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LEAP4SME ENERGY AUDIT POLICIES TO DRIVE ENERGY EFFICIENCY

D6.2 Report on impact scenarios framework and strategies to boost energy audits and energy efficiency implementation

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DELIVERABLE 6.2	REPORT ON IMPACT SCENARIOS FRAMEWORK AND STRATEGIES TO BOOST ENERGY AUDITS AND ENERGY EFFICIENCY IMPLEMENTATION
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Deliverable lead	ADENE – Portuguese Energy Agency
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[1] **R**=Document, report; **DEM**=Demonstrator, pilot, prototype; **DEC**=website, patent fillings, videos, etc.; **OTHER**=other
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Executive Summary

This report performs the identification of the main benefits from resource audits, analysing its **pertinence** and proposing a **quantitative methodology**. Nevertheless, firstly **energy audits** and **energy efficiency measures** were studied, to better understand their role within SMEs, as they have the capacity to influence the decision of SMEs to proceed with energy efficiency investments, the path to achieve the aimed reduction of energy consumed.

Furthermore, using the experience of the LEAP4SME consortium partners it was possible to collect relevant **information regarding audit programmes**, policies and/or initiatives that are currently enforced (or were in a recent past) in the participant countries. This helped to have an overview of the support given to audits execution, and the resulting implementation of efficiency measures.

Focusing on **resource efficiency audits**, it was studied that this type of audits can boost the implementation of energy efficiency measures, as well as decrease the use of energy, water, and materials, therefore increasing the companies' competitiveness and reducing the uncertainties of externalities. However, the starting point to the necessary quantification should be the **definition of suitable KPIs**, capable of creating a basis for decision making and efficiency measures implementation, supported by solid data.

Ideally, the information needed to calculate all the resource efficiency KPIs **should be collected** through on-site measurements, water and energy invoices direct checks, and face to face interviews with the companies' top management and resources management (energy, water, and materials) responsible. Nevertheless, the **definition of a quantification framework procedure** based on desk research focusing on national and international databases is feasible, even if limited.

Also, to monitor the suitable indicators to each company, as the presented list may not be equally applicable to all, **different levels of KPIs' evaluation** were drafted. The scenarios presented were organized in the form of a **decision tree**, where the KPIs are applied at levels, corresponding level D to the most elementary, and level A to the one where the higher number

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of the KPIs are suitable. Thus, with this configuration the enterprises may advance as the KPIs apply to their own specific case (in a general way) and/or as they have data available or interest.

Finally, it was performed a **theoretical evaluation** of the core KPIs scenario (level D). Firstly, it was established a baseline regarding water and energy consumptions, as well as its associated costs. The core indicator of this evaluation was the **total water consumption.** It was assessed that the savings potential of this indicator alone may not seem very high, nevertheless its monitoring does not require a great amount of effort from the company, and small and/or indirect interventions would have a great impact on it. Furthermore, the energy costs associated with pumping and distribution of self-supply water were not considered, nor the ones associated with the water use during the production process, so the **real value of energy consumption of water use is presumably considerably higher** than the one presented.

The analysis of the numbers presented should be **done very carefully**, as they are based on proxy values and some strong assumptions. From the values computed, it is possible to conclude that the **savings potential is higher for micro enterprises**, as their energy prices are also higher when compared with small and medium enterprises. Nevertheless, the difference is marginal (less than 1%), even when comparing the micro and medium sized enterprises with 100% use of electricity to heat water, with hot water uses within their processes. These can be justified by the fact that in this particular analysis, the **savings potential is being mainly influenced by the water prices and not by the energy prices**. Therefore, the variations on energy consumptions and prices are not reflected, as they represent a small share of the value computed. This type of constraints is simply overcome **through on-site measurements and a direct contact with the enterprise to audit.** Thus, this report should be seen as, most of all, a **methodology approach definition**.

The **next step of this work** should be focused on the quantification and analysis of the drafted scenarios through resource efficiency audits, allowing **on site measurements to perform KPIs' real quantification**, and fully assess the energy, water and raw materials saving potential of the theoretical model proposed.

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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).

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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 second deliverable (D6.2) performs the identification of the main benefits from SMEs audits, proposing a first **quantification methodology**. Furthermore, the relevance of a **resource efficiency audit** is analysed, through the identification and comparison of resource consumption levels. The deliverable also aims to support LEAP4SME WP4 to understand the potential of measures to be transferred, as well as align the work developed with European auditing schemes and national policies and strategies, to facilitate the implementation of comprehensive energy audits within the SMEs.

1.2 Report structure

This report is structured into four chapters. The **first chapter** – Introduction – gives a brief overview of the project and report main goals. The **second chapter** – Energy Audits and Energy Efficiency Implementation – identifies typical energy efficiency improvements, as well as performs an overview of the status of energy audits on LEAP4SME countries, based on partners' contributions. The **third chapter** – Resource Efficiency in Energy Audits – describes in detail the resource efficiency key performance indicators proposed and establishes their quantification framework. Moreover, evaluation scenarios are defined and theoretically assessed. The report ends with the **fourth chapter** – Conclusions and Next Steps – where the main conclusions of the report are outlined, as well as the next steps for future work.

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2. Energy Audits and Energy Efficiency Implementation

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", and do not constitute effective energy management.

[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).

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There are several **reasons** that can lead a company into an energy audit, namely (SEAI, 2017):

- Compliance with legal requirements (national and/or European), such as the EED, Industrial Emissions Directive, Environmental Protection Agency's waste license requirements, or other laws and requirements.
- Improve energy performance and minimize the environmental impacts of the operation.
- Identify opportunities for behavioural change, through the evaluation of operation and maintenance practices.
- Identify opportunities for technical improvement, through the evaluation of processes/equipment that intensively use energy (boilers, ventilation systems, fleets, etc.).
- Provide clear financial information regarding energy saving opportunities, to facilitate the decision-making process.
- Understand energy usage patterns and energy consumption.
- Identify the potential for using renewable energy sources.
- Answer to the expectations of consumers and stakeholders.
- Define a strategic plan aimed at minimizing the carbon footprint.
- Comply with corporate social responsibility goals.
- Contribute to the process for certification of a formal Energy Management System, as set out in ISO 50001.

In fact, energy audits **influence the decision** of SMEs to proceed with energy efficiency investments and help to overcome information barriers to energy efficiency investments, being the first step towards energy efficiency improvements (EIB, 2019).

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2.1 Identification and implementation of energy efficiency improvements

The aim of an energy efficiency measure (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). Nevertheless, firstly it is necessary to proceed to the correct **identification of the necessary efficiency improvements**, namely including a set of detailed information such as (for example): date of the identification; detailed description of the measure; covered area; nature of the proposed alteration (technical, management or behaviour); data used during the EEM identification; estimate energy savings calculations; estimate implementation cost; simple payback; fuel saved and CO_{2eq} reduction estimated. Also, it is important to consider each **company's needs** when evaluating the measures to implement. Furthermore, the EEMs should be **prioritized** considering their technical and financial feasibility. Typically, factors as saving scales, costs of the proposed improvements, implementation easiness, interdependencies with other identified opportunities and overall savings' impacts should be taken into account.

2.1.1 Typical energy efficiency measures

There are some **key areas** where EEMs are often recommended and the impact on the reduction of the final energy consumption is higher. The identification of these key areas was performed taking into account the experience of the Portuguese Intensive Energy Consumption Management System (managed by ADENE) and the Italian Energy Audits database (managed by ENEA). Thus, the areas with highest energy savings potential are:

- **Lighting:** one of the most visible energy consumers in any building or facility, where developments in technology and effective controls may offer significant opportunities for energy efficiency improvements. These EEMs can be (for example): checking lighting levels as stairwells, corridors, and circulation areas; replacing high-intensity lighting with more energy efficient alternatives; installing additional switching, to facilitate turning off some lights when not required; running an awareness campaign to inform all employees of the importance of turning off lighting when the area is unoccupied; installing automatic controls; etc. (SEAI, 2017).

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- **Electric engines:** Systems as pumps are one of the largest consumers of electricity and have widespread application in buildings, industrial processes and water and wastewater treatment. EEMs focusing on engines optimization, pumping, compression, and ventilation systems are usually very effective (SEAI, 2017).
- **Heating, ventilation, and air conditioning (HVAC):** HVAC accounts for significant energy consumption of both electricity and thermal fuel in a wide variety of buildings and also in industry. Some of the EMMs advocated are (for example): matching variable speed control on fans, refrigerant compressors, and circulation pumps to demand; reviewing HVAC operational controls; adapting ventilation rate to occupancy through CO_2 controls; improving temperature and time controls; replacing steam heating with low pressure hot water system (SEAI, 2017).
- **Industrial processes:** The processes must be sufficiently understood by the auditor before establishing coherent EEMs. These EMMs are usually focused on human resources training, processes integration, thermal insulation, equipment maintenance and effluents treatment (SEAI, 2017).
- **Compressed air systems:** Compressed air is one of the largest energy users in industry. Due to its ease of use, it is often used inappropriately. EEMs may concentrate on (for example): repairing compressed air leaks; recovering the waste heat from the air compressor to use for space heating or potentially pre-heating combustion air for a boiler; installing a variable-speed air compressor instead of a fixed-speed air compressor for partial load operations; isolating compressed air distribution systems during out of production hours, among others (SEAI, 2017).

