

Challenges and opportunities for improving energy efficiency in SMEs: learnings from seven European projects

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Challenges and opportunities for improving energy efficiency in SMEs: learnings from seven European projects

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Abstract This paper analyses challenges and opportunities for improving energy efficiency in small and medium enterprises (SMEs) by reviewing research design and results out of seven European projects: SPEEDIER, SMemPower Efficiency, E2Driver, Innoveas, Triple-A, DEESME and ICCEE. These projects aim to improve SMEs' awareness of energy efficiency and support an effective decision-making-oriented approach to it. Drivers and barriers to energy efficiency improvements in European SMEs

of various industrial sectors have been investigated by means of surveys, focused group discussions and interviews. A meta-analysis of the results of the seven EU projects was carried out to discover trends related to energy efficiency in European SMEs; this was supported by the use of a unifying analytic framework that enabled merging and cross-validation of the findings of the seven projects. The analysis indicated, by means of new data collected by the seven projects, that staff training, facilitation of energy audits,

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development of corporate policy measures and collaboration between SMEs involved in the same supply chain are key mechanisms to improve the uptake of energy efficiency measures in SMEs which has significant potential to achieve higher energy savings and energy cost reductions.

Keywords Energy efficiency · SMEs · Energy conservation measures · Energy audit

Introduction

Paper overview

The objective of the research is to systematically analyse the barriers, drivers and influencing factors determining the adoption of energy efficiency measures in SMEs throughout the whole Europe and for a broad range of industrial sectors, using data recently collected and processed by the authors across seven European projects. In addition, we also aim at elaborating on the lessons learned in the projects. The methodology adopted is to use data gathered in seven EU projects by the authors by means of surveys, interviews and focus groups and to analyse them using a unifying framework that enables classification of barriers and drivers to energy efficiency in SMEs and locate them in the three dimensions: environmental, corporate and individual. The framework also provides some insights on the effects of these factors on the decision-making process of SMEs. The

data available from the seven projects are merged and jointly analysed, to establish a larger and more robust dataset and to support the development of broader findings and conclusions. The research questions considered are the following:

- What are the barriers and drivers to energy efficiency faced by the SMEs in Europe?
- How to improve energy efficiency in SMEs across different sectors?
- What are the lessons learned from recent research project about energy efficiency in SMEs in Europe?

The European Commission is committed to supporting increased energy efficiency within SMEs and have granted funds to various projects under the Horizon 2020 programme¹ (as well as under other programmes like the European Regional Development Fund). SPEEDIER, SMEPower Efficiency, E2DRIVER, Innoveas, Triple-A, DEESME and ICCEE are the European projects with the common goal of assisting SMEs to reduce their energy consumption and to increase awareness of energy efficiency and its benefits. These projects were included in this research because they collected new data regarding energy efficiency in SMEs and provided new insights through their surveys, interviews, focus groups and stakeholders' engagement activities.

The 'Introduction' section introduces the methodology used to analyse the data collected from European SMEs related to energy efficiency improvements and to perform the meta-analysis of the projects. The research framework for energy efficiency improvement in SMEs used in this paper is introduced in the 'Methodology and research framework' section. The 'Comparative analysis of the seven projects and future research' section synthesises the findings from the seven projects and performs their comparative analysis and discussion. Finally, conclusions are presented in the 'Conclusion' section. Two appendices have been included. Appendix 1 includes a description of the energy audit obligations in various EU-countries. Appendix 2 presents introductions of the

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¹ https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-2020_en

analysed projects and summarises their outcomes (literature review/online survey/face-to-face discussion/interviews) comparing results against other works found in the literature.

Energy consumption patterns in SMEs

Article 8 of the European Energy Efficiency Directive (EED) requires Member States to encourage small- and medium-sized enterprises (SMEs) to undertake energy audits and implement energy efficiency recommendations by developing national incentive programmes to support them (European Commission, 2022). SMEs account for 98.9% of European enterprises (EUROSTAT, 2022) and are responsible for approximately 13% of Europe's total energy demand (IEA, 2017). Hence, SMEs have substantial potential to save energy and reduce carbon emissions, at an individual level and collectively, leading to big savings at EU level even if, due to their limited dimensions, often they do not have resources to implement energy efficiency measures. Furthermore, their energy savings will be critical for Member States to contribute towards achieving the overall European target, under the EED, of 32.5% improvement in energy efficiency by 2030.

The energy consumption breakdown in SMEs is individual to the SME and the sector that they operate in. In many cases, specific energy efficiency measures can be applied to individual production processes to reduce energy consumption, but typically facilities, steam production, motor-driven systems, process cooling and direct heating were typically found to be the largest users of energy within SMEs (Hasanbeigi & Price, 2012). Electric motors consume 60–80% of the electrical energy used in the industrial sector and about 35% in the commercial sector. Small efficiency improvements of electric motors may produce very large energy savings (De Almeida et al., 2012). A significant share of the total motor electricity consumption is represented by pumps, fans and compressors, respectively 62% and 83% in the industrial and in the services sectors in the EU (de Almeida et al., 2003). Energy efficiency measures applicable to compressed air systems are leak prevention, use of outside intake air, reducing pressure drop, recovering waste heat, use of efficient nozzles and the use of variable displacement compressor (Saidur et al., 2010).

Other energy efficiency measures are associated with improving heating system. The efficiency of boilers may be optimised by cleaning and adjusting burners to improve the mixing of fuel and air minimising excess air for the specific firing rate (Naik and Mallur, 2018). Boiler efficiency can be increased by 1% for each 15% reduction in excess air or 22 °C reduction in stack gas temperature (U.S. Department of Energy, 2012). Energy savings achievable using a Building Energy Management System (BEMS) for heating, ventilation, air conditioning (HVAC) and refrigerating equipment, artificial lighting systems, motors and others were analysed in (Lee & Cheng, 2016). Energy savings from BEMS increased from 11.39 to 16.22% yearly from 1976 to 2014. Artificial lighting systems were estimated to achieve up to 39.5% savings when controlled by an EMS. For HVAC, energy savings are 14.07%, whereas for other equipment they are 16.66%.

Previous research

The barriers and drivers faced by SMEs with respect to the adoption of energy efficiency measures do vary as time passes; therefore, consensus on the barriers and drivers has not been reached previously. This research reassesses them by means of novel studies performed by the authors within seven EU projects, using data collected from the field.

It is clear, due to the pace of change of technology and the accelerating requirements to reduce CO₂ emissions and fight climate change, regulations, technologies and markets relevant to energy efficiency in SMEs are evolving rapidly. Previous broad reviews and research (Trianni & Cagno, 2012; Thollander et al., 2007) could now be considered outdated and therefore most of their findings need to be reassessed.

Catarino et al. (2015) focused on Portuguese SMEs only and Hampton (2019) considered only three SMEs in the UK. Hasanbeigi and Price (2012) considered only technologies for the textile industry. Hrovatin et al. (2021) limited their investigation to the SMEs of the manufacturing sector, whereas James and James (2010) to the food cold-chain and Johansson et al. (2019) to SMEs of the industrial sector. Johansson (2015) presented an analysis restricted to the Swedish steel industry. Katchasuwanmanee et al. (2017) presented an integrated approach restricted to automotive manufacturing systems. König et al.

