AUDIT2MEASURE

D3.2: Assessment of Energy Saving Measures to support the strategy of decision makers and of companies' energy management maturity

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Author organisation	NTUA
Reviewers	ESCAN, ADELPHI
Contributors	Nikos Vourgidis (NTUA) Ioanna Makarouni (NTUA) Dimitris Dimitrakopoulos (NTUA) Constantinos Theofylaktos (NTUA)
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LEGAL NOTICE

ABOUT

Industry is a key player in energy consumption and economic impact in the European Union (EU) and energy audits represent an important tool to improve energy efficiency in the sector; despite both the spread of energy audits and the knowledge of their benefits, the actual implementation rate of the Energy Savings Measures (ESM) proposed by energy audits is relatively low. **The main aim** of the AUDIT-TO-MEASURE (Leading businesses towards climate neutrality by speeding up the uptake of energy efficiency measures from the energy audits) project **is to support companies in the uptake of audits measures necessary to reduce the energy consumption supporting their energy transition**. AUDIT-TO-MEASURE will develop and implement a new engagement strategy (called "Audit2Action") to put into action the opportunities emerging from energy audits.

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PROJECT PARTNERS

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ABBREVIATIONS

BAFA	German Federal Office for Economic Affairs and Export Control
CHP	Combined Heat and Power
EMS	Energy Management Systems
EMMM	Energy Management Maturity Model
EnPI	Energy Performance Indicator
ESM	Energy Saving Measure(s)
EU-MERCI	EU coordinated MEthods and procedures based on Real Cases for the effective implementation of policies and measures supporting energy efficiency in the Industry
HVAC	Heating, ventilation and air conditioning
ICT	Information and Communication Technology
ISO	International Organization for Standardization
KPI	Key Performance Indicator
LED	Light Emitting Diode
NEBs	Non-Energy Benefits
SEU	Significant Energy Use
SME(s)	Small and Medium size Enterprise(s) (EU definition)
VOC	Volatile Organic Compounds

1. INTRODUCTION

Considering the EU's climate ambitions and goals to ensure that the target of at least a 55%[1] reduction in greenhouse gas emissions is met, the revised Energy Efficiency Directive[2], which was published in the Official Journal on 20 September 2023, significantly raises the EU's ambition on energy efficiency, placing it at the forefront of energy policies and significant investment decisions taken across the energy and non-energy sectors.

The industrial sector is one of the largest energy consumers and a significant contributor to greenhouse gas emissions[3]. Considering this reality and the directive's expanded scope of energy audit requirements, which establishes criteria based on energy consumption regardless of company size, the adoption of energy audit proposals and the subsequent implementation of Energy-Saving Measures (ESM) is not merely a prudent choice but a strategic necessity. Consequently, the pressing need for energy savings requires a comprehensive analysis of energy-saving measures.

Ten partners (RSE, IEECP, ESCAN, NTUA, HERA, ENVIROS, AEDHE, POVAS, CCIK and ADELPHI) from six EU countries (Czech Republic, Germany, Greece, Italy, Netherlands and Spain) joined forces within the AUDIT2MEASURE project.

The primary objective of AUDIT2MEASURE is to lead industrial businesses toward climate neutrality by accelerating the adoption of energy saving measures (ESM) resulting from energy audits. This will be accomplished mainly through:

1. The analysis of different auditing systems across partner countries and the identification of barriers and drivers of ESM implementation;
2. The development of the AUDIT2ACTION Strategy;
3. The methodological assessment and benchmarking of various energy-saving measures proposed in energy audits and/or implemented by industrial companies, as well as the provision of technical and engineering tools to support the process;
4. The assessment of the companies' energy management maturity, according to ISO 50001 standard and the provision of tools to support the companies' self-assessment.
5. The capacity building to speed up the uptake of ESM;
6. The direct and sustainable support to industries;
7. The appropriate platforms, engagement, communication and dissemination.

Deliverable "D3.2: Assessment of Energy Saving Measures to support the strategy of decision makers (and of companies' energy management maturity)" addresses points 3 and 4 of the above list. Such a deliverable is organised in two parts:

- Part 1 (chapter 2 and 3): This part addresses the methodological assessment and benchmarking of various ESM proposed in energy audits and/or implemented by

[1] *The European Green Deal*. (2021, July 14). European Commission. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en.
[2] *EUR-Lex - 32023L1791 - EN - EUR-Lex*. (n.d.). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ%3AJOL_2023_231_R_0001&qid=1695186598766.
[3] *Energy efficiency directive*. (n.d.). Energy. https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficiency-targets-directive-and-rules/energy-efficiency-directive_en#the-revised-directive.

industrial companies, as well as the provision of technical and engineering tools to support the process;

- Part 2 (chapter 4): This part addresses the assessment of the companies' energy management maturity, according to ISO 50001 standard and the provision of tools to support the companies' self-assessment.

2. ASSESSMENT OF ESM: METHODOLOGY & STRUCTURE OF APPROACH

Chapters 2 and 3 cover the first part of the deliverable, which addresses the methodological assessment and benchmarking of various ESM proposed in energy audits and/or implemented by industrial companies, as well as the provision of technical and engineering tools to support the process.

The assessment of ESM is a critical component of the Audit2Action strategy to inform and motivate managers and other decision-makers to adopt ESM by providing reliable and comprehensive information in the decision-making process and mitigate perceived risks. The objective of this work is to provide data and a technical/engineering framework to support industrial companies in overcoming the barriers hindering the adoption of cost-effective ESM, through enabling the comparison of ESM and their respective KPIs.

This first part aims to present work implemented for the "Assessment of KPIs and ESM to support the strategy of decision makers" (Task 3.2) of Work Package 3.

The Work is developed in the following main steps:

- Initially, a set of KPIs is identified for benchmarking and ranking different ESM, considering different areas of improvement: energy savings, environmental impacts, economic feasibility and Non-Energy Benefits (NEBs) (also considering social responsibility). Once KPIs are defined, industry data are gathered and KPIs were refined where required, by using the collected information from industries, their associations and energy experts. Following the identification of KPIs, the project team assesses the results of numerous ESM coming both from energy audits and best practices from partners' experiences, third parties and other EU and national projects. The analysis is complemented with the KPIs assessment and with the information received directly from the companies in some cases;
- For a set of ESM, an executive sheet is prepared: each sheet contains a short description of the measure and the main data to characterize it, using the most relevant KPIs defined in the first part of T3.2; In parallel, a database is developed to store, organise and visualise ESM information and assessment data in technology groups (e.g., heat, compressed air, lighting, etc.) and industrial sectors. ESM are assessed and ranked using a merit scale considering their effectiveness in terms of energy, cost, environment and non-energy benefits. This provides a database for decision makers, with which the results stemming from the audits can be scooted and compared and thus their effectiveness can be assessed.

As per the steps identified above, this deliverable aims to present the methodological framework for the assessment and benchmarking of energy-saving measures in the industrial context. It addresses ESM in different partner countries, in varied industrial sectors, intervening in different technological groups. The methodology introduces a set of Key Performance Indicators (KPIs) that address energy, environmental and financial aspects, highlighting also the value of Non-Energy Benefits when considering the implementation of such measures. The deliverable also aims at providing the results from the assessment and benchmarking methodology applied on a large number of ESM (over 3,000 ESM) collected by the A2M partners, providing thus the companies executives and staff with a valuable source of information and a supporting database of energy saving experiences in industries.

The first part of the deliverable is structured as follows:

- Information on Data collection procedure for ESM from energy audits: During the data collection procedure, these measures were reported on the A2M Data Collection template, which was used to collect the most crucial technical and quantitative information about energy-saving measures and qualitative information about the companies that have either being proposed or have implemented the measures. Principal sources of information included national and European databases, such as the EU-MERCI project database and the BAFA Database, as well as direct input from energy audits and energy auditors;
- Information on Key Performance Indicators for the ESM Assessment: Considering the variances and different approaches followed in each country, as well as availability of relevant data, a set of Key Performance Indicators (KPIs) is introduced to address the assessment of energy aspects, environmental aspects, financial aspects as well as other non-energy benefits of the ESM. This section provides information on each one of the KPIs, noting also if it is considered a mandatory or not indicator for the evaluation and benchmarking exercise to follow;
- Defining the Evaluation and Benchmarking System for the ESM Ranking: A methodology to score the ESM and a benchmarking system based on the evaluation of the afore-mentioned KPIs are presented;
- An ESM database for informed decision making: The A2M Database hosts over 3,000 ESM obtained during the project's activities and presents the results of their assessment and benchmarking in a visual, comprehensive manner, with appropriate levels of aggregation and selection filters;
- Statistical Analysis and Assessment of ESM Across 8 Industrial Sectors: In these sections, a statistical analysis of the assessment and benchmarking results is presented, per industrial sector and technology group. A set of key findings is also highlighted, always considering the specificities of the pool of ESM the analysis is applied on;
- Executive Sheets: The project developed executive sheets of selected ESM that have been identified as being of particular interest for the stakeholders. The executive sheets are brief and concise documents, targeted for the information needs of company executives. This part of the deliverable presents the executive sheets template and the selection process of the related ESM;
- Next steps and Connection with other WPs' activities: The deliverable presents in this section the next steps with respect to the use, the enrichment and the validation of the methodology, the results and the database. This is also reflected in the connection with the other WPs, especially WP4, WP5 and WP6.

At the end of the deliverable, the authors summarize key findings and concluding remarks.

2.1 Data collection procedure for ESM from energy audits

Addressing the diverse energy-saving measures proposed in energy audits of industrial facilities presents a multifaceted challenge, particularly when these audits follow varying structures and formats due to the legal specificities and audit guidelines introduced by the different national local legislations. Each audit report might emphasize different facets of energy conservation, prioritize various metrics and utilize unique methodologies, thereby complicating the task of providing a unified approach in assessing ESM. In order to address the disparities that hinder direct comparisons, aggregating data and discerning overarching trends across audits of different countries, the A2M project has provided a data template in order to receive the most relevant qualitative and quantitative information on the ESM proposed by energy audits of industries across the projects partner countries.

Since the homogeneity of a dataset is the very first pre-requisite to enable a fair and relevant comparison among different data sources, a set of data fields which is common among all partners countries was needed. In general, the data fields should gather the following information:

- Information about the audited company regarding the size, industrial sector by NACE codification, turnover, etc.;
- Information about the ESM, including its description, lifetime, reference year, status (either proposed and/or implemented), technology group, etc.;
- Information about the energy and carbon savings estimated by each energy auditor conducting the audit and proposing the measure;
- Information about the financial metrics employed to techno-economically assess each ESM in the audit report;
- Information about the perceived non-energy benefits of each ESM.

Since non-energy benefits are not frequently reported in energy audit reports, the project partners were asked to rate each ESM proposed in energy audits using a predefined list of non-energy benefits, most commonly mentioned in industrial energy efficiency literature. NEBs in the context of energy-saving measures proposed in industrial energy audits provides valuable insight into these measures' global impact. However, the limitations of the evaluation should be addressed. Since energy experts bring their individual perspectives, experiences and biases to the evaluation of NEBs, the majority of these limitations derive from the inherent subjectivity of the evaluation. Consequently, not only can the evaluation of NEBs vary from auditor to auditor, but also from country to country. Additionally, the evaluation procedure may be limited by the predefined list of NEBs from which auditors must select. Even though the Non-Energy Benefits used in the context of A2M are the most commonly cited in the scientific literature, such a list can inadvertently restrict the scope of NEBs considered, potentially overlooking less conventional but equally essential benefits.

Instead of predefining the industrial sectors, the project partners could concentrate on their respective national industries of interest.

In addition, the industry data reported in the template included not only the measures proposed in energy audits, but also measures that were implemented, thereby utilizing the project partners' expertise in industrial energy efficiency and best practices.

After considering these basic specifications within the project, a total of 3,191 ESM were obtained and analysed as indicated in Table 1.

Table 1: Industries and ESM identified through the data collection process.

NACE Code	Industrial Sector	Number of Measures
10	Food	245
20	Chemicals	251
21	Pharmaceuticals	86
22	Plastics	194
23	Ceramic	219
24-25	Metal	680
28	Machinery	1,221
29-30	Automotive	295
	Total	3,191

However, some difficulties were encountered during the data acquisition process, which largely stemmed from the differentiation of the sources used. The EU-MERCI Database and the BAFA Database along with energy audit reports that were either accessed directly or provided by energy auditors, were the primary sources utilised for the data collection. A significant challenge identified during this process was the different legislative auditing frameworks, which resulted in disparate reporting standards and requirements, making it difficult to not only compile a unified dataset but compare and evaluate ESM across partner countries. In addition, the reliability and precision of proposed measures are intricately linked to the knowledge and methodologies utilised by energy auditors from different countries.

When proposing ESM, energy auditors with diverse educational backgrounds and professional experiences may employ distinctive calculation techniques and techno-economic analysis approaches. These variations are underscored by the results obtained from D2.1 "Report of state-of-the-art auditing system and ESM implementation", which provided an all-encompassing analysis and comparison of the six project partner countries' national audit systems, policies and guidelines. Even though audit processes and reporting methodologies largely adhere to the EN 16247 guidelines, there is considerable variation among the surveyed countries regarding the evaluation and prioritization of ESM. According to these specific findings, this variation is most pronounced in the techno-economic criteria for ESM recommendations and the mandatory criteria for mandatory ESM implementation.

Harmonizing these diverse approaches and addressing the unique requirements of each country's energy auditing system laws is a crucial obstacle that must be overcome to ensure the accuracy and credibility of the quantitative assessment.

2.2 Defining the Key Performance Indicators for the ESM Assessment

In order to facilitate the project's need for a consistent and comprehensive evaluation and comparison of energy saving measures of different geographies, industries and processes, the selected KPIs have to provide a consistent framework for ESM evaluation in terms of energy savings, environmental impacts, economic feasibility, while also taking into account the perceived non – energy benefits of each ESM.

The KPIs provide a transparent method for objectively quantifying the benefits of ESM, evaluating their impact and efficacy through a structured and standardised methodology and fostering data-driven decision making. Taking into consideration the relevant literature regarding the main attributes of industrial ESM (Trianni et al., 2014) and the research conducted by Realini et al. (2017) and Maggiore et al. (2020) concerning the development of evaluation criteria that accurately reflect the effectiveness of measures, the KPIs used to evaluate the multiple effects of ESM are categorised into four groups and presented in Figure 1:

- Four KPIs used to assess an ESM on the Energy Pillar;
- Four KPIs used to assess an ESM on the Environmental Pillar;
- Four KPIs used to assess an ESM on the Financial Pillar;
- Four KPIs used to assess an ESM on the Non-Energy Benefits Pillar.

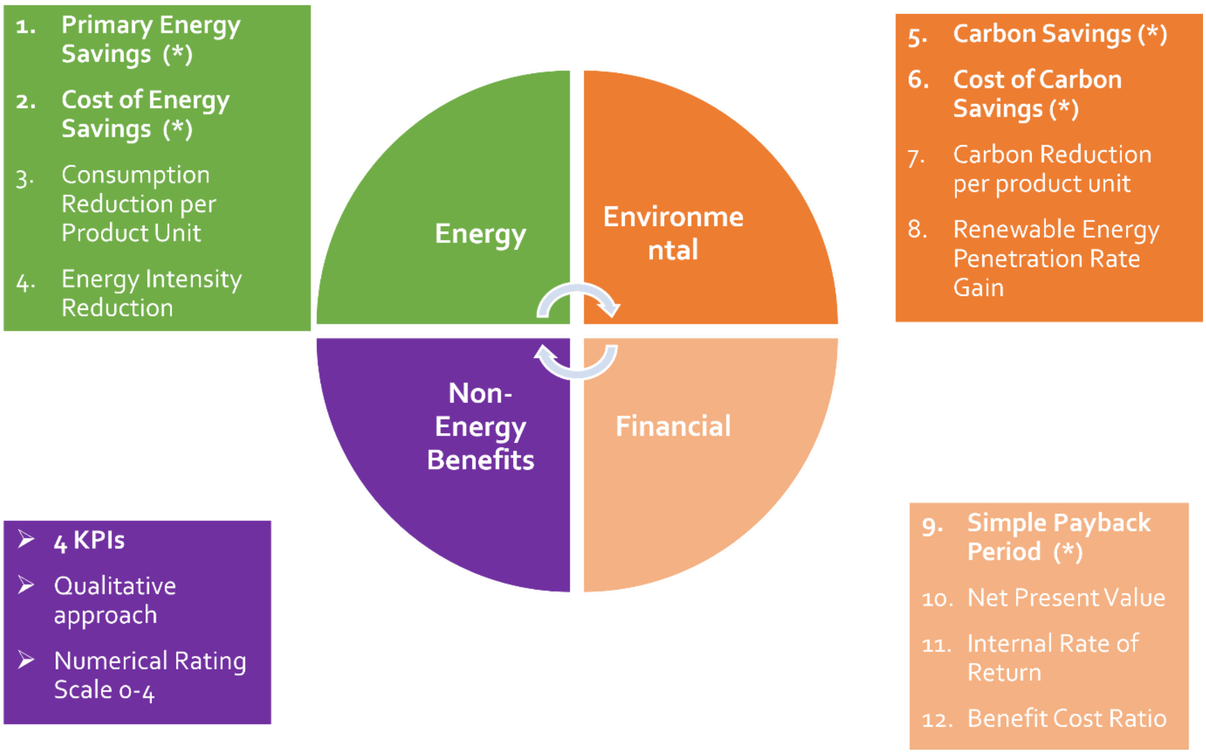


Figure 1: A2M KPIs

The KPIs were developed prior to the creation of the data collection template to ensure that the template would request the exact information required to calculate these KPIs, thereby establishing a unified and targeted data collection strategy.

