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RESEARCH

From compliance to impact: evaluating energy efficiency measures in Portugal and Italy

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Abstract Data collection and analysis on the implementation of energy efficiency measures (EEMs) under Article 8 of the Energy Efficiency Directive (EED) vary widely across European countries. This paper focuses on the management and enforcement of Energy Audits (EAs) obligation, and the associated EEMs information, in Portugal and Italy, two countries with distinct approaches. Specifically, the study delves into the Portuguese SGCIE (*Sistema de Gestão dos Consumos Intensivos de Energia*), and the implementation of the Italian Legislative Decree *102/2014* along with Ministerial Decree 256/2024 (*Decreto Energivori)*. In Portugal, SGCIE plays a pivotal role in monitoring energy-intensive installations, mainly from the industrial sector, fostering the adoption of EEMs through a mandatory framework. This paper investigates how SGCIE collects data from EAs, enforces the implementation of EEMs, and tracks energy savings, contributing to national and EU energy efficiency goals. Similarly, the study delves into the Italian framework, analysing EAs obligations governance and EEMs data managing, particularly for energy-intensive industries. Emphasis is placed on the effectiveness of these mechanisms in gathering and utilizing information on EEMs. This analysis highlights the strengths of each system, underscoring key differences in how Portugal and Italy have transposed Art. 8 EED obligations into national law. The findings show that both countries have developed robust digital systems to collect and analyse EEMs data, offering valuable insights into energy consumption trends and policy impacts. These approaches improve data quality, support company-level energy management, and provide a foundation to meet the more stringent requirements of the revised EED (EU/2023/1791).

Keywords Energy audits · Energy management systems · Energy efficiency directive · Energy policy evaluation

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Introduction

Energy audits (EAs) and Energy Management Systems (EnMS) have been widely recognized as essential instruments in promoting energy efficiency (EE) across European companies. By identifying energy-saving potentials and supporting the implementation of targeted energy efficiency measures (EEMs), these mechanisms contribute significantly to reducing greenhouse gas emissions and achieving the European Union's ambitious EE targets (Bertoldi & Mosconi, 2020; Román-Collado & Economidou, 2021). Over the years, European policies have evolved to strengthen the role of EAs and EnMS in driving EE improvements. The Energy Efficiency Directive (EED) 2012/27/EU, under Art. 8, required all large enterprises — excluding small and medium-sized enterprises (SMEs) — to undergo EAs conducted by accredited experts or through independent supervision by national authorities. These audits must be repeated every four years, with an exemption granted to enterprises that had already implemented a certified energy or environmental management system. The revised EED (EU) 2023/1791 introduced a more stringent regulatory framework. Art. 11 now extends the EAs obligation to all enterprises with an average annual energy consumption exceeding 10 TJ over the previous three years, irrespective of their size. Moreover, enterprises consuming more than 85 TJ per year are now required to implement an EnMS, ensuring a structured and continuous effort to improve EE. For companies subject to these obligations, the revised EED requires not only the submission of detailed information on the implementation of EEMs but also the development of Action Plans as set out in Article 11(2). These Plans should be developed based on the recommendations derived from the EAs if they are technically or economically viable. This underscores the critical importance of obtaining reliable data from businesses regarding both the measures they have already implemented and those they plan to deploy. As a result, different Member States (MS) have developed varied approaches to managing and enforcing EAs obligations and the associated data collection on EEMs (Claus et al., 2024; Johnsson et al., 2025).

Although policies related to EAs and EnMS are central to Europe's efforts to reach savings targets, the literature lacks comprehensive studies analysing the impact of obligations in terms of EEMs adoption (Nabitz & Hirzel, 2019). Only few works are focused on the impact of the Art.8 of the EED in obligated companies (Kubule et al., 2020) compared to the voluntary programmes for SMEs (Fleiter et al., 2012; Paramonova & Thollander, 2016). Additionally, there is a gap in research on national policies, as even in countries where data is collected within policy frameworks, it is neither fully utilized nor published in the literature. While national reports are available, there is a lack of internationally published studies that could enhance the replicability of effective policy approaches and contribute to the development of benchmarks.

The novelty of this study lies in its detailed analysis of the policies of Portugal and Italy, both of which have implemented mechanisms for systematic and standardized data collection on EE measures. These mechanisms rely on digital platforms that gather structured information—such as types of implemented EEMs, associated energy savings, investment costs, and payback times—from mandatory EAs. By doing so, both countries create a direct link between policy enforcement and data management, enabling more effective monitoring, benchmarking, and support for the implementation of EEMs.

To understand how these regulations are applied, this paper, developed in the framework of the LEAPto11 EU funded project (LEAPto11, 2025), compares the implementation, enforcement, and data management practices in Portugal and Italy. Both countries have adopted distinct compliance mechanisms under the EED framework. Specifically, the study examines the Portuguese SGCIE (*Sistema de Gestão dos Consumos Intensivos de Energia*), established under Decree-Law 71/2008, and the implementation of the Italian Legislative Decree 102/2014 and Ministerial Decree 256/2024 (*Decreto Energivori*). In Portugal, SGCIE serves as a cornerstone of industrial EE policy, ensuring systematic monitoring and management of energy consumption in energy-intensive installations, mainly from industry. Through a structured process of mandatory EAs, PREn (Energy Consumption Rationalization Plans), and compliance verification, the system enforces the implementation of EEMs and tracks energy savings. Similarly, the Italian framework, governed *by Decreto 102/2014* and *Decreto Energivori*, establishes obligations for EAs and the reporting of EEMs, particularly for energy-intensive enterprises.

This paper investigates how SGCIE collects, analyses, and utilizes data from EAs to drive compliance and enhance EE at both national and EU levels. By adopting a comparative approach, this paper aims to highlight the differences, and best practices in the way Portugal and Italy have transposed and implemented Art. 8 EED obligations. The findings provide insights for policymakers in optimising national EE frameworks and ensuring a more effective integration of Art. 11 of the revised EED (EU/2023/1791).

The work presented in this paper is based on a questionnaire developed within the LEAPto11 project and completed by experts from the national energy agencies of 10 European countries. The questionnaire was designed to investigate how different Member States manage the collection and use of data on EEMs under Art. 8 EED. Specifically, it included closed and open-ended questions covering: (i) the type of data collected from EAs (e.g., investment costs, energy savings, payback periods), (ii) the digital tools or platforms used for data submission and analysis, (iii) whether data is used for compliance checks, policy evaluation or benchmarking, and (iv) examples of national good practices supporting the uptake of EEMs, including regulatory incentives or supportive actions beyond Art. 8 obligations. The insights gathered through this questionnaire directly informed the comparative analysis between Portugal and Italy presented in this paper, particularly in terms of data management systems, implementation rates of EEMs, and the role of digital tools in enabling policy impact.