Table 1 Financial and non-financial barriers to energy efficiency (Fresner et al., 2017)

Problems	Detailed barriers	References
Financial problems	Large capital investment requirement for energy efficiency upgrades and small funds available with SMEs to invest, longer payback period for some of the potential energy saving investment opportunity and difficulties for securing loans from banks	Catarino et al. (2015); Thiede et al. (2013); Prasad Painuly (2009); Nigohosyan et al. (2021); Viesi et al. (2017); Lee (2015); Meath et al. (2016)
Non-financial problems	Lack of in-house expertise to identify and implement any energy saving measures, lack of information (a) on their energy cost, (b) on importance and benefits of energy efficiency and (c) by technology providers to the SMEs	Fuchs et al. (2020); Rohdin et al. (2007); O’Keeffe et al. (2016); Kostka et al. (2013)
	Small businesses lack resources to assign energy management responsibility to any staff member	Eurochambres (2010); Sorrell et al. (2000); Henriques and Catarino (2016)
	Lack of knowledge and awareness preventing SMEs to access any available financial scheme supporting energy efficiency investments	Prashar (2017a); Hrovatin et al. (2021); Trianni et al. (2013); Fresner et al. (2017)
	Lack of time or too much of other work for SME employees make energy efficiency a lesser priority for them	Paramonova and Thollander (2016); Henriques and Catarino (2016); Rohdin et al. (2007); Johansson (2015)

(2020) analysed the drivers for energy efficiency only for the German SMEs of the manufacturing sector. Kostka et al. (2013) restricted their analysis to the SMEs in China. López-Bernabé et al. (2021) presented an analysis restricted to the Spanish SMEs of the hotel industry. Nigohosyan et al. (2021) proposed an analysis only of the SMEs in Bulgaria. Redmond and Walker (2016) discussed the value of the energy audits only for Australian SMEs. Rohdin et al. (2007) considered only the SMEs of the Swedish foundry industry. The investigation of Trianni et al. (2013) covers only the Italian manufacturing SMEs, and therefore its findings cannot be generalised to other countries or other sectors of SMEs. These focussed pieces of research are limited by their specific scope and limit the development of generalised recommendations and conclusions for the sector.

This research covers SMEs from multiple sectors: manufacturing, services, energy, education, commercial, hospitality, automotive, industrial, building sector, food supply chain (with refrigeration) from multiple Member States—Ireland, Spain, Italy, Romania, Cyprus, Germany, Greece, Slovenia, UK, Belgium, Poland, Bulgaria, Czech Republic, Lithuania, The Netherlands.

In Fresner et al. (2017), an innovative auditing approach was introduced and tested on 280 SMEs in 7 European countries. The paper reports case studies regarding implementation of energy efficiency

measures in SMEs; however, the study had a different objective in comparison with this research, which is more focussed on the challenges associated with a lack of financial resources, lack of information and limited in-house skills. A focus on the auditing process only inhibits consideration of awareness raising and training for SMEs’ employees and mechanisms for financing of energy efficiency projects, as well as the barriers and drivers found in the three dimensions (institutional, organisational and the individual), which are addressed in this paper.

Barriers to the implementation of energy efficiency measures by SMEs have previously been categorised into financial and non-financial barriers (Fresner et al., 2017). Financial factors are one of the main barriers to the investment in energy efficiency upgrades (Trianni et al., 2016). Previous work has identified detailed barriers to energy efficiency which may refer either to financial or non-financial problems (Table 1).

Research on drivers is in many cases still at early stages and will benefit from a better understanding of the current barriers with respect to different types of SMEs. In Fatima et al. (2021), some barriers are assessed but the paper did not sufficiently elaborate on possible drivers for energy efficiency. Energy management refers to the practices based on monitoring and operational procedures, knowledge of processes and their energy efficiency at a SME site, which

contribute to reduce the energy efficiency gap (i.e. the difference between optimal level of energy efficiency and the actual level of achieved energy efficiency). Relatively few energy management drivers have been identified, as opposed to the more numerous identified drivers of energy efficiency or specific energy efficiency measures (Jalo et al., 2021).

Some of the most significant barriers to energy efficiency in SMEs identified in Jalo et al. (2021) are as follows: a lack of time/other priorities, prioritisation of non-energy related working tasks and an organisational structure that does not facilitate consideration of sustainability and energy efficiency. The limitation of the study is that only data from Swedish SMEs was considered, and the numerous barriers found were grouped into organisational, knowledge-related and economic barriers, which limits identification of the institutional 'regulatory' issues and more subtle differences which may exist between the organisational and individual levels. In Latapí et al. (2021), the barriers related to corporate social responsibility were identified and categorised, but the study was limited to Nordic energy companies. The main conclusion in Fatima et al. (2021) is that the manager must focus more on the management of skills, employees, knowledge and culture, which is a positive suggestion, but should not be seen as the main means to improve energy efficiency in SMEs (which requires a more significant involvement of external experts, e.g. to develop better energy auditing and training programmes). In Reddy (2013), a new framework for classification and explanation of barriers and drivers to energy efficiency was introduced. An 'actor-oriented approach' was proposed to identify the drivers and barriers determining the success or failure of energy efficiency investments and the institutions creating these barriers and drivers. Although the framework is potentially powerful and valuable, it has not been used to study the actual barriers and drivers to energy efficiency faced by the SMEs.

Barriers to the implementation of energy efficiency measures

Previous work has determined that the ten most energy intensive industrial sectors consume 72.1% of the total net domestic energy consumption of the 64 NACE production activities considered in EUROSTAT (2019), while accounting for only the 12.9% of

the total gross value added. This approach to measuring energy efficiency could be viewed as unfair and energy savings should, instead, be compared against the profits achieved by the company rather than against total production costs or gross value added.

According to the Sustainable Energy Authority of Ireland (SEAI), 'Energy use can be a significant cost to any small business and can represent a high proportion of operating costs' (SEAI, 2017). Profit margins for SMEs depend on the specific industry. For some industries such as retail and construction, profit margins are as low as 5%; therefore, energy savings and associated costs savings can be significant. For example, if a company has a 5% profit margin over 3 years, a €500-a-year saving from energy efficiency makes the same profit as €30,000 of extra sales, which may require an effort even higher than implementing energy efficiency measures to be achieved. Examples of cost-benefit analyses and energy savings given by three prominent energy efficiency measures are provided in Adisorn et al. (2020). Moreover, even if the individual energy consumption of SMEs is not high, their aggregated energy demand is considerable as well as their potential for energy efficiency (Henriques & Catarino, 2016).

Barriers to the implementation of energy efficiency measures have been classified into three main groups: economic, behavioural and organisational (Rohdin et al., 2007; Sorrell et al., 2000). According to the theory of economic rationality, the firms would systematically try to minimise their cost for energy services and spontaneously implement profitable economy measures (Weber, 1997). However, the rationality of humans is bounded because of limitations in the access to information and computational capacities available (Simon, 1990). Bounded rationality can skew the assessment resulting in a disproportionate importance to upfront costs, and more value to costs than benefits of increased efficiency (Linares & Labandeira, 2010). The individual barriers to the implementation of energy efficiency measures must be removed to allow the organisations to assume fully rational behaviour (Banks et al., 2012).

There is clearly a gap between the technical potential of energy efficiency measures and the practice of their acceptance and implementation. If the measures are cost-effective, and if individual consumers behave in a rational manner, such a gap should not exist (Shove, 1998). Behavioural barriers have been

defined as the barriers inside individuals (Weber, 1997). Lack of adequate credibility and trust in the information sources, inertia of conservative individuals and their lack of ambition affect the actual adoption of energy efficiency measures. And there are the main individual barriers preventing implementation of energy efficiency measures (Trianni & Cagno, 2012). Other possible barriers are related to the organisation, its culture and the power of individuals working in the organisation (Sorrell et al., 2000). To overcome lack of power of employees, the involvement of operational top-managers was found very effective (Blass et al., 2014).

Drivers supporting the implementation of energy efficiency measures

Developed economies have typically developed more favourable legislative frameworks and financial markets to overcome the energy efficiency gap, that is the under-investment in energy-efficient technologies or relatively slow adoption of those technologies (Ozbugday et al., 2022). SMEs are typically focussed on carrying on their routine work for achieving their production targets and ensuring the quality of products and place less emphasis on equipment maintenance and utilisation of energy efficient equipment (Bagodi et al., 2022). However, the selection of energy-efficient-technologies may be hindered by economic-related concerns and lack of trust, like the awareness of lower life cycle and fear of high running costs (Camarasa et al., 2021).

