LEAP4SME
ENERGY AUDIT POLICIES TO DRIVE ENERGY EFFICIENCY

D6.1 Report on the literature review analysis of multiple benefits

June 2022

FINAL

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 893924.

DELIVERABLE 6.1	REPORT ON THE LITERATURE REVIEW ANALYSIS OF MULTIPLE BENEFITS
Related Work Package	WP6 – Analysis of further benefits and impact scenarios
Deliverable lead	ADENE – Portuguese Energy Agency
Author(s)	Ana Cardoso, ADENE; Joana Fernandes, ADENE; Paulo Calau, ADENE; Filipa Newton, ADENE
Contact	ana.cardoso@adene.pt
Revised and approved	Enrico Biele, ENEA
Grant Agreement Number/ Funding body	893924 / Horizon 2020 Research and Innovation Programme
Start date / Project Duration	1 SEP 2020 / 36 months
Type of Deliverable (R, DEM, DEC, Other)[1]	R
Dissemination Level (PU, CO, CI)[2]	PU
Date of Last Update	30.06.2022
Project Website	www.leap4sme.eu

REVISION NO	DATE	DESCRIPTION	AUTHOR(S)
1.0	28.06.2022	REVISION OF THE DRAFT VERSION	ENEA/ADENE
1.1	30.06.2022	FINAL VERSION	ADENE

[1] **R**=Document, report; **DEM**=Demonstrator, pilot, prototype; **DEC**=website, patent fillings, videos, etc.; **OTHER**=other
[2] **PU**=Public, **CO**=Confidential, only for members of the consortium (including the Commission Services), **CI**=Classified

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 893924.

Table of Contents

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 893924.

Executive Summary

This report performs a literature review analysis of multiple benefits, also accessing the implementation of recommended energy efficiency measures, including a comparison of approaches to integrate resource efficiency audits, namely contemplating the water-energy nexus.

An **energy audit** is an organised procedure during which the energy consumption of a productive site is accessed, and the potential energy savings and efficiency recommendations are detailed, discussed, and presented. It is acknowledged that it is one of the most cost-effective ways, and comprehensive methods, to improve energy efficiency and achieve energy savings, being a first step to optimize energy consumption. Nevertheless, an audit itself does not result in energy savings, as it will only help to identify areas for improvement, as companies are frequently not obligated to implement the efficiency measures identified through the audit. The aim of **energy efficiency measures** is to reduce the amount of energy consumed within a particular task or process by using the available energy more efficiently. Nevertheless, there are still barriers that continue to limit their uptake, and **energy management systems** could provide an organizational structure for overcoming them.

Non-energy benefits (NEBs) can be defined as benefits related to energy efficiency investments, beyond energy savings, that are quantifiable at a certain level and arise at some point in time. Some authors consider that if NEBs were to be included in energy audit programs, the benefit of the audits would increase. However, the correct identification of NEBs, that is fundamental to adequately integrate this approach in a policy pathway, requires additional efforts in terms of data gathering. Furthermore, the research consensus is that NEBs quantification is not an easy task, despite their potential impact on financial metrics of energy efficiency investments. In fact, quantifiable and possible to translate into monetary values NEBs can contribute to a higher and faster return, which can counterbalance known barriers and increase the priority level for energy efficiency investments against other investments. As NEBs are seldom considered when energy efficiency measures are evaluated, the resultant gains are underestimated. The literature has several findings regarding NEBs' quantification, but the general remark is that their mapping and evaluation

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 893924.

will need to be based on a mixture of experience, observations, calculations, and/or estimations in various ways.

The ability to address NEBs and combine strategies between energy and **resources efficiency** (water and/or materials efficiency) is also often neglected, and this reduces the potential for continuous energy efficiency improvements. The interest from companies regarding NEBs and resource efficiency is clear, and real added value can derive from their study. Furthermore, in the current global energy market disruption addressed by the European Union in the REPowerEU plan, the concern on energy costs drives the awareness on energy efficiency in small and medium-sized enterprises. The quantification of NEBs in the energy audits could boost the implementation of energy efficiency measures to increase the competitiveness and reduce the uncertainties on energy externalities.

Nevertheless, their integration within common energy audit procedures reinforces the need to adequately define suitable key performance indicators (KPIs), able to create an analytical basis for decision making and efficiency measures implementation. Regardless the numerous examples of KPIs linked to NEBs, and more concretely to resource efficiency, it is still difficult to find literature that collects indicators related to the multiple dimensions of resource efficiency in an integrated way. In this sense, a new set of KPIs is here proposed, using data easily collectable during an audit procedure, or that is already systematized within the companies' legal or voluntary requirements. These KPIs intend to assist the quantification of NEBs resulting from energy audits, namely, to contribute to the comparison of resource consumption levels supported by specific data.

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 893924.

1. Introduction

1.1 LEAP4SME project goals

The LEAP4SME project aims to support Member States (MS) in establishing or improving effective policies for small and medium-sized enterprises (SMEs[3]) to undergo energy audits and implement cost-effective, recommended energy efficiency measures. This will be achieved mainly by:

- Mapping national programmes.
- Developing innovative energy audit policy schemes with key stakeholders.
- Interacting with policy makers and business associations.
- Proposing policy recommendations.

Therefore, the LEAP4SME main objectives are to:

- Identify main barriers for unlocking the potential of energy efficiency measures through energy audit recommendations.
- Mobilise and inform private stakeholders of existing opportunities, facilitating discourse with policy makers.
- Propose solutions for policy makers for energy efficiency schemes with energy and non-energy benefits.
- Research, analyse and involve stakeholders in the current debate on SMEs within Article 8 of the Energy Efficiency Directive.

The LEAP4SME Work Package (WP) 6 - Analysis of further benefits and impact scenarios - intends to investigate and evaluate what lies beyond energy audits and energy efficiency in SMEs, in terms of non-energy benefits and other resources optimization, and to provide an effective impact assessment framework. It has two main objectives:

- O6.1) Multiple energy benefits and other resources optimization (namely water and materials): analyse and assess the co-benefits and inter-dependencies of energy audits' performance that address non-direct energy benefits or co-benefits (e.g.,

[3] The category of micro, small and medium-sized enterprises (SMEs) is made up of enterprises which employ fewer than 250 persons and which have an annual turnover not exceeding EUR 50 million, and/or an annual balance sheet total not exceeding EUR 43 million (Point 1. of Article 2 of the Annex to Recommendation 2003/361/EC).

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 893924.

energy-water nexus) and therefore encourage SMEs to undergo energy audits and implement the recommended energy-saving measures.

- O.6.2) Impact assessment framework: study the impact scenarios and develop an impact assessment framework. Its outputs will be used to improve the setting of national supporting schemes for SMEs.

Having this in mind, this first deliverable (D6.1) performs a literature review analysis of multiple benefits, also accessing the implementation of recommended energy efficiency measures, including a comparison of approaches to integrate resource efficiency audits, namely contemplating the water-energy nexus.

1.2 Report structure

This literature review report is structured in six chapters. The **first chapter** – Introduction – gives a brief overview of the project's main goals, as well as this report's objectives. The **second chapter** – Energy Audits – clarifies the concept of energy audit and its objectives. It also focuses on energy management practices, namely energy management systems and their applicability to water management. The **third chapter** – Non-energy benefits in Energy Audits – describes what is a non-energy (or multiple) benefit, namely its relevance within the energy audit context. Some examples of non-energy benefits and their categorization are provided, and the link with the Sustainable Development Goals is also explored. Also, the different schools of thought regarding non-energy benefits quantification are presented. The **fourth chapter** – Approaches to Integrate Resource Efficiency in Energy Audits – focus on resource efficiency definition and relevance, namely during an energy audit, and also presents non-energy benefits indicators, both from literature review and newly proposed ones. The **fifth chapter** – Policy Instruments, Programmes and Other Initiatives – details best practices identified, regarding the policy instruments and programmes directed to non-energy benefits promotion in SMEs. The report ends with the **sixth chapter** – Conclusions and Next Steps – where the main conclusions of the report are outlined, as well as the next steps for future work.

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 893924.

2. Energy Audits

The European Energy Efficiency Directive (EED, Directive 2012/27/EU) establishes a common framework for improving energy efficiency in the European Union (EU) Member States. Particularly, one of the measures of the EED, as outlined in its Article 8, is the requirement for **energy audits and energy management systems** for large enterprises (non-SMEs). In this sense, according to Article 8, the European Member States shall promote the availability of independent cost-effective high quality energy audits, therefore complying with the energy audit obligation. In addition, «Member States shall also develop programmes to encourage SMEs to undergo energy audits and the subsequent implementation of the recommendations from these audits». Nonetheless, while SMEs are **encouraged** to conduct energy audits and implement energy saving practices, the EED energy audits are an **obligation** to enterprises that are not SMEs[4].

An **energy audit** is defined by the EED as a «systematic procedure with the purpose of obtaining adequate knowledge of the existing energy consumption profile of a building or group of buildings, an industrial or commercial operation or installation or a private or public service, identifying and quantifying cost-effective energy savings opportunities, and reporting the findings». Therefore, in simple terms, it is an organised procedure, that analyses in detail the overall energy consumption of a structure. In this sense, during an energy auditing process, potential energy savings and efficiency recommendations are detailed, discussed, and presented. Nevertheless, they are often only "energy driven".

The energy audit is one of the most cost-effective ways, and comprehensive methods, to **improve energy efficiency** and achieve energy savings, so that wasteful consumption of energy is minimized (Kluczek and Olszewski, 2016). Kalantzis and Revoltella consider that energy audits help companies to assess their energy consumption, understand the potential for energy savings and suggest measures (investments or behavioural changes) to improve energy performance. One of the aims of an energy audit is to provide recommendations to

[4] Member States shall ensure that enterprises that are not SMEs are subject to an energy audit carried out in an independent and cost-effective manner by qualified and/or accredited experts or implemented and supervised by independent authorities under national legislation by 5 December 2015 and at least every four years from the date of the previous energy audit (Point 4. of Article 8 of the EED).

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 893924.

overcome the **information gap,** consequently bridging the **energy efficiency gap**. Therefore, conducting an energy audit is a first step in optimizing energy consumption, and the SMEs that perform it are positively influenced to implement the recommended energy efficiency measures (Kalantzis and Revoltella, 2019). This was also confirmed by Nehler who said that regardless of the type or size of a company, improvements in energy efficiency are typically initiated by conducting an energy audit. In fact, the results of an audit provide knowledge about the key processes where energy is being wasted or not used optimally (Nehler, 2018).

Nevertheless, **an audit itself does not result in energy savings,** as it will only help to identify areas for improvement, as well as potential for energy efficiency solutions (Kalantzis and Revoltella, 2019), as there are frequently no obligations regarding the implementation of identified measures as a result of an energy audit (Vermeeren, 2016). In this sense, the potential for energy efficiency improvements remains untapped, referred to as "the energy efficiency gap" in SMEs, where energy consumption is not always seen as a major cost factor within the industrial production (Kluczek and Olszewski, 2016). However, an energy audit is frequently the **first step** toward adopting energy management practices, pushing for the implementation of the identified key factors, that very often are lacking in SMEs (Johansson and Thollander, 2019). Cooremans and Schönenberger also conclude that governments have a role in encouraging firms to adopt energy management procedures, for example by offering subsidies for energy audits (Cooremans and Schönenberger, 2019).