The paper is structured as follows: the first section gives details about the methodology used in this study to collect and analyse the information presented. The second section provides an overview of existing policies in Italy and Portugal related to EAs and EnMS, including a review of the relevant literature and a focus on the digital tools adopted by these two countries for data collection and management. The results are divided into two parts: the first includes an analysis of the quantitative data available on EEMs in Italy and Portugal, while the second examines procedures, tools and best practices in both countries that impact the implementation of EEMs. Finally, the paper concludes with general findings and key takeaways.

Methodology

To gather a comprehensive understanding of national approaches to the implementation and monitoring of EEMs under Art. 8 of the EED, a structured questionnaire was developed within the LEAPto11 project. The questionnaire was distributed to national experts from 10 EU MS and aimed to collect detailed information on how countries collect, manage, and use data related to EAs and EEMs.

The questionnaire was developed through an iterative process: an initial draft was prepared by the project team and reviewed by national representatives from participating MS. Based on their feedback, the final version included 22 questions, combining closed-ended and open-ended formats. The questions were grouped into four main sections:

1. General policy framework – e.g., presence of obligations for EAs and EnMS, responsible authorities.
2. Data collection and management – e.g., whether national platforms exist, what types of data are collected (e.g., investment costs, energy savings, payback periods), who manages the data, and for what purpose.
3. Use of data and monitoring – e.g., whether data is used for benchmarking, compliance, or policymaking.
4. Good practices and forward-looking aspects – e.g., integration with other policies, digital tools, or capacity-building initiatives.

The questionnaire was distributed in June 2024 and responses were collected until October 2024. Each country coordinated a national reply, generally compiled by energy agency experts through desk research, internal databases, and consultations with relevant ministries. All ten contacted countries completed the questionnaire (100% response rate). Specifically, in the case of Portugal and Italy, the replies were provided respectively by ADENE and ENEA, who also contributed to clarifying and validating the interpretation of responses through follow-up interviews.

In this paper, while the broader survey informs the overall context, the focus is placed on the in-depth analysis of the cases of Italy and Portugal, using their questionnaire responses as a primary source. These responses were integrated into the analysis in several ways:

- Section “Analysis of Energy Efficiency Measures data collection in Portugal and Italy"directly builds on questionnaire data about the national data platforms, implementation rates, and types of information collected (e.g., cost, savings, PBT).
- Section"Art. 8 EED good practices to support EEMs implementation"reflects the country-specific good practices reported in the last section of the questionnaire.
- Further contextual information from the survey also helped define the comparative table summarizing key differences between the two countries (Table 1).

Further details on the questionnaire design, including the full list of questions and methodological notes, are available in Martini et al. (2024).

Literature review

Policies based on EAs remain the most common tool for supporting EE in industry and enterprises (Bertoldi, 2001), primarily because they offer better cost-effectiveness compared to other EE policies (Thollander et al., 2015). The 2012 EED introduced a mandatory EA every four years for all large enterprises in the European Union. In its 2023 recast, the EED extended this obligation to all companies with an annual energy consumption exceeding 10 TJ, also requiring the implementation of EnMs for companies consuming more than 85 TJ per year.

Despite the maturity of EA policies and the significant efforts of EU MS, several challenges persist. These include a notable lack of publicly available information (Herce et al., 2024), limited harmonization in the EAs data management and utilization (Johnsson et al., 2025), and heterogeneity on the evaluation of the programmes (Andersson et al., 2017). Therefore, the development and analysis of policies for industrial EE is still a challenging task (Andrei et al., 2021).

Two comprehensive introductory overviews on energy policies have been published by the International Energy Agency (IEA, 2021, 2023**)**. However, specific studies focusing on individual countries are still lacking. In the following sections, we will examine in detail the cases of Portugal and Italy, two countries where the EA ecosystem is well-structured.

Portugal

The topics of EE policies and EEMs implementation in industry in Portugal are still scarcely studied in scientific literature. Portugal is a pioneer in the diversification of its energy mix, in the creation of energy and environmental laws, and, in the creation of mechanism for decarbonization and EE (a comprehensive overview of the policies since 1944 is presented in Felício et al. (2024). Similar to electrification based on renewables, implementing EEMs is recognized as a main driver for decarbonisation in the energy sector (Martini et al., 2022). However, most of the literature

Table 1 Comparative overview of EAs and EnMs frameworks in Portugal and Italy

Aspect	Portugal – SGCIE	Italy – Decree 102/2014 and Related Acts
Main legislation	Decree-Law 71/2008 (amended by DL 68-A/2015)	Legislative Decree 102/2014 and 73/2020
Target entities	Industries consuming ≥ 500 toe/year; ≥ 1000 toe/year with stricter targets	Large enterprises; energy-intensive companies seeking incentive eligibility
Audit frequency	Every 8 years	Every 4 years
Exemptions	EnMS-certified companies exempt if not already under SGCIE	EnMS-certified companies exempt from EAs
Mandatory EEMs	PREn must include measures with payback ≤ 3 or ≤ 5 years based on consumption level	Mandatory for *energivori* every 4 years under D.Lgs. 73/2020
Digital platform	SGCIE portal (managed by ADENE in collaboration with DGEG)	Audit 102 portal (managed by ENEA)
Recent developments	Threshold lowered to 240 toe; 4-year audit cycle to align with EED 2023/1791	Decree 131/2023 introduced “green conditionalities” (Guarantees of Origin or certified CO_2-cuts)

is focused on EE in buildings (Bandeiras et al., 2020; Capelo et al., 2023; Olasolo-Alonso et al., 2023; Zuhaib et al., 2022).

The EED 2018/2002 included a set of binding measures to achieve EU objectives. Some topics have been addressed in literature, such as the energy savings targets (Art.7) (Rodríguez et al., 2023), the EE obligation schemes (Art.7) (Thomas et al., 2022), the energy poverty (Art.7.7) (Koengkan et al., 2023; Matos et al., 2022), or the consumer information and empowering programme (Art.12) where Portugal is a best practice on transparency and data availability on the electrical system (Fernandes & Silva, 2022). Previously, Moreira et al. (2007) analysed critically the impact of the 2004 Cogeneration Directive proposing specific measures for the effective implementation of micro-CHP systems mainly in the services sector. However, there are no references to EAs and EnMS systems (Art. 8) or impact evaluation of energy savings.