Previous research has concluded that successful business models will require that SMEs would relate the external drivers of eco-innovation (consumer preferences, incentives/penalties of the legal framework, stakeholders' pressure) to internal drivers, like increasing the market share while simultaneously reducing internal energy consumption and utilisation of raw materials (Calvo et al., 2022). Energy efficiency is a driver of entrepreneurship and one of the economic drivers for the development of a more effective business strategy (Drago & Gatto, 2022). Energy efficiency network programmes may be an external driver for increasing energy efficiency of SMEs, but assessing their effectiveness is still a significant issue (Johansson et al., 2022). Information campaigns are a factor that support the implementation of energy efficiency measures in energy intensive

companies, but usually it is not one of the main drivers (Preziosi et al., 2022). Training on energy efficiency is effective to improve daily energy habits of individuals and in turn the energy culture of a company (Millán et al., 2022). Other drivers recognised by frontline workers are 'the amount of money that can be saved', 'long-term energy strategy' and 'green image for the company' (Smith et al., 2022).

Methodology and research framework

Methodology

Datasets were systematically collected and curated from seven different European projects (SPEEDIER, SMeMPower Efficiency, E2DRIVER, Innoveas, Triple-A, DEESME and ICCEE) by the authors of this paper and other researchers using surveys, interviews, focus groups and stakeholders' engagement activities. The datasets were jointly analysed according to a 'meta-analysis' methodology, which involves the examination of data from several independent studies on the same subject (energy efficiency in European SMEs), in order to systematically compare results, enable their cross-validation and identify broad conclusions. The projects were selected based on their relevance and envisaged impacts with respect to the issue of improving energy efficiency in SMEs across different European countries.

A systematic approach, to the assessment and evaluation of the projects, was followed as per the following:

1. A research framework has been established to enable the meta-analysis of the projects, which reflects both the state-of-the-art in the literature and the original assumptions of this work. The features and purpose of such framework are detailed in the '[Methodology and research framework](#)' section.
2. An analysis of key findings from each of the seven projects was identified reflecting the information collected, focusing particularly on barriers and drivers to energy efficiency in the set of SMEs analysed, which has been used as a starting point for the meta-analysis presented in the '[Conclusion](#)' section. The analyses of the individual projects have been summarised in the '[Com-](#)

parative analysis of the seven projects and future research’ section.

3. A summary of envisaged impacts of the projects with respect to the areas *energy culture of the organisation, primary energy savings, reduction in greenhouse gas emissions, investment in sustainable energy and capacity building* was prepared and were compared against each other (‘Conclusion’ section).
4. Further comparative analysis of the projects was performed considering their *focus, participants, research hypothesis, methods, results and main recommendations* (‘Conclusion’ section).
5. The research framework has been used to perform a comparative analysis of the projects according to (i) *localisation of barriers and drivers in three different dimensions* (introduced in the ‘Methodology and research framework’ section); (ii) *other factors affecting energy efficiency in the considered SMEs*; (iii) *main findings associated with each project*. Results were summarised in a table and then evaluated in more detailed as presented in the ‘Conclusion’ section.
6. Overall conclusions have been developed considering findings of both the ‘Comparative analysis of the seven projects and future research’ and ‘Conclusion’ sections.

The reliability of the data, collected from the survey’s questionnaires from the seven different EU projects, has been assessed using the Cronbach’s alpha method, which requires the calculation of a reliability coefficient that provides a method of measuring internal consistency of tests (reliability). The test can be applied transforming the categorical variables into numerical representing the observed score X_i of question i , and then applying the following formula:

$$\rho_T = \frac{k}{k-1} \left(1 - \frac{\sum_{i=1}^k \sigma_i^2}{\sigma_X^2} \right)$$

where

σ_i^2 is the variance of X_i ,

$$\sigma_X^2 = \sum_{i=1}^k \sigma_i^2 + \sum_{i=1}^k \sum_{j \neq i}^k \sigma_{ij}$$

$$\sigma_{ij} = \frac{1}{k^2} \sum_{t=1}^k \sum_{s=1}^k (X_{i,t} - X_{i,s})(X_{j,t} - X_{j,s})$$

is the covariance of X_i and X_j ,

k is the number of questions of the survey.

The assumptions to use this method are:

- (i) data is unidimensional
- (ii) data has equal covariance σ_{ij} (data are tau-equivalent)
- (iii) errors are independent.

The threshold for reliability was $\rho_T \geq 0.8$.

The key barriers investigated in the seven projects and in this research are the lack of finance, lack of knowledge, lack of time, lack of trust in energy efficiency experts, lack of commitment and limited ability to analyse energy efficiency measures.

Research framework

The main hypothesis examined in this research is that there exist cost-effective measures which can be implemented to improve energy efficiency in SMEs and that this process greatly benefits from the analysis and advice of an expert which is provided through an energy audit (SEAI, 2017). New aspects of the research are related to the comparison of recent data about energy efficiency gathered from SMEs (the source of such data are the employees of such SMEs), which in turn enable determination of barriers and drivers to improvements to energy efficiency in European SMEs located in different countries (Cyprus, France, Germany, Greece, Ireland, Italy, Poland, Romania, Slovenia, Spain, and UK), and the comparison of findings from different EU projects which also focus on SMEs from diverse sectors (construction, manufacturing, food industry, services, chemicals and chemical products, hospitality, commercial and trade, heavy industry, education, energy and the automotive industry).

With respect to the research framework for energy efficiency improvements in SMEs considered in this research, it can be observed that (i) the classic barriers and drivers’ approach is an appropriate approach to analyse in a structured way the energy efficiency improvement processes in SMEs and can facilitate the design of energy policies (Reddy, 2013); (ii) barriers and drivers may not account for all the factors related to decision-making in SMEs, which are heavily influenced by personal, professional and organisational

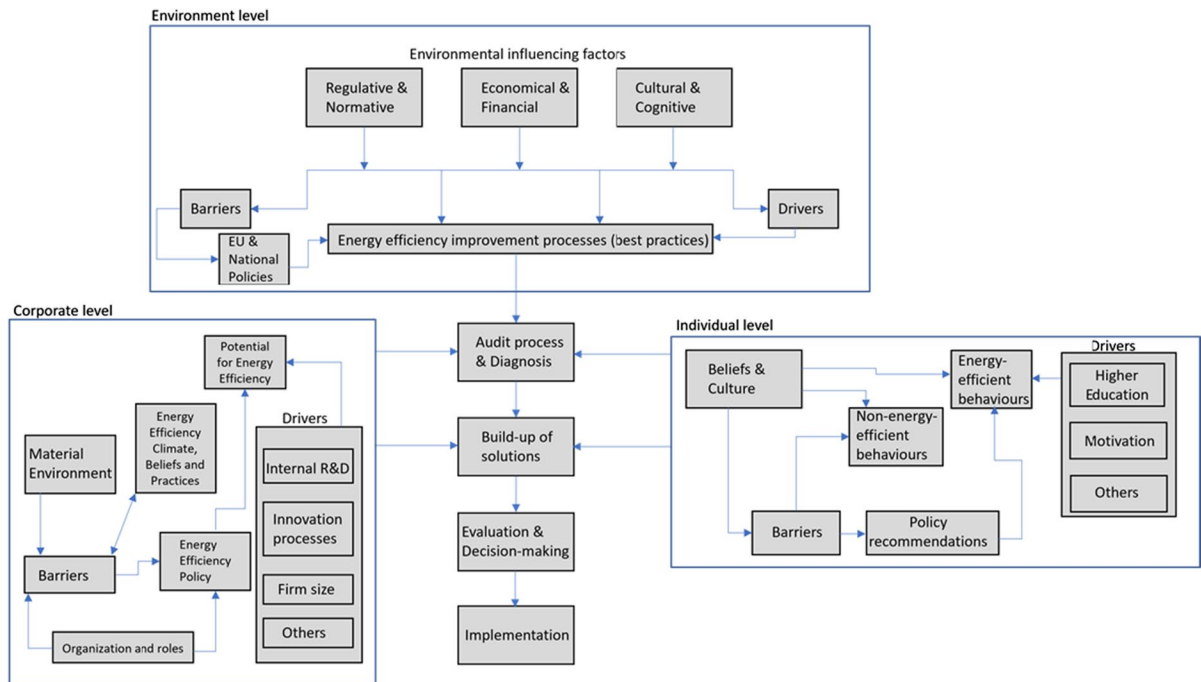


Fig. 1 Research framework for energy efficiency improvements in SMEs

values and therefore need to be augmented with contexts and relationships. The assumption that the simple removal of barriers will improve energy efficiency in SMEs is considered nowadays unrealistic because it does not fully consider the complexity of organisational decision-making process and the heterogeneity of the SME population (Blundel & Hampton, 2021).