In addition, whereas each KPI for the first three categories was designed to generate numeric results (quantitative approach), the non-energy benefits assessment of the ESM employed a qualitative approach.

The primary requirement for the KPIs was that they can be calculated using the available data about the ESM or directly inputted into the template for data collection distributed to the partners. Those explicitly entered by project partners on the data template are denoted by (I), while those calculated from the provided data are indicated by (C).

The second requirement arise from the need to guarantee a minimum number of calculable KPIs, which requires an adequate quality of data to calculate such KPIs from. Due to the two above mentioned reasons and the fact that auditors in various European countries use different metrics when proposing ESM, it was determined that the primary energy savings, the carbon savings, the capex of each measure and the simple payback period would be the compulsory input data required for the template completion.

As a result, a set of mandatory KPIs was created to ensure basic data availability to facilitate the analysis.

2.2.1 Energy KPIs

In the energy assessment pillar, the KPIs used for the assessment were:

- **Primary Energy Savings (Toe/Year, [I], Mandatory)**: Primary Energy Savings are the entire annual energy savings produced by an ESM, expressed in tons of oil equivalent. To account for and compare the various energy carriers, it has been decided to collect and evaluate the primary energy savings as an energy KPI. This data is not calculated and is entered directly by project partners into the data template either as a result of an audit report (proposed measure) or an implemented measure (best practices from partners' experiences);

- **Energy Intensity Reduction (%, [C])**: The energy intensity reduction relates the magnitude of energy savings to the amount of primary energy consumed by each industry. This key performance indicator provides a comprehensive view of energy efficiency within the context of overall energy utilization, providing a meaningful metric that correlates energy-saving efforts to the facility's general energy consumption patterns. This metric provides a more nuanced comprehension of the effectiveness of proposed measures concerning the energy requirements of the entire operation by focusing on the percentage of energy saved rather than absolute numbers. Energy Intensity Reduction aligns energy efficiency initiatives with operational scale and complexity, allowing for comparison across diverse facilities and ensuring that energy-saving efforts are appropriately tailored to each industrial operation's particular requirements and characteristics;

- **Cost of Energy Savings (k€/Toe/Year, [C], Mandatory)**: The KPI compares the ESM's costs to its annual energy consumption reduction. Cost of Energy Savings is an essential KPI that quantifies the economic viability of implementing industrial energy-saving measures. This KPI provides an understanding of the financial investment required to achieve a specified amount of energy savings, as opposed to solely examining energy reduction. By evaluating the monetary cost per unit of energy saved, organizations can directly compare different measures to determine the most cost-effective interventions. The Cost of Energy Savings enables decision-makers to align ESM with budget constraints and economic objectives. By integrating this KPI into the assessment process, industries can gain a nuanced perspective on the value proposition of various ESM, fostering a more strategic, economically sustainable approach to energy efficiency;

- **Consumption Reduction per Product Unit (Toe/Year/Tons of Product, [C]**): Energy Consumption Reduction per Product Unit is a highly relevant and targeted KPI for evaluating industrial energy-saving measures. This KPI narrows the assessment to the energy consumed per unit of product produced, revealing the direct relationship between production efficiency and energy consumption, in contrast to broader metrics. By monitoring and endeavouring to reduce the energy required to produce a single product unit, industries can identify inefficiencies, optimize processes and implement ESM that directly result in improved production performance.

2.2.2 Environmental KPIs

In the environmental assessment pillar, the KPIs used for the assessment were:

- **Carbon Savings [tCO_2/Year, [I], Mandatory)**: Carbon Savings as a Key Performance Indicator provides direct insight into the environmental impact of industrial energy-saving measures, reflecting the measurable reduction in greenhouse gas emissions associated with energy consumption. This KPI aligns industrial activities with the broader climate by quantifying the amount of carbon dioxide or other greenhouse gases mitigated through the implementation of ESM, while also facilitating the navigation of regulatory landscapes where emission reductions may be incentivised or mandated. In addition, it enables industries to prioritize ESM with substantial environmental benefits, thereby nurturing a greener industrial process;

- **Cost of Carbon Savings (k€/ tCO_2/Year, [C], Mandatory):** The Cost of Carbon Savings, expressed as the capital expenditure (CAPEX) per tonne of carbon dioxide equivalent (tCO_{2e}) saved, emerges as a crucial KPI for evaluating industrial ESM. This KPI provides a tangible metric for evaluating the economic efficacy of carbon mitigation efforts by correlating the financial investment required to implement a specific measure with the corresponding reduction in greenhouse gas emissions. It enables businesses to compare the financial costs of various energy-saving measures with their environmental benefits, facilitating a more nuanced and targeted approach to investing in sustainability;

- **Carbon Reduction per product unit (tCO_2/Year/Tons of Product, [C]):** Carbon Reduction per Product Unit, serves as an actionable KPI by measuring the reduction of greenhouse gas emissions relative to the production output. This KPI offers a nuanced view of environmental performance beyond mere energy efficiency;

- **Renewable Energy Penetration Rate Gain (%, [C]):** Renewable Energy Penetration Rate Gain serves as KPI for assessing industrial ESM, focusing on the proportion of renewable energy integrated into the overall energy mix.

2.2.3 Financial KPIs

In the financial assessment pillar, the KPIs used for the assessment were:

- **Simple Payback Period (Years, [I], Mandatory):** The Simple Payback period is a metric used to determine the profitability of an investment. It is a straightforward metric that calculates the time an ESM's savings takes to pay back its initial investment. This key performance indicator is particularly attractive due to its clarity and simplicity of interpretation, allowing decision-makers to evaluate the economic attractiveness of various energy-saving opportunities rapidly. Simple Payback Period is a useful preliminary screening tool for assessing potential initiatives, although it does not account for the time value of money or ongoing operational costs;

- **Net Present Value (k€, [I]):** The Net Present Value (NPV) provides a clear indication of the measure's profitability over a defined period and unlike rudimentary metrics such as the Simple Payback Period, NPV considers both the time value of money and the entire lifecycle of the energy-saving project, with a positive NPV indicating that the project is expected to generate value beyond its costs, making it an appealing investment and a negative NPV indicating a loss**.**

While SPP and NPV are important and valuable, the project explored additional financial KPIs that can provide a more complete picture of the financial benefits of energy-saving initiatives. These additional KPIs, included:

- **Internal Rate of Return (%, [I]):** The Internal Rate of Return (IRR) is a financial metric that is used as a key performance indicator (KPI) to assess the profitability of industrial energy-saving solutions. In essence, the IRR is the estimated annual rate of return on investment for a certain ESM and it is crucial in evaluating and ranking various initiatives. A greater IRR suggests a more appealing investment, implying that the ESM will provide a better return relative to its costs;

- **Benefit Cost Ratio (-, [I]):** The Benefit-Cost Ratio (BCR) is a useful key performance indicator for assessing the economic feasibility of industrial energy-saving solutions. It compares the present value of anticipated benefits, such as energy cost reductions and prospective revenue gains, to the present value of forecasted costs, including the initial investment and ongoing operational expenses. A BCR larger than one shows that the predicted benefits surpass the costs, indicating that the investment could be profitable. A BCR smaller than one, on the other hand, suggests that the costs may outweigh the benefits. The BCR enables for an easy comparison of alternative energy-saving strategies by providing a ratio that incorporates the relationship between the predicted returns and the associated expenditures. It assists decision-makers in identifying and prioritizing projects that are likely to give the best return on investment.

2.2.4 Non-Energy Benefits KPIs

Within industrial sectors, the pursuit of energy efficiency often focuses on reducing energy consumption and associated expenses, which are primarily assessed using standard metrics and Key Performance Indicators (KPIs). However, focusing entirely on these quantitative factors has frequently resulted in unintentionally ignoring non-energy benefits (NEBs), such as higher productivity, operational efficiency, employee well-being and environmental compliance. While these NEBs may not be found in standard energy audit reports, their absence implies a significant missed opportunity.

To this end, in the context of the Audit2Measure project, a qualitative assessment of the perceived Non-Energy Benefits of ESM was employed, addressing the Productivity, Operation & Maintenance, Work Environment and Other Non-Energy Benefits, a categorisation of Non-Energy Benefits similar to Finman and Laitner, 2001; Worrell et al. 2003; Nehler, 2016. Four non-energy benefits were identified in each category based on the idea that the non-energy benefits addressed should be linked with the most regularly reported ones in the industrial energy efficiency literature.

Non-Energy Benefits in Productivity [I] relate to improvements in product quality, production cost and the efficiency and general performance of industrial processes achieved through implementing ESM. The productivity Non-Energy Benefits addressed in the A2M project context include:

- Improved Product Quality (Pye and McKane, 2000; Finman and Laitner, 2001);
- Production Cost Reduction (Pye and McKane, 2000);
- Improved Production Efficiency (Nehler, 2018);
- Improved Equipment Performance (Finman and Laitner, 2001; Worrell et al., 2003).

Non-Energy Benefits in Operation & Maintenance [I] relate to improvements in the efficiency, reliability and safety of the equipment and systems that are achieved by implementing ESM. The Operations and Maintenance (O&M) Non-Energy Benefits addressed in the A2M project context include:

- Reduced Need for Maintenance (Skumatz et al., 2000);
- Reduced Maintenance Cost (Lilly and Pearson, 1999);
- Increased Equipment Lifetime (Lilly and Pearson, 1999);
- Enhanced Asset Value (IEA,2012).

Non-Energy Benefits in Work Environment [I] relate to improvements in the physical conditions and general quality of the workplace. ESM can contribute to a more comfortable, pleasant and productive work environment, which can improve employee satisfaction and retention as well as customer perceptions of the company or organization. The Work Environment Non-Energy Benefits addressed in the A2M project context include:

- Improved Lighting Conditions (Cagno et al., 2016);
- Improved Air Quality (Finman and Laitner, 2001; Worrell et al., 2003);
- Reduction of Noise (Finman and Laitner, 2001; Worrell et al., 2003);
- Increased Worker Safety (Pye and McKane, 2000; Lung et al., 2005).

Other Non-Energy Benefits [I] present a category that captures a variety of additional benefits that can result from implementing ESM related to reputation, sustainability, health and safety and regulatory Compliance. The Other Non-Energy Benefits addressed in the A2M project context include:

- Improved Corporate Reputation (combining the improved competitiveness and improved public image NEBs taken from Nehler, 2018);
- Improved Compliance with target agreements, laws and quality systems (Wagner et al., 2020);
- Increased Sales (Hall and Roth, 2003);
- Increased Employee Morale (Nehler, 2018).

To provide a ranking of the ESM based on value of the respective KPIs, it was necessary to provide a quantification for the NEBs; such a quantification represented a major challenge, due to their qualitative nature: for example, their quantification could largely depend upon personal/subjective features of the person who is assessing a certain NEB. Therefore, in order to render the assessment method as most objective as possible and for the sake of data homogeneity, the below explained benchmarking criterion has been ideated for NEBs assessment. By following this latter criterion, project partners should indicate with a "X" each non-energy benefit they deem pertinent to a specific ESM. The sum of the number of "X" marks in each category yields a score extending from 0 to 4. The scores obtained for each category are classified according to the following scale to indicate the degree of improvement in each category's non-energy benefit:

- Score 0: No Improvement
- Score 1: Slight Improvement
- Score 2: Moderate Improvement
- Score 3: Considerable Improvement
- Score 4: Significant Improvement

The following table provides an overview of the KPIs, the assessment pillar to which they belong, the calculation method and the polarity of each KPI.

Table 2: The A2M KPIs.

Assessment Pillar	Name of KPI	Formula	Polarity
Energy	Primary Energy Savings **(toe/year)**	Directly obtained from the template	Positive
	Cost of Energy Savings **(k€/toe/year)**	$\frac{CAPEX\ [k€]}{PES\ \left[\frac{toe}{y}\right]}$	Negative
	Energy Intensity Reduction **(%)**	$\frac{PES\ \left[\frac{toe}{y}\right]}{Primary\ Energy\ Consumption\ [toe]}$	Positive
	Consumption Reduction per Product Unit (toe)	$\frac{PES\ \left[\frac{toe}{year}\right]}{Production\ Output\ [kTones/y]}$	Positive
Environmental	Carbon Savings **(tCO_2/year)**	Directly obtained from the data template	Positive

	Cost of Carbon Savings (**k€/ tCO_2/Year**)	$\frac{CAPEX\ [k€]}{Carbon\ Savings\ \left[\frac{tCO_{2e}}{y}\right]}$	Negative
	Carbon Reduction per Product Unit (**tCO_2/Year/tons of Product**)	$\frac{Carbon\ Savings\ \left[\frac{tCO_{2e}}{y}\right]}{Production\ Output\ [kTones/y]}$	Positive
	Renewable Energy Penetration Rate Gain **(%)**	$\frac{REU_{after} - REU_{before}}{PEC} \times 10$	Positive
Financial	Simple Payback Period **(Years)**	Directly obtained from the data template	Negative
	Net Present Value **(k€)**	Directly obtained from the data template	Positive
	Internal Rate of Return **(%)**	Directly obtained from the data template	Positive
	Cost Benefit Ratio	Directly obtained from the data template	-
Non-Energy	Productivity	Numerical rating scale ranging from 0-4	Positive
	Operation & Maintenance	Numerical rating scale ranging from 0-4	Positive
	Work Environment	Numerical rating scale ranging from 0-4	Positive
	Other Non-Energy Benefits	Numerical rating scale ranging from 0-4	Positive

2.3 Defining the Benchmarking System for the ESM Ranking

After establishing the KPIs that will be used to assess the energy-saving measures, it is critical to develop a system for aggregating various KPIs stated in entirely different units into one global indicator to provide a more thorough perspective of how a project performs overall in every assessment pillar.

Because each KPI is expressed in a different unit and each measure may exhibit different behaviours in different KPIs (for example, an ESM may yield significant energy and carbon savings but may not be chosen for implementation by decision-makers due to a long payback period), it is necessary to convert the different KPI units to a common scale so that individual KPI values of a measure can be aggregated, resulting in a total score for both each assessment pillar and for the overall assessment.

To facilitate this method, each KPI value is assigned a score ranging from 0 to 100 points based on the maximum and minimum values in the sector's dataset. As previously stated, lower numbers are favoured for KPIs with negative polarity, whereas higher values are preferred for KPIs with positive polarity. For example, the ESM with the quickest payback period in a specific industry will be awarded 100 points. In contrast, the measure with the highest cost of carbon savings in the same sector will be awarded zero points. As a result, the position of each value in the dataset is expressed as a percentage of the highest/lowest KPI value in the dataset. The percentage is multiplied by 100 to determine how many points each ESM is awarded for each KPI value, with 100 representing the highest possible score.

Due to the high availability of data indicating a standardised and coherent assessment of various ESM, the KPIs used in the aforementioned method were narrowed to those marked as mandatory in order to maintain a common ground for ranking and interpretation of ranking results. The following table provides an overview of the KPIs used for benchmarking purposes for each assessment pillar, as well as their respective weighting factors.

Table 3: Weighting factors of KPIs and Assessment pillars.

Assessment Pillar	KPIs	KPI Weighting Factor	Assessment Pillar Weighting Factor
Energy	Primary Energy Savings **(toe/Y)**	0.5	0.25
	Cost of Energy Savings (**k€/toe/Year)**	0.5	
Environmental	Carbon Savings (**tCO_2/Year)**	0.5	0.25
	Cost of Carbon Savings (**k€/ tCO_2/Year)**	0.5	
Financial	Simple Payback Period **(Years)**	1	0.25
Non-Energy Benefits	Productivity	0.25	0.25
	Operation & Maintenance	0.25	
	Work Environment	0.25	
	Other NEBs	0.25	

The method is repeated for each of the KPIs utilised in each assessment pillar, yielding a total score for each assessment pillar, i.e., four scores for each measure because of the four assessment pillars.

Each pillar's aggregate score (ranging from 0 to 100) is then combined with equal weights, for simplicity reasons to obtain the total score of each energy-saving measure.

Measures obtained from multiple partner countries for the automotive industry are compiled into a single file. The total ESM score is the weighted sum of the ratings for each assessment pillar. The measures are then ordered by their cumulative score. This technique is used for all ESM within the same industrial sector. Each step mentioned above is replicated in the files generated for the other industrial sectors.