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2.2 Energy audits on LEAP4SME countries

The LEAP4SME consortium comprises nine energy agencies, making it possible to collect very relevant information regarding the audit programmes, policies and/or initiatives that are currently enforced (or were in a recent past) in those countries. In this sense, a **questionnaire** was shared with the LEAP4SME partners from the end of July 2022 until mid-September 2022, to gather data on energy audits, implementation of energy efficiency measures (and their potential savings), as well as energy audit costs for comparison and benchmarking purposes. The main answers from these questionnaires are summarized below.

2.2.1 Energy efficiency measures: implementation, costs, and savings

The first part of the questionnaire shared with the LEAP4SME partners was focused on programmes, policies and/or initiatives aimed both at **non-SMEs and SMEs**.

They were analysed thirteen programmes, from seven different countries, that included **energy audit** execution, allowing to clearly identify the energy efficiency measures addressed during the conducted audit. Nevertheless, from these mentioned programmes only six of them clearly identified the **efficiency measures related to non-energy benefits**. These programmes were from:

1) Greece: Athens Business Green Toolkit - Upgrading businesses in the Historic Centre of Athens with terms of Green Operations. This programme in particular identified the efficiency measures related to the water-energy nexus.
2) Croatia: Mandatory Audits for large enterprises.
3) UK: Business Energy Scotland; Invest Northern Ireland and Coventry; and Warwickshire Green Business Programme.
4) Poland: Energy Plus.

The **implementation** of **efficiency measures** was required/mandatory within four of the thirteen programmes, namely the ones from Portugal, Croatia, and Poland. In particular, one of the Polish programmes (the Thermo-modernization Loan for Enterprises) obliged to

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investments in renewable energy sources and energy modernization of buildings, increasing energy efficiency by at least 25% compared to the baseline determined by the energy audit.

Concerning the **cost coverage of the efficiency measure implementation**, eight programmes proceed with it. These programmes were from:

1) Greece: Athens Business Green Toolkit - Upgrading businesses in the Historic Centre of Athens with terms of Green Operations.
2) Croatia: Public calls for energy audits and energy management systems and Public calls issued by local communities.
3) UK: Business Energy Scotland; Invest Northern Ireland; and Coventry and Warwickshire Green Business Programme.
4) Poland: Energy Plus and Thermo-modernization Loan for Enterprises.

Actually, in a broad sense, **the programmes that have mandatory implementation of its measures do not cover the implementation costs**, but **where the implementation is not mandatory the cost is covered**. The two exceptions are from the Polish initiatives, where the two mentioned programmes have mandatory implementation of efficiency measures, and also cover their costs.

There are different **schemes to cover the energy efficiency measures implementation costs**, varying from country to country and type of programme. In the Greek Athens Business Green Toolkit programme, the support can be given through a fixed percentage of the costs (80%). The UK programmes have different ways to support the companies: the SMEs are offered access to a loan to cover the cost of the chosen measures; the costs paid are 10% of the total eligible project costs for large businesses, 20% for medium and 30% for small and micro; or the grants are between £1,000 (1,165€) and £20,000 (23,314€) to fund up to 40% of the cost of installing energy efficiency measures. Finally, in the Polish case the support is given in the form of a loan of up to 85% of the eligible costs (with the possibility of a 30% write-off) or through a loan with a maximum cap (PLN 1,000,000, which are 213,668€), that the company may receive only once and for a maximum period of 120 months.

All the programmes **quantify the savings** that result from the energy efficiency measures addressed. For example, the global savings per audit can reach an average of 100 toe in Portugal and 260 toe in Austria. Nonetheless, the **savings from non-energy benefits are**

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only quantified through four programmes, from the previous six that identify the measures related to non-energy benefits. These four mentioned programmes are from:

1) Croatia: Mandatory energy audits for large enterprises.
2) UK: Invest Northern Ireland and Coventry and Warwickshire Green Business Programme
3) Poland: Energy Plus.

In particular, the UK programmes perform their quantification over cost savings, as water savings calculated in cubic meters or reduced carbon footprint in tons. The Polish programme has opened recently, so there is still no quantitative data collected. Nevertheless, it intends to monitor the reduction of primary raw materials consumption, namely through monitoring water consumption.

The second part of the shared questionnaire was focused on programmes, policies and/or initiatives aimed at **SMEs only**.

They were analysed eight programmes that included an **energy audit** execution. From these programmes, only one Italian regional programme (Regional programmes for energy efficiency/ energy audits (2016-2022) did not allow to clearly identify the energy efficiency measures addressed during the audit. Unfortunately, **none of the programmes identified the efficiency measures related to non-energy benefits.**

The **implementation** of **efficiency measures** was required/mandatory within only one of the focused programmes (the Italian Regional programme for energy efficiency/energy audits: Lombardy 2nd call, 2020), and the **cost of the efficiency measures** implementation was not covered by any of the initiatives.

From the eight programmes that were addressed, it was possible to **quantify the savings** that result from the energy efficiency measures implemented in six of them. They were the following:

1) Austria: Federal support programmes, programme modules with Energy Efficiency focus: example Vienna and the SME Energy Efficiency Voucher.
2) Italy: Regional programmes for energy efficiency/ energy audits: Lombardy 1st call (2017) and Regional programmes for energy efficiency/ energy audits: Lombardy 2nd call (2020)

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3) Malta: Promotion of Energy Audits in Small and Medium Enterprises and Managing Essential Resources in Retail through Consumption Analysis – MERCA.

In these cases, for example, the **global savings** per audit can reach an average of 5.7 toe in Austria, 8.7 to 6.7 toe in Italy and 6.6 toe in Malta. Again, none of the programmes quantified the savings from non-energy benefits.

2.2.2 Energy audit costs

According to a study on “Energy Efficiency in Enterprises” performed by the Directorate-General for Energy (European Commission, 2016), the **definition of average costs for energy audits** in different Member States is not straightforward, nor easy. It would be expected that these costs could rest on the entity type, audit required (buildings, industrial processes, or transport), or size of the organisation to be audited and its energy-intensity. In fact, the cost of energy audits for obligated companies varies in different ranges as function of the economic activities, such as for example:

- Manufacturing = 8,000€ – 100,000 €/audit
- Offices = 8,000€ – 60,000 €/audit
- Retail = 5,000€ – 10,000 €/audit
- Warehouses = 2,000€ – 25,000 €/audit
- Transport fleets = 3,000€ – 7,000 €/audit

Nevertheless, other additional features may influence the effort allocated by the auditors, and consequently the audit prices. The fact is that very often auditors, that need to evaluate real energy consumption data, have to search the required data, validate the elements reported by the company or conduct measurements to complete information gaps. These could be very time-consuming tasks. Moreover, the audit prices are also influenced across Member States by local tax laws, cost of living, energy costs, reporting requirements, auditor qualifications, among others.

Actually, the LEAP4SME questionnaire identified that for **non-SMEs** from the thirteen programmes addressed, four of them covered the costs of the energy audit and three had free audits, with no costs associated. These costs may be covered until a fixed amount (e.g., 2,500€ in the Greek Athens Business Green Toolkit case) or cap percentage (e.g., 10% as in the Energy Plus Polish initiative).

Nevertheless, regarding **SMEs'** audit costs the situation is different, as from the eight programmes addressed all covered the costs of the audit, in an extension that went from 100% to no less than 50%. The **average value of an energy audit** (within the addressed programmes) was: 6,000€ to 8,500€ in Italy; and 5,000€ for medium sized enterprises (NACE codes C and I), 3,000€ medium sized enterprises (all other NACE codes), 3,000€ small sized enterprises (NACE codes C and I) and 1,000€ small enterprises (all other NACE codes) in Malta. In the particular case of the Austrian SME Energy Efficient Voucher programme, the audits within it have a fixed cost of 750€, from which 90% is supported. On the other hand, the Austrian Federal support programmes (*Regionalprogramme der Bundesländer*), have programmes modules with an Energy Efficiency focus (*OekoBusiness Vienna*) where there is a maximum of co-financing of 1,680€.

Apart from the programmes formally addressed during the survey, additional information revealed that **the cost of an energy audit cannot be extrapolated from country to country**. In Portugal, for instance, the average cost of an energy audit ranges from 3,000€ to 5,000€ per site (auditor fee), for non-SMEs. If the company is a SME, the value ranges from 1,500€ to 2,000€ per site (auditor fee). On the other hand, in Croatia an industrial walk-through audit for a SMEs has a cost up to 10,000€, and a thorough audit (with efficiency measures definition and technical and economic assessment) can reach up to 20,000€ to 30,000€. However, in the UK the cost of these audits typically ranges 1% of the total electricity bill. In Poland the mandatory audits prices start as low as 1,100€, being the average price for service companies about 2,150€, and for manufacturing companies with two locations around 4,300€. These values can reach as high as 20,000€, for the largest enterprises. Finally, in Italy, the cost of energy audits varies from 1,000€ for a micro-SMEs to 20,000€ for industrial medium-sized SMEs, with a median value of 7,500€ according to partially funded diagnosis regional calls. The energy audit costs for SMEs in LEAP4SME countries (where is information is available) are summarized in Table 1 below.

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Table 1 – Energy audit cost for SMEs

Country	Energy audit cost [€]
Austria	750 - 1,680
Croatia	10,000 - 30,000
Italy	1,000 - 20,000
Malta	1,000 - 5,000
Poland	1,100 - 20,000
Portugal	1,500 - 2,000
UK	1% of the total electricity bill

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3. 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).

Regarding the reduction of **raw materials use**, material loss reduction is a general term to describe the process of systematically reducing losses at the source. It covers raw material and ingredient use, product loss, water consumption and effluent generation, paper and packaging, factory and office consumables, all other solid and liquid wastes, gaseous emissions and wasted effort. Companies that take steps to reduce the amount of losses generated do not only save the costs of managing these losses, but also make much greater savings on the cost of inputs to the production process. Reducing losses is therefore essential to maintaining business competitiveness. It also makes good business sense to reduce waste disposal costs by looking at ways of producing less waste (European Commission, 2016). This is also a way to save energy and promote efficiency.