2.1 Energy management practices

Research on energy management in SMEs showed that several key factors are needed to successfully implement **energy efficiency measures** (EEMs) and grasp their full potential (Johansson and Thollander, 2019). Some of these factors may be concrete goals, long term energy strategies or the designation of a resource specifically for the promotion of energy efficiency activities (Backlund et al., 2012).

The main aim of an EEM is to **reduce the amount of energy consumed** within a particular task or process by using the available energy more efficiently (Wagner et al., 2020). Industrial energy efficiency is crucial for sustainable development and industrial competitiveness. However, recent analyses from the International Energy Agency show that global energy

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 893924.

efficiency improvements are slowing. The adoption rate of EEMs is even lower in SMEs, fundamentally characterized by lack of a rigorous organizational structure, as well as internal resources and competences (Trianni et al., 2020).

Declich, Quinti and Signore identified a set of **barriers**, concerning the promotion of EEM and energy audits among SMEs: (1) Lack of funds and/or access to finance; (2) Fear of facing unnecessary costs (and the so-called "hidden costs"); (3) Lack of internal human resources or lack of appropriate skills among the human resources available; (4) Difficulty of using external human resources; (5) Lack or inadequacy of technical resources; (6) Difficulty of planning in the medium - long term and organizational deficiencies; (7) Lack of subsidies and incentives or the lack of knowledge about them; (8) Legislative and/or regulatory difficulties; (9) Lack of sensitivity to environmental issues; (10) Internal lack of time; (11) Plurality of interests and points of view and, more generally, the malfunctions in decision-making processes; (12) Lack of trust in the market, in other interlocutors, in the announced future benefits, in the future, etc. (Declich, Quinti and Signore, 2020). On the other hand, there are also known **drivers** for EEMs implementation: (1) Energy savings; (2) Cost reduction (energy, maintenance, others); (3) Legislative and/or regulatory obligation; (4) Operation time reduction; (5) Green image – stakeholders' pressure; (6) Non-energy benefits potential; (7) Environmental awareness (LEAP4SME, 2021).

Wagner et al. also performed an extensive identification of barriers and drivers for the implementation of EEMs, based on internal (financial, processes and attitude/others) and external (law & regulation and public image) factors, as presented in Figure 1 and *Figure 2*.

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 893924.

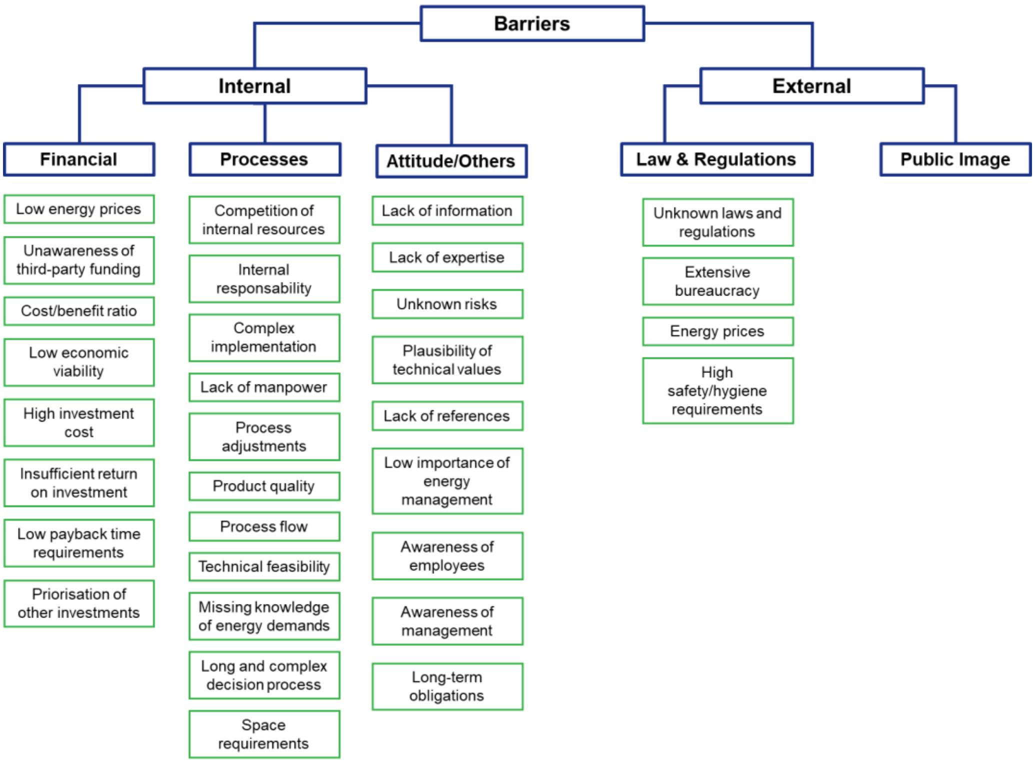

Figure 1 – Barriers for the implementation of EEMs (Wagner et al., 2020)

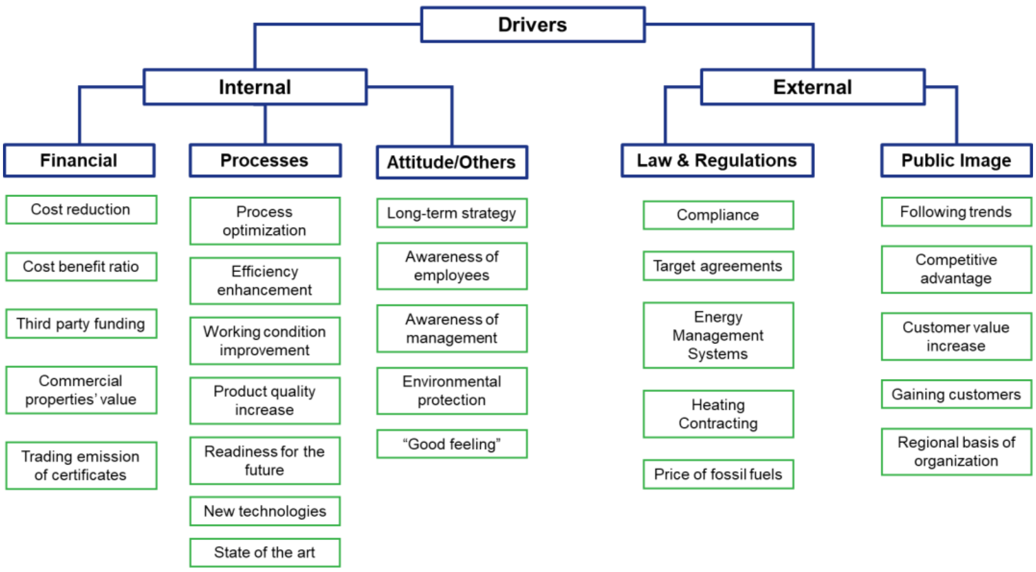

Figure 2 – Drivers for the implementation of EEMs (Wagner et al., 2020)

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 893924.

McKane et al. establish that, despite the significant potential for efficiency improvements and emissions reductions, as barriers continue to limit uptake of EEMs, **energy management systems** could provide an organizational structure for overcoming these barriers (McKane et al., 2017).

2.1.1 Energy management systems

Energy management (EM) is a management system, focusing on managing energy usages in a company. According to the international standard *ISO 50001: Energy Management Systems* (issued in 2011, modified in 2018), an **energy management system** (EnMS) is a "set of interrelated or interacting elements to establish an energy policy and energy objectives, and processes and procedures to achieve these objectives".

The **ISO 50001 standard** is voluntary and offers a flexible framework for organizations and facilities to integrate energy efficiency into their management practices. This standard can be applied in any sector and provides organizations with an internationally accepted structure for: improving the understanding of current energy use and consumption; identifying capital and operational energy efficiency opportunities; providing a business context for implementation decisions and evaluating post-implementation results. The business context and the management support required for the implementation of ISO 50001 can help overcome a number of the most common barriers to improving energy performance in organizations (McKane et al., 2017).

According to McKane et al., the **adoption of an EnMS and the implementation of monitoring systems** can lead to a reduction in energy consumption, gains in industrial productivity, and improvements in global enterprise performance, in addition to several other co-benefits positively affecting the overall company competitiveness. In the particular case of the ISO 50001 standard, certification may also be useful for a company strategy and image, on top of the cost saving issues. Considering a scenario by 2030 with 50% of the global enterprises under ISO 50001 management, the cumulative savings could reach nearly USD 700 billion, 105 EJ of primary energy, and 6500 million tons of avoided CO_2 equivalent emissions (McKane et al., 2017).

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 893924.

Cooremans and Schonenberger consider that, among other factors, company size and energy intensity seem to be the most important drivers influencing the adoption of an EnMS. EM acts as an organizational filter, which positively influences companies' perception of the **strategic character of energy efficiency investments**. The main contribution of EM is that it informs decision-makers with reliable and solid data regarding energy consumption and cost, energy-efficiency projects, and the energy savings they have the potential to generate (Cooremans and Schonenberger, 2019).

2.1.2 Water management vs. energy management

The focus of any industry is on its primary business, not on energy or water efficiency, although these may be incorporated into its larger objectives to achieve cost control and satisfy corporate and social responsibilities. Currently, there are already several opportunities for the joint development and management of water and energy infrastructure and technologies (Walsh et al., 2015).

Some organisations have already adopted water as a form of energy and managed it using standards, including ISO 50001. The ISO 50001 requires the demonstration of continual improvement through the reduction of energy use, or in this case water. This experience resulted in 18% of reduction in the total annual water usage. The smart use of data will also allow for the identification and exploitation of more opportunities for water efficiency (Walsh et al., 2015).

Increasing energy demands are restricting future water planning measures, again emphasising the requirement for a comprehensive integrated approach from policy makers. To achieve a system closer to a functioning circular economy, there needs to be an increased focus on water. Thus, **water and energy efficiency need to be addressed simultaneously in a cohesive manner** (Walsh et al., 2015).

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 893924.

3. Non-energy Benefits in Energy Audits

The term “multiple benefit of energy efficiency”, that has also been labelled as "co-benefit", "ancillary benefit" or "non-energy benefit", refers to any value created beyond the energy savings value attributed to an energy efficiency improvement (IEA, 2014). The International Energy Agency (IEA) uses the term “**multiple benefit**”, which is considered broad enough to reflect the heterogeneous nature of outcomes of energy efficiency improvements and to avoid prioritisation of various benefits, as different benefits will be of interest to different stakeholders (IEA, 2014).