Several specific industrial sectors have been analysed from different perspectives. The food industry has been studied to identify energy indicators, best available technologies and most promising EEMs (Nunes et al., 2016, 2025). Research on ceramics sector has explored advanced EE topics such as energy management and resources efficiency (Reaney et al., 2023; Ruivo et al., 2021). The information contained in EAs has been also used for directly proposing EEMs in the wine (Vela et al., 2017) and gypsum (Bernardo et al., 2015) sectors. A cross-sectoral analysis of industrial SMEs highlighted that internal behavioural change is crucial to develop strategies to overcome internal and external barriers, and behavioural impact can be higher than energy benefits due EE technologies or supportive instruments (such as economic incentives and information campaigns) (Catarino et al., 2015; Henriques & Catarino, 2016). In the services sector, SMEs face a significant lack of awareness regarding EE, which remains the primary barrier to implementing EEMs—especially in areas such as lighting and insulation (Cunha et al., 2020).

Due to hydric stress and environmental concerns, particular attention has been given to the water-energy nexus (Rezaei Kalvani et al., 2024), in comparison to other EU countries. Particularly interesting are the works on energy efficiency in the water sector (Cardoso et al., 2023a, 2023b; Cardoso, Gomes, et al., 2023), identifying barriers and drivers for the implementation of EEMs by means of several surveys of decision makers.

Several innovative models have been applied to support policy making in EE in Portugal. Simoes et al. (2014) assessed the impact of an efficient scenario that includes the replacement of all inefficient equipment in all sectors for 2% savings with a total cost of 3 billion EUR. Beyond cost savings for demand-side enterprises, the study highlighted benefits for the supply system, including a reduced need for large-scale infrastructure projects. Furthermore, Hou et al. (2021) identified a high potential for improving business performance by eliminating technical inefficiency. Key drivers include labour skill development (particularly in low-tech sectors) and the promotion of electrification, as technological change is biased towards fuel rather than electricity. Additionally, carbon pricing can be an option for promoting electrification and efficiency.

Finally, carbon tax and EE policies as complementary tools were analysed by Pereira and Pereira (2017). While EE measures reduce emissions and have positive economic effects, they can also increase public debt. Conversely, a carbon tax lowers emissions but may come at an economic cost while helping to reduce debt. Hence, a carbon tax of 35 € per tCO_2 was proposed to achieve an EE gain of 2–2.5% per year.

Italy

The topic of EE has been extensively studied in Italy with particular emphasis on technological improvements (i.e. Benedetti et al., 2018), industrial sectoral analysis (Lazzarin & Noro, 2015) and buildings (Asdrubali et al., 2008; Salvalai et al., 2015). Malinauskaite et al. (2019) presented an overview of EE policies in industry derived from the national transposition of the EED, highlighting the importance of "White Certificates" as historical main driver (Art. 7 EEOS). The evolution of White Certificates has been extensively studied (Caragliu, 2021; Di Santo et al., 2018), and several improvements have been proposed (Di Foggia et al., 2022). Other topics directly linked to the EED studied in Italy are energy poverty (Betto et al., 2020), the link of industries with district heating grids (Cioccolanti et al., 2021) or the implementation of EnMS (Bonacina et al., 2015; Tallini & Cedola, 2016).

The Politecnico di Milano and the Italian National Agency for New Technologies, Energy, and Sustainable Economic Development (ENEA) have been working on the analysis of the implementation of EEMs. The pioneering work from the Politecnico di Milano laid the foundations for a taxonomy of barriers to the implementation of EEMs (Cagno et al., 2013), and a characterization of EEMs by defining 17 attributes grouped into six categories (economic, energy, environmental, production-related, implementation-related and interaction with other systems) (Trianni et al., 2014). The methodology was extended to SMEs in order to understand their decision-making process (Trianni et al., 2016). More recently, it has been applied to analyse the adoption of specific technologies, such as electrical motors (Accordini et al., 2021), and to assess the impact of different EEMs at the shop floor level (Cagno et al., 2022).

ENEA is responsible for managing the regulatory obligations related to EAs for large enterprises and energy-intensive industries. In recent years, ENEA published numerous studies in collaboration with Italian universities. These studies leverage data from EAs to develop multilevel energy performance indicators (ranging from site-level to internal sub-processes) and assess the EE measure potential across various industrial sectors, such as cement (Bruni et al., 2021), refineries (Herce et al., 2022), pharmaceuticals (Bruni et al., 2023) or rubber industries (Piccioni et al., 2024). Other studies focus specifically on the technical implementation potential of EEMs in sectors such as glass production (Cantini et al., 2022) or foundries (Leoni et al., 2021). Additional research has examined complementary factors influencing the adoption of EEMs, including energy monitoring and management systems (Herce et al., 2021) or the economic performance of companies (Costantini et al., 2024).

Energy audit and energy management Systems policies framework in Italy and Portugal

This section examines the regulatory framework governing EAs and EnMS policies in Italy and Portugal. It outlines key legislative measures, compliance requirements for enterprises, and the role of digital platforms in monitoring and enforcing EE strategies. Understanding this framework is essential for interpreting the data presented in the following sections and for identifying the good practices that have emerged within these regulatory systems.

Legislative framework in Italy and Portugal

Portugal

The Intensive Energy Consumption Management System (SGCIE), introduced in Portugal in 2008 requires companies consuming more than 500 tons of oil equivalent (toe) to conduct EAs every eight years. Companies subject to the SGCIE must register in the system and undergo an EA conducted by certified auditors. They are then required to develop an Energy Consumption Rationalization Plan (Planos de Racionalização de Energia—PREn), outlining specific objectives such as reducing energy intensity and specific energy consumption by 6% or 4%, depending on their level of energy consumption as well as carbon intensity. Auditors upload the audit report and fill the PREn dashboards including all the relevant data.

The PREn is based on the reports of mandatory EAs and in the first three years must consider the implementation of all measures identified with a payback time (PBT) of less than or equal to five years, in the case of installations with energy consumption equal to or greater than 1 000 toe/year, or with a PBT of less than or equal to three years in the case of other installations.

Any company under Art. 8 EED obligations that implement certified EnMS can be exempted from EAs if they are not already under the SGCIE mandatory audit schemes.

The system is aligned with Art. 8 of Directive 2012/27 and is being updated to comply with Art. 11 of Directive 2023/1791. Reflecting this update, Portugal is revising the SGCIE by lowering the threshold to 240 toe (10 TJ) and introducing a four-year cycle for EAs. This regulatory change is expected to increase the number of obligated operators to over 4 000 by 2026, from the current number of around 1 400.

The SGCIE utilizes a digital platform to centralize EA data. This is facilitating policy development through the standardization of energy consumption benchmarks, sectoral benchmarking, compliance verification, and analysis of success rates in implementing EEM. The data is accessible to policymakers, auditors, and enterprises, allowing for a continuous assessment of Portugal's EE strategies.

