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Analysis of current barriers and solutions in the implementation of energy efficiency methods in the European industry

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Abstract. This research is a state of the art of the main barriers and solutions that can be found in the implementation of energy efficiency measures and methods in industry, such as Energy Audits or Energy Management Systems (EMS). It aims to bring together in a single document the lessons learned from the efforts of the European Union over the past decade to increase energy efficiency in industry. The article catalogues and analyses 20 legal, technical, economic, cultural and organisational barriers that are still present today and as an added value it provides with a table of multiple, accessible and current solutions as well as with potential improvement pathways to overcome each of them. The ultimate purpose of this work is to stablish a higher starting point, with more awareness and available solutions, from which to start in order to accelerate the decarbonisation of the industry and subsequently be able to achieve the latest and more ambitious objectives set in the 'Fit for 55' package in the EU.

Key words. Energy Efficiency Barriers, Energy Efficiency methods, Industrial decarbonization, Energy Audit, Energy Management System.

1. Introduction

In June 2021, the European Union approved the set of proposals of the "Fit for 55" package by which European Climate Law was adopted, committing its members to cutting net greenhouse gas emissions in the EU by at least 55% by 2030 (compared to 1990 levels) and to becoming the first climate-neutral continent by 2050, in line with the objectives of the European Green Deal. Projections indicate that, if current policies are fully implemented, greenhouse gas emission reductions by 2030 would be around 45% of 1990 levels [1]. Added to this, the conflict in Russia and Ukraine and the consequent energy crisis are pushing the EU to further reduce dependence on fossil fuels. As a result of this, the European Energy Efficiency Directive 2012/27/EU (EED in advance) is being revised again since last year in order to set more ambitious energy reduction targets. The last revision of the directive in 2018 set a target of 32.5% improvement in energy efficiency by 2030 (compared to 1990 levels). However, according to the latest communication of the European Commission, this percentage is expected to increase to 36-37% of final energy consumption and 39-41% of primary energy consumption in order to achieve the 55% target. In this regard, the annual energy savings in end-use consumption that it is currently set at 0.8% per year, is to be increased to 1.5% from 2024, through to 2030.

The European Union is already reducing its energy consumption and improving its energy performance since energy efficiency regulations were launched in the late first decade of the 2000s as shown in *Figure 1*. The target points marked in the graph will be located below if the new revision of the EED is finally approved. So, much more effort will be needed to bend the curve even further if the 2050 targets are to be met.

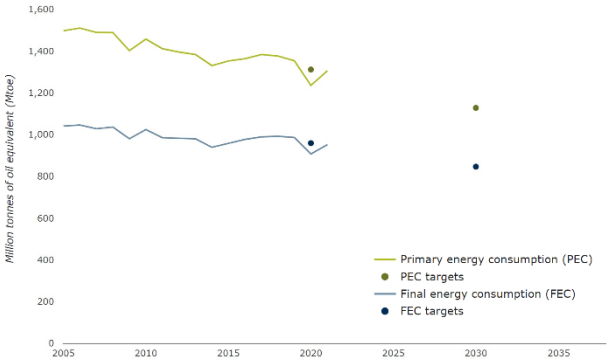

Figure 1 Final and primary energy consumption for EU-27 from 2005 to 2021 and EU targets for 2020 and 2030. Source: EEA & Eurostat.

Measures to reduce energy consumption and achieve the decarbonisation must reach all sectors, but companies and industries, especially the intensive ones, are particularly key. Businesses represented about 74% of the EU's final energy consumption in 2018, mainly in the transport (31%), industry (26%) and services (14%) sectors [2]. In fact, the EED, after its review in 2018, started to focus on this sector and announced that the large companies (250 employees or more) and the largest energy users (more than 100 TJ/year) shall be obliged to carry out a four-yearly energy audit or to have an Energy Management Systems equivalent in place to ensure that they are well aware of the cost-saving energy efficiency potential available for their business. In addition, it will become mandatory for companies in some EU countries to register their carbon footprint from this year onwards.