However, Rasmussen performed a methodical literature review of the existing literature covering the additional effects of EEMs and concluded that the term "**non-energy benefit**” (NEB) is the most appropriate concept to use in an industrial energy-efficiency context (Rasmussen, 2014 and Rasmussen, 2017). NEBs can be defined as the benefits related to industrial energy efficiency investments, beside energy savings, that are quantifiable at a certain level and arise at some point in time (Rasmussen, 2014 and Rasmussen, 2017).

Additionally, Cooremans and Schonenberger considered that NEBs positively contributed to companies’ value proposition, cost reduction and risk reduction, increasing companies’ competitiveness. This means that NEBs have the potential to raise the strategic character of energy efficiency investments, being **more important than energy benefits** in convincing the management to invest in energy efficiency (Cooremans and Schonenberger, 2019).

3.1 Non-energy benefits

NEBs are often situational, unique to the configuration of each individual company, which can lead to different interpretations on what are concrete examples of NEBs. In this sense, there are also different schools of thought regarding their categorisation and quantification.

This project has received funding from the European Union’s Horizon 2020 Research and Innovation Programme under grant agreement No 893924.

3.1.1 Non-energy benefits categorisation and examples

The categorisation and identification of NEBs are not always simple nor straightforward tasks. Rasmussen, in a literature review (Rasmussen, 2014 and Rasmussen, 2017), tried to collect some examples of the industrial NEBs classification performed until then, as in Figure 3.

	Mentioned NEBs	**Categorisation (if any)**
Pye and McKane (2000)	Increased productivity, reduced costs of environmental compliance, reduced production costs (labour, operations and maintenance, raw materials), reduced waste disposal costs, improved product quality (reduced scrap/rework costs, improved customer satisfaction), improved capacity utilisation, improved reliability, improved worker safety, improved efficiency, reduced emissions, extended life of equipment, reduced operating time, reduced ancillary operations, reduced cleaning and maintenance requirements, increased capacity, decreased noise.	
Finman and Laitner (2001) Worrell et al. (2003)	Use of waste fuels, reduced product waste, reduced waste water, reduced hazardous waste, materials reduction, reduced dust emissions, reduced CO, CO_2, NO_x, SO_x emissions, reduced need for engineering controls, lowered cooling requirements, increased facility reliability, reduced wear and tear on equipment/machinery, reductions in labour requirements, increased product output/yields, improved equipment performance, shorter process cycle times, improved product quality/purity, increased reliability in production, reduced need for personal protective equipment, improved lighting, reduced noise levels, improved temperature control, improved air quality, decreased liability, improved public image, delaying or reducing capital expenditures, additional space, improved worker morale.	Six categories: (1) Waste (2) Emissions (3) Operations and maintenance (4) Production (5) Working environment (6) Other
Cooremans (2011)	Follows Worrell et al. (2003) but adds reduced legal risks, carbon and energy price risks, disruption of energy supply and commercial risk.	Relates to competitive advantage: (1) Cost (2) Value (3) Risk
IEA (2012)	Health, increased asset values, industrial productivity, safer working conditions, improved quality, reduced capital and operating costs, reduced scrap and energy use, improved competitiveness.	By economic level: (1) Individual (2) Sectoral (3) National (4) International
Lilly and Pearson (1999)	Extended life of equipment, reduced air emissions and related fines, reduced wear and tear, reduced operations and maintenance expenses.	
Mills et al. (2008)	Improved productivity, improved process control, enhanced reliability, reduced operation and maintenance costs.	
Sauter and Volkery (2013)	Reduced operation and maintenance costs, increased motivation, safer working conditions, improved competitiveness, productivity gains, reduced resource use and pollution.	

Figure 3 – NEBs related to industrial energy efficiency (Source: Rasmussen, 2014)

From these examples, the work of Finman and Laitner (2001) and Worrel et al. (2003) is probably the most recognised, as it served as basis for Nehler's (Nehler, 2018) proposal of industrial NEBs organisation, as in Figure 4.

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 893924.

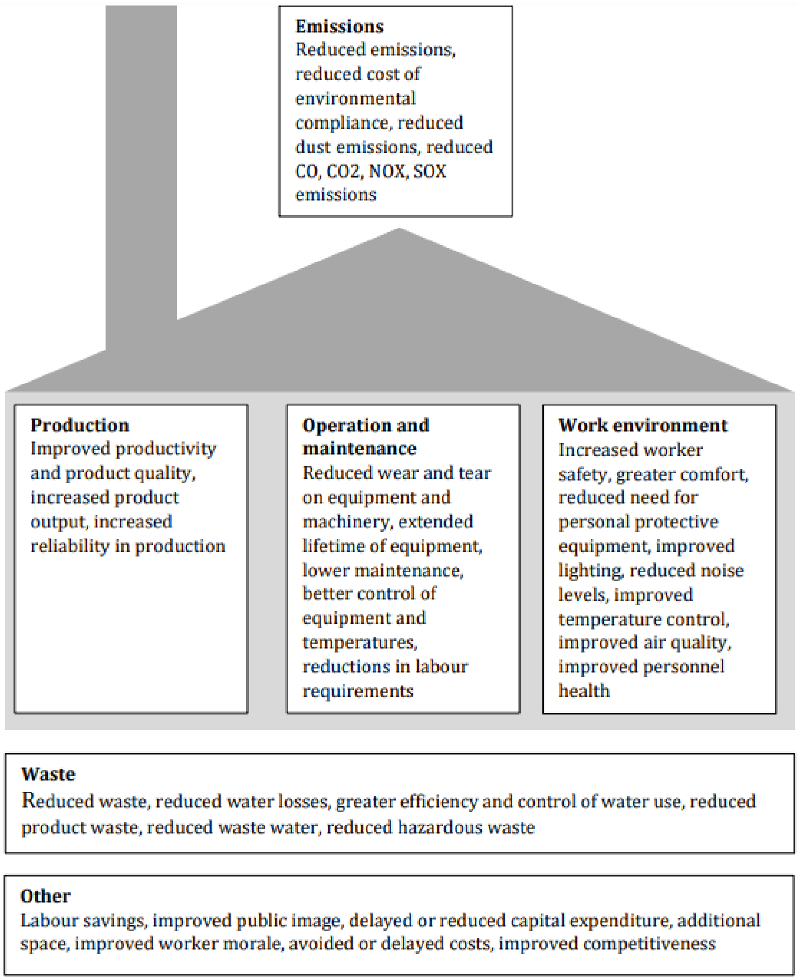

Figure 4 – Examples of industrial NEBs (Source: Nehler, 2018)

Additionally, Finnerty et al. using the six dimensions already proposed shared some **extra examples** of NEBs of energy efficiency investments (Finnerty et al., 2018) during their research, as summarized in Table 1.

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 893924.

Table 1 – Summary of other examples of NEBs of energy efficiency investments (Source: adapted from Finnerty et al., 2018)

Type	NEBs
Emissions	n.a
Production	Improved equipment performance; Shorter process cycle times; Worker safety
Operation and Maintenance	Reduced need for engineering controls; Lower cooling requirements; Increased facility reliability
Work Environment	n.a
Waste	Use of waste fuels, heat, gas; Materials reduction; Costs of environmental compliance
Other	Decreased liability

n.a – no additional NEBs provided by Finnerty et al., 2018, apart from the ones already mentioned on Figure 4.

Furthermore, there are other studies that tried to **identify the most common NEBs for SMEs**. Hall and Roth, who studied a sample that included a variety of commercial, institutional, and industrial facilities, reported the following benefit types: decreased non-energy operating costs, decreased maintenance, increased productivity, increased employee morale and satisfaction, decreased waste generation, decreased defect/error rates, decreased personnel needs, increased sales, and increased equipment life (Hall and Roth, 2003).

Woodroof et al. published a thorough list of improvements regarding the NEBs effect in businesses, with the businesses reporting the following benefit types: reduced maintenance cost (92%), reduced maintenance labour (71%), avoided procurement cost (63%), enhanced public relations image (44%), permanent capital expenditure avoidance (33%) and avoided purchases of carbon offsets (10%). These answers result from a survey conducted to 182 energy managers from which 63 valid answers were obtained (Woodroof et al., 2012).

Johansson and Thollander reported that in terms of production the most mentioned NEBs were increased lifetime of the equipment, longer lifetime of air compressors, and more reliable

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 893924.

production line (less unnecessary production stops). Particularly, regarding operation and maintenance, the reduced maintenance costs was the most noted NEB. Some of the most successful measures presented were the reduction of cooling demand, due to installation of LED lights, and the reduction of the energy demand, by shifting the compressor from areas with excess heat to other areas. Johansson and Thollander claimed that awareness to NEBs seemed to be related to a higher level of maturity when it comes to energy efficiency and in particular energy management practices. Moreover, if **NEBs were to be included in energy audit programs the benefit of the audits could be increased** (Johansson and Thollander, 2019).

Not focusing only on SMEs experiences, the IEA multiple benefits approach to energy efficiency reveals a broad range of potential positive impacts (IEA, 2014). IEA identified **fifteen classes of multiple benefits**, represented by a "flower" diagram (Figure 5). The list did not intend to be exhaustive, but representative of some of the most prominent benefits of energy efficiency identified to date. Overall, IEA's report focused on bringing together evidence in five key areas - macroeconomic development, public budgets, health and well-being, industrial productivity, and energy delivery.

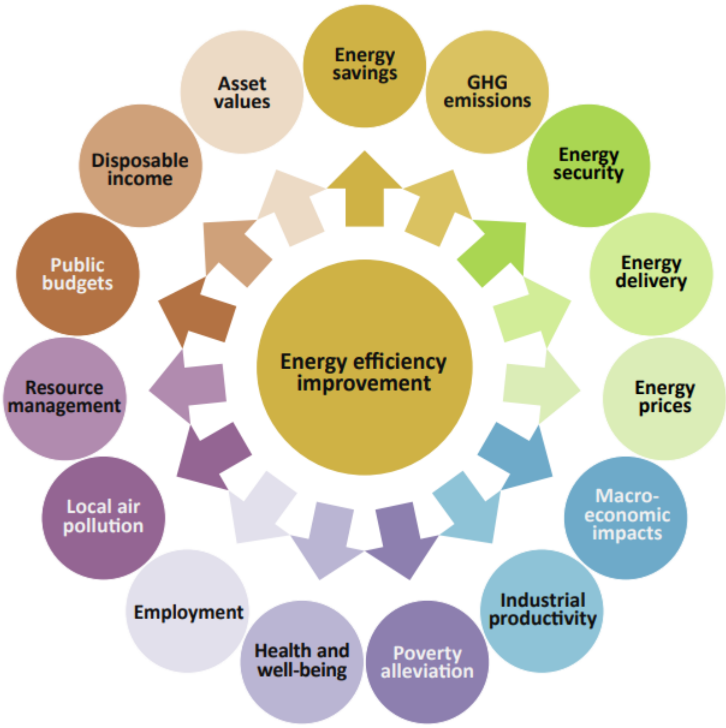

Figure 5 – The multiple benefits of energy efficiency (Source: IEA, 2014)

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 893924.