Focusing on **water** and the **water-energy nexus**[5], the efficient use of water means that when water pumping is reduced it directly leads to savings in electricity costs and associated greenhouse gas emissions, and also the amount of energy needed to treat wastewater is reduced, overall resulting in less energy demand (UNEP, 2010). This means that all water has energy incorporated, i.e., for each liter of water consumed, the water management entity consumes energy to capture, elevate, treat, and distribute that water. After its use, it is also necessary energy to transport and treat the water to return it to the environment. For this reason, water consumption reduction can lead to significant energy savings.

[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.

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Also, the EC report “Roadmap to resource efficient Europe” (European Commission, 2011) states that **40% of Europe’s water is wasted**. In this sense, the integration of resource-efficiency considerations consideration into policies is much needed. Additionally, the 7th Environmental Action Programme to 2020 concluded that there is likely to be a **global shortfall of 40% in water by 2030** unless there is significant progress made in improving resource efficiency. Furthermore, the risk of climate change further intensifies these problems, will result in global high costs. Thus, one of the programmes objectives is to make the **European Union a resource-efficient economy** (European Commission, 2013).

In short, the potential to address non-energy benefits 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 addition, sustainability and resource efficiency can be perceived by companies in different manners, and their interest and focus may differ. For companies resource efficiency will result in a **series of benefits**, namely: cost reduction regarding materials, chemicals, energy, and waste disposal; reduced cost for compliance with laws and regulations regarding waste, emissions, and the use of chemicals; over the long term, security of supply; and meeting the customer demand for sustainable business practice, to name a few.

However, energy audits usually do not include parameters such as **water or resource efficiency analysis**. Despite including those aspects will increase the cost of the audits, as well as create the need to develop new skilled auditors, literature review helps to understand that the **extra costs** associated are **easily internalized** by the SMEs. Firstly, there is a strong link between energy efficiency measures and other production resources. Specifically, the enterprises, independent of their energy-intensity, do pay attention when considering the adoption of an energy efficiency measure and the impact this may have on other production resources (Trianni et al., 2021). Secondly, an analysis with more than 37,000 SMEs between 2013 and 2017, shows that SMEs appear to be already aware of the multitude of benefits in employing resource efficiency actions from non-economic points of view (namely, cooperation, funding availability, advice, and macro-environmental indicators) (Chatzistamoulou et al.,

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2022), and that the benefits of this kind of sustainable approaches seem to be particularly beneficial for young SMEs (up to 10 years) (Neumann, 2021). Lastly, if an SME is spending at least 1% of its annual turnover on resource efficiency investments (average), then it is 13% to 18% more likely to have a better sales growth performance in comparison to an SME with very similar characteristics that does not invest as much in resource efficiency (Ozbugday et al., 2020).

Furthermore, an overview of the actions that European SMEs are currently undertaking to be **more resource efficient** is presented in the recent Flash Eurobarometer 498 (IPSOS-European Commission, 2022). The analysis is based on a wide scale survey on a sample of SMEs in all participant Countries. These enterprises were presented with a list of nine actions that SMEs can take to be more resource efficient – with resource efficiency defined as using natural resources in a sustainable and environmentally-friendly manner at different stages. The most relevant takeaways of the survey are:

- Most SMEs are positively **acting to be more resource efficient**: 89% of SMEs are taking at least one of the actions listed in the survey, while 9% that are not taking any action.
- The most popular action is minimising waste (64%), with a relevant interest also in saving energy (61%) and saving materials (57%).
- About 77% of the companies plan to implement additional measures to improve resource efficiency in their company. In this case, it is interesting to note that among the three most common actions planned for the following two years, two are saving energy (53%) and saving materials (48%).

The survey also included a section for large enterprises, in addition to SMEs. Comparing the results from the two categories, it comes out that large enterprises are more likely to report that they are carrying out the resource efficiency actions presented in the survey. In the case of the action “saving energy”, the figure increases from 61% for SMEs to 74% for large enterprises. Some relevant differences between SMEs and large enterprises are also found for the actions “selling of residues and waste to another company” and “using of predominantly renewable energy” (19% vs 40%, respectively).

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Regarding the interest in carrying out further actions in the next few years:

- More than 50% of SMEs plan to implement **additional energy savings actions** in the next two years.
- Around one third of the companies are looking to switch to **use predominantly renewable energy sources**, including own production trough solar panels.
- Half of the SMEs will implement additional measures to **reduce waste**.
- One quarter of SMEs plans to **sell their residues and waste** to another company.
- Around half of them are looking to implement (further) actions to **save materials**.

Additionally, towards a broader concept of circular economy, about one quarter of the SMEs plan to design products that are easier to maintain, repair or reuse.

Also, during 2019, ADENE – The Portuguese Energy Agency **launched a survey** aimed at entities within the Portuguese Intensive Energy Consumption Management System – Industry (SGCIE). Its goal 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 survey evaluated themes such as: use of by-products in the production process; energy recovery from waste; recycling; efficient use of materials; energy synergies between different intensive energy consumers; efficient use and reuse of water; and renewable energy.

From its around 50 valid answers it was possible to draw some main conclusions, namely:

- 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 **efficient use and re-use of water** was considered "very important" by 50% of the participants, and despite there is still very low penetration of water efficiency improvement measures, the interest is quite significant. Additionally, after being informed about the savings potential that result from water efficiency simple audits (that allow to save water and energy) the interest of the respondents increased.
- Regarding water efficiency, around 65% of the industries were interested in implementing an **alarm system** that reports the occurrence of water leaks, and about

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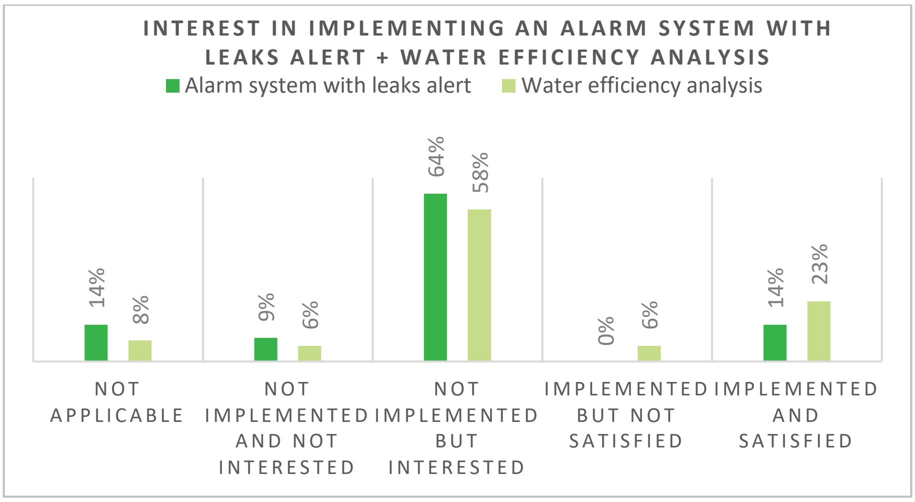
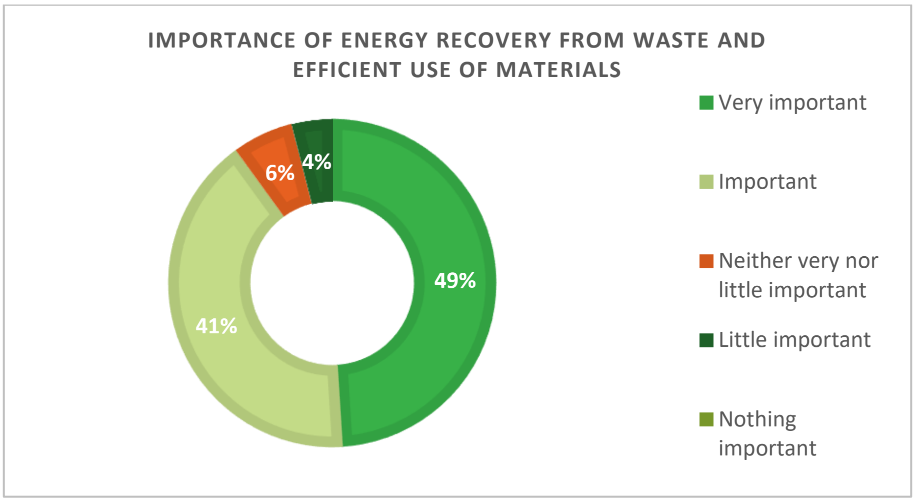
60% were interested in a **water efficiency analysis** to identify improvement measures, as in Graphic 1 below.



Graphic 1 – Interest in implementing an alarm system with leaks alert and in a water efficiency analysis

- Furthermore, **energy recovery from waste** and **efficient use of materials** were considered as "very important" by or "important" by 90% of the stakeholders, which is in fact very relevant, as in Graphic 2 below.



Graphic 2 – Importance of energy recovery from waste and efficient use of materials

Having all these in mind, it can be assumed that resource efficiency audits have the ability to **boost the implementation of energy efficiency measures**, as well as reduce the use of energy, water, and materials, therefore increasing the companies' competitiveness and reducing the uncertainties of externalities. Nevertheless, the **quantification** of the audits' potential savings is fundamental to support this affirmation.