Energy audits should be the first step in developing an organisation's energy management plan. These have evolved and expanded in scope over the years. What was once simply a matter of investing in more energy efficient equipment that directly influence production, has today more ways of attack, some not so easily

detectable, such as research into the staff behaviour and routines that encourage energy efficiency improvements. On the other hand, Energy Management Systems (EMS) regulated by the standard ISO 50001, are the most sophisticated option used in large companies (usually more familiar with technological advances and digitalisation) providing a jump in quality with respect to conventional audits, as they allow a continuous improvement in energy performance by monitoring consumption in real time and showing a clear pattern of the organisation's behaviour and energy use, thus making it easy to identify improvements, optimise consumption and follow up on the measures implemented to achieve maximum efficiency. This requires a considerable investment, training for the company, the involvement of the company's executive and maintenance staff and the establishment of an energy policy and strategy [3].

European Union is strongly promoting energy efficiency as the first essential step towards decarbonisation through various energy efficiency programmes, regulations and directives as well as funds for the creation of research projects that pursue this objective [4]. Energy efficiency, beyond fighting climate change and the decarbonisation of industry, is also important to ensure security of supply and competition for companies. Energy is a key production input in industrial processes since on average, it represents around 5-10% of total production costs in the European industry. For energy intensive industries, such as chemical, steel, paper, pharmaceutical, cement and construction materials, the costs are even higher, from 15% to 40% on average [5]. It is estimated that energy efficiency could reduce industrial energy use by more than 25%, according to the Institute for Industrial Productivity [6]. However, despite the many benefits of implementing energy efficiency in industries and after decades of promoting it, there are still some barriers that hinder it.

As result of the European Union's first effort to achieve the 20-20-20 objective set in previous decades, already exist in the literature some research that collects some of these barriers found during the past period [7], [8], [9], [10] or those that explain the main causes that make energy efficiency programmes and policies fail [11]. Some case studies of energy audits [12] [13] or Energy Management Systems [14] in industry can also be found. Also recently, some European projects have been funded to facilitate energy efficiency in companies and the exchange of experiences between different countries, such as DEESME [15], SMEmpower [16] or SPEEDIER [17]. However, all this information is widely dispersed, tends to focus on specific case studies for each type of industry and often do not offer clear or accessible solutions to overcome barriers. This article aims to bring together in a single document the lessons learned from that effort of previous decades by cataloguing the most important barriers in industry that still apply today and also proposing accessible and cutting-edge solutions as an added value. Numerous research studies from the literature, the EU government programmes, the best available practices, reports and success case studies from highly efficient companies in the industry, among other sources, have been reviewed for finding solutions with the aim of providing resources to pave the way towards the 55% GHG reduction by 2030.

2. Main barriers identified in implementation of energy efficiency methods in industry

The barriers that have been found to be the most incident and relevant following the research are classified, described and numbered below.

Legislative and regulatory barriers

i. Limited or difficult access to funding EE solutions.

Often the sources of funding offered by the authorities involve too much bureaucracy and administrative workpaper, including complex and difficult to understand legislative concepts. On the other hand, the eligibility criteria imposed by some financing programs may be very strict [10]. In addition, such aids are sometimes short-term and have a limited duration. Finally, it could be so easy to get lost due to the constant change in the regulative frameworks and incentive programmes.

ii. SMEs have hardly any obligations in terms of energy efficiency.

So far, only large companies are obliged to carry out energy audits or have EMS as well as to assign an energy manager. Although the impact on a large company can be greater than in a SMEs and in general it has more financial capacity for EE implementation, the fact is that the total amount of SMEs also represents a very significant percentage of energy consumption and the vast majority of energy efficiency measures should not be a problem to be assumed by SMEs. However, it is mostly SMEs that tend to encounter more of the barriers discussed here [9]. Nevertheless, they will have to overcome them soon as in some EU countries, almost every company in the industry will be required to register its carbon footprint in the coming years.

iii. Lack of standardized documents for EE methods.