Recently, the ODYSSEE-MURE project (ODYSSEE-MURE, 2022) developed a tool aimed at showing the different aspects of energy efficiency beyond energy savings and give a more holistic view on its benefit. The multiple benefits are classified into three groups: **environmental, economic, and social** (as in Figure 6). The first group contains the most relevant and direct aspects of energy efficiency such as energy savings and reduced GHG emissions. The second group comprises, among others, positive macro-economic impacts on economic growth, for innovation and competitiveness as well as import dependency. Finally, the third group of impacts covers aspects such as health benefits, poverty alleviation and employment. Each of the identified benefits was also linked to a quantitative indicator.

Figure 6 – Multiple benefits of energy efficiency (Source: Odyssee-Mure, 2022)

3.1.2 Non-energy benefits and policy making

Despite all the efforts to properly identify NEBs, it is fundamental to adequately integrate this approach in a policy pathway, which requires rigorous efforts in terms of data gathering, measurements, and a thorough approach to policy decision making. Bearing this in mind, the plan should be to **maximise the prioritised benefits**, while minimising both costs and negative impacts.

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 893924.

IEA (IEA, 2014) proposes a plan to integrate the multiple benefits approach, starting with the **identification of the problem,** where it is necessary to consider which benefits to assess, data availability, establish baselines, estimate the impacts on indicators, and finally integrate values and consideration of policy interaction into the chosen assessment framework. Secondly, **stakeholders should be engaged at an early stage**, especially stakeholders with expertise and interest in relevant benefit areas. After it, it is important to **establish a policy framework and action plan** by determining the best fit methodology for measuring progress in achieving multiple benefits, while also **securing resources**. As for the implementation stage, it is important to **raise awareness** by communicating targets and goals to implementers, recruiting experienced implementers, and effectively inform implementers and targets groups about the multi benefits approach during its implementation. Certainly, implementation will require **management,** to assess progress and ensures compliance. After implementation, it is necessary to **match data and analysis** to priorities and **evaluate**. A broad range of relevant experts beyond the energy efficiency field should be engaged. In addition, it is also important to analyse the data and assess policy results, while also considering whether outcomes are positive or negative. Finally, **lessons learnt** should be reported by ensuring that the results are disseminated to all departments with a potential stake in the outcomes, to facilitate prioritisation of multiple benefits in the future.

3.1.2.1 Links between non-energy benefits framing and the Sustainable Development Goals

Fawcett and Killip suggest in their study (Fawcett and Killip, 2018) that the NEBs framing could be better evidenced, namely by looking at the **links between a multiple impacts framing and the UN Sustainable Development Goals** (SDGs) (Figure 7).

Figure 7 – Sustainable Development Goals (Source: UN, 2020)

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 893924.

The UN's SDGs are at the heart of policy and investments, as they concern planning and investing for the long-term well-being of the population. The SDGs are important to the global economy and aim at creating a viable model for the future in which all economic growth is achieved without compromising the environment or placing unfair burdens on society (Shnapp et al., 2020). Actually, Shnapp et al. performed a thorough analysis of multiple benefits and their related SDGs, as in Table 2 below. This analysis helps to demonstrate NEBs framing, but also to show the importance of energy efficiency to achieve the SDGs.

Table 2 – Multiple benefits and their related SDGs (Source: adapted from Shnapp et al., 2020)

Category	Multiple benefit	SDGs
Environment	Energy savings	Goal 12; Goal 13; Goal 11
	GHG impacts	Goal 13
	Reduction of air pollution	Goal 7
	Resource management	Goal 12; Goal 11
Economic	Employment effects	Goal 8
	GDP	Goal 8
	Public budget	Goal 8
	Energy security	Goal 7; Goal 11; Goal 12
	Innovation and competitiveness	Goal 9; Goal 11
Social	Health & wellbeing: reduced mortality	Goal 3
	Health & wellbeing: reduced morbidity	Goal 3
	Poverty Alleviation	Goal 1; Goal 7; Goal 10
	Improved Productivity	Goal 4; Goal 8

3.2 Quantification of non-energy benefits

It is clear that a **comprehensive solution** to counteract the low implementation rate of EEMs is necessary. As a stronger appreciation of the existent multiple benefits may empower policy makers to make better use of existing budgets (Howard, 2014), it is of extreme importance to clearly identify their potential, as well as to **quantify** it when possible. Thus, it is crucial to

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 893924.

provide a comprehensive methodological solution, which can be applied to accelerate and support the trend towards improving energy efficiency. Consequently, there is a need to develop a standardized methodology to **assess the NEBs of energy efficiency measures**.

3.2.1 Non-energy benefits quantification context

The research consensus is that NEBs quantification is not an easy task. Nevertheless, it is recognised that NEBs can in fact **impact financial metrics of energy efficiency investments**, being essential components to the business case (Finnerty et al., 2018). Rasmussen concluded that quantifiable and possible to translate into monetary values NEBs can contribute to a **higher and faster return**, which can counterbalance known barriers and increase the priority level for energy efficiency investments against other investments. Therefore, NEBs are **important investment characteristics** related to energy efficiency investments, that should be considered ex-ante, i.e., already during the investment process (Rasmussen, 2017).

Despite the high level of awareness regarding NEBs, they are rarely included in the investment calculations, and there is a lack of knowledge about **how to quantify and monetise** them (Nehler and Rasmussen, 2015). Nehler et al. concluded that NEBs are seldom considered when EEMs are evaluated (Nehler et al., 2018) and Johansson and Thollander believed that the gains from NEBs are **underestimated**, since they are neglected when the financial attractiveness of investments is evaluated, resulting in energy efficiency potentials being left untapped (Johansson and Thollander, 2019).

Rasmussen also stated that if NEBs are included during the investment analysis, the **payback period** for energy efficiency investments will be **shorter** (Rasmussen, 2014). Actually, the IEA estimated that if quantified and monetised, the inclusion of NEBs can shorten payback times by around 50% (IEA, 2014). Other studies that have tried to quantify NEBs, obtained results such as payback time cut by a factor of 1,5, and NEBs being monetarily 2,5 times greater than the energy cost savings (Finman and Laitner, 2001), (Lung et al., 2005), (Hall and Roth, 2003). Recently, Wagner et al. showed that the consideration of monetizable multiple benefits may reduce the payback time of energy efficiency measures by up to 40–85% (Wagner et al., 2020).

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 893924.

Furthermore, Nehler assessed that even NEBs difficult to monetise can make energy efficiency investments more attractive in a qualitative way. Hence, NEBs can be a means to **overcome barriers to energy efficiency**, both economic and others, acting as drivers by increasing the interest in energy efficiency investments (Nehler, 2018). Worrell et al. reviewed the relations between energy efficiency improvements and productivity on the base of more than 70 industrial case studies from different sectors, being amongst the first to propose a methodology to include the identified benefits in the economic assessment of the potential for EEMs in the industrial sector (Worrell et al., 2003).

Nevertheless, despite the potential cost savings, energy efficiency investments are hindered by limited access to capital, a perceived slow return and firms not considering energy to be an important issue. These barriers highlight the importance of additional benefits of industrial energy efficiency investments, beyond energy savings (Rasmussen, 2017). In this sense, quantification has the potential to enable NEBs to be translated into monetary values, and therefore **included in the financial evaluation** and increasing the possibility for energy efficiency investments to meet the payback duration pre-defined by the investor.

3.2.2 Non-energy benefits quantification framework

In the literature reviewed there are several statements on how NEBs quantification should be performed. Killip et al. managed to distinguish two distinct schools of thought about the concept of multiple benefits, how to investigate it, and which methods are appropriate for their analysis and evaluation: the “monetisation approach” and the “salience approach” (Killip et al., 2019).

The **monetisation approach** is rooted in **cost-benefit analysis** and calculates simple **paybacks** for energy efficiency projects, based on the projects’ evaluations. These studies broadly agree that the inclusion of monetised NEBs leads to the reduction of the payback period by more than half (Killip et al., 2019).

Pye and McKane identified several NEBs that could be translated into monetary values, including increased production, reduced emissions, reduced material use, improved product

This project has received funding from the European Union’s Horizon 2020 Research and Innovation Programme under grant agreement No 893924.

quality and reduced needs for cleaning and maintenance. They expressed these NEBs in strictly financial terms and calculated the payback period, net present value, and internal rate of return, so the management could understand the potential of the energy efficiency investments from a business perspective. This study's results indicated that **profitability and payback period were the most critical factors** for the adaptation of an energy efficiency investment (Pye and McKane, 2000).

Lung et al. also conducted research on the importance of production benefits in industrial facilities based on 81 case studies. They described that common payback models for assessing the usefulness of energy efficiency efforts also include payback, net present value, and internal rate of return. Moreover, they highlighted that intangible ancillary savings could not be included in the economic assessment due to difficulties concerning their quantification (Lung et al., 2005).

Worrell et al. proposed a four-step framework for quantifying the productivity benefits of energy efficiency technologies: 1. Identify and describe the productivity benefits associated with a given measure; 2. Quantify these impacts as much as possible; 3. Identify all the assumptions needed to translate the benefits into cost impacts and 4. Calculate cost impacts of productivity benefits (Worrell et al., 2003). Additionally, Hall and Roth, to overcome the frequent lack of data, suggested that average figures for NEBs should be used for companies unable to report quantified savings (Hall and Roth, 2003).

On the other hand, the **salience approach** emphasises the importance of understanding the real **decision-making logic** of different stakeholders, starting from a shared observation that cost-benefit analysis is not salient. In this literature, two emerging themes can be identified: 1. a focus on strategic and core business objectives; 2. the importance of uncertainty and risk in shaping investment decisions, and the ways in which decision-makers think about and assess future impacts of their decisions (Killip et al., 2019). In fact, Cooremans says that the **strategic character** of an investment (defined as the contribution of this investment to a company's competitiveness in performing its core business) is the main influence on decision-making. In this sense, the three dimensions of competitive advantage are defined as: 1. value proposition (does the investment contribute to better product quality and reliability?); 2. cost

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 893924.

reduction (due to reduced product loss or maintenance cost); and 3. risk reduction (e.g., increased workplace safety) (Cooremans, 2019).

On a different note, Nehler and Rasmussen stated that NEBs should be expressed in terms of **costs and revenues** to determine how the benefits will affect the cash flow. Furthermore, they highlight that less quantifiable NEBs can be measured through other benefits that are easier to measure. This means that the indirect NEBs can be measured via their impact on direct NEBs. Nevertheless, to enable a more accurate estimation of an investment's payoff, the **time perspective** when measuring and quantifying NEBs was considered very relevant (Nehler and Rasmussen, 2015).

