories would reduce duplication, streamline reporting processes, and facilitate automated cross-checking of projections and historical data. Such alignment would enhance comparability while avoiding disproportionate administrative burden on Member States.

Greater sectoral detail and stronger data coordination would ultimately reinforce both national modelling quality and EU-level monitoring capacity. More granular data allow clearer identification of implementation gaps, support more accurate policy calibration, and increase confidence in reported efficiency trajectories. In the context of increasingly ambitious climate and energy targets, strengthening the empirical foundation of sectoral analysis is a necessary step toward ensuring that projected efficiency improvements are both technically plausible and policy-consistent.

6.8. Institutionalising Peer Exchange and Continuous Improvement

Methodological harmonisation is not solely a technical challenge but also an institutional one. Differences in modelling culture, administrative capacity, and data infrastructure influence reporting practices across Member States.

Structured peer exchange mechanisms should therefore be strengthened within WP5 and future governance cycles. Regular methodological workshops, development of shared technical guidance, dissemination of best practices in activity-based decomposition, and peer review of national methodological annexes would support gradual convergence while respecting national autonomy.

6.9. Toward a More Integrated EU Energy Efficiency Monitoring System

The experience gained in Deliverable D5.1 demonstrates that greater methodological coherence is both achievable and strategically valuable. Bridging ex-post and ex-ante assessment frameworks, systematically integrating structural drivers, and harmonising savings calculation approaches would significantly enhance the reliability and credibility of EU-level efficiency monitoring.

Embedding these improvements within future NECP revision cycles and EED reporting processes would strengthen the analytical backbone of EU energy efficiency governance. A more integrated monitoring system would improve identification of implementation gaps, support evidence-based policy adjustment, and reinforce confidence in the EU's ability to meet its climate and energy objectives.

The recommendations presented in this chapter therefore provide a pragmatic roadmap for progressively enhancing methodological coherence across Member States while preserving national flexibility. Strengthening comparability and transparency today will be essential for ensuring credible and coordinated efficiency progress in the decade ahead.

7. Conclusions

Deliverable D5.1 establishes a coherent methodological and empirical foundation for assessing both historical and projected energy efficiency developments across Member States in a harmonised and policy-relevant manner. By integrating the outcomes of Task T5.1 – Establishment of the data framework and Task T5.2 – Analysis and evaluation of methodologies, EE indicators and projections, the report demonstrates that a common analytical framework can be effectively applied to diverse national monitoring and projection systems while preserving national modelling autonomy.

A central conclusion of this work is that credible assessment of energy efficiency progress requires systematic linkage between energy consumption and its underlying activity drivers. Changes in total energy demand alone do not provide sufficient evidence of efficiency improvements, as they may reflect structural shifts, economic developments, or demographic trends. The harmonised data template developed under Task T5.1, combined with the ODEX-based methodology applied under Task T5.2, enables decomposition of energy demand into activity, structural, and intensity effects. This approach allows underlying efficiency improvements to be isolated and translated into quantifiable energy savings in a consistent and transparent manner.

The application of the ODEX methodology to both ex-post observations and ex-ante projections confirms its analytical value as a unified framework for bridging monitoring and scenario analysis. Extending ODEX to forward-looking contexts enhances comparability between historical performance and projected ambition, supporting evaluation of alignment with Article 4 targets under the Energy Efficiency Directive. The methodology provides a harmonised representation of efficiency trends across sectors, while maintaining sufficient granularity to capture sectoral dynamics and structural transformation pathways.

Importantly, the scientific and methodological contribution of this work has been recognised by the broader research community. The extension of the ODEX framework to ex-ante assessment and its application within a harmonised cross-country context has resulted in a peer-reviewed scientific publication (Pušnik et al., 2025). This recognition underscores both the methodological robustness and the research relevance of the approach, confirming its value not only for policy monitoring but also for advancing academic discourse on energy efficiency evaluation frameworks.

The assessment also highlights persistent methodological heterogeneity across Member States. Differences in baseline definitions, sectoral disaggregation, treatment of activity data, modelling assumptions, and savings calculation procedures affect the transparency and comparability of reported efficiency trajectories. While such diversity reflects legitimate national specificities, it underscores the importance of harmonised reporting structures and clearer documentation of modelling assumptions in order to strengthen EU-level monitoring.

Data availability and quality emerge as critical determinants of analytical robustness. Comprehensive and disaggregated activity data significantly improve the reliability of intensity calculations and decomposition results. Conversely, limited sectoral detail constrains analytical depth and increases reliance on aggregated modelling assumptions. Strengthening data infrastructure, improving interoperability between reporting platforms, and enhancing consistency between ex-post statistics and ex-ante projections remain key priorities for improving the credibility of efficiency assessments.