Annex VI of EED contains very briefly minimum criteria about auditing and EMS. Some standards, such as EN 16247 and ISO 50002, aim to capture the common aspects of energy audits, although these contain guidelines with a large degree of leeway [18]. Something similar occur with the EMS defined by ISO 50001.

iv. Reliable funding schemes for training, certification and recertification in audits.

The technical expertise to carry out a good energy audit or implement an EMS is quite complex and diverse [19]. In addition, technology advances and energy efficiency standards become more and more demanding, so it is also necessary to update auditors and energy managers so that they can adapt. Although there are some training courses available for acquiring the skills, they are often expensive and it is not easy to know how reliable they are.

v. Lower energy efficiency awareness or priority in some European countries.

Some countries such as Cyprus, Romania or Slovenia present a lack of well-defined national laws, regulations or strategies in energy efficiency [20]. This leads to a lack of funding and prioritisation by financial institutions, a lack of accessible tools and information in energy efficiency, a smart metering deployment delay, etc.

Technical barriers

vi. Deficits in information or expertise in EE in the staff of the company and lack of an energy manager.

Company staff or technicians with a lack of awareness or know-how in energy-efficiency practices may think that some energy efficiency measures proposed by an energy audit may lead to production inconveniences and it is beyond their scope to be able to propose energy efficiency improvements to the company. There is still a noticeable lack of practical training in EE of the company staff and there are usually a total dependence on suppliers to understand the energy aspects of their equipment [21]. On the other hand, if there is not enough knowledge to choose which equipment is energy optimal, decisions could be made on the basis of other criteria such as price. Finally, in energy intensive companies, process conditions (idling time, media flows, control of the temperature, etc.) have a big impact on the energy consumption so it is important to understand the process details. The role of an energy manager in a company is very useful to make energy efficiency an integral part of daily work and not a punctual project.

vii. Scope of conventional audits is usually limited

There is no sufficiently concrete standard to define the scope of an audit (as described in barrier iii) and this is usually adjusted and agreed between the auditing party and the company depending on the budget and time available or simply focused on a very specific point in the process. In addition, it often happens that once the audit has been carried out, the measures are not fully implemented or no follow-up of the energy improvement resulting from the investment is established. It has also been observed that conventional energy audit reports are no very focused in showing the other multiple benefits related to the energy efficiency implementation apart from the obvious ones (cost and emission reductions) and some studies remark that the non-energy benefits often outweigh the energy benefits [20].

viii. Not considering the installation of renewable energy, cogeneration, energy recovery systems or biogas production from waste as a measure in audits.

In the past, audits were limited to replacing old equipment with more efficient one, to change lighting, add insulation and little else. Today, an audit must look at the potential for finding new sources of energy in the vicinity of the company, whether from renewable resources, cogeneration or the use of waste energy from other processes as these are among the measures with the greatest potential for economic, energy and environmental savings.

ix. Lack and standardised energy indicators or European benchmarking for reference.

Sometimes companies are unaware of their potential for improvement simply because they do not know what the typical consumption of similar industries is.

x. Lack of monitoring of some crucial indicators for evaluating EE and ignorance of consumption and electricity bills by decision-makers.

Most industrial companies in the EU, especially SMEs, currently lack energy management and monitoring systems and therefore have no knowledge about their energy indicators. Without a reference of the current state of energy consumption it is not possible to quantify an improvement and therefore to consider whether it is worth implementing. Usually the only information that is available in most companies regarding energy consumption data comes from the monthly aggregate of the bill and often attention is not even paid to this value.

Economic barriers

xi. Lack of budget for energy efficiency solutions

Many companies, especially SMEs, do not have available budget to implement energy efficiency measures and sometimes, even if the budget is available, it will not be done if it is not considered a priority. However, certain sectors, such as the food and drink industry, are highly price-sensitive as they could be left out of the competitive market just because of electricity price reasons. However, the profit margin of their products is not very high, and fear or lack of knowledge leads to a lack of implementation.

xii. Long payback period or ignorance about the life cycle of the EE investment.