Rasmussen suggests a framework for the classification of NEBs depending on the **degree to which they can be quantified and the time frame**. Rasmussen's matrix (where the time frame is shown horizontally and the level of quantifiability is shown vertically, as in Figure 8) aims to facilitate the management's assessment of how and when to include NEBs in the decision-making process. Rasmussen set **three levels of quantifiability** (high, medium, and low), where high refers to those benefits that are easily quantified, medium represents the benefits which are possible to quantify although not as easily, and low refers to those benefits that are difficult or not possible to quantify. The time scale is divided into **short term and long term**. Therefore, according to Rasmussen, NEBs can be defined as the benefits related to industrial energy-efficiency investments, beside energy savings, that are quantifiable at a certain level (which can be zero) and arise at some point in time. Hence, by defining and categorising NEBs according to their level of quantifiability and time frame, they can be **included in the decision-making process** at several stages and altogether increase the probability for adopting energy efficiency investments. Additionally, NEBs of a low quantifiability level, especially those of a strategic character, can serve as extra arguments at a later step in the decision-making process to select between similar investment opportunities (Rasmussen, 2014 and Rasmussen, 2017).

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 893924.

Quantifiability	Short term	Long term
High	Increased production; reduced operating time; improved equipment performance; shorter process cycle times; reduced operational costs; reduced amount of raw material	Reduced labour costs; reduced maintenance costs; reduced wear and tear on equipment and machinery; extended life of equipments; reduced scrap/rework costs; improved reliability
Medium	Productivity gains; improved efficiency; improved product quality; increased capacity; improved capacity utilization; improved temperature control; lowered cooling requirements	Reduced waste and waste costs; reduced emissions; reduced costs of environmental compliance; reduced need for engineering controls; delaying or reducing capital expenditures; decreased liability; increased asset values; improved process control
Low	Improved worker safety; improved work environment; decreased noise; improved lighting; additional space; reduced need for personal protective equipments; improved air quality	Improved public image; increased job satisfaction; improved worker morale; competitive advantage; improved customer satisfaction; reduced risks (legal, energy price, energy supply, commercial), health benefits

Time

Figure 8 – Matrix classifying industrial benefits in terms of quantifiability and time horizon (Source: Rasmussen, 2014 and 2017)

Later, Nehler suggested that NEBs' value could be assessed as a **percentage of annual energy savings**. In this sense, the values should be calculated based on objective values or measurements. However, if this was not possible, it could be based on estimations (Nehler, 2018).

Wagner et al. developed a **three-phase standard methodology**, applicable to a wide range of industrial processes and EEMs. The primary objective of this methodology was to provide a comprehensive and standardized approach for the assessment of NEBs associated with EEMs in an industrial context. It should be considered that to assess NEBs qualitatively or quantitatively, a **significant amount of data is necessary**. Wagner et al. stated that all quantifiable NEBs were to be calculated via their percentage change, which means the difference between the benefit value before and after the implementation of an EEM. Moreover, for all quantifiable and monetizable NEBs, there is a distinction between direct and indirect quantifiable and monetizable benefits: direct quantification means that the NEB could be calculated directly from given values such as, e.g., operating times, human resource costs, sales, and others. The indirect quantification or monetization occurs whenever no direct values

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 893924.

are available, and different approaches such as, e.g., surveys, ratings, or weighting factors are required for the assessment (Wagner et al., 2020).

Wagner's et al. three phases methodology is further split into individual steps, each pursuing a specific goal to facilitate the implementation of energy efficiency measures (Figure 9). The first phase – delimitation – aims at defining the system boundaries of the considered industrial process(es). The second phase – assessment – involves the identification, the quantification, and the monetization of NEBs, as well as the qualitative assessment of non-monetizable NEBs. The last phase – evaluation – focusses on the integration of the obtained results into the financial valuation of the energy efficiency measure and, therefore, on the cash flow analysis and the determination of the payback time under consideration of the monetizable NEBs (Wagner et al., 2020).

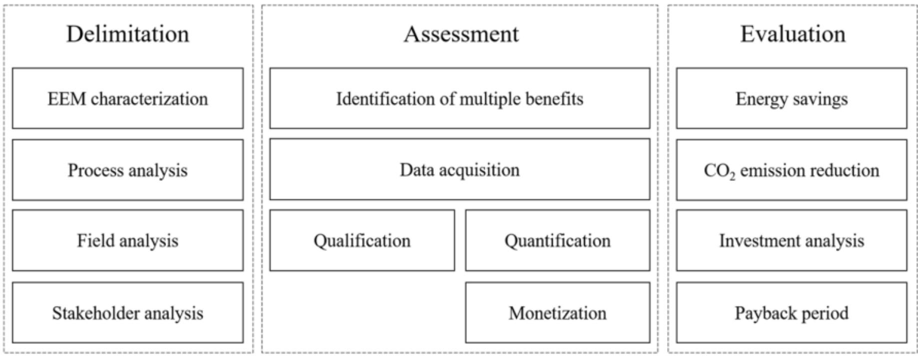

Figure 9 – Three-stage multiple benefits quantification methodology (Source: Wagner et al., 2020)

Therefore, even if observed, measured, and quantified at a specific level, **any attempt to generalise the values of NEBs might encounter challenges**. The mapping and evaluation of NEBs will probably be based on a mixture of experience, observations, calculations, and/or estimations in various ways.

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 893924.

4. Approaches to Integrate Resource Efficiency in Energy Audits

According to the United Nations Environment Programme, **resource efficiency** concerns the managing of raw materials, energy, and water along the value chain to minimize waste and detrimental impacts on the ecosystems throughout the entire lifecycle of production. Therefore, this will mean a careful selection of raw materials and energy resources; minimization of waste, emissions, hazards, and risks; responsible management of material and energy flows during the production process; accomplishment of a function, task, process or result with the minimal possible amount of water; and attention to the use, recycling, and disposal phases of the product life cycle (UNEP, 2010).

For companies resource efficiency will result in a **series of benefits**, namely: reduction in cost for materials, chemicals, and energy; reduction in cost for disposal of waste and treatment of emissions; reduced cost for compliance with laws and regulations regarding waste, emissions, and the use of chemicals; over the long term, security of supply; meeting the customer demand for sustainable business practice.

Concerning the water-energy nexus[5], the efficient use of water may mean that when water pumping is reduced it directly leads to savings in electricity costs and associated greenhouse gas emissions, and the amount of energy needed to treat wastewater is also reduced, overall resulting in less energy demand, for instance (UNEP, 2010)

4.1 Resource efficiency inclusion during an energy audit

The potential to address NEBs and combine strategies between energy efficiency and water and/or materials efficiency is often neglected. This reduces the **potential for continuous energy efficiency improvements**, even if these are related to water availability, waste, and wastewater reduction, decrease in CO_2 emissions and maintenance costs, improvement of the working environment conditions or production downtime, to name some examples. In

[5] The water-energy nexus is the relationship between how much water is used to generate and transmit energy, and how much energy it takes to collect, treat, transport, store, consume and dispose water.

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 893924.

addition, sustainability and resource efficiency can be perceived by companies in different manners, and their interest and focus may differ.

During 2019, a questionnaire was shared by ADENE – The Portuguese Energy Agency with the Portuguese Intensive Energy Consumption Management System (SGCIE) industries. Its aim was to understand their views, regarding the **relevance of introducing new topics** (other than energy) **during** the **energy audits** currently performed within this System. The questionnaire had 49 valid answers, that is not very representative, but enough to get a reasonable insight. Its main conclusions were the following:

- In addition to energy efficiency, the inclusion during an energy audit of **renewable energies use** was considered as "very important" (top mark) by 60% of the industries. Furthermore, **energy recovery from waste** and **efficient use of materials** were also considered as "very important" by 47% of the companies.
- The industries stated that **specific training** was fundamental for the materialization of resource efficiency inclusion during an energy audit. Additionally, if energy synergies between different intensive energy consumers are to be promoted, data availability for benchmarking is essential.
- The vast majority (80%) of the industries have already developed plans/projects regarding sustainability and efficient use of resources, at some point in time.
- Regarding water efficiency, 70% of the industries were interested in implementing an **alarm system** that reports the occurrence of water leaks, and 74% were interested in a **water efficiency analysis** to identify improvement measures.
- To implement a given water and water-energy nexus efficiency measure, the majority of the industries (53%) would need **25 to 50% water cost reduction** as an incentive. Regarding the energy cost, 38% of the industries would need **15 to 20% reduction** to implement the efficiency measure, and 28% would need only 10 to 15% energy costs' reduction.

Also, the LEAP4SME project (LEAP4SME, 2021) identified the most important benefits and NEBs resulting from EEMs implementation in SMEs, through a survey launched between October 10th and December 6th, 2021. The survey included two sections, one for SMEs and

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 893924.

another one for Organisations (Associations, Agencies, Ministries and auditors). The section Organisations collected 148 opinions and, among other conclusions, set that the **most relevant benefits and NEBs**, in this context, appear to be the reduction of energy cost, reduction of greenhouse gas emissions, efficiency improvement of the production process, reduction of maintenance and operation costs, and increase of technological competitiveness.

The survey included two questions directly related to NEBs. The first one was: "**Which co-benefits in your opinion can reasonably emerge from energy efficiency implementation measures in SMEs?**". The participants' perception is analysed in Figure 10. The reduction of energy cost and greenhouse gas emissions are considered a priority. However, the answers show that the other factors are also perceived as relevant, particularly the efficiency improvement of the production process and technological competitiveness and the reduction of maintenance and operation costs.

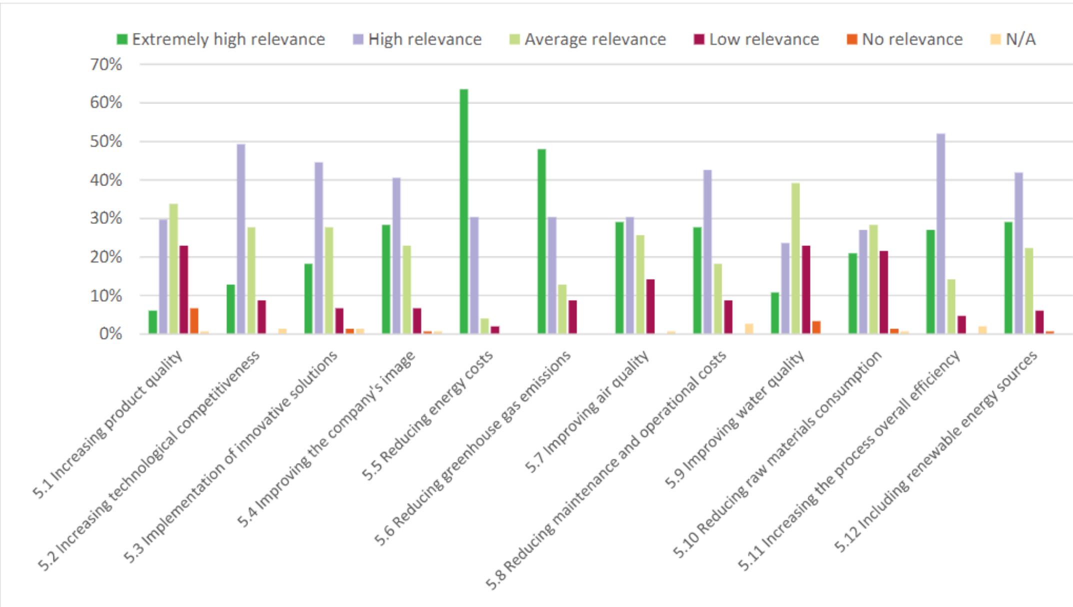

Figure 10 – Which co-benefits in your opinion can reasonably emerge from energy efficiency implementation measures in SMEs?" (Source: LEAP4SME, 2021)

The second question was: "**To increase the implementation of the recommended measures for SMEs do you think it is better to concentrate the efforts on…".** This question explores where the efforts to increase the implementation of the recommended

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 893924.

measures for SMEs should concentrate on. Answers indicating extremely high and high relevance significantly prevail for three options, namely incentives, quantification of multiple benefits and assessment of further opportunities from combining energy efficiency with other savings (Figure 11). This result highlights the importance of developing ways to **adequately evaluate** other benefits associated to energy efficiency measures.