The empirical research which was conducted by the seven projects used an enhanced framework extending the barriers and drivers framework with the other factors influencing the energy management practice in SMEs. The proposed framework is represented in Fig. 1. As per the methodology introduced in the SMEmpower Efficiency project and König et al. (2020), the influencing factors were grouped in three dimensions: the environmental (or institutional), the corporate (or organisational) and the individual. There are two main differences with respect to König et al. (2020) and they are (i) the importance of the barriers and drivers' framework as preferred methodology for driving the energy efficiency improvement process in an SME (barriers and drivers are explicitly included at the three levels influencing the decision-making of energy efficiency in Fig. 1) and (ii) the centrality of the audit process to enable the energy diagnosis, the generation of

possible energy efficiency solutions, their evaluation and final decision-making regarding the measures to be implemented. In fact, even though information about energy efficiency and carbon footprints may be sometimes absorbed into organisations in a chaotic and unpredictable ways, expert advice is one of the preferred approaches by the policymakers to decarbonise SMEs (Hampton, 2019).

The proposed framework acknowledges that the decision-making process related to energy efficiency is complex in SMEs and may be influenced by internal or external factors, which may have not been identified as barriers or drivers yet. These factors may be related to beliefs and culture of the company and its members, or more directly related to the company's organisation and professional roles defined in there. The energy audit process should bring into the company the best practices about the established processes for improving energy efficiency. Such processes may also be affected by barriers and drivers which are determined by multiple regulative and normative factors, economic and financial factors, risk of implementing energy efficiency measures and fluctuating prices, as well as cognitive and cultural factors, which in turn will affect the energy auditing processes in SMEs.

Barriers and drivers are also present at the organisational and the individual dimensions and have been identified by the seven EU projects through their surveys. The goal is to remove barriers wherever that is possible to foster the implementation of energy efficiency measures and to use drivers for building up the set of possible solutions. Barriers are interconnected by nature and policymakers should preferably address them in a holistic manner (Chai & Yeo, 2012). In our framework, it is assumed that policymaking influencing energy efficiency in SMEs may take places at the environment level as well as at corporate level. Moreover, corporate level policies may also consider the individual dimensions (Fig. 1). Moreover, the proposed framework identifies an energy policy (as well as specific roles related to energy efficiency such as the energy manager) within an SME as one of the key factors to support an effective decision-making.

The decision-making process can be structured in three stages: auditing and diagnosis of solutions, build-up of solutions, evaluation of the different solutions and final choice (Cooremans, 2012; Johansson et al., 2019). This structure highlights that the problem definition and search for solution is the process that eventually determines an investment choice (Cooremans, 2012; Fawcett & Hampton, 2020). When focussing uniquely on the investment decision, the influence of material, cultural, social and regulatory domains on the decision itself is not fully taken into account (Banks et al., 2012).

Although the proposed research framework concerns the evaluation/decision-making and the implementation of the energy efficiency measures, it also highlights the importance of identifying barriers and drivers in the early stages of the decision-making process, preferably during the auditing and diagnosis stage or while the solutions are built-up. This approach relies on solid skill sets regarding energy efficiency, for energy auditors and technical employees, which is in a strict relationship with the training needs identified in the EU projects. The goal is to reduce the decision-making and operational costs of energy efficiency and to build the trust of the company's owners and managers.

In summary, the proposed research framework aims to:

- localise barriers, drivers and other influencing factors relevant with the uptake of energy efficiency

measures by European SMEs at three distinct levels, namely the environment, the corporate and the individual;

- suggest interactions between barriers, drivers and the factors characterising the three levels;
- argue that the dynamics of these three levels may all influence the decision-making related to energy efficiency in SMEs and should be considered when analysing such processes.

Analysis of barriers, drivers and influencing factors using the framework enables in turn a better localisation and understanding of the interacting factors that may hinder energy efficiency improvements in European SMEs and be the starting point to determine which policy interventions (at different levels) might improve the ability of SMEs to achieve a higher level of energy efficiency. The proposed framework is used to compare the outcomes of different projects and different industrial sectors.

Individual, organisational and institutional determinants have been considered in the literature to explain behaviours of SMEs. Recently, they were used in Martin et al. (2019) to study the formal and informal inter-firm cooperation of SMEs. In this research, similar levels (individual, corporate and environment) are used to study the potential for improving energy efficiency in SMEs. In Solnørødal and Thyholdt (2017), possible drivers for energy efficiency in SMEs were identified at individual and organisational levels. At individual level, level of education, motivation of employees, autonomy and independence may be drivers with respect to the achievement of energy efficiency objectives. At corporate/organisational level, factors such as internal R&D, innovation processes and firm size may be drivers for energy efficiency.

The SME's internal environment and organisation roles may determine barriers which need to be properly addressed by a corporate policy. Finally, the environment level refers to the external environment for SMEs determined by the set of formal and informal rules established by institutions, which may significantly affect their behaviour and ability to pursue their goals, such as energy efficiency targets (North, 1990). In addition, the environment level accounts for the influence that development of the markets which are relevant with energy efficiency, such as technology markets and energy services market, as

well as for the cultural and cognitive factors which emerge in the society in relation to energy needs and consumption.

Comparative analysis of the seven projects and future research

Comparative analysis of the seven projects

Each project identified the attitudes of SMEs towards the importance of energy management and energy efficiency and a set of barriers to uptake of energy efficiency upgrades. These attitudes and barriers need to be closely analysed to ensure the successful implementation of each project. Also, opportunities for synergies between companies working within the same supply chain must be considered because the possible benefits might go beyond those achieved by the individual companies leading to more competitive products on the retail market.²

The projects were compared with respect to the impacts delivered in the following areas: energy culture, primary energy savings, reduction in greenhouse gas emissions, capacity building programme, investments in sustainable energy (Table 2).

The planned impacts of the seven projects reviewed in Table 2 are representative of the best efforts currently being undertaken within European research projects to identify barriers, difficulties and solutions in delivering energy efficiency measures to SMEs and decarbonisation. With respect to the framework in Fig. 1, energy culture, primary energy savings, reduction in greenhouse gas emissions, capacity building programme and investments in sustainable energy represent the areas where SMEs may undertake effective actions to counteract the barriers towards energy efficiency and decarbonisation existing at corporate level. Development of energy culture and capacity building programmes may also reduce the barriers at individual level.

² The ICCEE project will facilitate the food and beverage sector cold chains to undertake energy efficiency measures after carrying out supply chain energy assessments and audits. In fact, the cold chains of food and beverage sector have significant stages (refrigerated transport, processing and storage) with large energy saving potential.

The assessment of the barriers, drivers and influencing factors related to the adoption of energy efficiency measures in European SMEs is a very broad task that can be approached in a variety of different ways, prioritising different aspects in its investigation. For this reason, it is instructive to compare the focus on different aspects paid by the European projects analysed in this research, their research hypotheses, the methods used for the investigation and the main results and recommendations. Such comparison is reported in Table 3. Note that the research framework of Fig. 1 is the common framework proposed by this paper to perform the meta-analysis of the results of the seven projects that are summarised in Table 3 as well as (more extensively) in Appendix 2.

The information used to complete the Tables 2 and 3 have been obtained from the analysis of the projects included in Appendix 2.

Moreover, the barriers, drivers and other influencing factors have been studied using the research framework in Fig. 1 and identified within the three dimensions: environmental, corporate and individual. The comparative analysis of the projects with respect to barriers, drivers and other influencing factors is reported in Table 4. The research framework introduced in the 'Methodology and research framework' section was used to analyse the results obtained from the empirical research conducted in the seven projects through the surveys.

The information included in Table 4 enabled a cross-cutting analysis of the results of the seven projects. All the projects have identified barriers in the environmental dimension, with the exception of ICCEE. This indicates that such barriers are either not present or not perceived as important as the others, by the companies of the cold chains of food and beverage sector. Other barriers of the environmental dimension have been expressed in different manners by the projects, with the exception of the lack of an energy audit obligation for SMEs, which is considered a barrier created by the external environment by two projects (SPEEDIER and E2DRIVER). In the corporate dimension, lack of finance and lack of knowledge are recurrent barriers (which may be formulated in slightly different manners).