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3.1 Resource efficiency quantification framework

The conclusions from the Deliverable 6.1 – Report on the literature review analysis of multiple benefits (LEAP4SME, 2022) turned clear that the research consensus is that non-energy benefits, as well as resource efficiency, **quantification is not an easy task**. In this sense, the general remark is that the mapping and evaluation need to be based on a mixture of experience, observations, calculations, and/or estimations in various ways. Nevertheless, the starting point to an appropriate quantification should be the **definition of suitable key performance indicators** (KPIs), as following.

3.1.1 Resource efficiency key performance indicators

The integration of resource efficiency within the common energy audit procedures implies the need to adequately **define key performance indicators**, capable of creating a basis for decision making and efficiency measures implementation, supported by solid data. In this sense, despite the numerous examples of KPIs linked to resource efficiency collected during the literature review performed (LEAP4SME, 2022), it was not possible to find adequate literature, that collected indicators related to the multiple dimensions of resource efficiency (namely water, materials, and water-energy nexus) in an integrated way. Thus, a new set of KPIs is proposed, using data collectable during an audit procedure, or that is already systematized within the companies' legal or voluntary requirements (e.g., ISO standards, environmental licensing, etc.). **Resource efficiency indicators** can contribute to better informed decisions both from industrial agents and policy makers. The parameters that comprise the KPIs should provide comprehensible, reliable, and comparable information that can be used to improve resource efficiency in industrial (and other) processes (Danish Standards Association, 2017).

The KPIs, presented in Table 2 (below), intend to assist in the quantification of resource savings resulting from audits (resource efficiency audits), contributing to the comparison of resource consumption levels. 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).

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Table 2 – Resource efficiency key performance indicators

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 Value Added [m^3/€]
	Water specific consumption	Total yearly water consumption within the production process per annual production: water consumption per unit of product* [m^3/P.U.]
	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* [€/P.U.]
	Water productivity	Gross Value Added per total yearly water consumption [€/m^3]
Material Use	Materials specific consumption	Total yearly materials consumption per annual production* [kg/P.U.]
	Waste valorization rate	Waste valorization per annual waste production [%]
	Share of byproducts in production process	Quantity of byproducts per total yearly production [%]
	Materials productivity	Gross Value Added per total yearly material consumption [€/kg]
Water-Energy nexus	Energy specific cost resulting from the use of water	Cost of energy consumed per total yearly water consumption [€/m^3]
	Specific cost of water delivered	Cost of water delivered to the consumer [€/m^3]
	Energy specific consumption from the water use	Total yearly energy consumption resulting from the use of water [kWh/m^3]

** The production units (P.U.) depend on the analysed sector and can be defined as m^2, m^3, kg etc., in manufacturing sectors, while in service sectors other units will be adopted (e.g., working hours).*

3.1.2 Quantification framework

Ideally, the information needed to calculate all the resource efficiency KPIs **should be collected** through on-site measurements, water and energy invoices direct checks, and face to face interviews with the companies' top management and resources management (energy, water, and materials) responsible. Nevertheless, the **definition of a quantification framework procedure** based on desk research focusing on national and international databases is feasible. However, when trying to actually quantify these KPIs, based on this desk research, some of the barriers encountered were: general lack of data (national and at European level) regarding SME's; scattered and most of the times not updated databases; and not registered information needed to fully characterize the KPIs. This led to the conclusion that **on site measurements are fundamental to perform an adequate quantification of the proposed KPIs**.

During the following sections, each indicator formula will be detailed, as well as outlined the rationale behind its description, namely the data needed for its characterization (indicating the sources were to get it, when feasible).

3.1.2.1 Water consumption

The **total water consumption** is considered the "base" indicator, as it will be used to calculate several others. At least this value should be monitored by companies, to adequately manage it and promote resource efficiency. Nevertheless, if not monitored, the information to construct it can be collected from the water and waste services regulation authorities, and statistical databases. It should be noted that, unlike energy consumption driven indicators, the water consumption is **not influenced by facilities' areas**, but instead by the number of water consumers (inhabitants, employees, beds, etc.). Furthermore, the indicators related to water consumption are always calculated considering the specific **site's characteristics** that influence water use (e.g., hotel spas, rehabilitation centre with swimming pool, the office's showers, etc.). In Table 3 it is presented the KPI formula and data necessary to calculate it.

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Table 3 – Water consumption indicator

Indicator	Formula	Data
Total yearly water consumption [m³]	Yearly water consumption in the non-residential sector [m³] * Share of yearly water consumption of SMEs enterprises [%]	Yearly water consumption in the non-residential sector [m³]
		Share of yearly water consumption of SMEs enterprises [%]

Where the yearly water consumption in the non-residential sector is the water consumption of the whole non-residential sector and the share of yearly water consumption of SMEs enterprises is the share that is accountable only to SMEs.

3.1.2.2 Water intensity

The **water intensity indicators** have the goal of measuring the efficiency and sustainability of the water uses. The information to construct these indicators can be taken from statistical databases (namely, Gross Value Added (GVA), average annual production, and number of employees per sector). In Table 4 it is presented the KPIs formulas and data necessary to calculate them.

Table 4 – Water intensity indicators

Indicator	Formula	Data
Water consumption per GVA [m³/€]	Total yearly water consumption [m³] / Gross Value Added [€]	**Total yearly water consumption [m³]**
		Gross Value Added [€]
Water specific consumption [m³/P.U]	Total yearly water consumption within the production process [m³] / Annual production [P.U.]	Total yearly water consumption within the production process [m³]
		Annual production [P.U.]
Water consumption per employee [m³/employee]	Total yearly water consumption within the company [m³] / Nº of employees	**Total yearly water consumption [m³]**
		Nº of employees

Where the GVA is an economic productivity metric that measures the contribution of a company to an economy, producer, sector, or region; the total yearly water consumption within the production process is the water consumed annually within the production process of each

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company; the annual production is the average production of an enterprise per year (in case it has a production line); and the number of employees is the company's number of collaborators.

3.1.2.3 Water sources

The **water sources indicators** intend to evaluate the share of water consumed from alternative sources and the wastewater treated and use again by the enterprises. The information to build these indicators can be taken from the water and waste services regulation authorities. In Table 5 it is presented the KPIs formulas and data necessary to calculate them.

Table 5 – Water sources indicators

Indicator	Formula	Data
Share of alternative water sources used [%]	Total yearly water consumption from alternative sources [m^3] / Total yearly water consumption within the company [m^3]	Total yearly water consumption from alternative sources [m^3]
		Total yearly water consumption [m^3]
Share of wastewater treated and reused [%]	Total yearly treated and reused wastewater [m^3] / Total yearly wastewater produced [m^3]	Total yearly treated and reused wastewater [m^3]
		Total yearly wastewater produced [m^3]

Where the total yearly water consumption from alternative sources is the water consumed annually by a company coming from sources as rainwater, greywater, groundwater, or stormwater; the yearly treated, and reused wastewater is the wastewater that is treated and then used into the production process; and the total yearly wastewater produced is the wastewater produced during a year.

3.1.2.4 Water cost

The **water costs indicators** are focused on the costs associated with the use of water and its productivity, being the water productivity a **critical benchmark** for resource use efficiency. The information to construct these indicators can be taken from statistical databases. In Table 6 it is presented the KPIs formulas and data necessary to calculate them.

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Table 6 – Water cost indicators

Indicator	Formula	Data
Share of water costs in the total costs incurred [%]	Total yearly water costs [€] / Total yearly company costs [€]	Total yearly water costs [€]
		Total yearly company costs [€]
Water specific cost [€/P.U.]	Total yearly costs concerning water used within the production process [€] / Annual production [P.U.]	Total yearly costs concerning water used within the production process [€]
		Annual production [P.U.]
Water productivity [€/m^3]	Gross added value [€] / Total yearly water consumption [m^3]	Gross added value [€]
		Total yearly water consumption [m^3]

Where the total yearly water costs and total yearly company costs are the costs associated with the water use and the company functioning, respectively, and the total yearly costs concerning water used within the production process are the cost connected with the use of water.

3.1.2.5 Material use

The **material use indicators** are related with the use of raw materials and its productivity, as well as the waste valorization and byproducts generated. In particular, the materials productivity indicator, is the adaptation to the industrial environment of the resource productivity indicator, that quantifies the relation between economic activity and the consumption of material resources, which is an indicator derived from economy-wide material flow accounts. It is an important indicator of the sustainable development goal 12 “responsible consumption and production” (Eurostat, 2022). The information to construct the material use indicators can be taken from statistical databases. In Table 7 it is presented the KPIs formulas and data necessary to calculate them.

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Table 7 – Material use indicators

Indicator	Formula	Data
Materials specific consumption [kg/P.U.]	Total yearly materials consumption within the production process [kg] / Annual production [P.U.]	Total yearly materials consumption within the production process [kg]
		Annual production [P.U.]
Waste valorization rate [%]	Total yearly waste valorization [kg] / Total yearly waste production [kg]	Total yearly waste valorization [kg]
		Total yearly waste production [kg]
Share of byproducts in production process [%]	Quantity of yearly byproducts [kg] / Annual production [P.U.]	Total yearly byproducts [kg]
		Annual production [P.U.]
Materials productivity [€/kg]	Gross added value [€] / Total yearly materials consumption within the production process [kg]	Gross added value [€]
		Total yearly materials consumption within the production process [kg]

Where the total yearly materials consumption within the production process are the raw materials consumed during the production process, when it exists a production line; the total yearly waste valorization are the waste valorization activities[6] performed annually; the total yearly waste production is the waste produced within a year; and the total yearly by-products are the secondary products derived from the production process produced annually (in addition to the main product).