Notably, KPI values and reported scores for measures within the same industry are calculated and compared.

The objective is to extract indications of measures that outperform other measures within the same industrial sector and as such, no comparisons of data across different industrial sectors are performed.

3. RESULTS OF ANALYSIS OF ESM AND A DATABASE FOR INFORMED DECISION MAKING

3.1 Statistical Analysis

The A2M project collected measures of various industrial sectors, countries, company sizes, technology groups and implementation status among the 3,268 ESM collected using the data collection template. Before categorising the measures into industrial sectors for further analysis, the first step was to extract key insights, if any, regarding the implementation status and company size.

The analysis reveals, first and foremost, the undeniable dominance of audits as a main source of energy-saving measures within the industrial sector. In fact, 97% of the collected measures are the result of energy audits, highlighting the critical role that these audits play in developing effective and realistic/feasible energy-saving proposals. It should be noted, however, that the energy audit proposals are layered with subjectivity that can vary widely, particularly when viewed through the prism of various countries, each with its own industrial landscape, regulatory framework and energy challenges.

Most of the examined measures were proposed and/or implemented after 2020, so most of the data pertain to relatively new measures. Analysing these metrics provides a prospective viewpoint, ensuring that our recommendations are not only reflective of current best practices, but also poised to remain relevant in the future. This era's solutions are permeated with the most recent technological advances, making them more in tune with contemporary challenges and opportunities.

In addition, in the landscape of A2M data, 91.45% of the measures were proposed or implemented in large and medium-sized companies, which are the A2M project's target audience (Figure 2). This marked inclination is not merely a statistical anomaly; rather, it reflects a larger trend in the domain of industrial energy efficiency since large and medium-sized businesses have the scale and resources to invest in, experiment with and adopt innovative energy solutions. Their organisational structures often facilitate the incorporation of these advanced measures, placing them at the forefront of energy efficiency. Their predominance in our analysis highlights their central role in shaping and advancing the energy efficiency narrative, influencing not only their industry counterparts but also smaller businesses that look up to them as trendsetters.

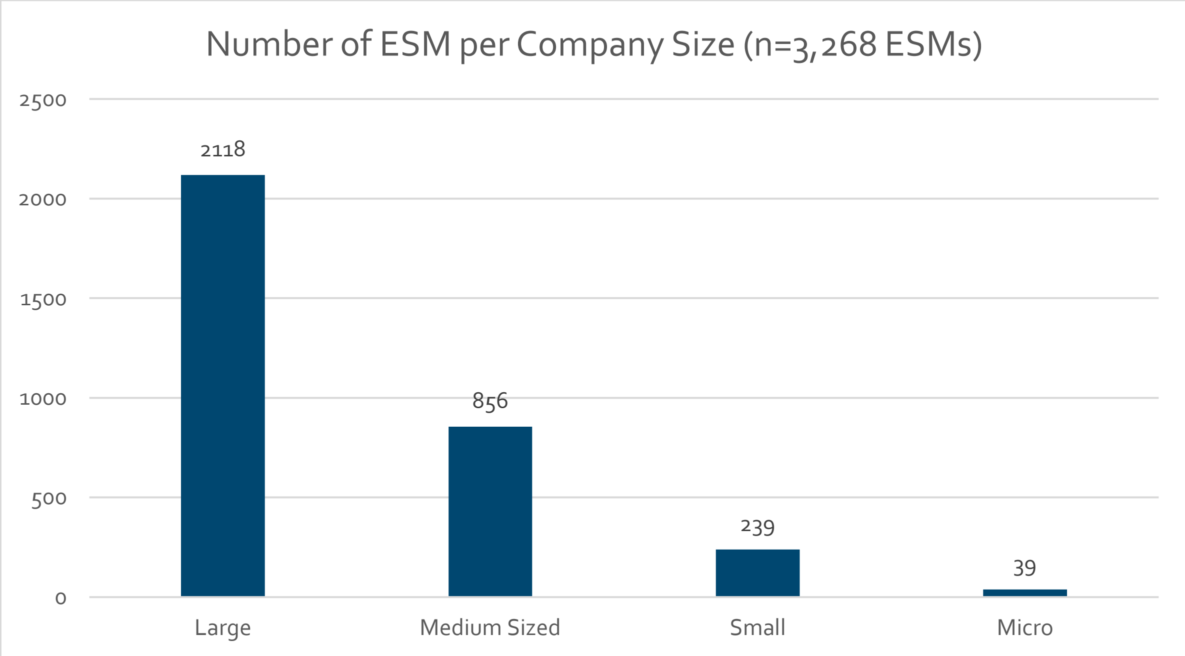


Figure 2: Number of ESM per Company Size.

Considering the technology of ESM, 11 distinct technology groups emerged, namely, Drives/Engines or Pumps, Lighting, Compressed Air, HVAC Systems, Building Envelope, Waste Heat Recovery, Power Generation, ICT, CHP, Process Heating / Cooling and Processes. The number of ESM identified in each group is presented in Table 4.

Table 4: Distribution of A2M ESM across technology groups.

Technology Groups	Number of ESM	Technology
Building Envelope	73	Cross – Cutting
Combined Heat and Power	4	Cross – Cutting
Compressed Air	524	Cross – Cutting
Drives/Engines or Pumps	153	Cross – Cutting
HVAC System	551	Cross – Cutting
ICT	66	Cross – Cutting
Lighting	1,289	Cross – Cutting
Other	6	Process Specific
Power Generation	365	Cross – Cutting
Process Heating/Cooling	112	Process – Specific
Processes	35	Process – Specific
Waste Heat Recovery	90	Cross – Cutting

The identified technologies are a combination of process-specific technologies (e.g., processes and process heating/cooling) that are tailored to specific industrial processes or industries and designed to accommodate the specific energy consumption characteristics of a given industrial process and cross-cutting technologies (e.g., Drives/Engines or Pumps, Compressed Air Systems, Lighting, ICT, Power Generation) that represent technologies and measures that can be applied across a wide range of industrial processes. Since the majority of ESM concerns cross-cutting technologies, the measures obtained and analysed within the context of the A2M project can offer the advantages of broad applicability and widespread dissemination across various industrial sectors.

Figure 3 depicts the average Primary Energy Savings per measure and the Capital Expenditure of ESM for the same technology group, providing a deeper look into the energy, environmental and economic aspects of the various technology groups.

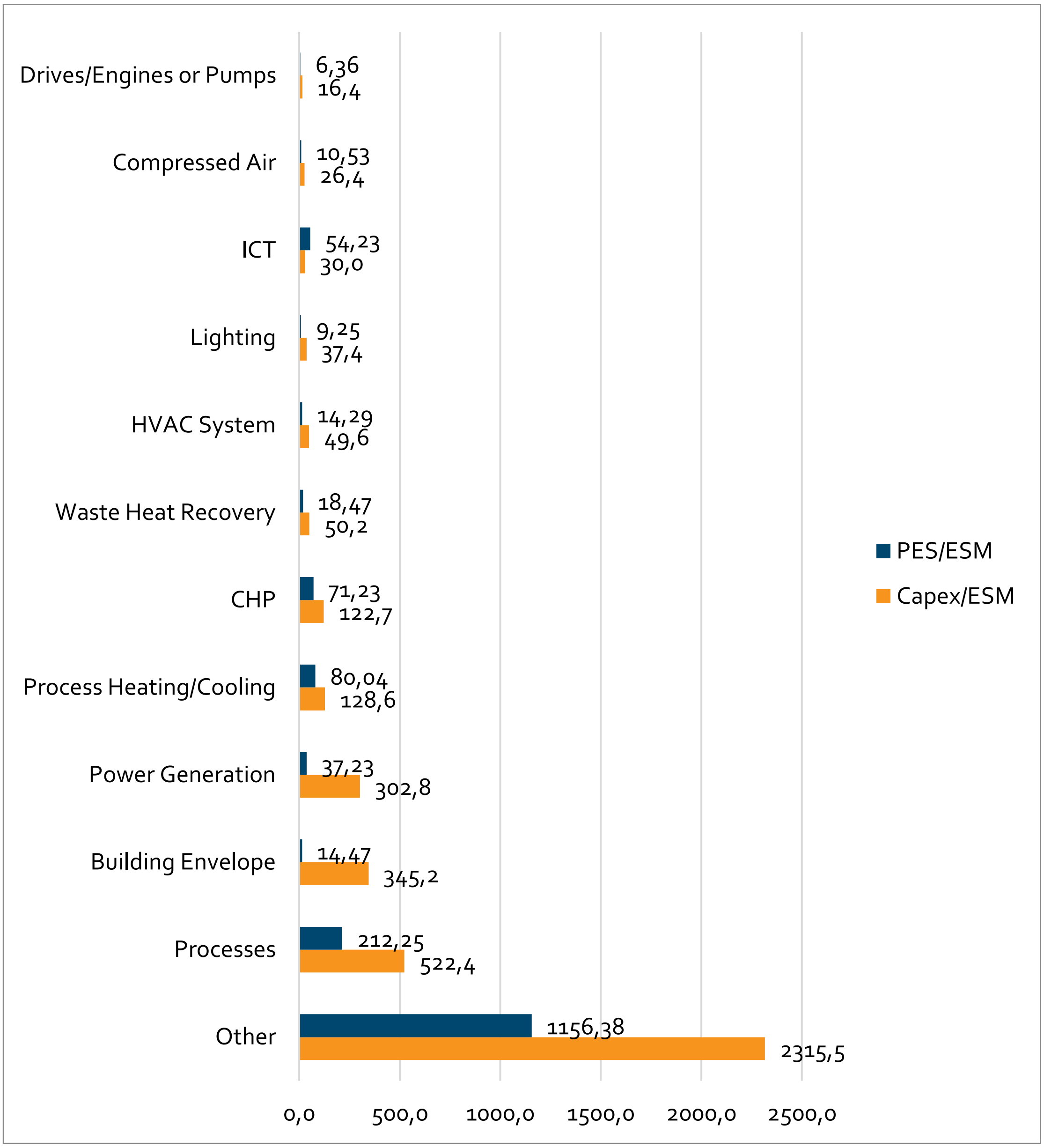


Figure 3:Comparison of PES/ESM (toe/year) and CAPEX/ESM (k€) per technology group (n=3,191 measures).

Lighting, Compressed Air and HVAC Systems offer significantly lower energy savings than their process-specific counterparts of measures pertinent to Process Heating/Cooling and core production Processes, with lighting technology offering the lowest average energy savings potential. The same conclusions also arise from Figure 4 which depicts the Carbon Savings (tCO_2/ESM) and the Capex per technology groups. Again, measures related to process heating/ cooling and core production processes offer significant Carbon Savings against measures of cross-cutting technologies such as Compressed Air, ICT, Lighting and HVAC systems.

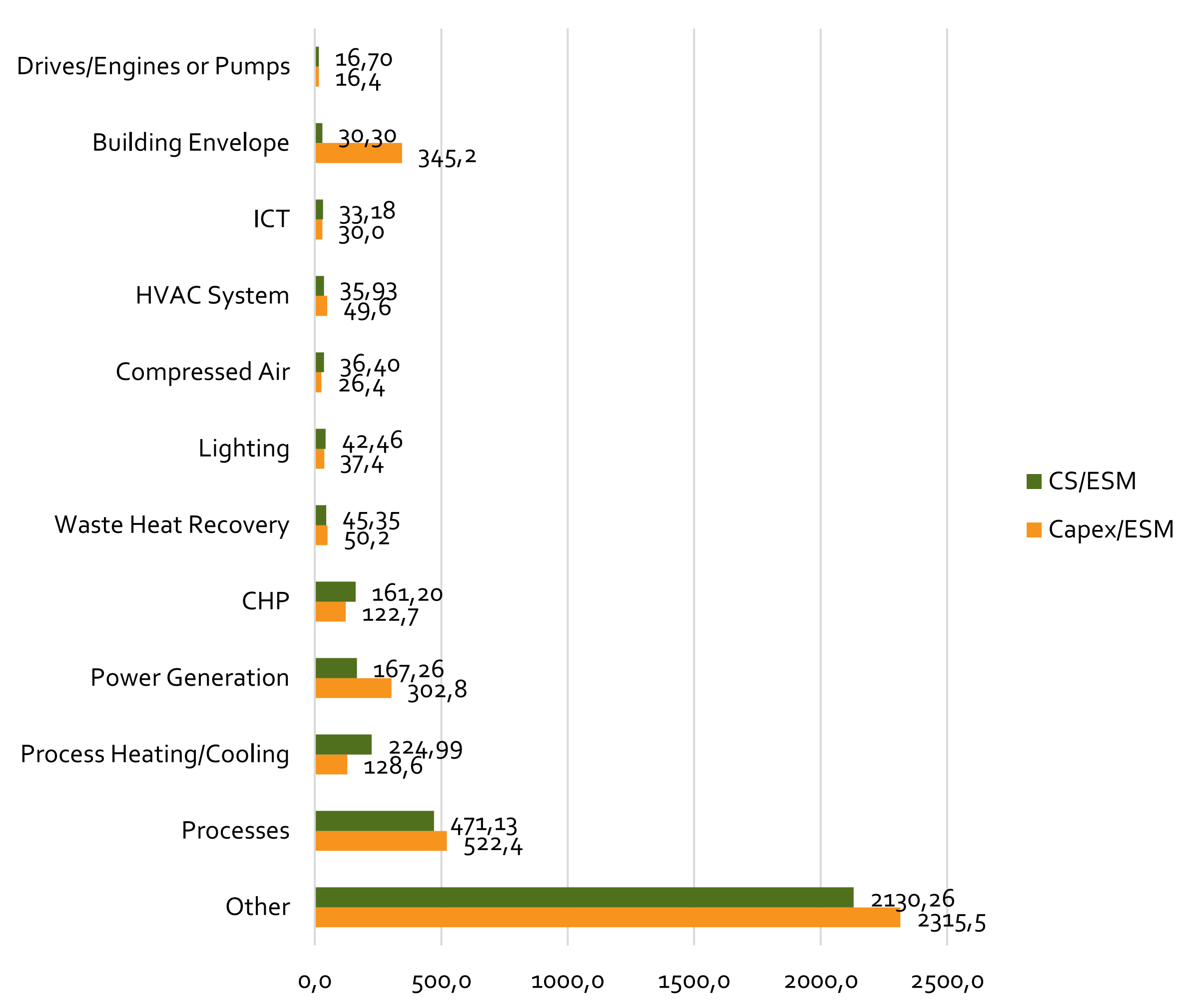


Figure 4: Comparison of CS/ESM (tCO2/Year) and CAPEX/ESM (k€) per technology group (n=3,191 measures).

In addition, it is evident that the measures with the lowest cost were those pertaining to cross-cutting technologies, in particular those related to Drives/Engines or Pumps at 16.4 k€ on average. In contrast, the technology group of processes has the second highest CAPEX, followed by the Building Envelope and Power Generation with the capital expenditures for these three technology groups ranging from 302 k€ to 522.4 k€.

Also, it is notable that the Other Technology Group category contains six measures from the Ceramic, Chemicals, Pharmaceutical and Plastics Sectors that pertain to very specific ESM addressing very specific industrial sector requirements. Such measures include, for instance:

- The replacement of the sieving plant of a ceramics Industry, the construction of a gaseous nitrogen production plant as alternative to the production, transportation and re-gasification of liquid nitrogen in a chemicals industrial company;
- Regenerative Thermal Oxidizer Replacement in a Pharmaceutical and a plastics Industry;
- Installation of a roto-concentrator for VOCs (Volatile Organic Compounds) abatement in a plastics industry.

Figure 4 demonstrates that while this technology group presents the highest CAPEX compared to the other technology groups, it also offers the greatest potential for energy and carbon reductions by a significant margin even though the nature of these ESM requires significant changes to core industrial processes and result in higher payback periods for the investment, as depicted in Figure 5.