The collection of information on the implementation of EEMs in Portugal is managed by ADENE, which oversees the operational management of the SGCIE system. This includes tasks such as maintaining a registry of energy-intensive facilities, receiving and submitting energy consumption rationalisation plans to the Directorate-General for Energy and Geology (DGEG) for approval, and monitoring accredited technicians and operators. The monitoring process has been in place since 2008.

Italy

In Italy, the EED 2012/27/EU was transposed with the Legislative Decree 102/2014, later amended by Legislative Decree 73/2020. The recast of the Directive, published in October 2023, must be transposed by October 2025. According to Art. 8 of Legislative Decree 102/2014, large enterprises are required by law to conduct EAs on their production sites every four years. A second category, energy-intensive enterprises, is not subject to the same obligation by default. However, if these companies wish to benefit from reduced electricity tariff surcharges (as defined under the "Decreto Energivori"), they must carry out an EA or implement a certified EnMS including an EA. However, if these companies wish to benefit from reduced electricity tariff surcharges (as defined under the "Decreto Energivori"), they must carry out an EA. In this context, the EA serves as a mandatory condition for accessing tax reliefs, rather than a stand-alone regulatory obligation.

These companies, both large and SMEs, present large energy consumptions (in absolute terms and relative to their internal costs), and they must be part of specific industrial sectors (mainly Annexes 3 and 5 of EU Guidelines 2014/C 200/01). These companies, known as"Energivori", consume more than 1 GWh of electricity per year. Under Legislative Decree 73/2020, they must implement at least one EEM from the EA every four years. SMEs in this category submit audits to ENEA under D.Lgs. 102/14. Since 2021, the programme has been extended to natural gas consumption, with similar requirements for companies using at least 1 GWh or 95 000 Nsm3 annually. In September 2023, the framework for EAs in energy-intensive companies was updated by Decree Law 131, followed by a recent implementing Ministerial Decree. This update introduced two additional green conditionalities as alternatives to the obligation of implementing EEMs with a payback period of less than three years. Under these new conditions, companies may comply by either procuring Guarantees of Origin (GO) from renewable energy sources for at least 50% of their total electricity consumption, or by achieving a certified reduction in greenhouse gas emissions equivalent to that expected from the implementation of cost-effective EEMs. These alternative options are intended to offer greater flexibility while still supporting national decarbonisation goals.

Companies submit their information on EAs and EEMs via the *Portale Audit 102* web portal (ENEA, 2019). ENEA can extract a spreadsheet file on specific obligation years or sectors. EEMs are categorised into homogenous intervention areas on the portal.[1] Information on investments, savings and simple payback times (PBT) is also collected on the portal and checked by ENEA experts before computing further indicators and publishing them. Information is published in an annual report for the Ministry (Salvio et al., 2024), in the EE Annual Report (ENEA, 2024) and in sectoral guidelines and studies, for example in foundries (Martini et al., 2022), plastics (De Santis, Martini et al., 2024) and hotels (De Santis, Ferrante, et al., 2024).

Following the detailed presentation of the national regulatory frameworks, Table 1 provides a comparative overview of the key features of EAs and EEMs implementation in Portugal and Italy. The table summarizes core aspects such as the main legislative references, obligated entities, audit frequency, exemption conditions, mandatory implementation requirements, and recent policy developments aligned with the recast EED (EU/2023/1791).

Digital tools for managing EAs & EnMS policies

A crucial aspect of implementing EAs and EnMS policies is ensuring robust data collection and monitoring, as they are essential for accurately assessing policy effectiveness and measuring progress towards

[1] The database is manually reviewed by an expert to identify outliers, with the assistance of statistical software, and the areas are subsequently standardised for further analysis.

set objectives. To address this, both Italy and Portugal have developed dedicated online platforms that allow for the systematic management of EAs, ensuring compliance with national and European regulations. These tools not only simplify the reporting process for companies but also provide policymakers with valuable insights into energy consumption trends and the effectiveness of efficiency measures.

In Italy, the *Portale Audit 102*, managed by ENEA, is the central platform for gathering data on EAs conducted under Legislative Decree 102/2014. This tool was designed to standardize and streamline the reporting process for enterprises subject to mandatory audits. Companies can submit their audit reports directly through the portal, ensuring that all data is collected in a structured and accessible format. The integration of benchmarking functionalities is planned. Sector-specific average energy performance indicators, calculated based on previously uploaded audits, is available to users in ENEA's EnPI database (ENEA, 2025). Beyond facilitating regulatory compliance verification, the collection and use of data through the portal plays a crucial role for both enterprises and policymakers. For enterprises, it facilitates data entry. The *Portale Audit 102* also includes a set of digital tools to assist in the preparation of EAs, even for non-mandatory entities, and to support the techno-economic analysis of EE measures. These tools are made available to professionals and companies with the aim of further standardising the collection of information on energy consumption and efficiency measures.

The *Portale Audit 102*includes a series of free digital tools designed to support companies in conducting EAs and improving their overall energy management. Among these tools is an Energy Management Tool that allows users to develop sensitivity analysis for key parameters to implement EEMs, such as energy prices and investment costs. A Self-Assessment Tool for SMEs is also available, helping small and medium-sized enterprises better understand their energy profile and identify potential areas for improvement in a guided and accessible manner. Additionally, the platform provides an Energy Maturity Questionnaire, which supports companies in evaluating their organizational readiness and strategic commitment to EE. These tools, all accessible directly through the *Portale Audit 102*, contribute to standardising the way energy-related data is collected and reported. At the same time, they offer practical guidance for companies that are not subject to mandatory audits but still wish to improve their energy performance.

For policymakers, it allows to monitor trends, identify best practices, and assess the effectiveness of EE measures. This data-driven approach supports more informed decision-making and helps to refine energy policies to better address sector-specific challenges.

Portugal has developed another digital platform as part of the SGCIE. This system, managed by the ADENE in collaboration with DGEG, serves as a centralized hub for monitoring energy consumption and efficiency measures in energy-intensive industries. All companies subject to SGCIE regulations must register on the platform, submit their EAs, and develop a PREn outlining concrete efficiency targets. Through this system, the authorities can track the companies' progress over time and monitor whether energy-saving commitments are met. The Portuguese platform is particularly effective because of its ability to analyse sectoral trends. The data collected feeds into the creation of Subsector Notebooks, which provide a comprehensive overview of energy consumption patterns, common efficiency measures, and expected payback periods across different industries. This allows businesses to take more informed decisions about which energy-saving strategies to prioritize. Within the portal, access statistical information on the SGCIE is publicly available, including aggregated data on energy carrier consumption, sectoral data, and annual savings achieved through the implementation of PREn from 2008 to the actual date. Additionally, the portal provides average and global techno-economic details on the implemented EEMs. It also includes a section for entities seeking recognition by the DGEG as auditors and authors of PREn.