Companies working in productive sectors are willing to invest with returns of one year maximum while those working in capital intensive sectors may be willing to accept longer returns of up to 3-4 years [21]. Although the vast majority of energy efficiency investments pay back quickly within a few years or even few months, if the cost of investment for actions is present just as a simply energy efficiency inversion without life cycle and the added value regarding quality, productivity or increased useful life of the plant, may lose interest.

xiii. Ownership of the property

Companies or industries that rent their facilities are less likely to invest in energy efficiency and develop strategies for the future. On the other hand, sometimes properties have different owners and it is difficult to reach an agreement.

xiv. High cost of an energy manager

Having one person simply manage the company's energy may be unfeasible or excessive in companies where energy consumption is not so significant. Sometimes this role could fall to the company's maintenance staff, but they are often not trained to envision energy efficiency improvements.

xv. Indirect costs associated with the implementation of certain measures

Introducing new technologies could disrupt existing production process costs involved with learning to operate new machinery and technology.

Cultural and organisational barriers

xvi. No prioritising energy efficiency in managerial decision.

According to SMEs surveys, the main motivation to implement energy efficiency solutions in small and medium companies is the reduction of the energy bill [20], especially in times of energy crisis. In the case of large companies, their legal obligations must be added to

this. In this regard, if the economic benefits of the proposed measures after an audit are not very obvious or straightforward, some measures are often not implemented or do so only to a limited extent (or even temporarily) in order to meet the minimum requirements. And if there is no obligation, most likely there will not even be an audit, nor effort and resources will be devoted to improving the energy efficiency of the company.

xvii. Work planning is not favourable for energy efficiency.

Work schedules or process scheduling calendars can lead to unnecessary over-consumption of energy. Demand-side management can have a significant impact on the energy efficiency of the company and usually has no costs associated with it, only a change in schedules and behaviour. However, looking at changing company schedules is not a measure that is usually reflected in industrial energy audits as it is sometimes assumed that these are rigid and immovable.

xviii. Dispense with external audits.

Large industries have the commitment to implement and certify the ISO 50001 Energy Management System, and thus they may need no more external energy auditors, if the law is not requesting this as mandatory action. However, it has been proven that many companies maintain the ISO 50001, but only update their energy efficiency action plans with internal recommendations, which is a significant limitation [22]. Managers can think that an external consultant will not be able to improve what an internal worker has not previously identified.

xix. Lack of commitment by the staff of the company and need for behavioural changes.

Sometimes the energy efficiency measures that are implemented require the collaboration of the company's staff. For example, it is no useful installing an insulated window with triple glazing if it is left open afterwards or it doesn't make much sense to leave an efficient equipment running longer than necessary.

xx. No information flows between departments of the company.

When it is unclear who is the person responsible for energy management in a company, the communication necessary to bring about changes in the company's energy efficiency does not take place. Perhaps the facilities or maintenance staff (if any) would have to take on this role, but they would not be able to act within the manufacturing perimeter. On the other hand, the manufacturing operations manager who is responsible for the manufacturing process is not usually concerned about energy consumption. Furthermore, there may not even be any communication between facilities and manufacturing departments. Communication is even more difficult when it comes to reaching the decision-maker with an energy efficiency improvement as this request goes beyond day-to-day and urgent communications.

3. Identification of solution and future directions for improving energy efficiency in industry

In the following table are collected some solutions concerning best available practices, tools or energy efficiency strategies together with some reference examples, informs or tools that support them in order to tackle the barriers discussed in the previous section.