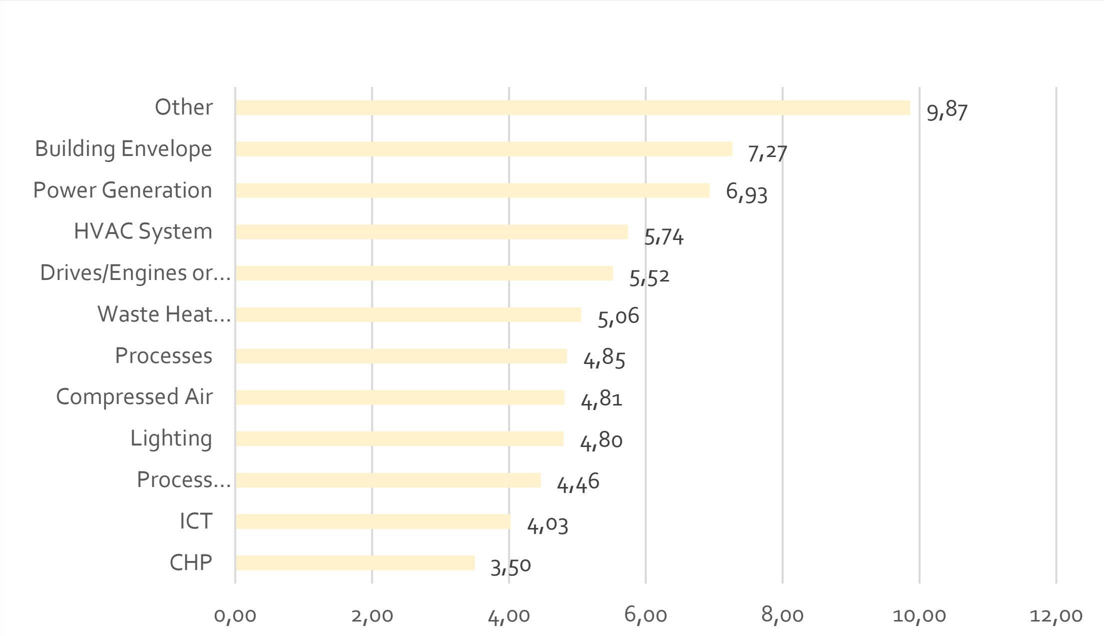


Figure 5: Comparison of simple payback period (years) values per technology group (n=3,191 measures).

The Cost of Energy Savings (k€/Toe saved) for each of the identified technology categories is illustrated in Figure 66. ICT group exhibits an average expenditure of 0.55 k€ per saved Toe. In contrast, most technology groups display values varying from 1.61 k€ to 4.04 k€ per saved Toe. The least cost-effective technology categories were Building Envelope and Power Generation, with the building envelope requiring an average of 23.86 k€ per Toe of energy savings.

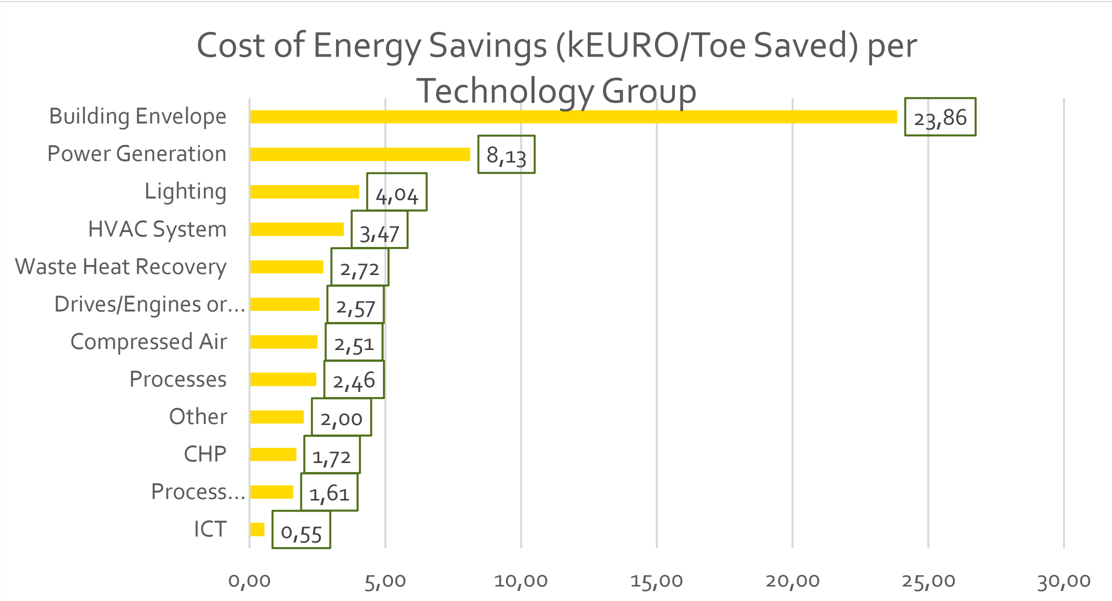


Figure 6: Comparison of Cost of Energy Savings (k€ / Toe saved) per technology group.

Furthermore, it is noteworthy that although ESM, classified as "Other technology group" displayed the highest average cost, it also exhibited substantial potential for energy conservation, with an average expenditure of 2,000 Euros for each Toe of energy saved.

Since the majority of ESM originating from Germany were extracted from the BAFA Database, which only contained numerical data for these ESM, it was determined that a non-energy benefits assessment for the German energy-saving measures could not be completed. Consequently, 126 ESM from partner countries, excluding Germany, were evaluated for the non-energy benefits assessment within the A2M project.

The most frequently observed non-energy benefits were improved production efficiency and equipment performance, which were observed in ESM across all technology groups except HVAC system and Building Envelope, followed by increased equipment lifetime (41 observations), reduced maintenance need (39 observations) and reduced maintenance cost (37 observations). These non-energy benefits are included in the Operation and Maintenance. Again, the non-energy benefit category is observed for all technology classes except HVAC systems and building envelopes. In the same category, process heating/cooling measures contributed most to the increased asset value, while Drives/Engines or Pumps, Compressed Air and Processes measures accounted for 8, 7 and 6 observations, respectively. Improved compliance with target agreements, laws and quality systems was observed for 31 ESM, primarily due to measures such as the installation of energy management systems (EMS). The installation of a heat recovery system, the replacement of gas boilers with a heat exchanger and the use of the waste gas from the co-generator to heat the air used in the atomizer to dry the raw material were among the process heating and cooling measures that appeared to contribute to a reduction in raw materials (18 observations).

In the work environment category, all the measures belonging to the lighting technology group, which consisted primarily of upgrades to LED lights, demonstrated improved lighting conditions (11 observations). In contrast, the improved air quality non-energy benefit was not present in the measures of the power generation, compressed air, lighting and ICT technology groups. Instead, it was observed in measures such as the replacement of thermal oxidizers, the installation of roto concentrators for VOCs abatement and the installation of a recirculation system for VOC. In addition, half of the noise-reduction NEBs (12 observations) belong to the Drives/Engines or Pumps technology group and include measures such as motor replacement with high-efficiency VSD motors.

Increased sales were the most frequently observed non-energy benefit of lighting upgrades, whereas improved employee morale was the most frequently observed non-energy benefit of power generation ESM. These two Non-Energy Benefits were the ones observed the least frequently.

Utilizing the methodology described in paragraph 2.2.4, the following table illustrates the various technology groups of the identified ESM and provides the improvement levels for each non-energy benefit category and for each technology group.

Table 5: Impact Assessment of Non-Energy Benefits per technology group (n=126 ESM).

Technology Groups	Number of ESM	Productivity	O&M	Work Environment	Other Non-Energy Benefits
Process Heating/Cooling	33	Moderate Improvement	Slight Improvement	No Improvement	No Improvement
Processes	17	Moderate Improvement	Slight Improvement	No Improvement	No Improvement
Drives/Engines or Pumps	15	Slight Improvement	Slight Improvement	No improvement	No improvement
Power Generation	13	No Improvement	No Improvement	No Improvement	Slight Improvement
Compressed Air	11	Moderate Improvement	Considerable improvement	No Improvement	Slight Improvement
Lighting	11	Slight Improvement	Moderate Improvement	Slight Improvement	Slight Improvement
ICT	9	Slight Improvement	Slight Improvement	No Improvement	Slight Improvement
HVAC System	8	No improvement	Slight Improvement	Slight Improvement	Slight Improvement
Building Envelope	3	No Improvement	No Improvement	Slight Improvement	Slight Improvement
Other	6	Slight Improvement	Slight Improvement	Slight Improvement	No Improvement

In conclusion, although easy-to-implement measures with relatively modest capital outlay and frequently shorter payback periods, emerge as the most frequently proposed measures in energy audits presenting a common and effective starting point, their adoption may be hindered by the fact that they do not present a significant impact on energy savings and carbon savings in comparison to measures that although may not be frequently recommended, are more difficult to implement, take longer to rebate and cost more to adopt, but have a more significant impact on energy and carbon savings. These may appear less desirable from a short-term financial standpoint. Yet, they have the potential to generate significant energy and carbon reductions. This dichotomy poses a dilemma for decision-makers, who must choose between immediate, cost-effective improvements and long-term investments for deeper, more significant energy and carbon reductions.

3.2 Assessment of ESM across 8 Industrial Sectors

As stated previously, the analysis of energy-saving measures is based on the results of the key performance indicators and the benchmarking methodology, yielding a total score for each ESM. The standard deviation of the scoring sample for all measures in each sector can serve as an indicator for the identification of measures with superior performance relative to all other records in the sample. The following diagram illustrates an example of a distribution curve (based on ESM from the A2M project's food sector).

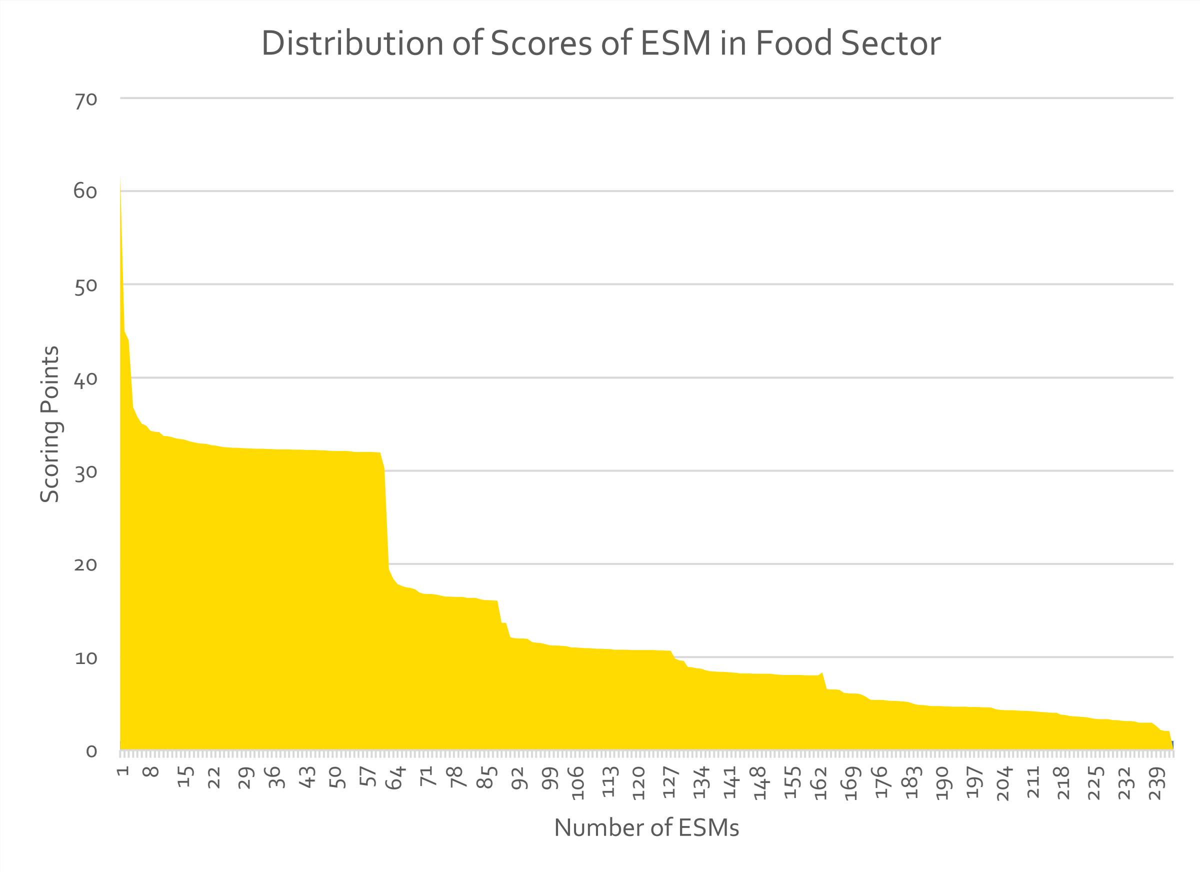


Figure 7: Distribution of Scores of ESM of Food Sector.

In the **Automotive industry**, 295 ESM from Germany, Spain and Italy were analysed for the years 2019 to 2021, with the results of the KPIs analysis presented in Table 6. Most of the measures (40%) involved lighting upgrades, with the most prevalent measure in this technology group being the conversion to LED lights, which resulted in average energy savings of 13.25 Toe/Year and a payback period of 6.26 years. Optimisation of cooling/thermal management in data centers and replacement of terminal equipment (e.g., printers, monitors, etc.) appear to have the shortest payback period among the technology groups in the same sector, despite producing the second-lowest energy and carbon savings. The building envelope technology group, which includes insulation measures for walls, roof and window renovation, has the second-lowest payback period (3 years) but the highest cost for energy and carbon reductions, whereas compressed air technology group measures offer moderate energy and carbon savings at low costs. With an average of 242,35 tCO_2/year, photovoltaic (PV) systems provide the greatest carbon reductions. Waste – Heat recovery measures provide, on average, the same amount of energy savings as compressed air measures but at a greater cost for both energy and carbon savings.

Table 6: KPI Results for the Automotive Industry (n=295 measures) per technology group.

Technology Groups	Number of ESM	PES (toe/Year)	CES (k€/toe/Year)	CS (tCO_2/Year)	CCS (k€/tCO_2/Y)	PBT (Years)
Building Envelope	5	22.98	17.07	52.01	7.54	3
Compressed Air	52	11.64	4.01	52.86	0.87	6.74
Drives/Engines or Pumps	12	10.45	5.58	35.79	1.35	6.94

HVAC System	46	21.88	4.64	65.74	1.91	5.28
ICT	5	3.68	5.06	17.13	1.09	2.8
Lighting	119	13.25	5.18	61.62	1.11	6.26
Power Generation	39	52.38	8.57	242.35	1.96	6.38
Process Heating/Cooling	6	20.07	12.81	34.85	2.95	11.21
Processes	1	5.29	1.7	11.97	0.75	4
Waste Heat Recovery	10	11.59	10.17	26.24	4.5	6.2

The results of the KPI analysis of 245 ESM in the **food industry** from Germany, Italy and Greece for the years 2019 to 2023 are presented in Table 7. Most of the measures analysed again belonged to the lighting technology group, with the Conversion to LED Lights and the Conversion to LED with daylight-dependent control and regulation being the most prevalent measures in this technology group. Measures in the ICT technology group, such as replacing terminal equipment (printers, monitors, etc.) and Optimizing ventilation/thermal management in data centers, had the shortest payback periods among all technology groups, but the most minor energy savings and second-lowest carbon savings. In addition, one measure was identified in the building envelope technology group (renovation of windows) and one was identified in the combined heat and Power technology group (Replacement of the existing BHKW[4]/Thermal Power Station – co-generation plant). However, their KPI results could not be compared with the KPI results of other technology groups due to lack of statistical significance. The processes technology group presented the most significant potential for energy savings with the longest payback period, while the process Heating/Cooling technology group was the second best in terms of energy savings with a relatively low average payback period of 4.37 years, consisting primarily of measures such as Replacement of the refrigeration system, Insulation of refrigeration system and fittings or pipelines and a new biogas boiler.

Table 7:KPI Results for the Food Industry (n=245 measures) per technology group.

Technology Groups	Number of ESM	PES (toe/year)	CES (k€/toe/Year)	CS (tCO_2/year)	CCS (k€/tCO2/year)	PBT (Years)
Building Envelope	1	4.93	12.97	11.17	5.73	7
Combined Heat and Power	1	12.41	18.14	28.08	8.01	8
Compressed Air	37	47.96	2.05	80.07	0.52	3.83
Drives/Engines or Pumps	12	8.77	5.79	25.16	1.4	3.96
HVAC System	32	19.77	2.81	48.01	1.04	4.84
ICT	7	4.37	4.24	23.59	0.91	2.59
Lighting	78	6.61	4.45	26.19	0.96	3.99
Power Generation	33	26.05	9.02	117.2	2.28	7.62
Process Heating/Cooling	19	110.42	4.51	311.88	1.51	4.37

[4] Blockheizkraftwerk, i.e. thermal power station in German.

Processes	8	150.7	3.47	382.01	1.31	8.54
Waste Heat Recovery	17	20.56	4.56	64.82	1.99	4.06

Ceramic

The results of analysing 219 ESM in the Ceramic industry are presented in Table 8. Similarly to the previous sectors, the lighting technology group was the most well-represented, with measures such as the conversion to LED lights offering the second-lowest primary energy savings and carbon savings and a payback period of 3.83 years on average. Comparable energy environmental and financial characteristics were presented in the ICT technology group, which consisted of only three measures. The technology groups with the most significant energy savings were those with process-specific measures, such as replacing furnaces with heat recovery system-based ones, kiln replacements and furnace burner replacements, even though the low number of ESM indicates that no safe conclusions can be drawn from this technology group. The same is true for the building envelope technology group, which consisted of two cavity wall insulation measures. Conversion to dark radiators, which is part of the HVAC system technology group, exhibited the same qualities as compressed air measures. Power Generation technologies including photovoltaics and waste heat recovery had the longest average payback periods of seven years.