Results and discussion

The results of this study are presented in two main sections, each focusing on a different aspect of EAs and EnMS policies in Italy and Portugal, focusing on the implementation of EEMs. The first part examines the outcomes data on EEMs collected from national databases. This analysis sheds light on trends, energy savings, cost-effectiveness, and payback periods associated with implemented and recommended interventions over recent years.

The second one focuses on good practices under Art. 8 EED, exploring the supportive policies, digital tools, and sector-specific initiatives that facilitate the implementation of EEMs. By comparing the approaches adopted in Italy and Portugal, this section highlights how structured data collection and targeted regulatory frameworks can drive EE improvements and provide companies with practical insights into their energy performance.

Together, these sections offer a comprehensive view of both the quantitative outcomes and the qualitative characteristics of the EAs ecosystem that support the data collection on EEMs and their implementation in the two countries.

Analysis of energy efficiency measures data collection in Portugal and Italy

This section presents key quantitative data on EEMs collected through mandatory audits in Portugal and Italy. It includes figures on the number and average energy savings of both implemented and recommended measures, as well as detailed information on their characteristics across sectors in each country.

Number of implemented and recommended EEMs

In Italy, data extracted from the ENEA database for 2023 shows that 10 559 EAs were conducted, leading to the implementation of 8 604 EEMs and 25 017 recommended EEMs. The recommended EEMs should be considered as a potential and a maximum threshold because not all of them will be implemented, and their execution will be spread out over time. ENEA oversees the analysis of this data, which shows significant variability in the average energy savings per EEM. This variability is mainly due to the mix of companies subject to mandatory EAs each year and the range of interventions that are either implemented or proposed. Additionally, the level of technological maturity and the presence of financial incentives also contribute to the fluctuating cost effectiveness of EEMs.

In Italy, the implementation rate of EEMs under Art. 8 EED is neither analysed nor published in official reports. In the annual report for the Ministry of the Environment and Energy Security, the implemented and recommended EEMs are described across seventeen intervention areas, detailing the number of interventions and the associated energy savings, as well as their distribution by payback time class. Data on EEMs are also analysed at the regional level, presenting both achieved and potential savings for NACE sectors (Salvio et al., 2024).

In Portugal, the data collected by ADENE from the SGCIE platform for 2023 indicates that 6 454 EEMs were implemented, with an equal number of recommended measures. According to ADENE, the average implementation rate of EEMs per company is approximately 100%. Implementation rates are tracked by type of EEM and sector using a monitoring platform and periodic reports that consider economic activity classification. Publicly available data can be accessed via the SGCIE platform (ADENE, 2025). ADENE is responsible for managing and analysing these data, ensuring that the PREn is properly applied. The high number of implemented EEMs in Portugal reflects the country's robust regulatory framework for EE, where companies are required to adhere to strict energy consumption rationalisation targets. Like Italy, the data shows variability in energy savings depending on sectoral factors and the type of energy interventions adopted. The consistency in applying the PREn across various industries has contributed to higher implementation rates in Portugal, though the fluctuations in annual data indicate that more standardized data collection methods may be needed to improve the comparability of results.

Detailed information on implemented and recommended EEMs

Since 2008, there have been on average 80 new installations registered in the SGCIE annually, reaching 1 365 in February 2025. Of these, 85% are from the industrial sector, and 60% of the facilities are listed in the Lisbon, Porto, Aveiro and Braga areas. Since 2008 until February 2025, these installations submitted 2 277 EAs and their PREn added up to 5 988 000 toe in primary energy consumption, corresponding to nearly 20% of the country's primary energy consumption, according to the 2019 National Energy Balance.

Among the EEMs promoted by the SGCIE, the most effective ones include waste heat recovery, motor optimization, thermal insulation, implementation of monitoring and control systems, and adoption of efficient lighting systems. The system provides detailed data on achieved energy savings, CO_2 emissions reductions, and financial returns, enabling industries to assess the economic feasibility of implemented measures. Over an eight-year period, cumulative savings are estimated to reach 235 000 toe of final energy, with a reduction of 969 000 tons of CO_2 equivalent and total savings of €1.52 billion. The analysis presented here is focused on the evaluation of key indicators such as energy savings, cost-effectiveness, payback periods (PBT), and environmental impact over the 2019–2023 period.

Table 2 provides an overview of the available data for Portugal from the SGCIE database. This dataset includes several key indicators for each year between 2019 and 2023, such as energy savings in final and primary energy, savings in electricity and fuels, cost-effectiveness, payback periods, and carbon emissions reductions. Energy savings are reported in tonnes of oil equivalent (toe), and the database provides disaggregated data for both electricity and fuel savings. The cost-effectiveness is expressed as Euro per toe, reflecting the cost of saving one toe of energy for each year. The PBT is also included, indicating the time required for businesses to recover their investments in EEMs.

Over the five-year period, the total savings in primary energy have varied, with the highest recorded in 2021 (27.25 ktoe) and the lowest in 2023 (16.54 ktoe). Notably, electricity savings consistently outpaced fuel savings, particularly in 2021 and 2022, observing a predominance of electricity savings, despite the potential increases in electricity consumption associated with EEMs involving fuel switching. Cost-effectiveness peaked in 2023 at €42 573 per toe, suggesting a higher cost for energy-saving interventions in more recent years. Despite this, the average payback period remained stable at around 4 years, indicating a relatively consistent return on investment for the measures implemented. Carbon emissions savings were highest in 2021 (60 766 tCO_{2e}) but saw a decline in 2023, correlating with the reduced energy savings that year. In 2022, the final energy consumption of the manufacturing industry in Portugal was 4 500 ktoe. The SGCIE installations accounted for 1 855 ktoe, representing nearly 40% of the total. Energy savings from SGCIE amounted to 5% of the final energy consumption in the manufacturing sector.