However, also some drivers are present, like the awareness of economic and non-economic benefits associated with installation of energy efficiency measures. These barriers and drivers may be considered a

Table 2 Comparison of the most significant results of the projects delivering the impacts

Project	Most significant results delivering the projects' impacts
Speedier	<p>Energy culture: 110 organisations and 650 individuals involved in pilot action and capacity building events; 225 organisations involved in awareness actions and engagement events</p> <p>Primary energy savings: 3.795 GWh/year across all the demonstration sites in Ireland, Spain, Romania and Italy</p> <p>Reduction in greenhouse gas emissions: 604 tCO₂e/year across all the demonstration sites</p> <p>Investments in sustainable energy: 438 k€</p> <p>Capacity building programme: 50 experts trained, 40 trainers trained, 5 experts trained by trainers each year</p>
SMEem-Power Efficiency	<p>Energy culture: at least 720 experts trained</p> <p>Primary energy savings: 24.87 GWh/year</p> <p>Investments in sustainable energy: 4 mil €, and 160 pilot installations completed as practical action</p>
E2Driver	<p>Energy culture: 60 trainers certified using the proposed training methodology</p> <p>Primary energy savings: 13 GWh/year (2.5 million €/year)</p> <p>Reduction in carbon emissions: 3500 tCO₂/year</p> <p>Capacity building programme: capacity to implement 65 energy efficiency measures</p>
Innoveas	<p>Energy culture and capacity building programme: 12 <i>Transdisciplinary Workshops</i> organised, involving more than 700 stakeholders (mainly small and medium enterprises in the manufacturing industries); 6 <i>Train the Trainers</i> organised, involving more than 150 stakeholders (mainly energy auditors, industrial associations and other intermediary organisation that aim to support companies in implementing energy efficiency procedures)</p>
Triple-A	<p>Energy culture: 3500 stakeholders engaged in Triple-A activities (meetings, events, surveys, newsletter)</p> <p>Capacity building programme: 500 stakeholders identified and trained (project developers, financiers, investors, policymakers, academia) across 8 case study countries</p> <p>Primary energy savings: more than 64.03 GWh/year</p> <p>Investments in sustainable energy: 27.68 million €</p>
DEESME	<p>Energy culture: 2500 companies approached with a communication campaign; 500 companies involved in energy management trainings</p> <p>Capacity building programme: policy scheme development for 11 EU member states and their development agencies; 50 trade associations and other aggregators contributing to the exchange of best practices</p>
ICCEE	<p>Primary energy savings: 118 GWh/year</p> <p>Investments in sustainable energy: 64 million €</p> <p>Reduction in carbon emissions: 40,376 tonCO₂/year</p> <p>Energy culture and capacity building programme: 2000 stakeholders involved in activities improving their energy culture</p>

trend identified by the meta-analysis of the projects.³ A positive exception is provided by the automotive sector where sufficient financial availability for energy efficiency improvements may be a driver or support for some SMEs.

In the individual dimension, typical barriers are lack of time, lack of trust in energy efficiency experts, lack of commitment and limited attitude to analyse rationally energy efficiency measures. These barriers seem also to emerge as a trend. However, two of the analysed projects have not highlighted barriers in the

individual dimension (Triple-A and ICCEE), which indicates that individuals are more conscious of energy efficiency opportunities in relation to building retrofitting (Triple-A) and to cold chains of food and beverage (ICCEE) with respect to other SMEs' industrial sectors. The analysis also indicated that there were relatively few differences identified between the different countries analysed (Cyprus, France, Germany, Greece, Ireland, Italy, Poland, Romania, Slovenia, Spain and UK).

In Ireland, SMEs may experience lower barriers associated with the environmental (institutional) dimension with respect to those in other countries, because free energy audits and a grant for installation of energy efficiency measures exist. In Slovenia and Italy,

³ It can be assumed that findings are cross-validated by the meta-analysis when at least two different projects show similar findings.

Table 3 Description of focus, participants, research hypothesis, methods, results of the seven EU projects analysed

Project	1—Speedier
Focus	Services for energy efficiency in SMEs: free energy audits, e-learning, access to finance, energy efficiency
Participants	6 SMEs in Ireland (manufacturing sector) 4 SMEs in Spain (1 in a multidisciplinary sector (performing arts, education, MICE) and 3 in the service sector) 15 SMEs in Italy (6 SMEs in the manufacturing sector, 2 in food, 5 in production, 2 in service) 17 SMEs in Romania (13 in hospitality, 3 in service, 1 in energy auditing)
Research hypothesis	Energy audits are a means to identify energy efficiency measures and improve energy efficiency in SMEs
Methods	Surveys and focus groups
Results	The SPEEDIER project identified some similarities and some differences among its pilot countries regarding barriers that prevent SMEs for the uptake of energy audit and energy efficiency implementation. Also, SPEEDIER project found difference in the opinion of SMEs and energy experts regarding same. The main barrier to energy efficiency upgrades for SMEs of Ireland is identified as lack of knowledge of which ECMs to implement and how to procure them, whereas for Spain, Italy and Romania it is lack of finances to invest in ECM implementation. Another notable finding is that SMEs are hesitant to pay for energy audit, as they are not confident enough to recover the energy audit cost by implementation of recommended energy saving measures. All the participants SMEs of Online survey (Except Spain) and Focus Group discussion expressed their willingness for outsourcing energy management to an external energy consultant. SPEEDIER also developed a self-financing ‘ring fencing mechanism’, which aims at implementing energy efficiency measures without the need of initial capital investment
Recommendations	Support, where appropriate, the outsourcing of energy management activities to an external consultant. Support the adoption of, in the first instance, no-cost energy efficiency measures and accumulate energy savings to facilitate the purchase of costlier measures
Project	2—SMEmpower Efficiency
Focus	Empowering SMEs to undergo energy audits and implement their proposals. Proposed a holistic methodology to address different barriers on three dimensions: individual, organisational and institutional
Participants	213 SMEs engaged in 8 countries (Cyprus, Germany, Greece, Italy, Romania, Slovenia, Spain and the UK) with a minimum 4973 employees Main sectors: manufacturing, electricity, gas, steam and air conditioning supply, water supply; sewerage; waste management and remediation activities, wholesale and retail trade; repair of motor vehicles and motorcycles, transporting and storage, accommodation and food service activities, professional, scientific and technical activities
Research hypothesis	Barriers to implementation of energy efficiency measures (legislative, institutional, technical, financial, communication) can be identified and removed
Methods	Questionnaire and targeted workshops
Results	Research performed in the SMEmpower project highlighted that most of the SMEs do not have an energy manager and did not implement environmental or energy standards. Moreover, energy audits have never been performed in the 50% of the SMEs that participated in the survey. Most of the SMEs use their own resources to fund energy efficiency investments and are not fully aware of the funding opportunities in their countries such as grants, loans and national support schemes. Some SMEs implemented energy efficiency measures with a quick payback time such as LED lighting, ventilation, heating/cooling and building automation. The main technical barriers identified in Germany, Romania and Spain are related to the fear of an interference with daily business routines and with the profitability of energy efficiency measures. In Germany, Romania, Slovenia and Spain, the SMEs did not develop an energy strategy for the forthcoming 3 years
Recommendations	Support SMEs to appoint an energy manager. Develop an energy efficiency strategy
Project	3—E2Driver
Focus	Creation of awareness about cost-effective energy efficiency improvements in the automotive industry and encouraging SMEs to perform energy audits
Participants	40 SMEs (12 pilot and 28 replication companies) in 4 countries (Germany, Italy, France and Spain) of the automotive supply industry
Research hypothesis	Energy audits may help to raise energy awareness and reduce energy consumption in SMEs
Methods	The methods to encourage SMEs to perform audits are based on an innovative learning platform and a tailored capacity building programme. A staff questionnaire and an energy assessment are used to characterise the participating SMEs

Table 3 (continued)