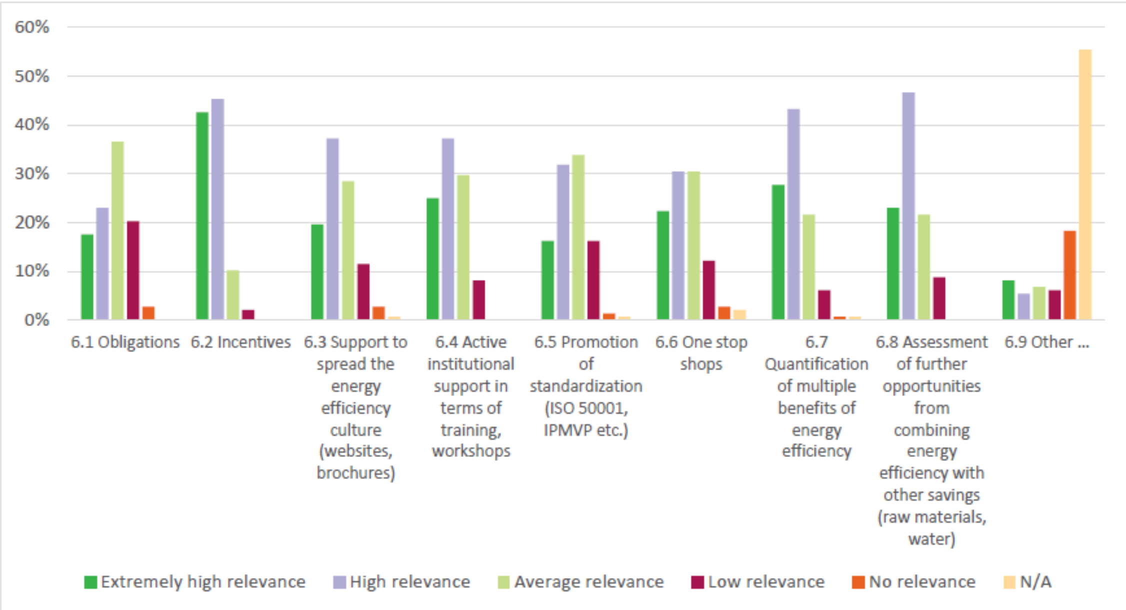

Figure 11 – To increase the implementation of the recommended measures for SMEs do you think it is better to concentrate the efforts on… (Source: LEAP4SME, 2021)

So, **companies interest** regarding NEBs and resource efficiency appear to be quite clear and real added value can derive from their study. Nevertheless, their integration within common energy audit procedures reinforces the need to adequately **define suitable key performance indicators** (KPIs), able to create an analytical basis for decision making and efficiency measures implementation.

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 893924.

4.2 Non-energy key performance indicators

Reuter et al. selected 20 KPIs, linked to what they considered to be the most important multiple benefits (see Table 3 below). The choice of indicators was based on a **trade-off between comprehensiveness and practicality**, having in mind data availability and the indicator's complexity. The goal was to set easy-to-use indicators, that allow the user to estimate the multiple benefits of energy savings without having to resort to time and data-intensive models (Reuter et al., 2020).

Table 3 – Set of indicators for the quantification of multiple benefits of energy efficiency (Source: adapted from Reuter et al., 2020)

Category	Benefit	Indicator
Environmental	*Energy/Resource Management*	
	Energy savings	Annual energy savings
	Savings of fossil fuels	Annual fossil fuels saved due to energy efficiency
	Impacts on Renewable Energy Sources targets	Lowering of Renewable Energy Sources targets due to energy efficiency
	Global and Local Pollutants	
	Greenhouse gases savings	Annual CO_2 savings linked to energy savings
	Local air pollution	Avoided local pollutants from $PM_{2.5}$, PM_{10} and NO_x
Social	*Energy Poverty*	
	Alleviation of energy poverty	Reduction of energy costs shares in disposable incomes because of energy
	Quality of life	
	Health and well-being	Externalities linked to health impacts
	Disposable household income	Changes in energy cost share in disposable households' income due to energy efficiency

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 893924.

Category	Benefit	Indicator
Economic	*Innovation/Competitiveness*	
	Innovation Impacts	Revealed Patent Advantage
	Competitiveness	Revealed Comparative Advantage
	Turnover of energy efficiency goods	Investments linked to energy savings
	Macro-economic	
	Impact on GDP	Impacts of energy savings on GDP growth
	Employment effects	Additional FTE (full-time equivalents) linked to energy savings
	Potential impact on energy prices	Lower energy prices based on price elasticities
	Impact on public budgets	Additional income tax revenue from employment based on energy savings
	Micro-economic	
	(Industrial) productivity	Change of productivity due to lowered cost
	Asset value	Change of asset value of commercial buildings due to energy efficiency benefits
	Energy Security/Energy Delivery	
	Energy security 1	Lower import dependency
	Energy security 2	Larger supplier diversity
	Impact on integration of RES	Demand response potential by country

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 893924.

Shnapp et al. also categorised the multiple benefits and linked KPIs into three main groups, to calculate and monetise them (Shnapp et al., 2020), as in Table 4.

Table 4 – Overview of multiple benefits and indicators (Source: adapted from Shnapp et al., 2020)

Category	Benefit	Indicator
Environment	Energy savings	Annual energy savings
	Greenhouse gases impacts	Annual CO_2 and other emissions savings linked to energy savings
	Reduction of air pollution	Emission factors per avoided pollutant: NO_x; SO_2; CO_2; $PM_{2.5}$
	Resource management	Savings on fossil fuels and metal ores
Economic	Employment effects	Input/output, economic activity-construction
	GDP	Impact of energy savings on GDP
	Energy security	Avoided electric power output & investment costs. Share of fossil fuels/energy imports in GDP
	Innovation & Competitiveness	Quantitative output: growth potential of the innovation markets for energy efficiency in buildings. Qualitative output: competitive advantage of European industries compared to non-EU players
Social	Health and well-being: reduced mortality	All in number of deaths per year: Excess winter mortality; Mortality ozone; Mortality $PM_{2.5}$
	Health and well-being: reduced morbidity	Indoor air pollution; Winter morbidity; Morbidity $PM_{2.5}$
	Poverty Alleviation	Utility costs / household. Diseases arising from thermal discomfort
	Improved Productivity	Active days gained (indoor exposure); Workforce performance (minimum workdays)

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 893924.

Furthermore, Wagner et al. performed the identification and description of multiple benefits, where **specific resource efficiency benefits KPIs were acknowledged** (Wagner et al., 2020).

Table 5 – Overview of multiple benefit indicators (Source: adapted from Wagner et al., 2020)

Indicator	Description
Total water consumption	Quantification of the total yearly water consumption within the company
Water recovery rate	Rate at which the used water is recovered within the company and reused for the same or other purposes. It has a direct impact on the yearly freshwater consumption and water disposal
Water contamination	Assessment of the level of contamination and the type of contaminants in the water
Total cost for waste	Total cost associated with the waste in terms of mitigation costs, storage, disposal, treatment, and any other costs
Risk level of waste	Qualitative assessment of the safety risks in terms of health issues or environmental hazards that could be triggered by waste
Health risks	Any health risks related to waste
Environmental hazard	Any environmental hazards related to waste
Resource availability	Assessment of the availability of resources. Especially useful in case of rare resources or when the availability is highly dependent on the current demand
Risk level of resources	Qualitative assessment of the safety risks in terms of health issues or environmental hazards that could be triggered by resources
Health risks	Any health risks related to resources
Environmental hazard	Any environmental hazards related to resources

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 893924.

4.2.1 Proposed non-energy key performance indicators

As presented, there are numerous examples of KPIs linked to NEBs, and more concretely to resource efficiency. Still, it is difficult to find literature that collects indicators related to the **multiple dimensions of resource efficiency** (namely water, materials, and water-energy nexus) in an integrated way.

Therefore, **a new set of KPIs** that uses data easily collectable during an audit procedure, or that is already systematized within the companies' legal or voluntary requirements is proposed (e.g., ISO standards, environmental licensing, etc.), as in Table 6.

Table 6 – Proposed resource efficiency key performance indicators (Source: ADENE, 2022)

Group	Indicator	Description
Water Consumption	Total water consumption	Total yearly water consumption within the company [m^3]
Water Intensity	Water consumption per GVA	Total yearly water consumption within the company per its Gross Added Value [m^3/€]
	Water specific consumption	Total yearly water consumption within the production process per annual production: water consumption per unit of product* [m^3/kg]
	Water consumption per employee	Total yearly water consumption within the company per employee [m^3/employee]
Water Sources	Share of alternative water sources used	Total yearly water consumption from alternative sources per total yearly water consumption within the company [%]
	Share of wastewater treated and reused	Total yearly treated and reused wastewater per total yearly wastewater produced [%]
Water cost	Share of water costs in the total costs incurred	Total yearly water costs per total yearly company costs [%]
	Water specific cost	Total yearly costs concerning water used within the production process per annual production* [€/kg]
	Water productivity	Gross added value per total yearly water consumption [€/m^3]

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 893924.

Group	Indicator	Description
Material use	Materials specific consumption	Total yearly materials consumption per annual production* [kg/kg]
	Waste valorization rate	Waste valorization per annual waste production [%]
	Share of subproducts in production process rate	Quantity of subproducts per total yearly materials consumption [%]
Water-Energy nexus	Energy specific cost of the hydraulic circuits	Cost of energy consumed within the hydraulic circuits per total yearly water consumption within the hydraulic circuits [€/m^3]
	Water specific cost of the hydraulic circuits	Cost of water consumed within the hydraulic circuits per total yearly water consumption within the hydraulic circuits [€/m^3]

** Considering that the production unit is [kg].*

These KPIs intend to assist the quantification of NEBs resulting from energy audits, namely, contributing to the **comparison of resource consumption levels**. Furthermore, the goal is to create a basis supported by **concrete data**, that assists efficiency investments choices and recommended measures implementation. Finally, it should be noted that this set of KPIs is focused on resource efficiency and additional to the one already proposed in LEAP4SME project D3.1- Guideline document on SMEs selection criteria and stakeholder engagement (LEAP4SME, 2021).

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 893924.