Analysing the top 10 interventions carried out within the framework of the SGCIE, some key trends emerge in terms of energy savings, emissions reduction, and intervention costs, as shown in Fig. 1. The measures with the highest energy savings potential in approved PREns mainly concern the integration of renewable energy sources and heat recovery, with values of 62 957 toe and 39 856 toe, respectively. Optimization of combustion systems and implementation of monitoring and control strategies also prove to be particularly effective. On the emissions reduction front, the most impactful solutions include the use of renewable sources (287 821 tCO_2e) and heat recovery (100 957 tCO_2e), confirming the strategic role of these interventions in industrial decarbonization processes. From an economic sustainability perspective, the most advantageous interventions in terms of cost per unit of energy saved focus on improving ventilation systems (€3 285/toe) and optimising electric motors (€3 560/toe). Regarding emissions reduction, the most cost-effective solutions include motor

Table 2 Detailed information on implemented EEMs in Portugal[a]

Year	Number of implemented EEMs	Total savings in final energy [ktoe]	Total savings in primary energy [ktoe]	Savings: electricity [%]	Savings: Fuels [%]	Average cost effectiveness of energy savings [Euro/toe]	Average PBT [years]	Achieved carbon emissions savings [tCO_{2e}]
2023	6454	10.99	16.54	56%	44%	42 573	4.4	35 133
2022	5861	10.86	19.58	74%	26%	29 118	4.3	46 794
2021	6070	14.29	27.25	79%	21%	21 974	4.2	60 766
2020	6703	11.32	23.49	86%	14%	28 151	3.9	53 314
2019	6437	14.28	27.42	80%	20%	20 228	3.7	62 169

Source: SGCIE Database

[a]As already explained, the average implementation rate of EEMs per company in Portugal is approximately 100%

optimization (€658/tCO_2e) and reactive energy reduction (€672/tCO_2e).

The overall results highlight the importance of targeted interventions in thermal and electrical system efficiency, energy recovery, and renewable energy integration in order to optimize consumption and reduce emissions in the Portuguese industry.

In Italy, energy savings data from 2019 to 2023 under Art. 8 EED are presented in Table 3 for implemented EEMs and Table 4 for recommended EEMs. Italy adopted a methodological change in 2023, shifting from reporting final energy savings for most areas to reporting savings in primary energy for all intervention areas. This change makes

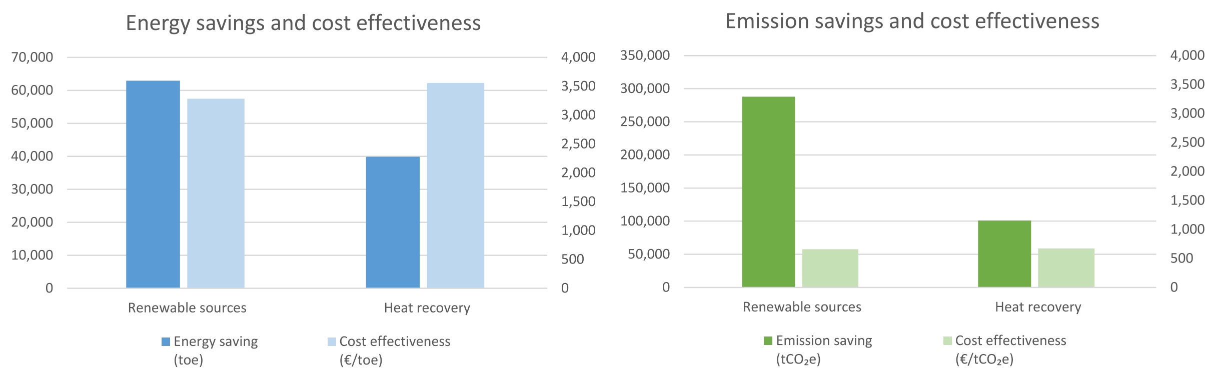

Fig. 1 Energy savings, emission savings and corresponding cost effectiveness for the two main areas of interventions carried out within the framework of the SGCIE

Table 3 Detailed information on implemented EEMs in Italy under Art. 8 EED

Year	Number of implemented EEMs	Total savings in final energy [ktoe]	Total savings in primary energy [ktoe]	Average cost effectiveness of energy savings [€/toe]
2023	8 850	N/A	425.5	6 091[a]
2022	356	3.3	15.8	8 107
2021	317	19.3	2.8	11 475
2020	348	37.0	2.4	12 672
2019	7 352	473.8	190.9	10 879

Source: *Portale Audit 102* Database

[a]This value is related to primary energy savings, as explained in the text, and not comparable with previous years

Table 4 Detailed information on recommended EEMs in Italy under Art. 8 EED

Year	Number of recommended EEMs	Total savings in final energy [ktoe]	Total savings in primary energy [ktoe]	Savings: electricity [%]	Savings: thermal energy [%]	Savings: fuels [%]	Savings: other [%]	Average cost effectiveness of energy savings [€/toe]	Average PBT years [€/toe]
2023	25 446	N/A	1 252.2	60%	N/A	N/A	N/A	5 384[a]	4.8
2022	1 659	22.8	37.6	49%	41%	3%	7%	8 812	4.6
2021	1 837	15.7	40.5	44%	29%	7%	20%	7 736	4.4
2020	1 190	26.1	39.1	59%	23%	5%	13%	6 986	4.5
2019	30 487	1 674.6	855.9	23%	13%	4%	60%	6 616	4.7

Source: *Portale Audit 102* Database

[a]This value is related to primary energy savings, as explained in the text, and not comparable with previous years

the data for 2023 not directly comparable with previous years.

Total energy savings in final energy were notably high in 2019 (473.8 ktoe), corresponding to the first year of the second obligation period. However, the cost-effectiveness of energy savings fluctuated throughout the years, with the highest values observed in 2020 (€12 672 per toe) and 2021 (€11 475 per toe), suggesting higher costs associated with these interventions. This indicates that, while energy savings were significant, their cost-effectiveness was not always optimal.

In 2023, primary energy savings amounted to 1 309 ktoe, but details on savings by energy type and final energy savings were not available due to the methodological changes. In previous years, electricity savings constituted the largest portion of total savings, peaking at 59% in 2020. The average cost-effectiveness also peaked in 2022 (€8 812 per toe), showing higher costs for energy savings in that year. The average payback period for investments remained relatively stable, ranging from 4.4 to 4.7 years, indicating that businesses consistently saw a reasonable return on their EE investments.

The 2023 report for the Ministry of the Environment and Energy Security also includes an analysis of the primary energy savings achieved compared to the consumption of the sites subject to audits at both national and regional levels with a more detailed focus on the manufacturing sector (Salvio et al., 2024). In 2023, the savings achieved represented approximately 1.12% of the total consumption of the audited sites. The potential savings, if all the measures were implemented, would allow for an estimated reduction of 3.43%. The report also includes an analysis of interventions by area. The highest number of implemented measures relate to lighting (26.1%), compressed air systems (14.1%), and production lines (11.3%), as shown in Fig. 2. However, in terms of recommended EEMs, the greatest percentage is related to renewable energy production (17.3%) followed by general energy management measures (15.3%), and compressed air systems (13.7%). Cogeneration/trigeneration, while identified as a recommended measure (2.0% of the total), represent only 2.3% of implemented measures. This is most likely due to higher investment costs and technical requirements. The gap between identified and implemented measures highlights the need for further efforts, particularly in areas with high energy saving potential.