Results	The E2DRIVER project has investigated energy efficiency within SMEs in the automotive sector. A staff questionnaire indicates that the operation, maintenance or energy efficiency of process systems could be improved by means of a policy/procedure to determine applicable interventions. Employees of SMEs of the automotive sector show interest in training workshops on energy efficiency and the implementation of energy audits. The SMEs prioritise in the short-term low-risk energy efficiency measures such as lighting, electric drives, compressed air systems and logistics. However, in some cases, the measures that involve changes to process specific technologies may be considered in the long term. Financial availability to sustain energy efficiency improvements does not seem to be a big concern in the considered sector; however, knowledge about energy efficiency regulations and about various incentives available must be improved to achieve a better implementation of complex measures
Recommendations	Develop a policy for energy efficiency and procedures to implement energy efficiency measures
Project	4—Innoveas
Focus	Creation of awareness about cost-effective energy efficiency improvements in the automotive industry
Participants	42 SMEs in 6 countries (Belgium, Germany, Italy, Poland, Slovenia and Spain) of the non-energy intensive sectors
Research hypothesis	Energy Audits are an instrument to abate energy costs in SMEs. Non-technical barriers hindering the diffusion of Energy Audits in SMEs exist in the participating countries. Regulatory and financial conditions influence the use of Energy Audits and the adoption of energy-saving measures
Methods	Questionnaire. Staff trainings and capacity building programmes
Results	The Innoveas project is contributing to increase the uptake of energy auditing practices by European SMEs. The SMEs are reluctant to implement an energy audit because do not realise economic and non-economic benefits and show a lack of sensitivity to environmental issues. In Slovenia and Italy, SMEs see energy efficiency as a burden for the production activities. The research performed in the project has identified some barriers such as the lack of qualified human resources to perform the energy manager role, economic concerns related to the adoption of energy efficiency measures and related to the costs of energy audits, lack of information about incentives, energy audits and legislative framework, lack of trust in the energy auditor, practical concerns in implementation related to confidentiality of production data or lack of commitment of employees
Recommendations	Implement energy audits. Seek advice of qualified experts in energy efficiency
Project	5—Triple-A
Focus	To assist financial institutions and project developers increase their deployment of capital in energy efficiency, making investments more transparent, predictable and attractive
Participants	443 stakeholders, including investors, project developers, policymakers, researchers and academia, other bodies in the following countries: Bulgaria, Czech Republic, Germany, Greece, Italy, Lithuania, Netherlands, Spain and International
Research hypothesis	Investments in energy efficiency in the EU countries can be pre-screened and classified considering the country context, the specific characteristics of sectors and the categorisation of financing instruments and risk mitigation strategies
Methods	In-country demonstrations of the investments using the standardised Triple-A Tools
Results	The Triple-A project enhances the investment value chain of energy efficiency projects, especially at an early stage. The main project's goal is to assist financial institutions to increase their capital investments in energy efficiency projects. Building owners tend not assess their energy performance of their assets when there is no such a legal requirement. Only a minority of the buildings have a voluntary Energy Performance Certificate (EPC); this might be due to the lack of incentives for the owners. Energy Efficiency Certification is not given much importance and is pursued in a limited number of cases. The high energy efficiency class of a building can significantly influence long-term capital investments; conversely, poor energy efficiency class is not considered one of the main reasons determining rejection of a property. Financial factors such as high cost, lack of capital and lack of standardised financing pathways discourage building owners from implementing energy efficiency measures. However, some retrofits such as those related to the building envelope, Heating, Ventilation, Air Conditioning and Refrigeration (HVAC&R) as well as lighting appliances may increase the value of the property, when applied
Recommendations	Support the adoption of Energy Performance Certificates. Implement retrofits involving building envelope, HVAC&R, lighting

Table 3 (continued)

Project	6—DEESME
Focus	To Empower National Authorities to implement national schemes under article 8 of the EU EED to increase the awareness of SMEs about energy efficiency solutions
Participants	500 companies (400 SMEs) participating in energy management trainings in 5 countries 50 companies implementing an energy audit and 25 companies advised for the implementation of an Energy Management System
Research hypothesis	National authorities may enhance the impact of energy audits by means of national schemes. Companies may achieve multiple benefits from energy management approaches such as environmental impact, safety on the job and production efficiency
Methods	Surveys and desk research
Results	The DEESME project is developing and sharing with SMEs more effective schemes for energy audits and energy management systems by identifying best practices from the national schemes, EU projects and other initiatives of national authorities. Audits can adequately identify the most effective energy efficiency measures such as those that apply to heating, ventilation and lighting. The project collected information from national legislation of EU Member States and conducted one-on-one interviews with NA representatives. Some challenges have been identified concerning the identification of obliged companies, how to ensure compliance, how to ensure quality of audits, achieving a good compromise between reporting effort and monitoring, increase the uptake of measures, the creation of support schemes, the overcome of limitation of available resources, encouragement of SMEs participation, boosting the awareness of energy efficiency opportunities
Recommendations	Improve national schemes and regulations to create more energy efficiency opportunities for SMEs
Project	7—ICCEE
Focus	To facilitate the food and beverage sector cold chains to undertake energy efficiency measures after carrying out supply chain energy audits. To enable the acceleration of energy efficiency opportunities into actual investments, focusing on supply chains involving European SMEs
Participants	61 SMEs and associations of the food industry from 11 different countries. Most participants were from Germany (16), Italy (15) and Spain (9)
Research hypothesis	The decision-making processes of the supply chain companies in estimating their energy saving potential demands a dedicated cold supply chain energy efficiency tool The change in the energy culture of companies required to improve their energy performance can be achieved by means of a capacity building programme, a community to exchange experiences in cold chains' sustainability and both direct training and e-learning
Methods	Interviews
Results	The ICCEE project is developing a methodology and tools for overall supply chain energy audits, which can help SMEs of the food and beverage sector to improve the implementation process of energy efficiency measures. One of the main challenges identified by the project is to get the companies of the food industry operating in different stages of the CSC (such as production and processing, storage and logistics, wholesale and retail) to develop synergies between them to achieve a better overall energy efficiency of the supply chain. In fact, although the awareness about energy efficiency measures (EEMs) is quite good for the needs of the individual companies of the sector, there is a lower awareness when considering the energy efficiency aspects of the complete CSCs. The exchanges of food products between companies of a CSC are mainly determined by regulatory and cost-related considerations and therefore implementation of EEMs may have an influence on the prices of products and the exchanged product volumes. The small organisations struggle with EEM implementation because of the high investment costs and might find interesting opportunities for a cooperation with other companies of their CSCs
Recommendations	Develop synergies between companies to improve the energy efficiency of the food supply chains

Table 4 Comparative analysis of the seven projects (B, barrier; D, driver)

Project	Environmental dimension	Corporate dimension	Individual dimension	Other factors	Findings
SPEEDIER	Lack of govt. support (B) No energy audit obligation at SME level (B)	Lack of finances (B) Lack of priority (B) Building ownership (B) Lack of expertise (B) Lack of information (B) One-stop-shop solution (D) Self-financing mechanism (D)	Lack of trust on external energy experts (B) Lack of time (B)	Uncertainty in barriers identification: some respondents to the survey could not indicate precise barriers to energy efficiency	Lower barrier from the institutional dimension in Ireland where free energy audits and grant for installation exist SMEs from services (and other businesses) and hospitality show an awareness barrier concerning the corporate energy policy whereas SMEs from manufacturing or other productive sectors are more aware of that
SMEmpower	Perceived legislative and institutional barriers (B)	Lack of expertise (B) Lack of finance (B) Lack of information (B) Teaming between SMEmpower Efficiency experts, SME consulting companies, financing entities, ESCOs and SME decision-makers (D)	Lack of communication (B) Bounded rationality (B)	SMEs expect to see an energy bill reduction in a short time when installing ECMS	Investments with short pay-back time are prioritised
E2Driver	No energy audit obligation at SME level (B)	Lack of knowledge about energy efficiency regulations/incentive schemes (B) Lack of communication with executives and board (B) Lack of awareness (B) Sufficient financial availability for energy efficiency improvements (D)	Lack of technical knowledge, need for training (B)	Low-risk proposition of the organisation and individuals Energy efficiency processes and management structures need support to be implemented	Low-risk measures with low revenues are prioritised (lighting, electric drives, compressed air systems, logistics). Cost-intensive measures concerning process specific technologies are only considered with higher time lapses
Innoveas	High bureaucracy (B) Lack of publicity and transparency (B) Lack of competencies (B)	Lack of competencies (B) Limited access to economic resources (B) Lack of information on incentives and tools (B) Lack of trust in the energy auditor (B) Non-economic benefits (D)	Lack of involvement of employees (B) Low commitment with energy efficiency (B)	Unwillingness to pay for an audit without certainty of results	Most of SMEs are unwilling to change. In Slovenia and Italy, SMEs only focus on production activities
Triple-A	Legal requirements to assess energy performance of a building (D) Lack of incentives for Energy Performance Certificate (B) Lack of standardised energy efficiency finance pathways (B)	High cost of energy efficiency upgrades (B) Lack of capital for investing in energy efficiency (B)		Rare or very rare willingness to pay a higher price for a building with energy efficiency upgrades	Most important measures in buildings are envelope, heating-ventilation-air-conditioning-refrigeration systems, lighting Poor energy efficiency not a reason to reject a property