Table I. – Solutions and references for concerning barriers

Barriers	Suggested solutions
i *xi* *xv*	Where subcontracting Energy Service Companies (ESCos) or appointment of an energy manager is not feasible, some accesible training material on forms of financing in energy efficiency can be found. **Useful references and tools:** ▪ All the information on European support for energy efficiency investments is available in the *InvestEU* portal of the European Commission. ▪ Free advice is available on reques by the or the *European Investment Advisory Hub*, where free advice is available on request. ▪ In this policy brief can be found the European forms of funding as well as the available national funds [23]
ii *xvii*	There is still a need for more awareness of energy efficiency and more publicity from governments, institutions and references. Energy efficiency measures should not only be carried out by obligation as they bring great benefits to both large companies and SMEs and are good and profitable enough in itself to encourage its implementation. **Useful references and tools:** ▪ Report on the multiple benefits of an energy audit in industry [24] ▪ Reference websites providing accessible and useful information on energy efficiency such as the international energy agency (iea.org) or the Institute for European Energy and Climate Policy (ieecp.org). ▪ Currently active European projects such as EnTRAINER or DEESME offer free energy efficiency training to companies.
iii	There are differences in the approach to energy audits in terms of scope, objectives and level of detail [4]. **Useful references and tools:** ▪ The European Commission's *Intelligent Energy eLibrary website* (iee-libray.eu) collects a lot of good methodologies, guides and tools as well as case studies of audits in industry.
iv	There are certification bodies that offer reliable training and certify auditors. At international level, there are certifications such as CEA for energy auditors and CEM for energy managers issued by the Association of Energy Engineers (EEA). In each country, national certifications are also issued by regulated bodies. Although official certifications usually have to be paid for, Europe funds many projects that offer free training to train and catch up energy auditors and managers. **Useful references and tools:** ▪ Projects such as ENTREINER, SMEmpower or EUREMnext, for example, offer free training for auditors and energy experts.
v	To participate in European cooperation programmes with more pioneering energy efficiency countries such as Germany or Denmark, who have been implementing energy efficiency measures during longest time, to be able to exchange experiences and update their regulations as well as to take examples of energy efficiency measures and strategies that are being implemented.

	Useful references and tools: ▪ The European cooperation programmes that currently offer energy efficiency lines are: Horizon Europe, Interreg, Life and Erasmus+.
vi *xiv* *xx*	When hiring or appointing an Energy Manager or ESCos is not feasible, it is possible to train the company's own staff through training. **Useful references and tools:** ▪ As already mentioned, there are many European projects with free and accessible capacity building programmes on energy audits and energy efficiency available for industrial companies (DEESME, SMEmpower, SPEEDIER, EUREMnext or ENTRAINER).
vii *viii* *xii* *xvii* *xviii*	The energy audit has been widely considered as one of the most cost-effective ways to improve energy [25] although would be useful to regulate the scope of audits according to consumption, size or type of company. However, the general scope and effectiveness of most of the audits carried out could be improved by adding some of the possibilities described below: ▪ Multi-benefit analysis ▪ Life cycle of recommended actions ▪ Inclusion of short and long term energy efficiency monitoring and improvement plans for the total decarbonization and mechanisms in decision making regarding measures. ▪ More in-depth study of demand-side and staff behaviour ▪ Considering the potential of installation of renewable energy, cogeneration, energy recovery systems or biogas production from waste. ▪ Provision of simple resources and tools for company staff to monitor the key energy indicators of the company. ▪ Present successful cases or simulations of the recommended measures tackle the lack of trust in the proposed improvements. ▪ Include public financing options and support to achieve them.
ix *x* *vi*	Appropriate analysis of the consumption data by the calculation of performance indicators and comparison with benchmark may give the manager a better perspective of the potential improvement in EE in the company. **Useful references and tools:** ▪ In the European Union the "BREFs" (Best available techniques Reference documents) gather emissions and consumption indicators as well as many of the best available techniques in the industry. These are accessible on the website of the European IPPC Bureau. ▪ The "Energy Star" by the Environmental Protection Agency of USA is one of the most comprehensive energy benchmarking also available. ▪ A benchmarking bibliography can be found on the European Commission's *Intelligent Energy eLibrary* website.
x	Sometimes it is enough to simply know the energy consumption pattern of an equipment or process to be able to understand how to improve it. Energy audits are useful to keep the company's decision-makers aware of their monthly and process consumptions. Although the best tool to monitor consumption is an EMS and submeters in each process, if there is no capacity to afford it, other simpler monitoring and targeting (M&T) tools and measurement and verification (M&V) techniques based on regression analysis are freely available as results of some European projects. This help to achieve the jump from an objective of means (energy audit, actions on equipment etc.) to an objective of results (improvement of energy performance), given the great tendency that there is to apply technical energy saving measures or individual actions instead of a global energy management approach. **Useful references and tools:** ▪ M&T and M&V available tools [26]
xi *xv*	It is possible to get free resources to carry out energy efficiency audits and training to discover actions that have no cost associated with them and can reduce energy consumption as shown in *solution ii and xix*. It is also possible to consult the funding grants proposed in *solution i* or to participate in European funded projects as discussed in *solution vi*.
xii *xiii*	Few energy efficiency measures have a long payback period, so there is always the possibility to implement some measures. The audits usually rank the proposed measures according to payback although it is recommended that they also show the full life cycle or other benefits (such as longer life span of equipment, low maintenance costs, increased productivity and profitability, improve indoor air quality, improvement of the company's competitive position in the global market, etc) as suggested in *solution vii*. On the other hand, many of the measures are not related to the physical premises of the company, so it is irrelevant who the owner is. **Useful references and tools:** ▪ Table 2 of [27] presents an extensive range of typical energy efficiency measures in industry in cross-cutting technologies (i.e. motors, compressed air, lighting and HVAC systems) showing their payback periods, among other relevant characteristics.
xix	Organizations may encourage energy efficiency by developing a culture characterized by environmental values. To this end, it can be useful: - To involve all company staff in energy efficiency targets by breaking down the corporate target into individual business areas or distinct phases. - Provide people working on the production lines with details of the process and energy consumption of the machines so that they can provide useful information on energy losses and make improvements. - Create an alarm system to remember certain actions that can increase efficiency such as stopping or starting processes, adjustment of systems to setpoint levels, closing spaces, etc. - Put up advertisements or banners reminding people of behaviours that can increase energy efficiency. - Create a system of rewards for those who take measures to reduce the energy in the company. **Useful references and tools:** ▪ There are few examples in the literature where such measures are implemented but some interesting ones include [28], [29].