The report also analyses interventions based on their payback time. Most identified interventions fall within a 3 to 5-year payback class (26.4%), which also accounts for the highest share of primary energy savings (28.5%). Classes of shorter payback periods of ≤ 1 year and 1–2 years together represent 32% of interventions and are associated to 33.2% of total energy savings. This indicates strong potential for quick returns. Interventions with longer payback periods of > 10 years are residual (7.7%) and contribute only 5.3% of energy savings. This suggests that while these measures are impactful, their feasibility is lower due to extended return on investment. The data highlights that most energy savings are concentrated in interventions with a medium-term PBT returns of 3–10 years.

The data collection systems in Portugal and Italy provide valuable insights into the effectiveness of EE interventions and the role of policies in driving energy savings. They highlight the potential that lies with structured data collection and evaluation systems in providing information to enterprises and policy makers.

The relatively short payback periods, typically under 5 years, demonstrate the potential for businesses to recover their investments in EEMs quickly. This makes them attractive in terms of both financial and environmental benefits.

Looking ahead, the reform of existing policies or the development of new ones should be based on real data, spanning multiple years and including the impact of energy prices' fluctuations. These findings underscore the importance of continued monitoring and analysis to ensure that EE policies remain effective and adaptable to changing circumstances.

Art. 8 EED good practices to support EEMs implementation

Both Italy and Portugal have developed a range of initiatives and tools to support companies in conducting EAs and implementing EEMs. The good practices were drawn from the questionnaire responses submitted by participating countries and were identified as such by experts, based on their impact on the implementation of EEMs and the generation of related quantitative data. These good practices align with the

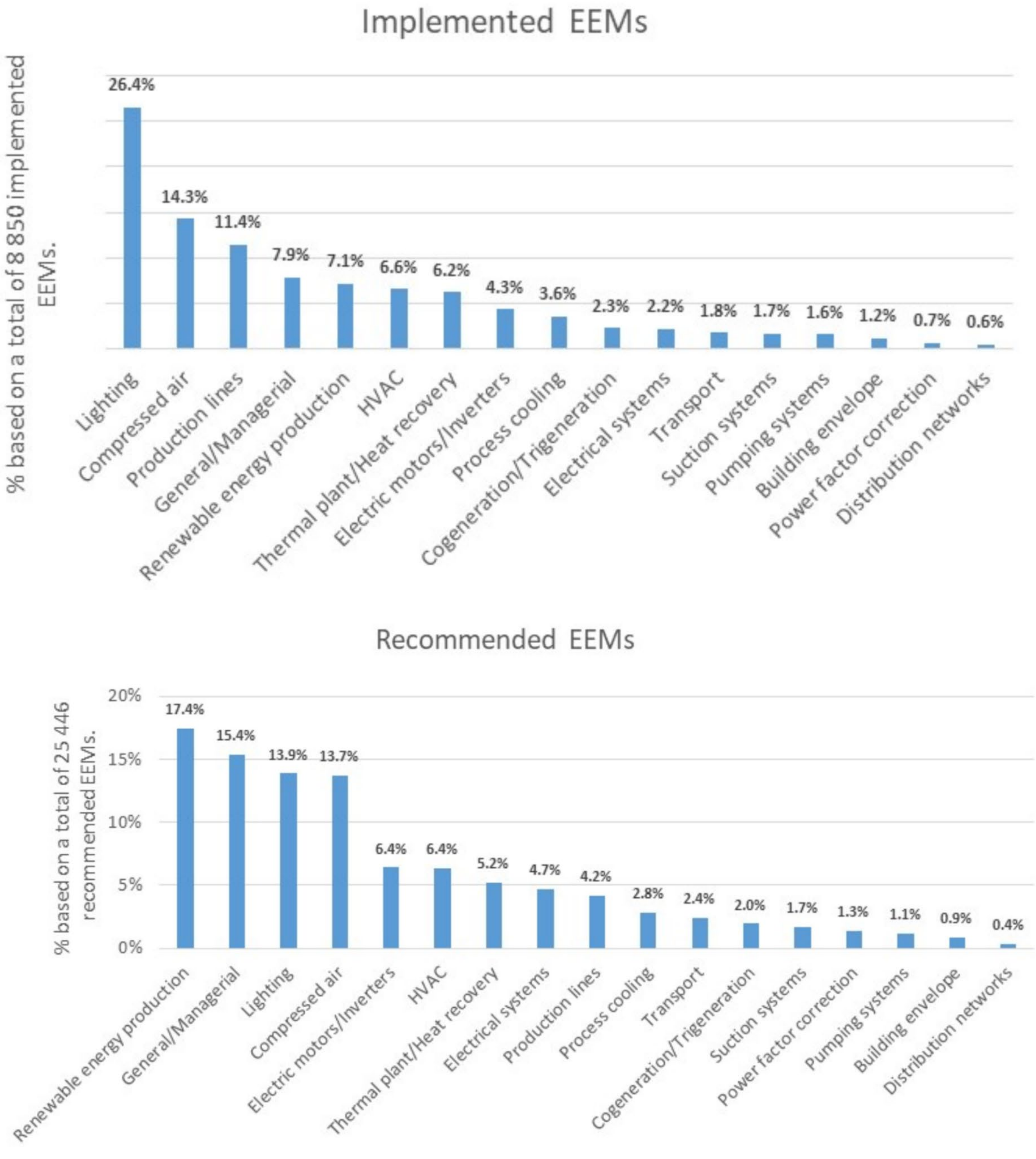

Fig. 2 Percentage distribution of recommended and implemented EEMs by intervention area in Italy under EED Art. 8 (Source: *Portale Audit 102* Database 2023)

obligations set out in Art. 8 EED and can be classified according to Tanaka's (Tanaka, 2011) taxonomy of EE policies. Both countries provide a mix of prescriptive, economic and supportive policies, with a key role of supportive policies in combination to prescriptive policies, which include regulations and mandatory requirements to develop EA. In particular, supportive policies focus on raising awareness and providing technical guidance; they also aim to provide information on existing economic policies, which provide financial incentives to make EE more economically attractive. In both countries, supportive policies also have a strong informational component, thanks to the availability of extensive data and the structured organization of EA databases, which facilitate informed decision-making and the dissemination of best practices.