From a governance perspective, the consistent application of the ODEX framework supports cross-country benchmarking and facilitates structured comparison of efficiency trajectories. As a standardised, consumption-weighted index embedded within the ODYSSEE-MURE initiative, ODEX ensures methodological consistency with EU monitoring practices and enables aggregation of sectoral indicators into national efficiency indices and total energy savings. By normalising diverse underlying variables into a dimensionless indicator of relative progress, it provides a clear and comparable signal of efficiency developments over time.

Overall, Deliverable D5.1 demonstrates that integrating harmonised data collection, structured methodological review, and ODEX-based decomposition significantly strengthens the analytical backbone of EU energy efficiency governance. Bridging ex-post monitoring and ex-ante projection assessment within a unified framework enhances transparency, comparability, and policy relevance. These methodological improvements, validated both in policy application and scientific publication, constitute an essential foundation for credible progress toward EU energy efficiency targets and long-term decarbonisation objectives.

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Annex I: Template for collecting information on methodologies, EE indicators and projections in pilot MS

Country: Name of the MS

Overview of National Methodological Approaches for Assessing Energy Efficiency

This section summarises the methodologies used to estimate and calculate energy savings, covering both ex-ante projections and ex-post evaluations, as well as baseline definitions, sectoral coverage, and attribution rules. It also outlines monitoring, reporting, and methodological practices applied to ensure consistency, additionality, and compliance with national and EU requirements.

Please fill in the tables below.

Methodologies (Ex-ante / Ex-post)

Category	Description
Ex-ante methodologies (future projections, i.e. simulation models, optimisation models, econometric models, etc..)	
Ex-post methodologies (past statistics, i.e. ODEX, JRC-IDEES, national statistics, Energy Agency reports, etc..)	

Approach to Calculating Energy Savings (Ex-post)

Category	Description
Baseline year (for latest Ex-post assessment)	
Use of standard values (national catalogue, other EU/national standardized values)	
Additionality & double counting handling	
Attribution of savings (sectoral)	
Sector coverage (state which sectors are included and which are not)	

Monitoring & Reporting Practices

Category	Description
Reporting frequency	
Tools/databases used (state the ones that are used in your country)	

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Top-down/Bottom-up reconciliation (which sectors are modelled top down and which bottom up)	

Energy Efficiency Indicators

In this section, list the main indicators used at national level to assess energy efficiency (e.g. ODEX or similar efficiency indices, policy-driven energy savings under Article 8, scenario comparisons). For each indicator, briefly describe its purpose, calculation basis, sectoral coverage, data sources, and how it is used to monitor trends, evaluate policy impacts, and track progress towards national and EU energy efficiency targets.

Projections and Scenario Methodologies

In this section, describe the models and tools used to develop energy efficiency projections and scenarios at national level. Briefly outline the main assumptions, baseline, input data, and scenario frameworks applied, and provide references or links to publicly available methodological documentation where available.

Roles and Institutional Responsibilities

This section describes the institutional framework for energy efficiency governance, outlining the roles and responsibilities of key public bodies involved in policy design, implementation, data collection, analysis, and reporting. It clarifies how ministries, agencies, statistical offices, research institutions, and other relevant bodies contribute to the coordination and delivery of national energy efficiency objectives.

Institution	Role	Responsibilities
Ministry responsible for energy		
National energy agency		
National statistical office		
Research institutes		
Other bodies		

Sectoral Data Availability & Quality

This section provides an overview of the availability and quality of energy-related data by sector, highlighting the robustness and limitations of existing data sources. It identifies key gaps, uncertainties, and strengths in sectoral data to support energy efficiency monitoring, analysis, and reporting.

Sector	Availability	Quality	Comments
Buildings (residential)	High / Medium / Low	High / Medium / Low	
Buildings (services)	High / Medium / Low	High / Medium / Low	
Industry	High / Medium / Low	High / Medium / Low	
Transport	High / Medium / Low	High / Medium / Low	

Agriculture	High / Medium / Low	High / Medium / Low	
Public sector	High / Medium / Low	High / Medium / Low	
Energy supply	High / Medium / Low	High / Medium / Low	

Key Challenges and Recommendations

In this section, briefly list the main challenges related to methodologies, indicators, projections, and data availability or quality that affect energy efficiency assessment and reporting.

Where relevant, indicate recommendations for improvement and highlight specific challenges that could be addressed through peer-to-peer (P2P) support under Task 5.3.

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