Table 4 (continued)

Project	Environmental dimension	Corporate dimension	Individual dimension	Other factors	Findings
DEESME	Difficulty to access financing for energy efficiency (B)	Economic benefits from downsizing or elimination of equipment (D) Non-economic benefits (D) Lack of awareness (B) Low availability of capital (B) Lack of technical human resources (B)	Doubts around actual saving potential (B)	National schemes and initiatives with the national authorities determining more effective schemes for energy audits and energy management systems	Support mechanisms required to deal with the limited available resources in SMEs SMEs need guidance for implementing energy audits and energy efficiency and initiative with national authorities may raise awareness
ICCEE		Energy efficiency considered relevant with cold supply chains (D) High initial investments required (B) Long amortisation periods of investments in energy efficiency (B) Increased productivity (D) Tangible economic benefits (D)		Regulatory and economic considerations influencing the decision making	Energy efficiency considered by most or even all decisions for ~70% of the organisations, considered in at least in some decisions by the 25%. From a whole cold supply chain perspective, ~60% indicate that it is considered in most or even all decisions; the 13% says that it is hardly considered

the SMEs focus mainly on production activities and show a lower interest in energy efficiency with respect to other countries. Lack of awareness and behavioural issues affecting the identification and evaluation of plausible energy efficiency measures were also identified by Trianni et al. (2016) for Italian SMEs, which is a finding consistent with our study. On the other hand, Slovenia is unlikely to meet its energy efficiency target for the industrial sector because of increasing final energy consumption, especially in the basic metal production sector (Malinauskaite et al., 2020).

Lack of finance is the major barrier to energy efficiency for SMEs in Ireland, Italy and Romania, whereas Spanish SMEs consider energy efficiency to be low priority (section A2.1). It was found in Brutscher et al. (2021) that SMEs which want to implement energy efficiency measures cannot finance; therefore, policies focusing on facilitating energy efficiency financing are needed. Policymakers should develop policy trials considering parameters

such as business size, sector, location, tenancy status and data availability, to design and test effective interventions (Fawcett & Hampton, 2020).

Lack of knowledge of unit price of electricity and gas may also hinder behaviours of SMEs' employees that may favour energy efficiency in Romania (SPEEDIER, D2.3). However, some Romanian SMEs indicated interest in sustainability and circular economy issues and have applied technologies to improve the use of secondary raw materials, increasing energy efficiency and reducing wastewater generation (Oncioiu et al., 2018).

The research indicated that SMEs had typically not developed an energy strategy for the following 3 years in Germany, Romania, Slovenia and Spain (section A2.2). A good energy strategy should prioritise enhancements of energy efficiency and adoption of energy management methods, whereas strategic objectives related to environmental and climate change issues or the presence of a manager responsible for climate change and environmental issues

will not be effective for improving energy efficiency (Ozbugday et al., 2022).

In Germany, France, Spain and Italy, it was found that the SMEs of the automotive industry prioritised short-term low-risk energy efficiency measures such as lighting, electric drives, compressed air systems and logistics (section A2.3). Low risk and short pay-back time were also identified by previous research as the main priorities for the adoption of energy efficiency measures in the Dutch, Slovak and Czech manufacturing sectors (Velthuisen, 1995).

Study limitations and future research

The main limitation of the methodology used by the seven projects analysed is related to the number of SMEs which can be analysed through surveys, interviews and focus groups (usually limited to few tens of SMEs). The approach used in this research, the meta-analysis of multiple projects, mitigates this limitation and enables consolidation of the findings using more data as well as comparison between different studies.

Looking beyond the typical framework of drivers and barriers, future research should develop tools based on social research to initiate a characterisation of people behaviours. Such an analysis should start with the definition of the future behaviour identifying first the task/critical behaviour, and then so-called antecedents or triggers, the behaviour and its consequences or rewards. Understanding the relationships between antecedents and consequents will be the key point for the modelling of human behaviour in organisations (Lopes et al., 2018).

In future research work, the research framework of the ‘[Methodology and research framework](#)’ section could be further refined to provide a causal model relating the successful improvement of energy efficiency in SMEs (dependent variable) to a number of relevant independent variables. The list of barriers and drivers will be augmented with the causal weight of those factors, which determines their ability to influence the energy efficiency of SMEs (Reddy, 2013).

Conclusion

This research contributes to the analysis of the decision-making of SMEs with respect to energy audit and energy efficiency implementation by systematically integrating the results of seven EU projects (SPEEDIER, SMEmPower Efficiency, E2Driver, Innoveas, Triple-A, DEESME and ICCEE). A research framework was developed which considers barriers and drivers and other influencing factors within the three dimensions (1) environmental, (2) corporate and (3) individual, and applies the work from König et al. (2020) to the research performed in the seven projects. The barriers and drivers to energy audits and energy efficiency implementation are contingent on the SME’s country of operation, business sector, size and building ownership.

This research investigated energy efficiency in European SMEs using very recent data collected through surveys, from a larger number of countries and industrial sectors than most of the recent publications whose findings cannot be considered representative of the whole Europe and of the diverse industrial sectors.

The meta-analysis of the seven projects has identified common and individual barriers and drivers for the European SMEs within the three dimensions of the research framework adopted, highlighting differences between different countries and, where applicable, different sectors. These barriers were identified using the aggregated datasets from surveys, interviews and focus groups from all seven projects. As possible drivers, the study found a certain level of existing awareness within the SMEs about economic and non-economic benefits associated with installation of energy efficiency measures, which is a positive development with respect to the interest of European SMEs in energy efficiency.

The lessons learned from the projects indicate the importance of increasing the training opportunities on energy efficiency for entrepreneurs and employees, and their awareness regarding the available incentive schemes. Training courses must be customised to the various professional roles to

maximise their effectiveness. SMEs need training actions which can help them to appoint an energy manager, to develop an energy efficiency strategy and a policy and to schedule energy audits and to engage with an energy consultant for the evaluation and planning of the most appropriate energy efficiency measures.

In some specific sectors, energy efficiency should be considered in the context of whole supply chains, like in the food and beverage sector to maximise the potential of the measures and reduce costs. In those sectors, the cooperation between the companies of the same supply chain may lead to considerable cost savings and possibly to more competitive products on the market. The engagement with the stakeholders to establish better financing mechanisms and pathways is fundamental to overcome the reluctance of SMEs in undertaking energy audits and implementing energy management systems and energy efficient retrofits.

The implementation of the seven projects' recommendations will contribute towards the improvement of energy efficiency in the European SMEs (across all the sectors) and ultimately towards the fulfilment of the requirement of Article 8 of EED for European Member States and towards achieving the Member States' collective target of 32.5% improvement in energy efficiency by 2030 under EED.

The implementation of energy efficiency measures is one of the key activities to enable a circular economy, along with waste management, optimum resource utilisation and others. Behavioural factors affecting the adoption of circular economy practices in SMEs are not known yet (Luthra et al., 2022). Future research, therefore, should include energy efficiency within a wider strategy promoting circular economy's principles in SMEs.