Table 8:KPI Results for the Ceramics Industry (n=219 measures) per technology group.

Technology Groups	**Number of ESM**	**PES (toe/year)**	**CES (k€/toe/Year)**	**CS (tCO_2/year)**	**CCS (k€/tCO_2/year)**	**PBT (years)**
Building Envelope	2	9.3	25.99	3	20.06	5.70
Compressed Air	56	6.73	5.83	19.39	1.27	5.47
Drives/Engines or Pumps	8	16.78	7.37	30.78	1.63	3.3
HVAC System	26	7.4	3.86	17.33	2.93	4.27
ICT	3	1.21	2.24	5.61	0.48	3.33
Lighting	96	3.41	3.63	15.88	0.78	3.83
Other	1	1100	0.10	2654.7	0.04	0.1
Power Generation	16	41.76	12.52	136.48	3.8	7.44
Process Heating/Cooling	5	359.3	1.24	867.1	0.51	1.89
Processes	3	934	1.81	2254.07	0.75	2.6
Waste Heat Recovery	3	23.63	2.78	53.48	1.23	7

Chemical

In the Chemical industry, 251 ESM from Germany, Italy and Spain were analysed. 42% of the measures provided involved the replacement of luminaires with LED technology, followed by measures concerning the use of PV systems in the power generation technology group and the replacement of heating furnaces and optimization of heat distribution in the HVAC technology group. Regarding energy and carbon savings, these two technology groups displayed similar characteristics, with an average payback period of seven years. Replacement of the existing BHKW was the only measure identified in the Combined Heat and Power technology group, while measures in the process heating/cooling and processes technology groups yielded the second most significant energy and carbon savings, second only to a very special measure belonging to the "other technology group" which was the Construction of a gaseous nitrogen production plant as an alternative to the production, transportation and re-gasification of liquefied natural gas (LNG). Building envelope, compressed air and HVAC Systems measures all had payback periods of up to 7 years, with HVAC system measures having the highest number in terms of energy and carbon savings and compressed air systems having the lowest number in terms of the cost of energy and carbon savings.

Table 9: KPI Results for the Chemicals Industry (n=251 measures) per technology group.

Technology Groups	**Number of ESM**	**PES (toe/year)**	**CES (k€/toe/year)**	**CS (tCO_2/year)**	**CCS (k€/tCO_2/year)**	**PBT (Years)**
Building Envelope	5	6.18	31.48	13.9	5.09	6.9
Combined Heat and Power	1	0.95	5.29	2.14	2.34	1
Compressed Air	23	4.95	3.7	23.02	0.8	6.22
Drives/Engines or Pumps	15	2.23	18	10.37	3.87	4.93
HVAC System	39	21.5	8	51.84	3.3	6.47
ICT	1	-	-	-	-	6
Lighting	106	6.43	5.24	29.89	1.13	5.22
Other	1	3742.3	2.64	5103.14	1.94	5.1
Power Generation	39	18.53	8.12	91.68	1.89	6.93
Process Heating/Cooling	11	248.35	1.1	811.82	0.41	3.41
Processes	3	416.9	0.26	919.01	0.09	0.54
Waste Heat Recovery	7	41.11	2.63	93.03	1.16	3

Machinery

In the machinery industry, 1221 ESM were collected and analysed and the findings are shown in Table 10. The payback period of building envelope measures was the longest on average, whereas the payback period for process/Heating/Cooling measures was the shortest, except for the combined heat and power technology group, which included only one measure. Also, in this technology group, the second-greatest energy and carbon savings were observed. In contrast, processes and power generation appeared to have the greatest impact on energy and carbon savings, with an average payback period of up to seven years. ICT measures such as optimization of cooling/thermal management in data centers, replacement of terminal equipment and energy monitoring in data centers had the second-lowest payback period, lowest energy savings and second-lowest carbon savings, trailing only measures in the Drives/Engines or Pumps technology group. The same characteristics were observed in the lighting technology group, which had lower energy and carbon savings costs and a payback period of nearly 5 years on average.

Table 10: KPI Results for the Machinery Industry (n=1,221 measures) per technology group.

Technology Groups	Number of ESM	PES (toe/year)	CES (k€/toe/Year)	CS (tCO_2/Year)	CCS (k€/tCO_2/Year)	PBT (years)
Building Envelope	30	15.16	19.76	34.31	8.73	9.97
Combined Heat and Power	1	1.02	20.41	2.3	9.02	1
Compressed Air	170	6.5	4.84	30.12	1.07	4.71
Drives/Engines or Pumps	49	3.77	10.1	12.54	2.19	5.03
HVAC System	215	13.43	11.99	33.72	5.21	5.68
ICT	28	3.01	16.59	22.47	3.57	4.04
Lighting	542	10.53	5.09	48.49	1.1	4.82
Power Generation	126	39.13	11.7	177.72	2.71	6.76
Process Heating/Cooling	27	18.55	5.38	58.65	1.24	3.85
Processes	6	69.25	5.29	162.72	2.33	6.35
Waste Heat Recovery	27	12.25	10.93	28.06	4.65	5.48

Metal

The results of the analysis of 680 ESM from the Czech Republic, the Netherlands, Greece and Germany's metal industry are presented in Table 11. Lighting and HVAC system measures were the most prevalent, followed by compressed air technology measures. It should be noted that these figures were calculated for only nine ESM. Processes measures exhibited the second highest energy savings, behind one CHP measure (Replacement of the existing BHKW) and the second highest carbon savings, only behind power generation measures. Drives/Engines or Pump measures presented the least amount of energy and carbon savings, followed by ICT measures such as installation of EMS and measuring devices in the natural gas system, which indicated high costs of said savings but the second-lowest payback period.

The power generation technology group measures had the highest average carbon savings and the longest average return period, whereas the Drives/Engines or pumps technology group measures had the lowest energy saving potential. The two most represented technology categories, HVAC Systems and Lighting, presented savings ranging from 5 to 9 toe/year and carbon savings from 35 to 41 tCO_2/year with payback periods between almost 5 and 6 years.

Table 11:KPI Results for the Metal Industry (n=680 measures) per technology group.

Technology Groups	Number of ESM	PES (toe/year)	CES (k€/toe/year)	CS (tCO_2/year)	CCS (k€/tCO_2/year)	PBT (years)
Building Envelope	24	16.31	12.51	30.99	16.94	5.06
Combined Heat and Power	1	270.55	0.89	612.3	0.39	4

Compressed Air	127	7.89	6.96	36.72	1.5	4.92
Drives/Engines or Pumps	38	1.85	8.07	8.04	1.89	6.93
HVAC System	131	14.36	5.13	34.52	2.3	5.94
ICT	15	4.83	11.08	4.97	3.01	3.89
Lighting	228	9.2	4.89	41.74	1.05	4.89
Power Generation	70	48.79	8.21	224.43	1.79	7.25
Process Heating/Cooling	20	16.36	7.13	68	1.56	6.04
Processes	9	75.71	5.01	139.46	2.46	3.54
Waste Heat Recovery	17	18.47	3.87	41.8	1.71	6.12

Pharmaceutical

In the pharmaceutical industry, 86 measures from Spain, Italy and Germany were analysed and their outcomes are shown in Table 12. Lighting improvements and HVAC System measures accounted for 56% of the total, followed by process heating/cooling, compressed air and power generation measures. Due to the small number of measurements and their limited distribution across technology groups, it is unlikely to draw reliable conclusions.

Table 12: KPI Results for the Pharmaceutical Industry (n=86 measures) per technology group.

Technology Groups	**Number of ESM**	**PES (toe/year)**	**CES (k€/toe/year)**	**CS (tCO_2/year)**	**CCS (k€/tCO_2/year)**	**PBT (years)**
Building Envelope	2	6.6	32.53	39.06	17.64	8
Compressed Air	10	8.41	1.78	32.16	0.4	2.62
Drives/Engines or Pumps	1	70	1	95.45	0.73	2.1
HVAC System	21	9.7	9.5	31.63	4.12	4.8
ICT	1	12.59	24.47	58.55	5.26	16
Lighting	28	7.02	8.46	32.66	1.82	5.21
Other	2	182.5	7.95	440.43	3.3	18.75
Power Generation	9	38.75	7.44	180.27	1.6	5.89
Process Heating/Cooling	11	98.95	2.5	211.7	0.75	3.52
Waste Heat Recovery	1	112.25	1.87	254.04	0.83	1

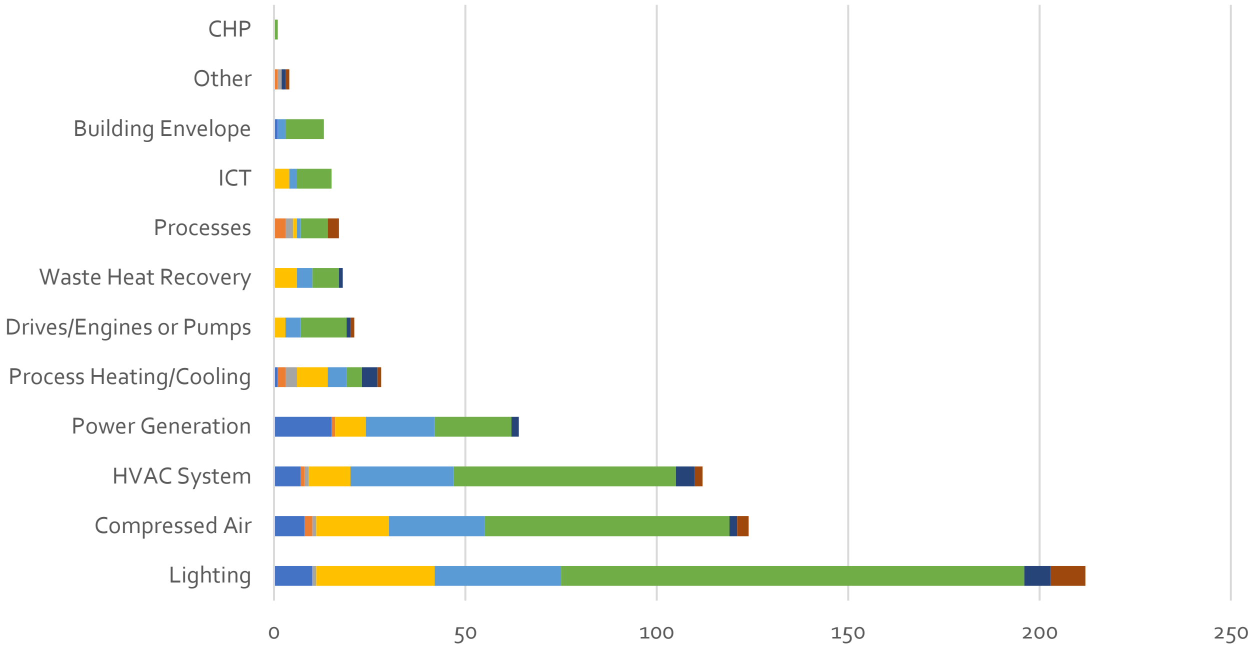
Plastics

In the plastics industry, 194 ESM from Italy, Germany, the Czech Republic and Greece were analysed. Again, as demonstrated in Table 13, most measures concerned lighting, compressed air and HVAC systems. Excluding the two measures from the Other Technology Group, process measures showed the greatest energy and emissions savings with a payback period of nearly four years, followed by heating, cooling and power generation measures, Building envelope, compressed air, lighting and HVAC System measures had the same average payback period of four years but significantly lower energy and carbon reductions than the above technology groups. In addition, process heating and cooling measures averaged the second-highest energy savings and the third-highest carbon savings, trailing only measures related to processes and waste heat recovery.

Table 13:KPI Results for the Plastics Industry (n=194 measures) per technology group.

Technology Groups	Number of ESM	PES (toe/year)	CES (k€/toe/year)	CS (tCO_2/year)	CCS (k€/tCO_2/year)	PBT (years)
Building Envelope	4	5.39	3.31	22.16	1.06	4.25
Compressed Air	40	12.26	5.8	42.87	1.77	4.12
Drives/Engines or Pumps	11	28.7	3.02	65.06	0.68	4.22
HVAC System	34	5.48	5.12	15.06	1.62	4.19
ICT	3	3.06	6.64	4.74	1.43	6
Lighting	61	12.82	4.09	52.12	1.09	3.41
Other	2	865.5	3.05	2071.42	1.27	8.25
Power Generation	19	26.8	7.46	32.93	2.31	7.25
Process Heating/Cooling	11	48.5	8.13	86.03	3.22	5.38
Processes	5	204.06	2.75	373.13	1.3	3.64
Waste Heat Recovery	4	29.1	4.17	121.24	1	5.5

After calculating the KPI values, a total score was computed for each assessment pillar based on the benchmarking methodology; the weighted sum of the scores in each assessment pillar was then computed for each ESM. The measures that scored higher than the standard deviation of the statistical sample created from the scores of all measures in each sector were extracted and considered promising candidates for higher performance relative to the remaining measures. A list of 629 measures was compiled and the distribution of those measures across technology categories is depicted in Figure 7.



	Lighting	Compressed Air	HVAC System	Power Generation	Process Heating/Cooling	Drives/Engines or Pumps	Waste Heat Recovery	Processes	ICT	Building Envelope	Other	CHP
Automotive	10	8	7	15	1					1		
Ceramic		2	1	1	2			3			1	
Chemicals	1	1	1		3			2			1	
Food	31	19	11	8	8	3	6	1	4			
Machinery	33	25	27	18	5	4	4	1	2	2		
Metal	121	64	58	20	4	12	7	7	9	10		1
Pharma	7	2	5	2	4	1	1				1	
Plastics	9	3	2		1	1		3			1	

Automotive Ceramic Chemicals Food Machinery Metal Pharma Plastics

Figure 6: Distribution of high scoring ESM per technology group and industrial sector.

Clearly, the preponderance of energy audit proposal measures is identified in HVAC Systems, Compressed Air and Lighting, which are the low-hanging fruit. This analysis may shed light on why these measures are frequently proposed in industrial energy audits, as they are frequently the simplest and most cost-effective improvements.

Despite the fact that cross-cutting technologies can be characterized as adaptable and applicable across multiple industries and technologies in different sectors, it is important to note that a comprehensive energy efficiency strategy should also include process-specific measures to address the unique challenges and opportunities within each industry context.

Moreover, even though, from a qualitative standpoint, cross-cutting energy-saving measures comprised the majority of the sample, in almost every industrial sector evaluation, the highest-ranking measures among the most promising candidates were almost always measures related to core industrial processes.

Thus, a balanced approach that utilizes both types of measures can provide the most comprehensive energy, financial and environmental benefits.

3.3 Executive Sheets: Analysing Selected ESM

Towards the objective of providing comprehensive information to the companies on the assessment of energy-saving measures, executive sheets have been prepared for a selected set of ESM.

Each executive sheet contains a short description of the measure and the main data to characterize it, the evaluation data using the KPIs identified in the A2M methodology, as well some information regarding the benchmarking of the ESM concerning other measures in the same industrial sector.

The task coordinator has developed, in consultation with the partners, the template with accompanying guidelines, considering the above contextual objectives and the requirement of having a brief and concise sheet that can inform and inspire high-level managers.

Annex 2 provides the Executive Sheets template, which includes information such as the KPI values, whenever that calculation was possible, the non-energy benefits assessment and the dedicated Audit2Measure evaluation label according to the Audit2Measure methodology, which provides the ranking of the measures in the specific industry, technology group and country.

The ESM for this analysis were chosen based on their scores as well as the objective of having a balanced, but not equal, distribution based on the following factors: industry, technology group and country. In addition, an emphasis has been placed on analyzing ESM that have already been implemented because they demonstrate actual results as opposed to estimated ones, as well as ESM that, according to the partners, may present a special or requested interest for replication by other companies, particularly those already included in our list of targeted stakeholders. The ESM selected for the executive sheets are listed in Table 14, along with their respective industrial sector, implementation status, technology group and country of origin.

Finally, the executive sheets are uploaded to the A2M Database to support the project's capacity building and replication activities by providing a concise overview of audit outcomes and KPI results, thereby facilitating the evaluation of their effectiveness.

Table 14: List of ESM included in the executive sheets.