3.1.2.6 Water-energy nexus

The **water-energy nexus indicators** aim to assess the energy costs and consumption, that result from the use of water within the production process. The specific costs of water delivered which include the energy costs associated with the water collection, treatment, transport, storage, and disposal are also included. The information to construct these indicators can be

[6] The waste valorization activities can comprise three different activities: recycling, backfilling, and energy recovery. Recycling is defined as any recovery operation by which waste materials are reprocessed into substances, materials, or products. Backfilling is the recovery operation where suitable waste is used for engineering purposes in landscaping or for reclamation purposes in excavated areas where the waste is a substitute for non-waste materials. Energy recover is the process which converts waste materials into electricity, fuel, or useable heat through a variety of methods which include combustion, gasification, and anaerobic digestion.

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gathered from statistical databases, European projects (as Odyssee-Mure) and literature reviews. In Table 8 it is presented the KPIs formulas and data necessary to calculate them.

Table 8 – Water-energy nexus indicators

Indicator	Formula	Data
Energy specific cost resulting from the use of water [€/m^3]	Total yearly cost of energy consumed [€] * Energy consumed from the use of water [%] / Total yearly water consumption [m^3]	Total yearly cost of energy consumed [€]
		Energy consumed from the use of water [%]
		Total yearly water consumption [m^3]
Specific cost of water delivered [€/m^3]	Total yearly cost of water delivered [€] / Total yearly water consumption [m^3]	Total yearly cost of water delivered [€]
		Total yearly water consumption [m^3]
Energy specific consumption from the water use [kWh/m^3]	Total yearly energy consumption [kWh] * Energy consumed from the use of water [%] / Total yearly water consumption [m^3]	Total yearly energy consumption [kWh]
		Energy consumed from the use of water [%]
		Total yearly water consumption [m^3]

Where the total yearly cost of energy consumed refers to the annually energy costs; the energy consumed from the use of water is the share of energy costs that result directly from the water use; the total yearly cost of water delivered are the costs imputed to the water distribution entity; and the total yearly energy consumption is annual energy consumption of the company.

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3.2 Impact scenarios framework

The resource efficiency KPIs proposed were presented to relevant external stakeholders, namely auditors, regulation authorities and financing funds, as well as to the consortium members. The general feedback was very positive, but some questions were raised, particularly related with the **number of KPIs**, their **applicability to companies from all sectors**, and the **data collection needed** to assess the KPIs.

In this sense, taking into account the comments received, **different levels of KPIs' evaluation** were drafted, intending to monitor the suitable indicators to each company. Finally, it was performed a simple assessment of one of the scenarios, which included its economic and energy savings calculation.

3.2.1 KPI applicability

The list of resource efficiency KPIs presented may not be **equally applicable to all companies**. Thus, the scenarios were organized in the form of "decision tree", where **the KPIs are applied at levels**, corresponding level D to the most elementary, and level A to the one where the higher number of the KPIs are suitable, an in Figure 1 below. With this configuration the enterprises may advance as the KPIs apply to their own specific case (in a general way) and/or as they have data available or interest.

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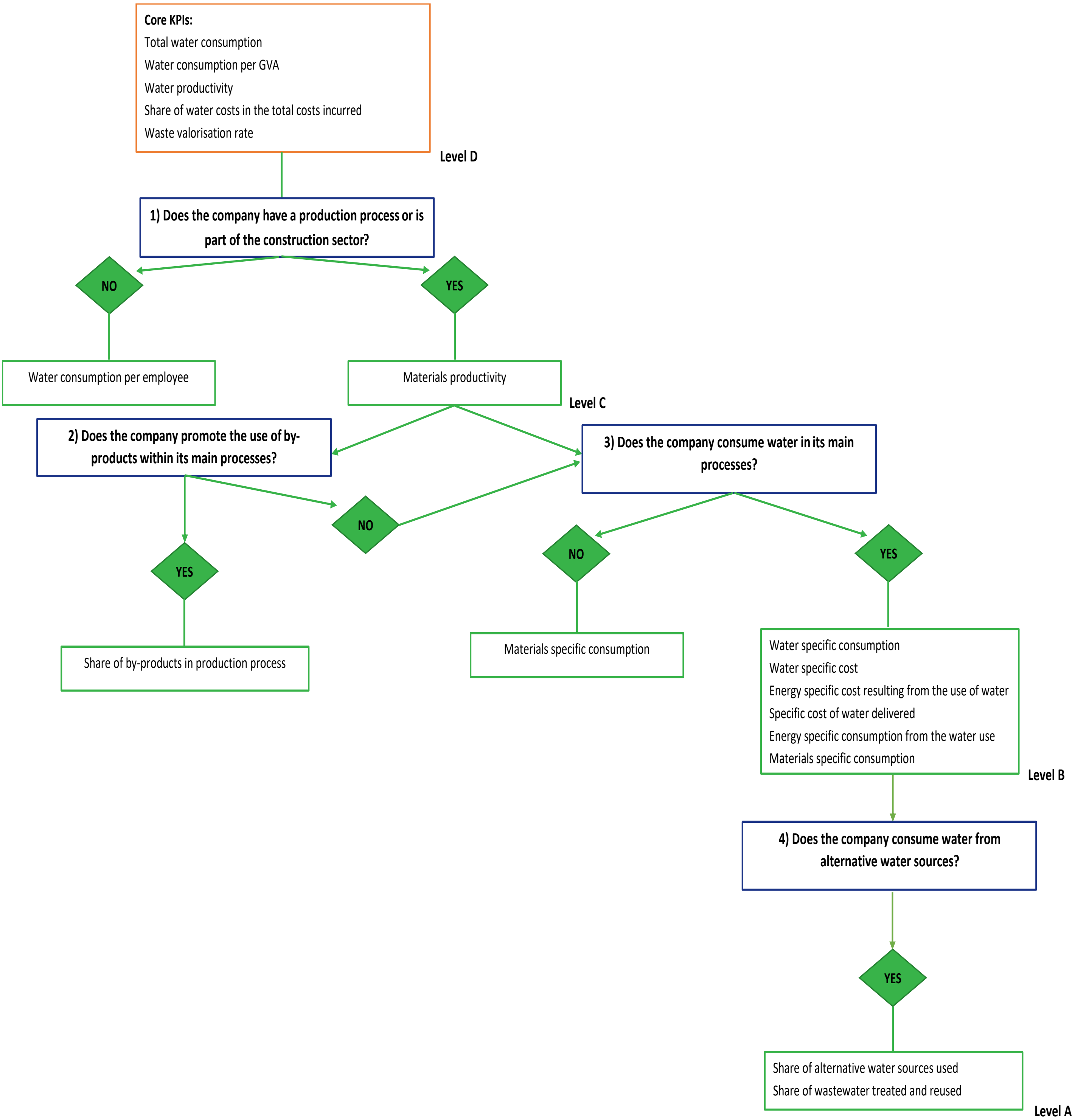

Figure 1 – Scenarios definition decision tree

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In this sense, the starting point is a set of **core KPIs** (level D), deemed as valid to most of the economic sectors. These KPIs were selected from four of the six indicator groups, and are the **total water consumption, water consumption per GVA, water productivity, share of water costs in the total costs incurred** and **waste valorization rate**. The information necessary to define these KPIs is considered not complex to obtain, namely the annual water consumption, GVA and annual water cost.

Proceeding from this, the question **1)** “**Does the company have a production process or is part of the construction sector?”** tries to establish whether the company is part of the production/construction sector or a service entity (with no physical production). If the entity does not have a production process associated, the water consumption should be mainly associated with its use by employees, and the **water consumption per employee** is to be monitored. On the other hand, if the company has a production process associated, its **materials productivity** should be assessed. This KPI is particularly relevant for SMEs with significant raw materials consumption. With this the **level C** of KPIs monitoring is established. It is important to stress, that the evaluation is cumulative, so level C includes KPIs from level C and D. This rational is extended to the rest of the decision tree.

Having established that the company has a production process associated or is part of the construction sector, the question **2) “Does the company promote the use of byproducts within its main processes?”** should be posed. If so, the **share of byproducts in production process** is to be monitored. Another issue to evaluate at the same level is if the company has a production process that effectively consumes water, assessed by the question **3) “Does the company consume water in its main processes?”**. If not, the **materials specific consumption** should be evaluated, and the decision tree **ends** here. If the company has water consumption within its productive processes, there are a set of additional KPIs to be monitored, namely the **water specific consumption**, **water specific cost**, **energy specific cost resulting from the use of water**, **specific cost of water delivered** and **energy specific consumption from the water use**. These KPIs intend to weigh the associated energy consumption and costs of both water and energy. This sets **level B** of KPIs monitoring.

Finally, for companies that consume water from alternative water sources (e.g., rainwater, greywater and wastewater treated) it is important to assess the water consumption from these

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sources. In this sense, the question **4) "Does the company consume water from alternative water sources?"** intends to check this. The KPIs to monitor are the following: **share of alternative water sources used** and **share of wastewater treated and reused** (only if the SME consumes wastewater treated). This sets the **top-level A** of KPI monitoring.

In Table 9 below the KPIs are presented **according to the evaluation level** where they can be applied. Note that, as stated before, the evaluation is cumulative so each level must include the KPIs from the levels before.