5. Policy Instruments, Programmes and Other Initiatives

The LEAP4SME D2.2 – "Existing support measures for energy audits and energy efficiency in SMEs" report identified a total of 173 policy instruments through a literature review conducted by the LEAP4SME partners, researching the policies and support programmes (including trainings and pertinent EU funded initiatives) available in their countries. These policy instruments were categorised as either financial support, information/advice, regulations, or national plans and strategies. The majority of the policy instruments identified (66) were specifically targeted at SMEs across all sectors, but others were targeted at all business types and sizes (44), or a combination of different stakeholders, including SMEs, large businesses, householder, and public bodies (LEAP4SME, 2021).

During the last years, energy audit policy programs have been a common policy approach. In addition to it, policy programs including energy management certification also started to appear, as **energy management**[6] is a **key driver for improving energy efficiency** (IETS, 2020). Nevertheless, as also shown by LEAP4SME D2.2 report, policy instruments that solely **support** the **carrying out of energy audits** within SMEs (either to provide information and advice on energy efficiency, or as a prerequisite to access financial support to implement energy efficiency measures) are **not enough**. In fact, SMEs' managers are reluctant to invest in in-depth audits without certainty of the results, and the **audits *per se* do not lead to energy efficiency improvements,** missing the necessary financing support for the energy efficiency investments. However, this issue has been tackled through several policy instruments, that combine energy audits with access to financial instruments (LEAP4SME, 2021). Despite the existence of policy programs adequately directed to energy audits and EEMs implementation, NEBs that result from these measures are often overlooked. Actually, from the policy instruments previously identified **none** is completely **focused on NEBs' promotion**.

[6] Despite term "energy management" is associated with the energy management system ISO 50001 standard, a vast array of policy programs and schemes in place, involving energy management, are not related to a determined framework or international standard.

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 893924.

5.1 Good practices identified

The instruments identified within the LEAP4SME D2.2 report do not have a NEB focus. Nevertheless, some do offer a significant boost to their incorporation during energy audits. This section intends to give an overview of some good practices identified by project partners, focusing on programmes managed by the energy agencies and with European funding. Furthermore, other European projects with NEBs focus were also identified. It should be noted that the aim is to present some pertinent examples, and not to be exhaustive.

5.1.1 Programmes managed by the energy agencies

- The *"Klimaaktiv* programme energy efficient businesses" (https://www.klimaaktiv.at/effizienz) is a programme delivered by the AEA (Austrian Energy Agency) with the involvement of the Austrian Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology. This programme increases the quality of audits through energy related trainings for energy auditors/consultants and companies, preparing guidelines for energy efficient technologies and auditing, and supporting peer to peer learning, among others. It also promotes the implementation of energy management systems according to ISO 50001. Moreover, within this ISO 50001 focus, an information brochure regarding non-energy benefits was created and published on the *klimaaktiv* website. Within the *klimaaktiv* programme all energy savings (kWh) were converted into CO_2 emission reductions in 2021, and a voluntary agreement programme for climate neutral SMEs was created, with kWh savings, renewable energies, and conversion into CO_2 reduction targets.

- Within the EED Article 8 framework a multi-year programme for awareness of SMEs towards the rational use of energy has been recently developed. This programme is financed by the Italian Ministry of Ecological Transition and includes the development of a self-energy audit tool for SMEs: the tool aims to support SMEs in the elaboration of an energy audit based on their energy consumption data and provides an evaluation of their energy consumption indexes. The tool provides insights on the SMEs environmental impact, providing an estimation of their CO_2 emissions and collecting information on the water consumed in their productive processes. This serves to raise SMEs awareness on

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 893924.

the environmental impact of their processes. Being part of a long-term program, the tool is also aimed to be a data collecting instrument, since the SMEs can send the results of their self-assessment to ENEA (Italian Agency for New technologies, Energy and Sustainable development). Based on the inputs received, the Agency will produce statistical analyses in support of the policy makers, as well as provide SMEs with general indicators on energy and non-energy benefits. The tool is developed in collaboration with the University of Basilicata and the tentative release is the end of 2022.

- AQUA+ (https://www.aquamais.pt/) is a voluntary system for assessing and classifying the water efficiency of buildings, on a scale from F (least efficient) to A+ (most efficient). This system was created by ADENE – Portuguese Energy Agency to promote the efficient use of water. It performs the diagnosis of improvement measures for water efficiency and reuse, enhancing market readiness, best practices and creative solutions in building design, construction and retrofit. This system is innovative, practical, and replicable by qualified and recognized experts, valuing buildings during their transaction and use, as well as to companies. AQUA+ is already available for households and hotels, and soon will be available for other types of buildings such as commercial buildings and services. AQUA+ system was finalist in the category of "Support to Sustainable Transition" in the grand European final of the EEPA 2021 Awards – European Enterprise Promotion Awards of the European Commission.

- The Slovakia Sustainable Energy Finance Facility (http://www.slovseff.eu/index.php/en/) is a financial program delivered by the Slovak Government, Banks (OTP bank, Slovenska sporitelna, VUB bank, Unicredit bank) and ESCOs, targeting industry (SMEs and large enterprises) and residential buildings. SlovSEFF III is a financial program for financing sustainable energy sources prepared by the European Bank for Reconstruction and Development (EBRD) in cooperation with the Ministry of the Environment of the Slovak Republic and the Ministry of Agriculture, Food, and the Environment of Spain. Under SlovSEFF III, local commercial banks are provided with loans in the amount of 90 million euros for the provision of loan instruments to finance projects aimed at renewable energy sources and increasing energy efficiency. Upon successful implementation and verification of the completeness of each project, an incentive payment is paid to the client calculated

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 893924.

(based on an estimate of future CO_2 savings that the project will bring) as a percentage of the amount of loan drawn from EBRD resources.

- The loan and grant Energia Plus (Energy Plus) programme is managed by the Polish National Fund for Environmental Protection and Water Management (NFOŚIGW). Since the beginning of the programme its budget amounts to 4000 million PLN (3950 million PLN refers to the loan and 50 million PLN to the grant). The programme will be implemented between 2019 and 2025, with contracts being signed by 2023 and the funds distributed by 2025. According to the programme, the eligibility of a project is subject to: 1. prior performance of an energy audit; 2. the investment covered by the co-financing results from the recommendation of the energy audit (verified by NFOŚiGW at the stage of the evaluation of co-financing applications, plus the energy savings are to be no less than 5%). This programme offers support, for example, in the field of raw material consumption reduction, new sources of heat and electricity, reducing or avoiding harmful emissions into the atmosphere, and modernisation/extension of heating networks. Furthermore, the energy audit recommendations are monitored, and the project is obliged to achieve and confirm the energy savings by presenting documentation (e.g., reports or ex-post audits).

5.1.2 European funded projects

- The PerManeNt – Integrated Platform for Smart Operational Monitoring and Efficient Energy Management of Water Supply Networks (https://www.permanent-project.gr/en/) is a project delivered by the Operational Program Competitiveness, Entrepreneurship & Innovation (EPANEK) with the involvement of the European Regional Development Fund (ERDF) and the Greek Ministry of Development and Investments. This project is targeted at Municipal Companies of Water Supply and Sewerage and intends to develop an integrated platform and remote monitoring applications, for the smart operational monitoring and efficient energy management of water supply networks, aiming at reducing their environmental footprint, energy consumption, and operating expenses, thus reducing the cost of water to the public.

- IMPAWATT (https://www.impawatt.com/) was a project coordinated by Planair (Switzerland) that had as partners Envipark (Italy), VTT (Finland) Chambre de Commerce

Rhone-Alpes, Auvergne (France), AEA (Austria) and SEnerCon (Germany). This project aimed at creating a staff training and capacity building platform to enhance corporate policy towards energy efficiency, energy culture and sustainable supply-chain initiatives. Different actors in a company, as well as external energy consultants, were targeted as users of the platform, which was developed as an online portal with a smart search engine for different resources/content/tools for capacity building and staff training material tailored to companies. The platform also allowed companies to exchange energy efficiency related experiences and to benchmark their energy efficiency. Finally, the platform gave access to the energy monitoring portal www.enerspot.com where companies could enter and follow their main energy consumption, and effects of energy efficiency measures.

- The project CONSUME-LESS in Mediterranean Touristic Communities (https://www.consumelessmed.org/) delivered by the Energy and Water Agency from Malta, aimed to reduce energy, water and waste generated by tourist influx specifically in coastal and tourist areas through the introduction of the territorial label called "ConsumelessMed Label". This label is assigned to private and/or public entities participating in the initiative, performing sustainable management actions towards the reduction of energy, water, and waste generation. Furthermore, the label is based on the qualification of the coastal territories as ConsumelessMed locations and on the enhancement of this peculiarity through an innovative communication and territorial marketing campaign, implemented by directly involving all interested actors (local authorities, tourism operators and service providers, tourists). The objectives of the project were to promote sustainable resource use with particular focus on the reduction of water and energy consumption, promote responsible behaviour among tourists and to promote sustainable tourism models based on the enhancement of local heritage, as well as natural resources and products. There were various participants who were involved in the project including local stakeholders, SMEs, sectoral agencies, public authorities (local, regional, and national) and tourism establishments such as restaurants, bars, and cafes. The project helped to set up the ConsumelessMed label and related guidelines and a policy paper to promote the model at a strategic model.

- The COLEOPTER project (https://coleopter.eu/), financed by Interreg Sudoe Programme, intends to develop an integrated approach to the energy efficiency of public buildings that

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 893924.

links technical, social, and economic challenges. COLEOPTER addresses two energy efficiency challenges in buildings: difficulties for rural municipalities to act and carry out work despite the positive local impact, and a lack of awareness of building challenges, which leads to irrational use of energy/water and low renovation rates. The main contributions of the project, namely the COLEOPTER approach and the work conducted on the test sites, benefits municipalities, citizens, and SMEs, leading to better planning of energy and water efficiency policies and increased public and private renovation rates. The project is coordinated by RURENER (The European network of rural communities committed to the energy transition) and has seven more partners (ADENE - PT, CETENMA – SP, Universitat Politècnica de Catalunya – SP, Comunidade Intermunicipal do Ave – PT, Ayuntamiento de Cartagena – SP, Município da Póvoa de Lanhoso – PT and Syndicat Mixte Ferme est Creuse – FR).

5.1.3 Non-energy benefits focus funded projects

- The COMBI project (https://combi-project.eu), financed by H2020 Programme, aimed at quantifying the multiple non-energy benefits of energy efficiency in the EU-28 area. It gathered existing approaches and evidence from the EU area and developed modelling approaches for impacts on emissions, resources, social welfare, macro economy and the energy system. Within the COMBI modelling/quantification work, more than 35 individual impacts were quantified, following individual cause-effect chains from energy efficiency improvement actions to the impacts. All data is available from an open-source online database and analysable via a graphic online-visualisation tool (launched at the final conference 17 May 2018). Also, insights for policy relevance were derived and policy recommendations elaborated to facilitate the communication of the non-energy benefits in the relevant policy areas. The consortium was coordinated by Wuppertal Institute with the research partners University of Antwerp, University of Manchester, Copenhagen Economics and ABUD/Advanced Buildings and Urban Design.