ESM Description	Country	Industrial Sector	Status of Implementation	Technology Group
Optimization of the supply pressure	Germany	Automotive	Proposed	Compressed air
Improving compressed air production by better pressure set point and switching off at the time factory is not producing	Spain	Automotive	Implemented	Compressed Air
Installing light sensors in existing LED lamps	Spain	Automotive	Implemented	Lighting
Installing reactive and harmonics reduction device for air compressors	Spain	Automotive	Implemented	Compressed Air
Replacement of the sieving plant with a more performant one, constituted by a battery of 7 double deck vibrating sieves, which allows to work with a denser slip with a water content of 32% against the previous 34%, ensuring a significant thermal energy saving in the next step of atomization.	Italy	Ceramic	Implemented	Other
Replacing the furnace burners with innovative burner models that allow best modulation. The expected savings are of the order of 10-15% compared to the ex-ante configuration consumption	Italy	Ceramic	Implemented	Processes
Heat recovery (process)	Italy	Ceramic	Implemented	Process Heating/Cooling
Implementation of Cavity Wall Insulation in the site office building leading to a reduction of 19.500m³ gas / year	Netherlands	Ceramic	Implemented	Building Envelope
Replacement of the current gas boiler with a heat pump.	Netherlands	Ceramic	Implemented	HVAC System
Replacement of 20+ year old gas boiler with a more efficient model (HR107 with weather dependent adjustment)	Netherlands	Ceramic	Implemented	HVAC System
Recovery of oxygen enriched air from a nearby plant in order to reduce the quantity of air required in oxidizing column and so reduce compressors electrical consumption	Italy	Chemicals	Implemented	Processes
Construction of a gaseous nitrogen production plant as alternative to the production, transportation and re-gasification of liquid nitrogen	Italy	Chemicals	Implemented	Other
Replacement of gas boilers by heat exchanger with BIOCEN. Biocen station nearby, no investment needed for infrastructure only switching contracts between the natural gas supplier for Biocen supplier	Spain	Chemicals	Proposed	Process Heating/Cooling
Installation of shelters at loading bays	Spain	Chemicals	Proposed	Building Envelope
Replacement of compressor(s)	Germany	Chemicals	Proposed	Compressed air
New biogas boiler	Italy	Food	Proposed	Process Heating/Cooling
Insulation of refrigeration system and fittings or pipelines	Germany	Food	Proposed	Process Heating/Cooling

Optimization cooling / thermal management in data centers	Germany	Food	Proposed	ICT
Renovation of steam system	Greece	Food	Proposed	Processes
Optimization cooling / thermal management in data centers	Germany	Machinery	Proposed	ICT
Installation of a PV system	Greece	Machinery	Proposed	Power Generation
Replacement of the existing BHKW	Germany	Metal	Proposed	CHP
Intro of EMS	Greece	Metal	Proposed	ICT
Measuring devices in the NG system	Greece	Metal	Proposed	ICT
Installation of 10kWp solar panels for an office facility	Netherlands	Metal	Implemented	Power Generation
Replacement of old (20 y) IE1 classed motor with IE3 (22kW) variable speed drive used in the production process (180 on time, load factor 0,5) @75%	Netherlands	Metal	Proposed	Drives/Engines or Pumps
Replacement of 200 conventional fluorescent lighting systems at 93w with more efficient LED lighting at 40w per unit + improved location of installations	Netherlands	Metal	Implemented	Lighting
Replacement of old (20 y) IE1 classed motor with IE4 (4kW) variable speed drive used in the production process (365 days, load factor 0.75; recoiled)	Netherlands	Metal	Implemented	Drives/Engines or Pumps
Replacement of old motor mused for production processes (machining) - never been recoiled (as far as aware)	Netherlands	Metal	Implemented	Drives/Engines or Pumps
Flash steam recovery system	Italy	Pharmaceuticals	Implemented	Process Heating/Cooling
Optimization of steam production both by enhancing the preheating temperature of the steam generator feed water (heat recovery from the compressors cooling system + boiler exhaust gas economizer) and by optimizing combustion efficiency (control system for optimizing the air-fuel ratio through adjustment of the combustion air delivery)	Italy	Pharmaceuticals	Implemented	Process Heating/Cooling
Retrofitting of control and regulation	Germany	Pharmaceuticals	Proposed	HVAC System
Heat recovery in compressor	Spain	Pharmaceuticals	Proposed	Compressed Air
Refrigeration plant and primary distribution pumps replacement with higher efficiency ones	Italy	Pharmaceuticals	Implemented	Drives/Engines or Pumps
Improvement in combustion by installing O2 sensor and speed variator in boiler combustion ventilator	Spain	Pharmaceuticals	Proposed	Process Heating/Cooling
Heat recovery by installing an economizer	Spain	Pharmaceuticals	Proposed	Process Heating/Cooling
Installation of insulating blankets on plastic injection molding machine	Italy	Plastics	Implemented	Processes

Regenerative-type VOCs post-combustors replacement with new ones. The new post combs are associated with an exhaust air/diathermic oil heat recovery system addressed to process employment within the thermal plant	Italy	Plastics	Implemented	Other
Optimization of the supply network	Germany	Plastics	Proposed	Compressed air
Optimization of the compressed air plant through deployment rationalization, leaks check and maintenance, compressors replacement with higher efficiency ones, as well as installation of a central control unit	Italy	Plastics	Implemented	Compressed Air
New refrigeration unit (compression and water-cooled)	Italy	Plastics	Implemented	Process Heating/Cooling
Installation of injection mold press	Greece	Plastics	Proposed	Processes
Optimization of heat distribution	Germany	Plastics	Proposed	HVAC System

3.4 Hosting the ESM: The A2M Database

The ESM Database serves as a host environment for the energy saving measures through energy audits in partner countries of the A2M project and their subsequent numerical analysis.

The incorporation of the Excel analysis, which includes a wide range of KPI values and a robust benchmarking system for ranking ESM, into a comprehensive database that enables the consolidation of diverse data into an accessible and navigable format, serves as a powerful tool for industrial decision-makers, fostering an environment where insights can be drawn quickly.

The ESM Database includes an efficient importing method that allows ESM from compatible XLSX files to be imported. This technique keeps the database up to date with the most recent ESM discovered during continuing energy audits. To ensure data accuracy and reliability, the system goes through extensive quality control processes that validate imported measures and alert users to missing values or errors during the process.

Furthermore, the ESM Database's user-friendly interface offers simplicity of navigation for all users, regardless of technical expertise. The database allows companies to search for ESM based on specific parameters such as industrial sector, country, technology group, company size and scoring on the four assessment pillars: Energy, Environmental, Financial and Non-Energy Benefits (NEBs). These filtering options allow businesses to customize their search and uncover relevant measures for their specific needs. Also, the main page of the ESM Database presents a comprehensive set of analytics that offer valuable insights to companies about the contents of the A2M Database (Figure 8).

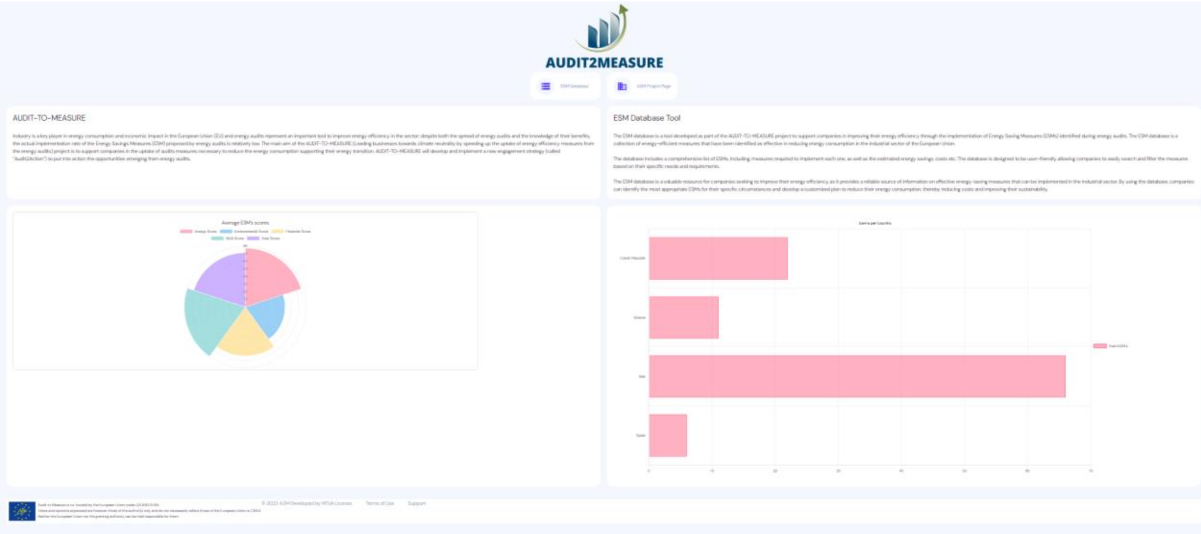


Figure 8: A2M ESM Database Main Page.

Most crucially, each ESM entry in the database includes detailed information such as the related industrial sector, the relevant technology group, expected lifetime, implementation status and KPI values. This extensive information enables companies to make informed decisions when deciding which steps to adopt as part of their energy transition strategies. Furthermore, the database provides users with a rapid visual depiction of benchmarking findings, allowing them to assess the relative effectiveness of each measure (Figure 9).

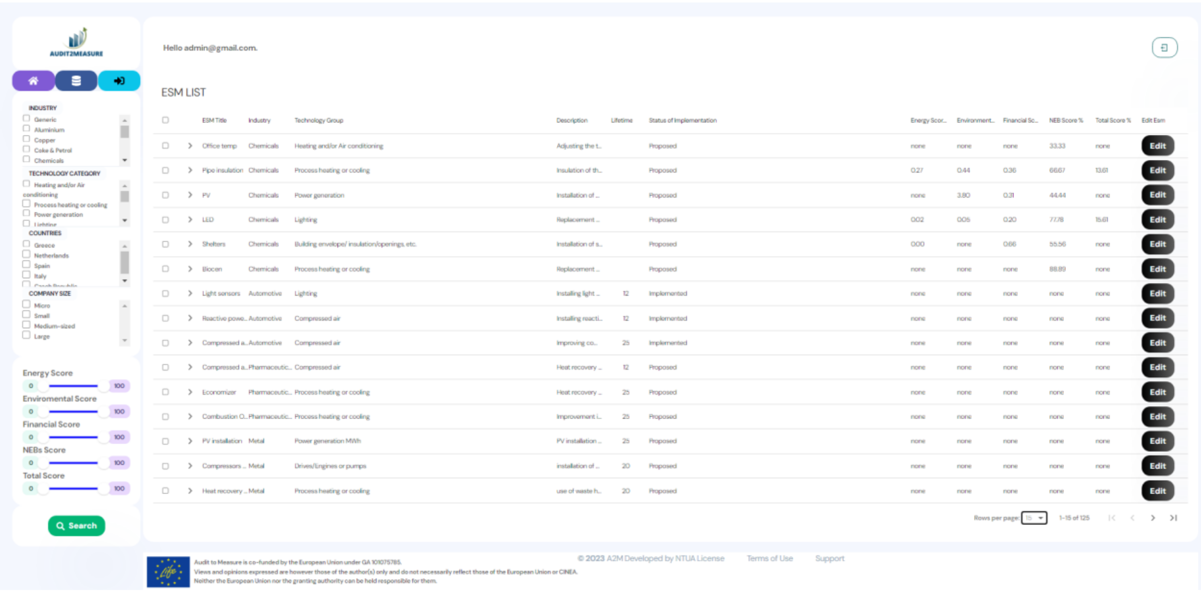


Figure 9: A2M ESM Database List page.

Regarding the technology employed, the application was thoroughly crafted utilizing a sophisticated development stack, integrating Docker for containerization, MongoDB for efficient database management, FastAPI for powerful backend capabilities and React.js for an engaging and responsive frontend interface. The orchestrated utilization of these cutting-edge technologies has led to a seamless development of a high-quality, user-friendly application that aligns with the latest technology standards.

4. ASSESSING THE ENERGY MANAGEMENT MATURITY: STEPPING UP FROM ENERGY AUDITS TO ISO50001

This chapter covers the second part of deliverable, which addresses the assessment of the companies' energy management maturity, according to ISO 50001 standard and the provision of tools to support the companies' self-assessment.

Energy management is the systematic process of monitoring, managing and conserving energy in an organization or facility. At its heart, it analyses energy use trends and implements methods to reduce energy usage, increasing efficiency and sustainability. When utilised appropriately, management systems significantly contribute to the ongoing consolidation, development and enhancement of an organization's processes while offering support to them, particularly in fulfilling corporate goals. The foundation of an organization is comprised of operational procedures, objectives, control systems and the delineation of responsibilities. At the same time, action plans specify who is responsible for what and when and internal assessments conduct independent system inspections. The dynamic model of the **"Plan-Do-Check-Act" (PDCA) cycle** provides the framework: it is a continuous improvement framework widely used in various management systems, including energy management. It consists of four key stages: Plan, Do, Check and Act, which are detailed below:

- **Plan**: In this stage, organizations establish objectives and targets, develop plans and define the processes necessary to achieve them. This involves setting energy management goals, identifying energy-saving opportunities and planning energy efficiency initiatives;
- **Do**: The Do stage involves implementing the plans developed in the previous stage. It includes executing energy efficiency projects, implementing energy management practices and collecting data related to energy consumption and performance;
- **Check**: In the Check stage, organizations assess and monitor the results achieved during the Do stage. This involves analyzing energy data, comparing actual performance against targets and evaluating the effectiveness of implemented measures. It helps identify deviations, trends and areas for improvement;
- **Act**: Based on the findings of the Check stage, organizations take corrective actions and make necessary adjustments to improve energy management performance. This can involve refining processes, modifying strategies, reallocating resources, or implementing new initiatives to enhance energy efficiency and achieve better results.

Following the conclusion of the Act phase, the PDCA cycle reverts to the Plan phase, thereby providing it with the characteristics of a continuous improvement (Pandolfo, 2010).

The **ISO 50001 (ISO, 2018)** standard defines an energy management system as a "set of interrelated or interacting elements to establish energy policy, energy objectives and processes and procedures to achieve those objectives." In essence, this internationally developed standard offers a versatile structure in an effort to enhance energy performance consistently by providing the standards for establishing, implementing, maintaining and upgrading an energy management system (EMS). This standard is intended to **assist companies in using a structured strategy to continuously improve energy performance, including energy efficiency, use and consumption.**

ISO 50001's scope is broad, encompassing any organization that wishes to ensure its energy management system adheres to a set policy, regardless of size, complexity, geographical location, or cultural factors. According to Kanneganti et al. (2017), ISO 50001 specifies energy use and consumption requirements, including measurement, documentation, reporting, design and procurement practices for equipment, systems, processes and personnel contributing to energy performance. This standard provides a **methodology for continual improvement in energy performance** without explicitly specifying any performance criteria that have to be satisfied concerning energy.

While EMS promotes ongoing improvement, on the other hand, energy audits assess energy demands and develop actions only at predetermined intervals; the two are, however, inextricably linked as energy audits are crucial for identifying potential energy savings, enabling organizations to assess their energy use and efficiency, pinpoint areas where energy can be saved and implement energy-saving measures more accurately. Particularly in terms of energy data acquisition, processing and analysis, the energy audit and EMS are comparable; therefore, significant portions of the EMS's workload may be delegated after an energy audit. By conducting energy audits within the ISO 50001 framework, industrial facilities can identify and integrate energy-conserving strategies and these practices into the fabric of their operations, thus ensuring long-term sustainability and efficiency. The energy audit functions as an intermediary between the practical, implementable strategies intended to improve energy efficiency and the strategic framework of the EMS.

4.1 A2M Energy Management Maturity Model

Even though EMS can support an organisation in continuous improvement of their energy practices, there is a gap between theory and reality – world implementation of best practices for energy management. Therefore, in the context of assessing an industrial companies' real – world readiness to implement EMS, maturity models can be utilised to assess the as-is situation of a company, derive and rank improvement measures and control implementation progress (Finnerty et al., 2017). Since the adoption of maturity models can demonstrate where organisations stand in the implementation of the Plan – Do – Check – Act cycle of their ISO 50001 process, it turns out to be necessary to create a dedicated self – assessment tool with the goal of assisting industrial companies identify gaps in their energy management practices.

The A2M Energy Management Maturity Model (EMMM), based on the work carried out by Wu et al. (2018), was created by outlining the categories of ISO50001 and inside each category, by outlining the required tasks and sub-tasks that correspond to ISO50001 processes. In particular the A2M EMMM is divided into seven categories, as follows:

1. **Organizational Context**: This section focuses on understanding the organization and its context. It entails recognizing external and internal concerns that are significant to the organization's purpose, strategic direction and ability to accomplish the desired results from its energy management system (EMS);

2. **Leadership**: Leadership entails senior management demonstrating commitment to the EMS. It involves developing energy policy, ensuring that energy objectives and strategies are formed and allocating roles, duties and authority within the company;
3. **Planning**: Planning includes taking actions to manage risks and opportunities, as well as identifying goals and planning how to attain them. It includes determining how to incorporate energy management into company processes and establishing objectives for increasing energy performance;
4. **Support**: This section addresses the support required for the EMS's establishment, implementation, maintenance and continuous improvement. It encompasses resources, competence, awareness, communication and documented data;
5. **Operations**: Operations involve dealing with the efficient planning, control and administration of activities that can affect energy performance. This includes operational planning and control, as well as the design and procurement of energy services, goods and equipment;
6. **Performance Evaluation**: Monitoring, measuring, analysing and evaluating energy performance and the EMS are all necessary for performance evaluation. It also involves internal audits and management reviews;
7. **Improvement**: This final section focuses on continuously increasing EMS and energy performance. It involves performing corrective actions when nonconformities are found and continuously improving energy performance and the EMS.