Table 9 – Evaluation levels KPIs

Evaluation level	Indicator
Level D	Total water consumption [m^3]
	Water consumption per GVA [m^3/€]
	Water productivity [€/m^3]
	Share of water costs in the total costs incurred [%]
	Waste valorization rate [%]
Level C	Water consumption/employee [m^3/employee]
	Materials productivity [€/P.U.]
Level B	Share of by-products in production process [%]
	Materials specific consumption [kg/P.U.]
	Water specific consumption [m^3/P.U.]
	Water specific cost [€/P.U.]
	Energy specific cost resulting from the use of water [€/m^3]
	Specific cost of water delivered [€/m^3]
	Energy specific consumption from the water use [kWh/m^3]
Level A	Share of alternative water sources used [%]
	Share of wastewater treated and reused [%]

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3.2.2 Scenario quantification

The scenario that will be theoretically quantified corresponds to the **level D** evaluation: monitoring of a set of core KPIs, that can be applied to most of the economic sectors. Actually, for some economic sectors or companies, this evaluation level could be sufficient, even if higher evaluation levels were applicable. This will depend on the characteristics of the enterprise, and the willing to pursue a higher level of evaluation or not.

It should be highlighted that, as the framework evaluation level increases, it is harder to find literature values capable of allowing KPIs' quantification without on-site measurements or at least direct contact with the company. Thus, this core **KPIs evaluation illustrates only partially the savings' potential** (water, energy and economic) of a resource efficiency audit.

Before the quantification of the level D associated KPIs, it was necessary to establish a baseline regarding water and energy consumptions, as well as its associated costs. Again, it was concluded that there is an overall lack of data, and the existing information is dispersed. Having this in mind, some **assumptions and literature values** were used, as in Table 10 below. These assumptions are also explained in detail.

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Table 10 – Assumptions and values to scenarios quantification

Id	Assumption short description	Value	Unit	Source
a)	Cost of public water (European average)	3.50	€/m^3	EurEau
b)	Costs of self-supply water	3.50	€/m^3	Assumption
c)	Water consumption from self-supply (cost of water is not charged by the water company)	50	%	Eurostat
d.1)	Energy consumption associated with water – applied to SMEs from the service sector	14	%	European Commission
d.2)	Energy consumption associated with water – applied to SMEs with production process that use hot water	30	%	Assumption
d.3)	Energy consumption associated with water – applied to SMEs with reduced hot water use within their processes	5	%	Assumption
e.1.1)	Electricity prices for non-household consumers, last 6-semester average (all taxes and levies included) - micro enterprises	3,045.95	€/toe	Eurostat
e.1.2)	Natural gas prices for non-household consumers, last 6-semester average (all taxes and levies included) - micro enterprises	771.54	€/toe	Eurostat
e.2.1)	Electricity prices for non-household consumers, last 6-semester average (all taxes and levies included) - small enterprises	2,294.01	€/toe	Eurostat
e.2.2)	Natural gas prices for non-household consumers, last 6-semester average (all taxes and levies included) - small enterprises	652.33	€/toe	Eurostat
e.3.1)	Electricity prices for non-household consumers, last 6-semester average (all taxes and levies included) - medium enterprises	1,953.12	€/toe	Eurostat
e.3.2)	Natural gas prices for non-household consumers, last 6-semester average (all taxes and levies included) - medium enterprises	523.09	€/toe	Eurostat
f)	Share of SMEs from all enterprises	99	%	Eurostat
g.1)	Water efficiency potential (water consumption reduction)	30	%	European Commission
g.2)	Water efficiency potential (water consumption reduction)	40	%	European Commission
g.3)	Water efficiency potential (water consumption reduction)	50	%	European Commission
h)	Final energy consumption in Europe (without households)	637,328	toe	PORDATA
i)	Number of enterprises in Europe	27,835,901	nr	PORDATA
j)	Number of SMEs in Portugal	1,314,944	nr	PORDATA
k)	Water consumption for non-residential buildings in Portugal	183,107,796	m^3	ERSAR
l)	Portuguese GVA (2020)	174,309.6	€	PORDATA
m)	Increase of prices due to average inflation (2022 value)	8	%	European Central Bank

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a) The cost of water from public water supply greatly varies between countries and even amongst cities and municipalities. The main elements of the water tariff (price per cubic meter) are the costs to provide drinking water and wastewater services. Depending on the country, it may comprise additional elements such as taxes, fees, or rainwater charges. It was considered the average European water price of **3.5€/m^3** (EurEau, 2021).

b) The company's water consumption may be from public water supply, self-water supply or other supply sources. Nevertheless, despite the company only needs to pay for the water from public water supply, the self-supply water has associated costs, as the company needs to **capture and pump the water to use it**. Given the lack of information on self-supply costs, it was **assumed that they are similar to the public water supply costs.** This assumption is mainly based on the fact that there are European countries where the water management authorities charge less (for the delivered water) than the value that they spend to deliver it (which is comprised by the water cost and the energy necessary to deliver it). Nevertheless, this strongly varies from country to country. Thus, if the costs of the management authorities are typically higher than the ones actually charged, it is a conservative approach to assume that the self-supply water has the same value as the public water supply costs. Furthermore, it is important to notice these costs are mainly **energy costs** and will be reflected on the energy bill (due to the pumping system). Thus, the interventions in this field are also greatly connected with the energy efficiency measures identified during an energy audit. In this sense, efficiency measures over the pumping system will have multiple benefits in terms of reduced energy consumption, as well as reduction of water use and costs. Additionally, particularly in Southern Europe self-supply water needs to be collected at high depths, due to water scarcity and quality issues, which brings extra energy costs associated (European Environment Agency, 2022).

c) It was assumed that **50% of the water consumed in SMEs come from public water supply and that the other 50% is water from self-supply** (not charged by the water company). This estimate may be conservative as it is known that, for example, in Europe the manufacturing sector consumes around 94% of its water from self-supply or other water supply sources (Eurostat, 2022). This means that assumption k) water consumption for non-residential buildings (data from the water and wastewater

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managing authority) refers to only 50% of the consumed water. Considering that, this value should be multiplied by two to account for all the water consumption.

d) The European Commission report "Mapping and analyses of the current and future (2020 - 2030) heating/cooling fuel deployment (fossil/renewables)" states that **14% of the energy consumption** in the tertiary sector is used to **heat water** (European Commission, 2016). So, it was considered that for the service sector the energy consumption associated with heating water would be 14%. Nevertheless, as this strongly varies from sector to sector, it was also assumed that this value would be sensibly higher (about 30%) for SMEs with hot water consumption within its production process (or steam production, for example), and lower for other sectors with reduced hot water consumption (about 5%).

e) The energy cost estimation was performed considering the **Electricity and Natural Gas prices for non-household consumers**, performing an average of the last 6-semester (2S 2019 – 1S 2022) with all the taxes and levies included (Eurostat, 2022), as conservative approach. As these prices strongly vary from country to country it was considered the **EU-27 average value**. Furthermore, as the **consumption threshold** is also a factor that greatly influences the energy prices, they were divided to allow the scenario computation for **micro** (electricity Band IA: Consumption < 20MWh and natural gas Band I1< 1,000GJ), **small** (Band IB: 20MWh < Consumption < 500MWh and natural gas Band I2: 1,000GJ < Consumption < 10,000GJ) **and medium enterprises** (electricity Band IC: 500MWh < Consumption < 2,000MWh and natural gas Band I3: 10,000GJ < Consumption < 100,000GJ).

f) The LEAP4SME Deliverable 2.1 – Mapping SMEs in Europe: Data collection, analysis, and methodologies for estimating energy consumptions at Country levels, defined that more than **99% of all enterprises are SMEs**, whereas large companies only have a marginal share (LEAP4SME, 2021). Therefore, the literature values found namely to assumption h) final energy consumption in Europe and i) number of enterprises in Europe, were assumed to be **equally applied to SMEs**. **However, this is a very strong assumption (in the lack of better data), as the 1% of enterprises that are not SMEs are accountable for a large share of the final energy consumption reported.**

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g) Buildings have a **water efficiency potential of 30% to 50%** in Europe, depending on its construction period, with payback periods of 1-2 years, e.g., related to the installation of more efficient equipment (European Commission, 2017). Based on a water efficiency rationale framing the water-energy nexus, it is estimated that the combined potential for water and energy savings for families in Portugal can reach the equivalent of **50% of the water bill** (Poças et al, 2020; Newton, 2018). It was assumed that the water efficiency potential range (30% to 50%) is the same across European SMEs, extending this potential to enterprises and production processes.

m) According to the projections of the European Central Bank[7], **inflation is expected to be 8.1% in 2022** (and this was the value assumed for quantification purposes). However, this should decline to 5.5% in 2023 and 2.3% in 2024. Thus, it is likely that this high inflation scenario will not be maintained in the near future.

The remaining assumptions are **literature values**, taken from statistical databases, to assist in the scenario quantification calculation. It is important to notice that despite assumptions j), k) and l) refer to Portuguese values it was assumed that **European values will not vary significantly**. Also, it was assumed that the values are transversely applicable to all SMEs (micro, small and medium size from the sectors considered).

These assumptions and values, were necessary to support the **calculation methodology** to compute the KPIs, summarized in Table 11 below. This calculation methodology is based on the KPIs formulas presented in 3.1.2 Quantification framework, adapted to accommodate the existing theoretical values.