4. Conclusions

It is crucial that the main measure to enhance energy efficiency in a country come from governments. If governments consider energy efficiency as a priority and impose it through their legislation, industrial companies

and society will eventually consider it as well (even if only collaterally). However, the measures proposed by the governments to encourage and promote energy efficiency such as subsidy schemes, development programmes or tax incentives, are often not sufficient or do not reach their audience properly for many of the reasons discussed in section 2. On the other hand, it should also be highlighted that the most common reasons for energy efficiency not penetrating in companies come from the cultural and organisational side and not from the economic or technical barriers as might be expected. Section 3 proposes a several solutions to these problems by providing with more resources for energy efficiency and industrial actors.

This paper also reveals the need to go beyond conventional energy audits and explore new methodologies that include more concretely some of the solutions proposed here, such as the inclusion of a multi-benefit analysis and the life cycle of the measures, a more in-depth study on demand management and employee behaviour, the inclusion of studies on new energy sources (renewables, cogeneration, heat recovery or biogas) as a general rule of and the provision of accessible tools for company staff to monitor the key energy indicators of the company. It would also be helpful to present examples and energy simulations, apart from the public funding possibilities, to encourage and convince key decision-makers in the company to carry out the measures. There is a gap between conventional audits and the EMS which could be covered by this type of more comprehensive audits for those companies that do not yet have the capacity to take on an EMS. It is also necessary to undertake from the very beginning a focused evaluation, resulting in a short and long-term decarbonization plan rather than considering the audit as a punctual action to completely achieve the industrial site decarbonization. Capacity building programmes within the company are also very relevant to increase the effectiveness and replicability of energy efficiency in the company. In short, information gathered on this analysis shows many of the actions and efforts that will need to be brought together in order to truly decarbonise the industrial sector by 2050.

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