In each category, tasks and sub-tasks are identified, leading to a total of 25 tasks and over 80 sub-tasks. A set of five statements are provided for each sub-task. Each statement reflects the progressive level of maturity or level of development and is assigned a score from 0 (zero) to 4 (four): a score of 0 (zero) signifies uncertainty regarding the sub-task's meaning, while a score of four indicates a thoroughly developed energy management activity that embodies escalating levels of maturity. The associated statements and the levels of task – implementation are presented in Table 15.

Table 15: Statements of increasing energy management maturity.

Statements	Score	Description
We are uncertain what this sub - task means	0	This statement demonstrates awareness of a learning opportunity
We understand what is required for this sub-task but have not yet started acting on it	1	This statement demonstrates knowledge of the company's future energy management operations which have not started to be developed
We are taking some action on this sub task but not yet to the extent of the description provided in the above two choices	2	This statement provides a solid foundation of energy management activities that are relatively immature but functioning
Our operations for this sub-task are currently functional, but we believe that they could benefit from further improvement in the future	3	This statement highlights activities that are in accordance with a newly developed energy management system
We have taken systematic and well-planned actions in this subtask and these actions have been tested over time	4	This statement pertains to a well – developed energy management system that has been tested over - time

As each task is comprised of sub-tasks, it was determined that in order to derive maturity scores for the seven sections of ISO50001 that were previously stated, it was important to calculate scores for each of the twenty-five tasks and subsequently aggregate the outcomes of each task. The final score for each task is determined using the subsequent formula:

$$Maturity\ of\ each\ task = \frac{\sum_{i=1}^{n} SubTaskMaturityScore}{4\ \times n} \times 100$$

Where:

I= 1, 2, 3, …, n is the number of subtasks that each task consists of.

The maturity score for each of the seven categories is the weighted sum of the task maturity scores that are part of the same category and every maturity score is calculated on a 0-100 scale. In regard to task maturity, 5 levels of task maturity were identified based on the task maturity score as indicated on Table 16 and 17.

Table 16: Levels, scores and characterization of task maturity

Level	Task Maturity Scores	Task Maturity Characterization
1	[0-20)	Informal
2	[20-40)	Documented
3	[40-60)	Integrated
4	[60-80)	Strategic
5	[80-100]	Optimized

Table 17: Levels, scores and characterization of category maturity

Level	ISO 50001 Category Maturity Scores	ISO50001 Category Maturity Characterization
1	[0-20)	Learner
2	[20-40)	Beginner
3	[40-60)	Organized
4	[60-80)	Achiever
5	[80-100]	World Class

A screenshot of the maturity model is presented in Figure 10.

AUDIT2MEASURE	A2M ENERGY MANAGEMENT MATURITY MODEL EXCEL TOOL IMPROVEMENT					
		Levels of Task Implementation				
TASK	SUB-Task	Score: 0 - "We are uncertain what this sub - task means"	Score: 1 - "We understand what is required for this sub-task but have not yet started acting on it"	Score 2: - "We are taking some action on this sub task but not yet to the extent of the description provided in the above two choices"	Score 3: - "Our operations for this sub-task are currently functional, but we believe that they could benefit from further improvement in the future."	Score: 4 - "We have taken systematic and well-planned actions in this subtask, and these actions have been tested over time."
		Select Level of Task Implementation				
Task 24: NonConformity and Corrective Actions	Do you develop and implement a process for taking corrective action at your organization?					
	Do you define roles, responsibilities, and authorities for the various steps in the corrective action process?					
	Do you document the results of the various stages of the corrective action process?					

Figure 10: Screenshot of the A2M Maturity Model.

Furthermore, as a result of the complexity and time-intensive nature of responding to the maturity model in its entirety, a simplified variation was developed in the shape of a questionnaire, without altering the goal of self – assessment. The simplified version involved reducing the number of tasks that needed to be completed, considering only those that were most pertinent to the project's requirements and scope. Additionally, the statements did not consider the factor of time; consequently, the evaluation was reduced to a straightforward binary checklist consisting of yes and no selections concerning the implementation of each task. The maturity score was then calculated on a scale of 0-100 with the following formula:

$$Maturity\ of\ each\ category = \frac{k}{N} \times 100,$$

Where:

k: number of questions answered with "Yes."

N: number of questions constituting the category

AUDIT2MEASURE	A2M ENERGY MANAGEMENT MATURITY QUESTIONNAIRE			
	Please respond in Column D "Yes", if the elements listed in column C are being implemented in your organization. Otherwise, respond "No"			
Categories	Tasks	Required Elements	*Implementation (Yes / No)*	*Comments*
Organizational Context	A1.Understanding the organization and its context	•Identification internal and external strategic issues		
	A2.Needs and Expectations of Interested Parties	•Identification of interested parties		
	A3.Scope and Boundaries of the EnMS	•Determination and documentation of the scope and boundaries of the EnMS		

Figure 11: Screenshot of the simplified version – questionnaire.

It should be noted that both the detailed maturity model and the simplified questionnaire were developed in a spreadsheet format. This format enabled the provision of an immediate visual representation of the results of the self–assessment for the engaged companies after the completion of either version as depicted in Figures 12 and 13.

Figure 12: Radar Chart presenting the maturity scores after the self-assessment.

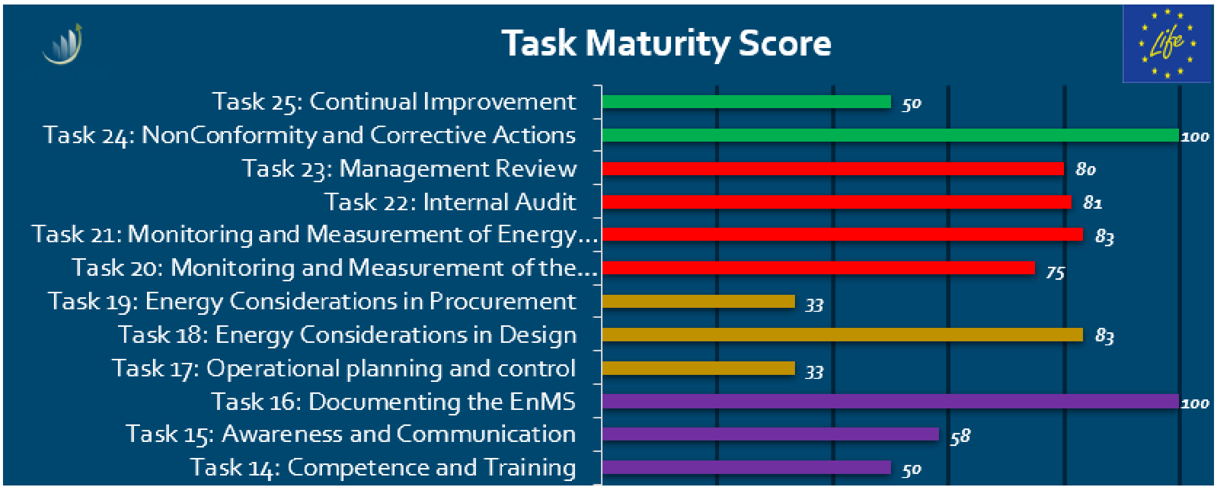


Figure 13: Bar Chart presenting the ISO50001 task maturity scores after the self-assessment.

Initially, it was intended that the companies would receive the Maturity Model, whether in its detailed or simplified iteration, to develop a more profound understanding of their present status regarding energy management practices. Nevertheless, to obtain more perceptive responses and guarantee a comprehensive evaluation, it was deemed crucial to involve personnel who have an extensive understanding of each company's operations and energy management approaches. As a result, a decision was made to administer the questionnaires throughout the "laboratory of ideas", a collaborative workshop with relevant personnel within the company that aimed to stimulate greater corporate participation and engament in A2M activities, resulting in a three-month delay in completing and submitting this deliverable.

4.2 RESULTS FROM COMPANIES

A diverse range of seventeen industrial companies, each with its own size, country of origin and industry, provided us with responses. The obligations of these industries with respect to energy audits and the extent to which they had implemented an active energy management system varied. Six of the seventeen industries surveyed stated they do not use an EMS at this time and have no intention of doing so in the near future. Five industries stated that they intend to implement an EMS despite not using one at this point in time. Three industries reported using an EMS, but its implementation is still in its early stages. Additionally, three industries reported having a fully developed EMS. Table 18 presents a comprehensive overview of the qualitative characteristics pertaining to the energy management maturity of industrial companies.

Table 18: Characteristics of involved companies and respondents

Role of respondents	Size	Audit Obligation (X / -)	EMS in place
N/A	Large	X	**Yes**: We have a fully developed EMS in place
N/A	Large	X	**Yes**: We have a fully developed EMS in place
Mid and Lower management	Large	X	**No**: We do not currently use an EMS but we are planning to implement one
Mid and Lower management	Small	-	**No**: We do not have an EMS and we do not plan to implement one
Mid and Lower management	Large	X	**Yes**: We use an EMS but it is still in early stages of implementation
Mid and Lower management	Medium Sized	X	**No**: We do not have an EMS and we do not plan to implement one
Operational Staff	Large	-	**No**: We do not have an EMS and we do not plan to implement one
Mid and Lower management	Medium Sized	-	**Yes**: We use an EMS but it is still in early stages of implementation
Management Board: Decision Maker	Large	X	**No**: We do not currently use an EMS but we are planning to implement one
Management Board: Decision Maker	Large	X	**No**: We do not currently use an EMS but we are planning to implement one
Management Board: Decision Maker	Small	-	**No**: We do not have an EMS and we do not plan to implement one
Mid and Lower management	Medium Sized	-	**No**: We do not have an EMS and we do not plan to implement one

Management Board: Decision Maker	Small	-	**No**: We do not have an EMS and we do not plan to implement one
Management Board: Decision Maker	Large	X	**No**: We do not currently use an EMS but we are planning to implement one
Management Board: Decision Maker	Large	X	**No**: We do not currently use an EMS but we are planning to implement one
Mid and Lower management	Large	X	**Yes**: We have a fully developed EMS in place
Mid and Lower management	Large	X	**Yes**: We use an EMS but it is still in early stages of implementation

Additionally, it is noteworthy to mention that among the six companies that responded that they have no intention of implementing an EMS, one medium-sized company was required to perform energy audits. However, companies that expressed a future intention to implement an EMS were all obligated to conduct energy audits. Additionally, one respondent was part of the operational staff. Six respondents served as decision-makers on the management council, while eight were mid-level or lower management members. Two respondents did not disclose their role within the industrial company.

Although all elements of ISO 50001 are crucial for establishing and maintaining effective energy management practices, for the needs of this task, we placed particular emphasis on the following five sections—Planning, Support, Operations, Performance Evaluation and Improvement.

Planning addresses the identification of risks and opportunities that impact energy performance, the development and implementation of a data collection plan, the identification of Significant Energy Uses (SEU), the development of Energy performance indicators and an Energy Baseline in order to determine energy performance improvement and the performance of energy review based on energy targets and objectives.

Support addresses the documentation of the EMS along with the required competence and training of internal and external personnel as well as the internal and external communication of the EMS.

Operations address the operational planning and control along with definition of criteria that can lead to significant deviation from the anticipated energy performance. It also addresses the identification of sites, equipment etc., that can have significant impact on energy performance.

Performance Evaluation determines the needed information to track, measure, analyse and evaluate the outcomes of the EMS as well as what needs to be monitored and measured for energy performance, including the key characteristics of operations affecting energy performance.

Improvement identifies non – conformities and addresses them with the implementation of corrective actions, ensuring that said actions are systematically in place to improve the EMS and energy performance.

4.2.1 Results from ISO50001 certified Companies

Six industrial companies already implementing an EMS undertook the assessment. The findings are presented in Table 19. The outcomes indicate that all the companies in the planning category were classified as world-class, with maturity scores of 92, 90, 80 and 100, 100 and 60, respectively. Three companies in the support category achieved world-class maturity, earning scores of 85, 100 and 100, respectively, while the remaining three achieved scores of 69 and 33, and zero for a total average of 65.

Table 19: Maturity Results of Industrial Companies with implemented EMS

Category	Company 1 Maturity Score	Company 2 Maturity Score	Company 3 Maturity Score	Company 4 Maturity Score	Company 5 Maturity Score	Company 6 Maturity Score
Planning	92	90	80	100	100	60
Support	85	69	33	100	100	0
Operations	69	50	100	100	100	33
Performance Evaluation	92	80	100	100	100	33
Improvemen t	100	75	100	100	100	0

It should be mentioned that the company that scored 33 in the support category, even though it had established the required competence and training, the awareness and communication along with the process of documenting their EMS is still in progress.

An average of 75 was computed for the operations category using the following scores: 69, 50, 100, 100, 33, 100. The pattern of performance evaluation and continuous improvement was consistent, as four of the six companies achieved a World Class maturity level, with an average score of around 84 and 79 in the two respective categories.

With the exception of company 6, which was a medium-sized organization exempt from audit requirements and whose responses suggested that their EMS was in its earliest phases of implementation, thus yielding inaccurate outcomes, for the certified companies, we see a trend that the lowest maturity level is that of the achiever and the most prominent maturity characterization is world-class. We observe a trend among certified organizations in which the achiever is the lowest maturity level, while world-class is the most prominent maturity characterization. This exemplifies how industrial companies with EMS methodically approach their planning, their performance evaluation and continuous improvement: they monitor energy consumption, identify resource-efficient methods and implement continuous improvement procedures that meet or surpass industry standards. Moreover, they gather and analyse data, guaranteeing that facilities and appropriately trained personnel understand energy efficiency, utilization and consumption. Furthermore, they monitor significant energy uses (SEUs) through the development of Energy Performance Indicators and Energy Baselines and they determine efficacy of the action plans that were executed in order to attain energy conservation, ensuring continuous improvement of the energy performance.

4.2.2 Results from not ISO50001 certified Companies

A distinct image emerges regarding the eleven companies that stated they do not implement an energy management system (Table 20).

Table 20: Maturity Results of Industrial Companies without EMS.

Category	Company 1 Maturity Score	Company 2 Maturity Score	Company 3 Maturity Score	Company 4 Maturity Score	Company 5 Maturity Score	Company 6 Maturity Score	Company 7 Maturity Score	Company 8 Maturity Score	Company 9 Maturity Score	Company 10 Maturity Score	Company 11 Maturity Score
Planning	40	100	80	20	80	60	40	60	40	60	40
Support	0	33	67	33	33	0	33	0	0	33	0
Operations	0	67	67	0	67	33	67	100	33	33	0
Performance Evaluation	67	67	0	0	0	0	33	0	0	0	0
Improvement	0	50	0	0	50	50	50	0	0	50	50

Currently, the averages are significantly diminished compared to the previous levels. As depicted in Figure 14, the Planning maturity score is the highest without an EMS, suggesting that these organizations may have implemented a certain level of structured planning. Nonetheless, the score is slightly above the midpoint of full maturity, indicating that substantial progress remains to be made.

The operations score is moderate, suggesting that, although operational controls and processes are present, they could be further developed and refined through implementing an EMS.

The maturity scores for Performance Evaluation, Improvement and Support are all below the midpoint toward complete maturity. This indicates that these companies could have made more significant efforts to continuously develop, support organizational processes and structures and evaluate performance.

The analysis underscores a possible area of apprehension, specifically regarding Performance Evaluation, which possesses the least developed score. These industrial companies may have difficulty evaluating and managing their energy performance effectively in the absence of an EMS, which may result in inefficiencies and increased expenses. The companies' subpar performance in the Improvement and Support categories indicates that they encounter difficulties in maintaining consistent progress and delivering sufficient assistance for energy management initiatives. Overall, the findings, which cannot be generalised due to the small sample size, imply that the introduction of an EMS might potentially drive considerable improvements across all these categories, leading to better energy management, cost savings and, possibly, more sustainable production and business practices.