- The Multiple Benefits project (https://www.mbenefits.eu/), financed by H2020 Programme, developed a training platform and tools, and tested these with organisations, to analyse and propose energy-saving projects. In parallel, the project partners compiled an evidence base of case studies, project examples and results to bolster the business case for projects.

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 893924.

The Multiple Benefits approach was to quantify and communicate the strategic impacts of investments that enhance energy performance. Through a process of training, analyses, using tools and a growing evidence base, the Multiple Benefits approach systematically identified and quantified core business impacts of energy efficiency measures. This project had 15 partners and was led by Fraunhofer ISI in Germany. The partners represented 11 European countries, and the partner networks covered all European countries, as well as most world regions.

- The MICAT project (https://micat-project.eu/), financed by H2020 Programme, aims to develop a comprehensive approach to estimate Multiple Impacts of Energy Efficiency (MI-EE) by co-creating a free, easy-to-use, scientifically sound online tool (MICATool). The MICATool will enable holistic analyses of MI-EE at the European, national, and local level to strengthen the climate strategy of the Energy Union and accelerate an affordable and just, sustainable energy transition by addressing the challenges and needs of important target groups: policy makers, practitioners, and evaluators. The project is coordinated by Fraunhofer ISI (DE) and implemented together with six European partners.

- The REFEREE project (https://refereetool.eu/), financed by H2020 Programme, intends to develop an online decision-support tool for energy efficiency measures, to analyse and quantify the multiple benefits of energy efficiency, e.g., in terms of CO_2 and pollution reduction, health improvement and well-being, employment and monetary gains. The project is working with a Policy Advisory Group, composed of policymakers, investors, businesses, and researchers at local, national and EU level. The tool prototype will also be tested through pilot case studies on real-world energy efficiency measures, and a diversity of resources will be available for users, including training workshops. The project is coordinated by ISINNOVA (IT) and has 6 European partners: Cambridge Econometrics (UK), MCRIT (SP), Center for the Study of Democracy (BG), Jacques Delors Institute (FR), B.A.U.M. Consult GmbH (DE), and the European Environmental Bureau.

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 893924.

6. Conclusions and Next Steps

This report presents a literature review analysis of energy efficiency multiple benefits, also accessing the implementation of recommended energy efficiency measures, including a comparison of approaches to integrate resource efficiency audits, namely contemplating the water-energy nexus.

Throughout the literature review it was clear that, as an energy audit does not result in energy savings *per se*, energy efficiency measures should be supported aiming their implementation. Furthermore, energy management systems could also provide an organizational structure for overcoming some of the barriers that limit the uptake of the efficiency measures.

In the same manner, quantifiable, and translatable into monetary values, NEBs can counterbalance acknowledged barriers, and increase the priority level for energy efficiency investments against other investments. Moreover, as NEBs are seldom considered when energy efficiency measures are evaluated, the resultant gains are often underestimated. Thus, the correct identification of NEBs is fundamental to adequately integrate them into a policy pathway, despite the various schools of thought regarding their categorization and quantification. Likewise, the combination between energy efficiency and resources efficiency (water and/or materials efficiency) is also neglected, reducing the potential for continuous energy efficiency improvements. However, the interest of companies in NEBs and resource efficiency is evident, and real added value can derive from their study.

NEBs integration within the common energy audit procedures implies the need to adequately define suitable KPIs, able to create an analytical basis for decision making and efficiency measures implementation, supported by solid data. Nevertheless, and despite the numerous examples of KPIs linked to NEBs, and more concretely to resource efficiency, it is still difficult to find literature that collects indicators related to the multiple dimensions of resource efficiency in an integrated way. In this sense, a new set of KPIs is proposed, using data easily collectable during an audit procedure, or that is already systematized within the companies' legal or voluntary requirements. These KPIs intend to assist the quantification of NEBs resulting from energy audits, namely contributing to the comparison of resource consumption levels.

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 893924.

The next step of the work will be focused on the quantification and analysis of scenarios and strategies to boost energy audits, and energy efficiency implementation, including enhancing savings through other resource analyses (namely, water-energy nexus and materials).

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 893924.

References

Backlund, S., Thollander, P., Palm, J., & Ottosson, M. (2012). Extending the energy efficiency gap. Energy Policy.

Cooremans, C., Schonenberger, A. (2019). Energy management: A key driver of energy-efficiency investment? Journal of Cleaner Production 230.

Declich, A., Quinti, G., Signore, P. (2020). SME's, energy efficiency, innovation: a reflection on materials and energy transition emerging from a research on SMEs and the practice of Energy Audit. Matériaux & Techniques 108.

DEESME (2021). D2.3: Requirement-based report on best-practice for policies on energy audits, energy management and multiple-benefits.

Fawcett, T., Killip, G. (2018). Re-thinking energy efficiency in European policy: Practitioners' use of 'multiple benefits' arguments. Journal of Cleaner Production 210.

Finman, H., Laitner, J. (2001). Industry, energy efficiency and productivity improvements. Proceedings ACEEE Summer Study on Energy Efficiency in Industry, 561-570.

Finnerty, N., Sterling, R., Contreras, S., Coakley D., Keane, M. (2018). Defining corporate energy policy and strategy to achieve carbon emissions reduction targets via energy management in non-energy intensive multi-site manufacturing organisations. Energy 151.

Hall, N., Roth, J. (2003). Non-energy benefits from commercial and industrial energy efficiency programs: energy efficiency may not be the best story. Proceeding of the 2003 International Energy Program Evaluation Conference.

Howard, R. (2014). Warmer Homes: Improving fuel poverty and energy efficiency policy in the UK. Policy Exchange, London.

Herce, C. Biele, E.; Martini, C.; Salvio, M.; Toro, C. (2021). Impact of Energy Monitoring and Management Systems on the Implementation and Planning of Energy Performance Improvement Actions: An Empirical Analysis Based on Energy Audits in Italy. Energies 2021.

IEA (2014). Capturing the Multiple Benefits Of Energy Efficiency. OECD/IEA, 2014.

IETS (2020). Energy efficiency in SMEs – key research findings from the IETS TCP. IETS Annex XVI Energy Efficiency in SMEs. November 30th, 2020.

Johansson, I., Thollander, P. (2019). Non-energy benefits in energy audit and energy efficiency network policy programs for industrial SMEs. ECEE Summer Study Proceedings, 2019.

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 893924.

Kalantzis, F., Revoltella, D. (2019). Do energy audits help SMEs to realize energy-efficiency opportunities? Energy Economics 83.

Killip, G., Fawcett, T., Cooremans, C., Crijns-Graus, W., Krishnan, S., Voswinkel, F. (2019). Multiple benefits of energy efficiency at the firm level: a literature review. ECEEE Industrial Summer Study Proceedings, 2019.

Kluczeka, A.; Olszewskib, P. (2016). Energy audits in industrial processes. Journal of Cleaner Production 142.

LEAP4SME (2021). D2.2 - Existing support measures for energy audits and energy efficiency in SMEs.

LEAP4SME (2021). D2.3 - Energy audits market overview and main barriers to SMEs.

LEAP4SME (2021). D3.1 - Guideline document on SMEs selection criteria and stakeholders engagement.

LEAP4SME (2021). D3.2 - Report on SMEs characterization to address an effective policy development.

Lung, R., Mckane, A., Leach, R., & Marsh, D. (2005). Ancillary savings and production benefits in the evaluation of industrial energy efficiency measures. Proceedings ACEEE Summer Study on Energy Efficiency in Industry, 2005.

McKane, A. et al. (2017). Predicting the quantifiable impacts of ISO 50001 on climate change mitigation. Energy Policy 107.

Nehler, T., Thollander, P., Ottosson, M., & Dahlgren, M. (2014). Including non-energy benefits in investment cal-culations in industry – empirical findings from Sweden. ECEEE Industrial Summer Study Proceedings, 2014.

Nehler, T., Rasmussen, J. (2015). How do firms consider non-energy benefits? Empirical findings on energy-efficiency investments in Swedish industry. Journal of Cleaner Production 113, 2015.

Nehler, T., Thollander, P., Fredriksson, L., Friberg, S., Nordberg, T. (2018). Non-energy benefits of Swedish energy efficiency policy instruments – a three-levelled perspective. ECEEE Industrial Summer Study Proceedings, 2018.

Nehler, T. (2018). A Systematic Literature Review of Methods for Improved Utilisation of the Non-Energy Benefits of Industrial Energy Efficiency. Energies 2018.

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 893924.

Odyssee-Mure (2022). Odyssee-Mure Project - Decision-support tool for energy efficiency policy evaluation. Co-funded by the H2020 programme of the European Union (https://www.odyssee-mure.eu/).

Pye, M., McKane, A., (2000). Making a stronger case for industrial energy efficiency by quantifying non-energy benefits. Resources, Conservation and Recycling, Volume 28, 2000.

Rasmussen, J. (2014). Energy-efficiency investments and the concepts of non-energy benefits and investment behaviour. ECEEE Industrial Summer Study Proceedings, 2014.

Rasmussen, J. (2017). The additional benefits of energy efficiency investments— a systematic literature review and a framework for categorisation. Energy Efficiency, 2017.

Reuter, M., Patel, M., Eichhammer, W., Lapillonne, B., Pollier, K. (2020). A comprehensive indicator set for measuring multiple benefits of energy efficiency. Energy Policy 139, 2020.

Russell, C. (2015). Multiple Benefits of Business-Sector Energy Efficiency: A Survey of Existing and Potential Measures. American Council for an Energy-Efficient Economy.

Shnapp, S., Paci, D., Bertoldi, P. (2020). Untapping multiple benefits: hidden values in environmental and building policies. JRC Technical Report.

Thollander, P., Palm, J. (2013). Improving Energy Efficiency. Springer Verlag, 2013.

Trianni, A., Cagno, E., Dolsak, J., Hrovatin, N. (2020). Implementing energy efficiency measures: do other production resources matter? A broad study in Slovenian manufacturing small and medium-sized enterprises. Journal of Cleaner Production 287.

Vermeeren, R. (2016). Steam, energy, and management practices: how is industry doing? And what can we do to make them do better? ECEEE Industrial Summer Study Proceedings, 2016.

Wagner, C., Obermeyer, M., Lüchinger, R. (2020). A methodology for the assessment of multiple benefits of industrial energy efficiency measures. Springer Nature Switzerland AG 2020.

Walsh, B., Murray, S., O'Sullivan, D.T.J. (2015). The water energy nexus, an ISO50001 water case study and the need for a water value system. Water Resources and Industry 10.

Woodroof, E., Turner, W., Heffington, W., & Capehart, B. (2012). Energy Conservation Also Yields: Capital, Operations, Recognition, and Environmental Benefits.

Worrell, E., Laitner, J., Ruth, M., & Finman, H. (2003). Productivity benefits of industrial energy efficiency measures. Energy vol.28.

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 893924.