In Italy, several key initiatives and supportive policies have been implemented to guide industries towards greater EE. These initiatives focus on providing sector-specific resources, training, and tools to help companies optimize energy consumption and integrate energy-efficient practices.

A sector benchmarking initiative was undertaken by ENEA, funded by the Ministry of Environment and Energy Security through the publication of the"*Quaderni dell'efficienza Energetica*"series. These sector-specific guides were created to help companies and professionals navigate the EAs process by providing detailed insights into energy performance indicators, monitoring systems, and best practices for efficiency improvements. The guides cover a wide range of industries, including glass, cement, pharmaceuticals, waste incineration, foundries, hotels, and offices, with additional sectors (such as ceramics, plastics, and textiles) set to be included in the future. These guidelines serve as a valuable tool for companies, offering concrete examples of implemented EEMs along with their estimated energy and financial benefits. By providing sectoral benchmarks and detailed case studies, the *Quaderni* help enterprises to take informed decisions on how to optimize their energy consumption. The development of energy benchmarks and the analysis of interventions was achieved by examining the EAs conducted by Italian companies and uploaded to the *Portale Audit102* since 2019. This activity demonstrates how structured data collection enhances the value of EAs by providing companies with practical tools that increase the awareness of their EE performance.

Another key initiative in Italy is the EE Awareness Plan for SMEs, which falls under the category of supportive policies. This program aims to bridge the knowledge gap among SMEs by offering training, workshops, and informational materials on energy management and efficiency strategies. Since SMEs are often exempt from mandatory EAs, these awareness initiatives play a crucial role in voluntarily driving efficiency improvements within the sector. During the campaign, sectoral guidelines were also presented alongside a suite of digital tools available on the national portal. Both are further supporting the adoption of effective EE practices. The Italian experience demonstrates how the prescriptive policy under Art. 8 EED, combined with appropriate data collection, has made it possible to develop information and data that have subsequently been conveyed to businesses through support actions in the form of guidelines and tools which have been disseminated through an information campaign across the territory.

In Portugal, the approach to EE is heavily data-driven, with an emphasis on detailed analysis and compliance mechanisms. The country has developed numerous initiatives aimed at promoting energy savings through sector-specific data and regulatory frameworks. This ensures that companies are supported in their efforts to reduce energy consumption and meet national targets.

One of the key initiatives is the development of Subsector Notebooks ("*Cadernos Sectoriais*"), created by ADENE using data from the SGCIE system. These notebooks analyse energy consumption patterns and efficiency indicators in industries that have implemented PREn. The notebooks provide companies with a roadmap for implementing energy-saving measures. They highlight the most effective strategies and their expected payback periods. By presenting real-world data and sector-specific benchmarks, the notebooks help companies to identify the most impactful interventions for reducing their energy intensity and carbon footprint.

From a regulatory standpoint, Portugal's SGCIE system ensures that energy-intensive industries comply with EAs obligations and efficiency targets. Companies consuming more than 500 toe per year are required to conduct audits and implement EE measures every eight years, with specific targets to reduce energy intensity by at least 6% for large installations and 4% for smaller ones. The program also prioritizes measures with short payback periods, making efficiency improvements more financially attractive for businesses.

Another interesting example of a prescriptive policy is the Energy Consumption Management Regulation for the Transport Sector (RGCEST), which mandates EAs and efficiency measures for transport companies and businesses with energy-intensive fleets. By requiring companies to develop and monitor Energy Consumption Rationalization Plans (PRCEs), this initiative helps reduce fuel consumption and CO_2 emissions in the transport sector.

Conclusions

This paper highlights the policy frameworks for EAs and EnMS in Italy and Portugal, with a particular focus on EEMs data collection procedures within the respective national policies, such as the Portuguese SGCIE system and the Italian Legislative Decree 102/2014. The data collected and analysed highlight the extensive data collection efforts in Portugal and Italy regarding the implementation of EEMs under the frameworks established by national policies. These efforts, stemming from the obligations set out in Art. 8 EED, focus primarily on gathering comprehensive data from EAs and the subsequent implementation of EEMs across various sectors. While energy savings are a key outcome, the primary emphasis has been on systematically collecting and analysing data to monitor progress and ensure compliance with national and EU energy efficiency goals.

Both countries demonstrate structured data collection mechanisms that provide valuable insights into the effectiveness of EAs obligation and its role in driving EE. The availability of data over multiple years enables an understanding of the impact of economic cycles on energy consumption and savings, offering a foundation for future policy refinement. In this context, the ongoing monitoring and analysis of these data are crucial for ensuring that EE policies remain adaptive and effective in the face of changing circumstances.

Looking ahead, the implementation of these measures will be further shaped by the transposition of the revised EED, particularly Art. 11, which introduces more stringent requirements for monitoring, reporting and data collection. Both Italy and Portugal should further enhance their systems in response to these new obligations. Portugal, with the development of PREn and the obligation to implement measures under SGCIE, appears to be more aligned with the transposition of Art. 11. Italy has a well-structured framework for energy-intensive enterprises, although there are currently no obligations requiring the implementation of Action Plans.

Both countries have focused on reducing energy consumption in energy-intensive enterprises, albeit with different approaches: a prescriptive policy in Portugal and access constraints to incentives in Italy through the"*Energivori*"program. The digitalization of EAs management in these countries plays a key role in this transition, improving data quality, compliance monitoring, and strategic decision-making. The systems used provide insights into national and sectoral EE trends, fostering a culture of continuous improvement and enabling businesses to benchmark their performance.

In conclusion, the integration of prescriptive, economic, and supportive policies in both Italy and Portugal, combined with advancements in digitalization, strengthens their approach to EE governance. These efforts not only contribute to national and EU sustainability goals but also offer valuable lessons for other countries seeking to optimize their own EAs and EnMS ecosystem in line with the evolving requirements of the EED.

For companies, the systematic collection and analysis of energy data—supported by digital tools -facilitates informed investment decisions, enhances internal energy management, and provides benchmarks to assess performance against peers. This not only increases energy savings but also strengthens long-term competitiveness and resilience in energy-intensive sectors. Looking forward, the main challenge for both Portugal and Italy will be to ensure that existing frameworks for EAs and EnMS evolve to support more dynamic, real-time monitoring and enable the integration of new data sources, such as smart metering and ESG reporting frameworks. Furthermore, aligning policy enforcement with industrial decarbonization goals, while ensuring cost-effectiveness and minimizing administrative burdens, will be essential to maintaining engagement from obligated parties and achieving long-term energy efficiency targets.

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Data availability No datasets were generated or analysed during the current study.

Declarations

Competing interests The authors declare no competing interests.

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