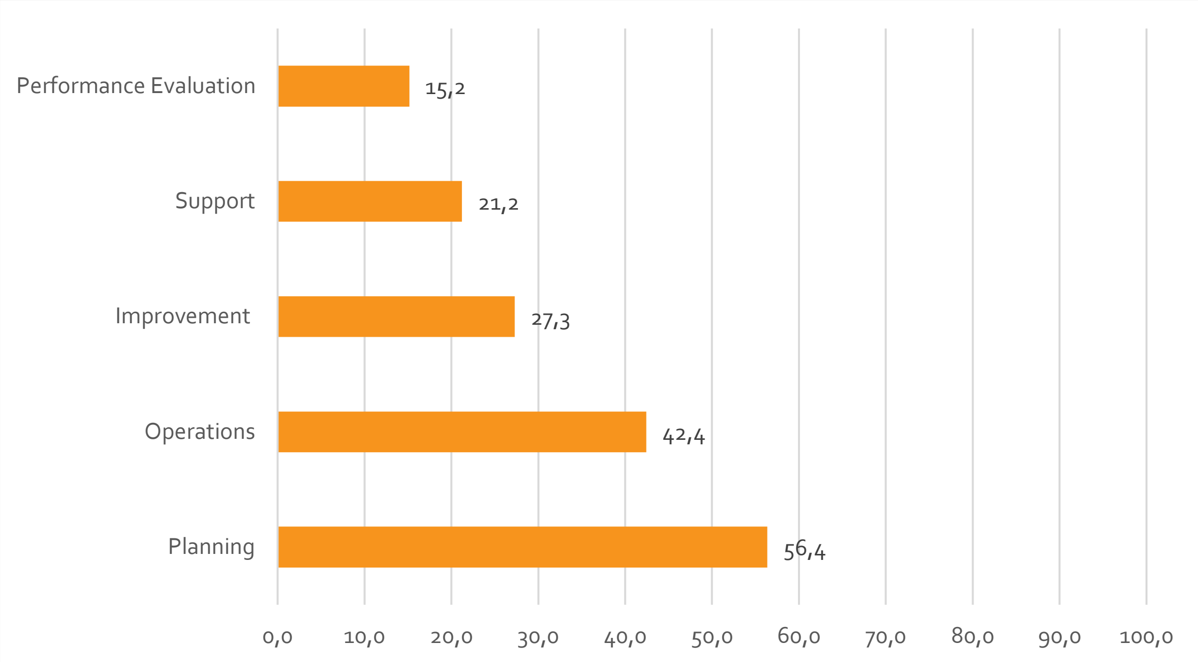


Figure 14: Results of maturity scores for industrial companies without EMS.

4.3 Added Value offered to the uptake of ESMs due to high maturity levels.

Figure 15 depicts the comparison of the overall maturity levels of various organizational aspects of the assessed companies.

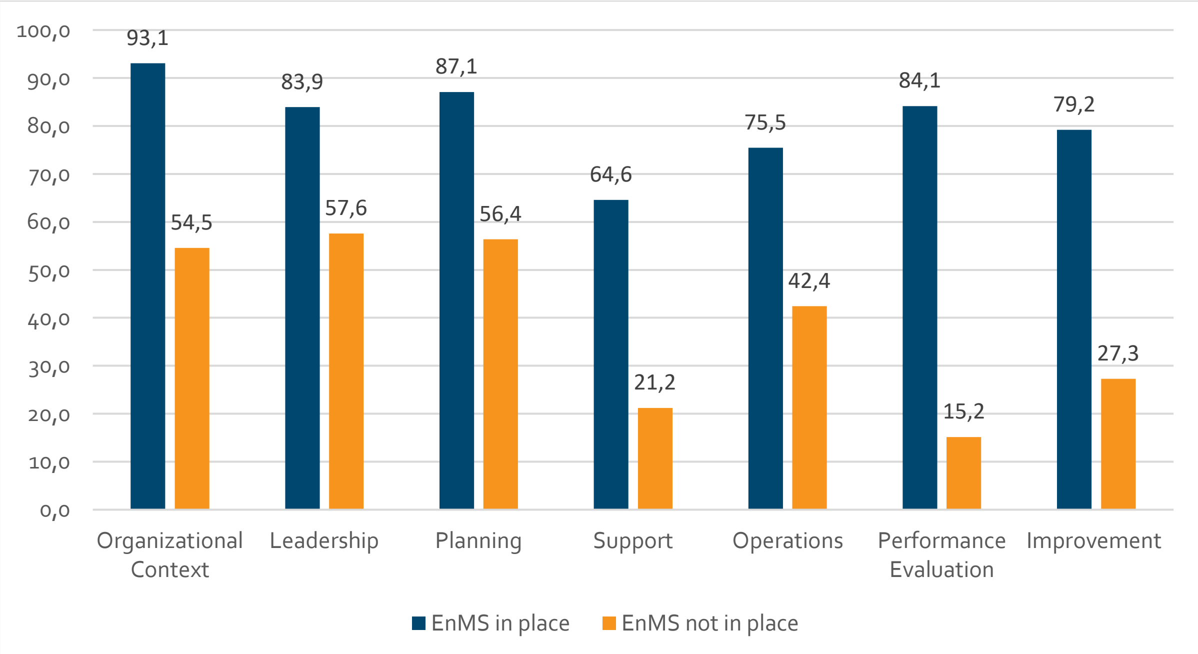


Figure 15: Comparison of maturity level scores of varying EMS implementation status of industrial companies (n=17).

On the organizational context, industrial companies implementing Energy Management Systems (EMS) achieved an exceptionally high maturity score of 93.1, signifying a deep understanding of integrating energy management practices into the framework of business objectives and organizational structure. In the absence of an EMS, organizations have a moderate maturity score (54.5), indicating that they lack a comprehensive understanding of the significance and integration of energy management in their day-to-day operations.

In the leadership category, the high maturity score (83.9) of EMS indicates that the leadership of these organizations is committed to and prioritizes energy management. The absence of an Energy Management Systems Maturity Score (57.6) suggests a moderate level of dedication and a dearth of well-defined leadership guidance in this area.

Regarding Planning, companies with EMS have achieved a high maturity score of 87.1, indicating their energy management planning proficiency. Without an EMS, the organization has achieved a moderate maturity score of 56.4, potentially indicating a lack of comprehensive planning or integration of energy management into the overarching business strategy.

Regarding Support, EMS has achieved a respectable maturity score of 64.6, indicating the presence of a support infrastructure that is adequate for energy management; however, further enhancements are possible. In the absence of an EMS, the maturity score is 20.2, indicating a substantial deficiency in the support systems for energy management endeavors.

In the Operations category, EMS achieved a commendable maturity score of 75.5, indicating the presence and effectiveness of operational controls and processes pertaining to energy management. The absence of an EMS may result in a low maturity score (42.4), suggesting that operational energy efficiency could be optimised.

The high maturity score (84.1) on the performance evaluation indicates that organizations utilizing EMS evaluate and monitor their energy management performance on a consistent basis in an efficient manner. In the absence of EMS, the maturation score is an extremely low 15.2, which is the lowest of all aspects and indicates a substantial inadequacy in assessing and enhancing energy performance.

In the improvement category, EMS achieved a high maturity score of 79.2, signifying the presence of a robust process for ongoing enhancement in the realm of energy management. Without EMS, the maturity score is relatively low at 27.3, indicating a limited commitment to ongoing energy efficiency enhancements.

By utilizing the structured framework provided by EMS and ISO50001, in particular, companies can increase their adoption of ESM. The potential benefits of incorporating EMS are extensive in nature.

The importance of a structured framework for systematically implementing energy-saving measures is emphasised initially. The EMS facilitates the conversion of recommendations into actionable tasks, assigns responsibility, establishes timelines, enables continuous monitoring and tracking of energy consumption to observe the effects of implemented measures directly and enables industrial companies to establish clear energy performance targets. When these findings fail to align with the actual energy performance assessment deriving from the energy audit, further emphasis is placed on the recommendations to achieve said targets.

Furthermore, an EMS can help organizations benchmark their energy performance against similar organizations or industry standards. This external benchmarking can further drive the uptake of energy-saving measures. Also, since EMS provides tools for verifying and validating the results of energy-saving measures, this can build confidence in the effectiveness of the measures and encourage further investment in energy efficiency. In addition, an EMS often incorporates training and awareness programs. These programs can focus on the findings of the energy audit, educating operational staff about the importance of the recommended measures and how they can contribute to their implementation, while the provision of tools for verifying and validating the results of energy-saving measures can lead to increased confidence in the effectiveness of the measures as well as encourage further investments in energy efficiency. Finally, the documentation that comes with the implementation of an EMS ensures that all actions, from audit recommendations to implemented measures and their impacts, are well-documented, thus aiding in transparency, knowledge transfer and future planning while the emphasis placed on continuous improvement through regular reviews, additional audits and corrective actions can enhance the additional identification of energy saving opportunities.

5. CONCLUDING REMARKS

This report provides quantitative insights on the energy, environmental, financial and non-energy benefit aspects of ESM in partner countries with varying auditing policy contexts. Based on a comprehensive data collection template that attempts to capture the most pertinent information about ESM proposed in industrial energy audits or implemented by industrial companies, key performance indicators that account for the multifaceted nature of industrial ESM were utilised for the evaluation. Based on the results of the KPIs that provided statistically significant results and the categorisation of measures according to the industrial sector to which they belonged, independently of the country of origin, the highest-ranking measures were extracted using a benchmarking methodology.

From this report, it emerged that the frequency with which cross-cutting measures, such as lighting, compressed air and drives, engines and pumps, are proposed in energy audits can be attributed to their immediate visibility and cost-effectiveness. These measures frequently represent the "low-hanging fruits" in energy efficiency, promising short payback periods and significant energy and carbon savings. In contrast, although process-specific measures are proposed less frequently, they have the potential for substantial energy and carbon reductions, albeit with extended payback periods.

In addition, an important finding of the analysis is the prominence of non-energy benefits in measures related to core industrial processes. Notably, two of the most frequently observed non-energy benefits, namely the improved production efficiency and the enhanced equipment performance, fall under productivity-related non-energy benefits.

The decision-making environment encircling these measures reflects a trade-off between short-term financial gains and long-term sustainability. While the immediate financial impact may be more pronounced, the long-term benefits in terms of energy and cost savings, coupled with a positive environmental footprint, can make these measures a strategic choice for industries.

Consequently, most of the higher-scoring measures belonged to technology groups such as lighting, compressed air HVAC systems and power generation. However, the highest-scoring measures in each industrial sector were measures of core industrial processes within the Process Heating/Cooling and Processes technology groups. Furthermore, these groups were the technology areas that encompassed a great non energy benefits potential.

The analysis results are presented in the A2M Database and the measures that emerged as the most promising and of particular interest are presented in executive sheets in a concise format. These sheets contain the most useful information for industrial decision-makers to facilitate informed decisions for an effective ESM adoption procedure.

To enhance the significance of audit recommendations and highlight the added corporate value that an EMS can contribute to an industrial company, the A2M Energy Management Maturity Model, which is based on ISO50001 categories and ISO50001 processes, was designed to help industrial companies identify gaps in their energy management practices. A survey of seventeen industrial companies with mixed EMS implementation status showcased many disparities in maturity scores that can serve as considerable evidence of the added value of implementing an EMS. EMS users are in a stronger position to make well-informed decisions regarding energy consumption, which may result in increased operational efficiency, decreased expenses and even a competitive edge. The companies' elevated Performance Evaluation and Improvement scores indicate that they diligently monitor their energy performance and proactively pursue opportunities to improve their energy management practices, resulting in ongoing cost reductions and enhancements. This is a compelling case for the advantages that high levels of energy management maturity provide, such as the potential for substantial energy savings and the overall enhancement of the energy audit proposals. Through the continuous monitoring and tracking of energy consumption, setting clear targets, engaging staff and promoting continuous improvement while ensuring alignment with overall organizational goals, implementing EMS can facilitate, at the very least, the increasing adoption rate of ESM.

6. NEXT STEPS AND CONNECTION WITH OTHER WPS

The methodological tools, the A2M Database and the work described in this deliverable are intended to serve as valuable input for the following A2M project work packages in the following sense:

Connection with WP4:

The executive sheets, the evaluation and benchmarking methodology and the database are all tools that will be presented to the companies during the "Laboratories of Ideas" and, at a different level of analysis, to the staff and energy experts of the companies during the training sessions and workshops that will be organised. The developed content and self – assessment tools can also supplement the training material in terms of creating training exercises, analysing case studies and so on.

Connection with WP5:

The evaluation and benchmarking methodologies provide a valuable foundation and input to the methodology used to assess and monitor the impact of ESM, which the project team will support as part of the practical assistance offered to industries. The ESM identified as part of WP5 can be analysed further and published to the A2M Database. This will permit benchmarking and comparison with other ESM in the same industrial sector and/or technological field, as well as information exchange with other businesses/stakeholders. New executive sheets can be created for the WP5 ESM in order to expand the library of executive sheets. The energy management maturity self-assessment tool can significantly influence the transformation of corporate level culture towards greener objectives by educating employees, establishing defined goals, engaging and empowering the workforce, promoting continuous improvement and aligning energy efficiency with the company's strategic objectives.

Connection with WP6:

The A2M Database constitutes an element of the Knowledge Exchange Space and serves as a source of information for the engaged stakeholders. To maintain an up-to-date database, all partners are encouraged to contribute by adding new ESM or revising the existing ones. This collaboration, devoted to database enhancement and expansion, will be facilitated predominantly by WP4 and WP5 and will last until the conclusion of the A2M project. In addition, a continuous update protocol will be implemented until the end of the project, with a focus on technical implementation, bug fixing, database maintenance and the incorporation of new features as they are identified by the partners to enhance the utility and effectiveness of the application, ensuring that it remains a robust and valuable tool for its intended purpose. In addition, integrating the procedures delineated in the energy management maturity self-assessment tool into the knowledge exchange space can make them readily available to many industrial stakeholders participating in the A2M project.

Connection with WP7:

The analysis results in this deliverable can be utilized as a foundation for policy recommendations concerning the obligations of ESM assessment as well as methods to mitigate biases.

ANNEX 1: DATA COLLECTION TEMPLATE

Key Data Points in the Data Collection Template included:

- A2M Partner
- ESM Short Title
- Reference Year
- NACE CODE
- Industrial Sector
- Country
- Company's Size
- Company's Turnover (k€)
- Company's Primary Energy Consumption (toe)
- Company's Production Output (tons of product)
- Comments or links
- Measure Description
- Status of Implementation
- Capital Expenditure (k€)
- ESM's Lifetime (Years)
- ESM's Technology Group
- Energy Carriers
- Energy Carrier Primary Consumption Before and after in toe (if the measure was implemented) (TOE)
- Energy Carrier per energy carrier (toe)
- Total Primary Energy Saved (toe)
- Renewable Energy Use Before (toe)
- Renewable Energy Use After (toe)
- Simple Payback Period (Years)
- Total avoided energy cost (k€)
- Net Present Value (k€)
- Discount rate used (%)
- Benefit Cost Ratio

- Internal Rate of Return (%)
- Percentage of CAPEX subsidy (%)
- % Waste Reduction
- Carbon Savings (tCO_2/Year)
- *Improved Product Quality*
- *Raw Material Use Reduction*
- *Improved Production Efficiency*
- *Improved Equipment Performance*
- *Reduced need for maintenance*
- *Reduced Maintenance Cost*
- *Increased Equipment Lifetime*
- *Enhanced Asset Value*
- *Improved Lighting Conditions*
- *Improved Air Quality*
- *Reduction of Noise*
- *Increased Worker Safety*
- *Improved Company Reputation*
- *Improved Compliance with target agreements, laws and quality systems*
- *Increased sales*
- *Increased employee morale*

ANNEX 2: TEMPLATE FOR EXECUTIVE SHEETS

EXECUTIVE SHEET

For Energy Saving Measures (ESM's) identified through energy audits

ESM Code: X / version: Y / Date: XX/YY/ZZ

Industrial Sector:			
Title of ESM:			
Technology Group:			
Country:		**Year of reference data:**	
Description of ESM:			
Proposed or/and implemented Measure:		**Proposed**	
Other comment			
Key Performance Indicators			
ENERGY	**Primary Energy Savings (toe/year):**	___________________________	
	Cost of Energy Savings (k€/toe/year):	___________________________	
	Energy Intensity Reduction (%):	___________________________	
	Consumption Reduction per Unit Product: ***(toe/year/tones of product)***	___________________________	
ENVIRONMENTAL	**CO_2 Savings (tCO_2/year):**	___________________________	
	Cost of Carbon Savings (tCO_2/year/):	___________________________	
	Renewable Energy Penetration Rate Gain (%):	__________________________	
	Carbon Reduction per product unit:	___________________________	
	(tCO_2/year/ tones of product)		
FINANCIAL	**CAPEX (k€):**	___________________________	
	Payback Period (Years):	___________________________	

Net Present Value (k€):	____________________
IRR (%)	____________________

Other benefits expected from the ESM			
Productivity benefits		**Operation &Maintenance benefits**	
Improved Product Quality		Reduced Need for Maintenance	
Raw Material Reduction		Reduced Maintenance Cost	
Improved Production Efficiency		Increased Equipment Lifetime	
Improved Equipment Performance		Enhanced Asset Value	
Work environment benefits		**Other Non-Energy benefits**	
Improved Lighting		Improved industry's reputation	
Improved Air-Quality		Compliance with laws and regulations	
Reduction of Noise		Increased sales	
Increased Worker Safety		Increased employee morale	

Ranking	Industry	Technology Group	Country

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