[7] https://www.ecb.europa.eu/pub/projections/html/ecb.projections202209_ecbstaff~3eafaaee1a.en.html#toc7

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Table 11 – Core KPIs baseline and savings calculation methodology

KPI	Methodology
Total water consumption baseline [m^3]	(Water consumption for non-residential buildings in Portugal [m^3] * Number of SMEs in Portugal [nr]) / Percentage of water consumption from self-supply (not charged by the water company [%])
Energy consumption associated with water baseline [toe]	(Final energy consumption in Europe [toe] / Number of enterprises in Europe [nr]) * Energy consumption associated with water [%]
Cost baseline [€]	(Total water consumption baseline [m^3] * Water cost [€]) + (Energy consumption associated with water baseline [toe] * Energy mix cost [€])
Water consumption per GVA [m^3/€]	Total water consumption [m^3] / Portuguese GVA (2020)
Water productivity [€/m^3]	Eurostat database; World Bank database
Share of water costs in the total costs incurred [%]	(Total water consumption [m^3] * Cost of water (European average) [€/m^3]) / Total yearly company cost [€]
Waste valorization rate [%]	(Recycling [kg] + Backfilling [kg] + Energy recovery [kg]) + / Total yearly waste production [kg]

In this sense, after the methodology was established, it was applied to cover the **scenarios** set, namely the energy consumption associated with water per sector (with different ranges of water savings potential, based on literature), and the energy prices per size of enterprise (with different energy mixes).

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3.2.2.1 SMEs from the service sector

Considering all the assumptions and values from Table *10*, it was quantified the **total water consumption** and savings baseline for a European SME from the service sector, as in Table 12 below.

Table 12 – Total water consumption and savings baseline for SMEs from the service sector (average values per SME, per year, in Europe)

Baseline		Savings		
Total water consumption [m³]	**Energy consumption associated with hot water [toe]**	**Water savings potential [%]**	**Water savings [m³]**	**Energy reduction associated with water savings [toe]**
		30%	83.6	0.0010
278.5	0.0032	40%	111.4	0.0013
		50%	139.3	0.0016

Thus, using the baseline established, it was possible to quantify the water and energy savings per enterprise dimension (micro, small and medium) and with different energy mixes to heat the water used (100% electricity, 50% electricity with 50% natural gas and 100% natural gas). These values are in Table 13 below.

Table 13 – Water and energy savings per enterprise dimension and energy mix (average values per SME, per year, in Europe)

Savings (Water + Energy) [€]								
Micro enterprises			**Small enterprises**			**Medium enterprises**		
100% Electricity	**50% E.- 50% NG**	**100% NG**	**100% Electricity**	**50% E. - 50% NG**	**100% NG**	**100% Electricity**	**50% E. - 50% NG**	**100% NG**
295.4	294.3	293.2	294.6	293.8	293.1	294.3	293.6	292.9
393.8	392.4	390.9	392.8	391.8	390.7	392.4	391.5	390.6
492.3	490.4	488.6	**491.1**	489.7	488.4	**490.5**	489.4	488.2

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The savings potential is higher for micro enterprises, aligned with their higher energy prices. Moreover, it was also tested the influence of the prices' increase (water and energy) due to inflation (8% increase), as in Table 14.

Table 14 – Water and energy savings per enterprise dimension and energy mix, considering 8% of inflation (average values per SME, per year, in Europe)

Savings (Water + Energy) [€] + 8%								
Micro enterprises			**Small enterprises**			**Medium enterprises**		
100% Electricity	**50% E. - 50% NG**	**100% NG**	**100% Electricity**	**50% E. - 50% NG**	**100% NG**	**100% Electricity**	**50% E. - 50% NG**	**100% NG**
319.0	317.8	316.6	318.2	317.4	316.5	317.9	317.1	316.4
425.3	423.7	422.2	424.3	423.1	422.0	423.8	422.8	421.8
531.6	529.7	527.7	**530.3**	528.9	527.5	**529.8**	528.5	527.3

It should be noted that these savings are **only** related to **water heating needs**. As previously stated, the energy costs associated with pumping and distribution of self-supply water were not considered, nor the ones associated with the water use during the production process (as these values cannot be found in literature), so the **real value of energy consumption of water use is presumably considerably higher**. Furthermore, this is a very simple to monitor and act indicator, and small and/or indirect interventions (as energy efficiency measures in the production process that affect the water use) would have a great impact on it.

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3.2.2.2 SMEs with production processes that use hot water

Considering the assumptions and values from Table *10*, it was quantified the **total water consumption** and savings baseline for SMEs with water consumption within their processes, as in Table 15 below.

Table 15 – Total water consumption and savings baseline for SMEs with production processes that use hot water (average values per SME, per year, in Europe)

Baseline		Savings		
Total water consumption [m³]	**Energy consumption associated with hot water [toe]**	**Water savings potential [%]**	**Water savings [m³]**	**Energy reduction associated with water savings [toe]**
		30%	83.6	0.0021
278.5	0.0069	40%	111.4	0.0027
		50%	139.3	0.0034

As previously, using the baseline established, it was possible to quantify the water and energy savings per enterprise dimension (micro, small and medium) and with different energy mixes to heat the water used (100% electricity, 50% electricity with 50% natural gas and 100% natural gas). These values are in Table 16.

Table 16 – Water and energy savings per enterprise dimension and energy mix (average values per SME, per year, in Europe)

Savings (Water + Energy) [€]								
Micro enterprises			**Small enterprises**			**Medium enterprises**		
100% Electricity	**50% E.- 50% NG**	**100% NG**	**100% Electricity**	**50% E. - 50% NG**	**100% NG**	**100% Electricity**	**50% E. - 50% NG**	**100% NG**
298.7	296.4	294.0	297.2	295.5	293.8	296.5	295.0	293.5
398.3	395.1	392.0	396.2	394.0	391.7	395.3	393.3	391.3
497.8	493.9	490.0	**495.3**	492.4	489.6	**494.1**	491.6	489.2

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Also, it was also tested the influence of the prices' increase (water and energy) due to inflation (8% increase), as in Table 17.

Table 17 – Water and energy savings per enterprise dimension and energy mix, considering 8% of inflation (average values per SME, per year, in Europe)

Savings (Water + Energy) [€] + 8%								
Micro enterprises			Small enterprises			Medium enterprises		
100% Electricity	50% E. - 50% NG	100% NG	100% Electricity	50% E. - 50% NG	100% NG	100% Electricity	50% E. - 50% NG	100% NG
322.6	320.1	317.5	320.9	319.1	317.3	320.2	318.6	317.0
430.1	426.8	423.4	427.9	425.5	423.0	426.9	424.8	422.6
537.7	533.5	529.2	**534.9**	531.8	528.8	**533.6**	531.0	528.3

3.2.2.3 SMEs with reduced hot water use within their processes

Considering the assumptions and values from Table *10*, it was quantified the **total water consumption** and savings baseline for the service sector, as in Table 18 below. These are average annual values per European SME.

Table 18 – Total water consumption and savings baseline for SMEs with reduced hot water use within their processes (average values per SME, per year, in Europe)

Baseline		Savings		
Total water consumption [m³]	Energy consumption associated with hot water [toe]	Water savings potential [%]	Water savings [m³]	Energy reduction associated with water savings [toe]
		30%	83.6	0.0003
278.5	0.0011	40%	111.4	0.0005
		50%	139.3	0.0006

Thus, using the baseline established, it was possible to quantify the water and energy savings per enterprise dimension (micro, small and medium) and with different energy mixes to heat the water used (100% electricity, 50% electricity with 50% natural gas and 100% natural gas). These values are in Table 19 below.

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Table 19 – Water and energy savings per enterprise dimension and energy mix (average values per SME, per year, in Europe)

Savings (Water + Energy) [€]								
Micro enterprises			**Small enterprises**			**Medium enterprises**		
100% Electricity	**50% E.- 50% NG**	**100% NG**	**100% Electricity**	**50% E. - 50% NG**	**100% NG**	**100% Electricity**	**50% E. - 50% NG**	**100% NG**
293.5	293.1	292.7	293.2	292.9	292.7	293.1	292.9	292.6
391.3	390.8	390.3	391.0	390.6	390.2	390.8	390.5	390.1
489.1	488.5	487.8	**488.7**	488.2	487.8	**488.5**	488.1	487.7

Moreover, it was also tested the influence of the prices' increase (water and energy) due to inflation (8% increase), as in Table 20.

Table 20 – Water and energy savings per enterprise dimension and energy mix, considering 8% of inflation (average values per SME, per year, in Europe)

Savings (Water + Energy) [€] + 8%								
Micro enterprises			**Small enterprises**			**Medium enterprises**		
100% Electricity	**50% E. - 50% NG**	**100% NG**	**100% Electricity**	**50% E. - 50% NG**	**100% NG**	**100% Electricity**	**50% E. - 50% NG**	**100% NG**
317.0	316.5	316.1	316.7	316.4	316.1	316.5	316.3	316.0
422.6	422.0	421.5	422.2	421.8	421.4	422.1	421.7	421.4
528.3	527.6	526.8	**527.8**	527.3	526.8	**527.6**	527.1	526.7

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3.2.2.4 All SMEs

The following KPIs were considered to be **equally applied to all SMEs**, independently of their dimension and operating characteristics.

Regarding the **water consumption per GVA**, the savings potential associated was calculated using the total water consumption baseline value, that is the same for all SMEs and sectors. The computed values are in Table 21.

Table 21 – Water consumption per GVA

Water consumption per GVA, baseline [m³/€]	Water savings potential [%]	Water consumption per GVA, reduction [m³/€]]	Water consumption per GVA, final value [m³/€]
0.0016	30%	0.0005	0.0011
	40%	0.0006	0.0010
	50%	0.0008	0.0008

The water intensity indicators, like the water consumption per GVA, intend to measure the efficiency and sustainability of the water uses. Thus, a **lower value will reflect a more efficient enterprise** on this matter. The energy and cost savings associated with this KPI were already calculated, as this KPI uses the total water consumption baseline value in its computation.

The **water productivity** indicator serves as a measure of the efficiency of water use and is capable of indicating how much economic output is produced per cubic meter of fresh water abstracted. The corresponding values can be found per country in Eurostat and World Bank database, as in Table 22. The water productivity values were also compared with the energy productivity, that measures the productivity of energy consumption and provides a picture of the degree of decoupling of energy use from growth in GDP. A quick analysis shows that water productivity is far superior to energy productivity.

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Table 22 - Water and energy productivity in LEAP4SME countries (Source: Eurostat, 2022; World Bank, 2022)

Country	Water productivity, Eurostat 2020 [€/m³]	Water productivity, World Bank 2018 [€/m³]	Energy productivity, Eurostat 2020 [€/Kgoe]
Italy	n.a	47.5	10.3
Portugal	n.a	29.9	8.0
Austria	n.a	99.2	9.8
Greece	17.1	16.8	7.8
Slovakia	146.1	147.1	5.0
Croatia	71.1	69.6	5.7
Malta	253.7	266.2	3.6
Poland	53.6	48.1	4.7
United Kingdom	n.a	316.0	n.a
Average LEAP4SME countries	**108.3**	**115.6**	**6.9**
Average EU-27	**146.0**	**65.3**	**8.6**

n.a: not available

The values presented are merely illustrative, as they do not refer to a single company (for that purpose it should be calculated with real data), but to a set of countries performance. Furthermore, it should be stressed that the comparison of the water productivity indicator between countries is pointless, as water productivity depends on the structure of economies, which cannot be modified in the short term. Moreover, as this indicator is calculated at national level, intra-country differences are not accounted for. Additionally, the water productivity indicator does not allow for credible comparison over time in a country, as GDP is calculated in current prices. There are also limits regarding data availability and water data collection, as the practice differs between Member States and sectors, resulting in differences in data quality (Vladimirova, et al., 2018). This indicator was introduced to support policy makers in taking informed decisions when faced with both short- and long-term pressure on water resources but can easily be transposed to companies to **help top-management to take adequate choices concerning the enterprises' water uses**.

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To calculate the KPI **share of water costs in the total costs incurred** it is necessary to use the value of total water consumption, cost with water consumption and total yearly company costs. The last one depends on the type, size and/or sector of the company and is not available in the literature or databases consulted. Thus, in this case the theoretical quantification was not possible. Nevertheless, the energy and cost savings associated with this KPI were already calculated, as this KPI again directly uses the total water consumption in its calculation.

Finally, the basis behind the **waste valorization rate** KPI is focused on increasing the amount of waste send to valorization, that will consequently decrease the amount of waste send to landfill, as well as maximize the energy recovering associated. The Directive 2008/98/EC to promote the moving towards a European recycling society with a high level of resource efficiency, urged the Member States to take the necessary measures to until 2020 increase the minimum of preparing for re-use, recycling and other material recovery to 70%, by weight of the generated waste. As in general the landfill fee is higher than the valorization fee (and in several cases there is no fee for recycling), the increase of the recycling process will decrease the companies' costs. Theoretically, increasing the waste valorization rate through recycling by 10% (from 60% to 70%) would lead to up to an indicative economic benefit[8] of 2,000€. Note that in this case, as the taxes and fees applied strongly vary from region to region it is difficult to make general assumptions. Furthermore, it is also possible to use the **waste to energy recovery purposes**, applying the concept of *Waste-to-Energy*, fundamental in a circular economy, which comprises different types of systems and technologies. For example, the biomass waste from sawmills and other wood industries has an enormous energy recovery potential, namely through cogeneration.

[8] Considering the specific case of an SME part of the construction sector, producing 1.000 ton/year of construction and demolition waste, assuming that no additional containers are needed and the distance of the recycling operation or to the landfill is the same. The taxes and fees applied, refer to Portugal, 2022.

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4. Conclusions and Next Steps

This report performs the identification of the main benefits from resource audits, analysing its the **pertinence** and proposing a **quantitative methodology**. Nevertheless, firstly **energy audits** and **energy efficiency measures** were studied, to better understand their role within SMEs.

It is a fact that energy audits have the ability to **influence the decision** of SMEs to proceed with energy efficiency investments and help to overcome information barriers to energy efficiency investments, being energy efficiency measures the path to achieve the aimed **reduction of energy consumed.** However, the implementation of these measures cannot be done without the adequate identification of the necessary efficiency improvements.

Furthermore, using the experience of the LEAP4SME consortium partners it was possible to collect very relevant **information regarding the audit programmes**, policies and/or initiatives that are currently enforced (or were in a recent past) in the participant countries. This helped to have an overview of the support given to audits execution, and the resulting implementation of efficiency measures. From the this it was possible to draw some **general conclusions**, namely: (1) the programmes that have mandatory implementation of its measures do not cover the implementation costs, but where the implementation is not mandatory the cost is covered; (2) the quantification of savings that result from the energy efficiency measures addressed is commonly done; (3) on the other hand, the quantification of non-energy benefits' savings is seldom performed; (4) the definition of average costs for energy audits in Member States is not straightforward – the values can range from 1,000€ to more than 20,000€ depending on the entity type, audit required, size of the organisation, its energy-intensity or location country; (5) SMEs' audit costs are often totally covered by support programmes.

It was also studied that as the potential to **address non-energy benefits** and combine strategies between energy efficiency and water and/or materials efficiency is often neglected, the potential for continuous energy efficiency improvements is likewise reduced. **Resource efficiency audits** have the capacity to boost the implementation of energy efficiency measures, as well as reduce the use of energy, water, and materials, therefore increasing the

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companies' competitiveness and reducing the uncertainties of externalities. Nevertheless, the **quantification** of the audits' potential savings is fundamental, and not an easy task. Thus, mapping and evaluation need to be based on a mixture of experience, observations, calculations, and/or estimations in various ways. However, the starting point to an appropriate quantification should be the **definition of suitable KPIs**, capable of creating a basis for decision making and efficiency measures implementation, supported by solid data. The defined KPIs intend to **quantify the savings** resulting from audits and were divided into six main groups: water consumption, water intensity, water sources, water cost, materials use and water-energy nexus.

Ideally, the information needed to calculate all the resource efficiency KPIs **should be collected** through on-site measurements, water and energy invoices direct checks, and face to face interviews with the companies' top management and resources management (energy, water, and materials) responsible. Nevertheless, the **definition of a quantification framework procedure** based on desk research focusing on national and international databases is feasible. However, some limitations were encountered, as: general lack of data (national and at European level) regarding SME's; scattered and most of the times not updated databases; and not registered information needed to fully characterize the KPIs. This led to the conclusion that **on site measurements are fundamental to perform an adequate KPIs' quantification.**

Also, **different levels of KPIs' evaluation** were drafted, intending to monitor the suitable indicators to each company, as the presented list may not be equally applicable to all. Thus, the scenarios presented were organized in the form of a **decision tree**, where the KPIs are applied at levels, corresponding level D to the most elementary, and level A to the one where the higher number of the KPIs are suitable. With this configuration the enterprises may advance as the KPIs apply to their own specific case (in a general way) and/or as they have data available or interest. In this sense, the starting point is a set of **core KPIs** (level D), six indicator groups, and are the **total water consumption, water consumption per GVA, water productivity, share of water costs in the total costs incurred** and **waste valorization rate**. It should be highlighted that, as the framework evaluation level increases, it is harder to find literature values capable of allowing KPIs' quantification without on-site measurements or at least direct contact with the company.

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Finally, it was performed a **theoretical evaluation** of the core KPIs scenario (level D). Firstly, it was established a baseline regarding water and energy consumptions, as well as its associated costs. Again, it was concluded that there is a general lack of data, and the existing information is dispersed. Having this in mind, some general assumptions needed to be made.

The core indicator of this evaluation was the **total water consumption.** It was assessed that the savings potential of this indicator alone may not seem very high, nevertheless it is a very simple to monitor and act indicator, and small and/or indirect interventions (as energy efficiency measures in the production process that affect the water use) would have a great impact on it. Furthermore, the energy costs associated with pumping and distribution of self-supply water were not considered, nor the ones associated with the water use during the production process (as these values cannot be found in literature), so the **real value of energy consumption of water use is presumably considerably higher** than the one presented.

The analysis of the numbers presented should be **done very carefully**, as they are based on proxy values and some strong assumptions (as, for example, the final energy consumption value (non-household) that was considered to be applied equally to SMEs, despite the 1% of enterprises that are not SMEs being accountable for a large share of the final energy consumption reported). From the values computed, it is possible to conclude that the **savings potential is higher for micro enterprises**, as their energy prices are also higher when compared with small and medium enterprises. Nevertheless, the difference is marginal (less than 1%), even when comparing the micro and medium sized enterprises with 100% use of electricity to heat water, with hot water uses within their processes. These can be justified by the fact that in this particular analysis, the **savings potential is being mainly influenced by the water prices and not by the energy prices**. Therefore, the variations on energy consumptions and prices are not reflected, as they represent a small share of the value computed. This type of constraints is simply overcome **through on-site measurements and a direct contact with the enterprise to audit.** Thus, this report should be seen as, most of all, a methodology approach definition.

Additionally, the **waste valorization**, namely the waste to energy recovery purposes, applying the concept of *Waste-to-Energy*, should also be mentioned. For example, the biomass waste from sawmills and other wood industries has an enormous energy recovery potential, namely

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through cogeneration. There are also other non-energy benefits, byproducts related, that are worth further study, as the production of biogas and hydrogen through industrial processes, namely when treating wastewaters or water.

The **next step of this work** should be focused on the quantification and analysis of the drafted scenarios through resource efficiency audits, allowing **on-site measurements to perform KPIs' real quantification**, and fully assess the energy, water and raw materials saving potential of the theoretical model proposed.

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