Moreover, future research should also look to determine the relative importance associated with the different barriers and drivers such that appropriate response measures to remove, reduce or avoid the barriers, as well as exploiting the available drivers, may be prioritised and implemented with the end goal of maximising the uptake of energy efficiency measures in SMEs. Such insights will also be useful to improve energy efficiency policies for European SMEs.

Appendix 1. Energy audit obligations in various EU countries

The Innoveas project has investigated differences with respect to energy efficiency between SMEs and non-SMEs in Germany, Slovenia, Poland, Italy, Spain and Belgium (Czogalla, 2020).⁴

In Germany, Energy Audits are required for non-SMEs as opposed to SMEs and follow specific regulations which prescribe the time intervals between audits (EN 16,247: Audit every 4th year, ISO 50001: Recertification every year, EMAS: Declaration every year, ISO 14001: Recertification every 3rd year). Non-SMEs have internal departments dealing with energy-related issues whereas SMEs may not have dedicated personnel. Financial funding programmes are available only for SMEs whereas they are not available for non-SMEs. Non-SMEs must upload their EA data and EA report not later than 2 months after completing the audit to the Federal Office of Economic Affairs and Export Controls (BAFA), whereas SMEs do not need to do that (CMS, 2022a).

In Slovenia, non-SMEs are obliged to prepare energy audit every 4 years, while SMEs do not have that obligation. The process of energy auditing is the same for both non-SMEs and SMEs. SMEs may occasionally obtain subsidies for preparation of energy audit on public tenders. Non-SMEs often have personnel that oversees energy efficiency and other energy-related issues (CMS, 2022b).

In Poland, both energy audits in SME and non-SME follow the EN-16247 standard and the procedure is adapted to consider the type of industry and specifically its activity (CMS, 2022c).

In Italy, the energy audit is mandatory only for large enterprises and for energy-intensive SMEs. Energy-intensive enterprises are those which consume more than 2.4 GWh of electricity (or other Energy source) and whose energy cost exceeds 3% of their turnover (Decree of April 5th, 2013, Ministry of economy and finance). There are no differences in audit implementation for SMEs and non-SMEs: both follow the norm UNI CEI EN 16,247, which requires the commitment of economic resources which not all the SMEs can afford though (CMS, 2022d).

In Spain, there are no significant differences between audits in SMEs and non-SMEs; however, differences

⁴ Similar outcomes have been referenced by all the projects.

exist between different types of industries. Since 2016, non-SMEs are obliged to implement energy audits every four years; however, those who have an Energy Management System implemented are exempted (CMS, 2022e).

In Belgium, there are in principle no differences between SMEs and non-SMEs. Differences regarding the energy audits arise between the diverse sectors. The audits are not limited to energy efficiency but may also cover direct and indirect CO₂ emissions and utilisation of renewables. Legislation also refers to simplified audit procedures, which may investigate specific issues such as energy efficient building, efficient lighting or improvements in insulation (CMS, 2022f).

Appendix 2. Projects and their surveys

SPEEDIER

SPEEDIER is an innovative ‘one-stop-solution’ for SMEs to manage their energy efficiency by providing information, advice, capacity building training, energy auditing, energy efficiency implementation, financing advice and impact monitoring.

An online survey and focus group discussion with SMEs and stakeholders in the energy efficiency value chain (energy auditor, energy consultant, energy managers, landlords, finance providers and vendors of energy efficiency technology) were carried out. The objective of the survey was to understand SME’s attitude including barriers and drivers towards energy management and energy efficiency of their organisation.

Online survey and its key learnings

The survey collected 84 (20, Ireland; 20, Italy; 21, Spain; and 23, Romania) responses. The survey results provided insights into the level of energy awareness and energy management activities in SMEs in four European countries.

The most significant and notable similarity between SMEs of Ireland, Spain, Italy and Romania is that the majority of the answering organisations do not have an energy manager, energy policy or energy reduction target and they have not undertaken an energy audit in the last 5 years (SPEEDIER, 2020).

Figure 2 shows the survey results about the funds available to SMEs for investing in energy efficiency.

Results of the survey show that most of the participant organisations do not have dedicated funds available to invest in energy efficiency upgrades of their organisation. Figure 3 shows the results of the survey regarding Government’s support or incentives used by SMEs for implementation of energy efficiency measures in four pilot countries. Results show that many organisations do not have knowledge of available government’s financial scheme to support their energy efficiency upgrade, for which they might be eligible to avail.

Most important difference among the pilot countries is the main barriers, which prevent them for implementing recommended ECMs (Fig. 4). For Ireland, the main barrier is lack of knowledge of which ECMs to implement and how to procure them. For the rest of the pilot country, lack of finances to invest in ECM implementation is regarded as main barrier by the participants. Other studies have identified imperfect information and access to capital as two possible barriers for ECM implementation (Sorrell et al., 2000; Trianni & Cagno, 2012). In Spain, another prevailing barrier is lack of control of building to make changes for ECM implementation, which indicates a considerable number of SMEs are operating on rented premises. Moreover, the significant differences in the adoption of ECMs between owners and renters are one of the well-known split incentive effects arising when those who pay for the ECM implementation are not those who eventually enjoy the benefits. A recent study highlighted that this barrier exists also in the Netherlands, Germany and Belgium (Nie et al., 2020).

There are some differences between the opinion of SMEs and stakeholders regarding the main barrier to energy efficiency for SMEs. According to the majority of the respondent stakeholders, lack of finance to invest in ECM implementation is a major barrier for SMEs based in Ireland, Italy and Romania, whereas for Spanish SME energy efficiency is low priority. These different perceptions of barrier to energy efficiency is critical and very important to consider for the success of the project.

Focus group discussion and its key learnings

To supplement the results of online survey, focus group discussions with SMEs and energy experts were organised in each pilot region. The aim of organizing focus group discussion was to gather opinions and experience of SMEs and energy experts in more detailed manner as compared to online survey.

In Spain, separate focus group discussion was organised for SMEs and energy experts, whereas in other pilot regions SMEs and energy experts participated in the same focus discussion.

Focus group discussion in Italy was organised along with the Smart Building conference and 5 SMEs and 3 experts participated in the SPEEDIER focus group discussion.

The experts commented that lack of finance to invest in ECMs implementation is major barrier to implement energy efficiency upgrade for SMEs. As per the energy experts, SMEs consider energy efficiency as an opportunity rather than a need, and because of this selling an energy audit to SMEs is difficult. However, most of the SMEs would be willing in engaging in free and in situ energy audits if research funds could be used for this purpose rather than the SMEs having to pay for the costs associated to the audits (Redmond & Walker, 2016). Apart from above-stated barriers, participants agreed that lack of time and lack of in-house expertise to implement recommended ECMs are other considerable challenges for SMEs to implement energy efficiency upgrades; therefore, a professional auditor going on-site would significantly contribute to increasing the level of engagement of SMEs with energy efficiency issues (Redmond & Walker, 2016).

Propensity of SMEs to implement an energy audit depends on several factors such as financial and operational objectives, environmental concerns, number of operating years of SME, their location and ownership (Kalantzis & Revoltella, 2019). The SPEEDIER project found that not only lack of finance to implement ECMs is a major barrier, but SMEs struggle to justify the cost of energy audit. SMEs are unsure if implementation of recommended ECMs (if any) will even payback the energy audit cost. However, energy experts are extremely confident about recovering the cost of energy audit through the implementation of simple measures. The classification of ECMs into no cost, low cost, medium cost and high cost helps to determine the measures that can be prioritised and applied first, being no cost or low cost. No-cost ECMs like the blower door tests to detect air leaks and the thermographic imaging to locate heat loss by detecting surface temperature variations over interior or exterior walls were also considered in (Palmer et al., 2013).

Further participants from all focus groups agreed that SMEs lack interest towards managing their energy efficiency; rather, they are more focused towards managing their day-to-day business activities and business needs (Thollander et al., 2007). Additionally, most of the SMEs do not have in-house expertise dedicated to energy management; sometimes it is combined with other organisational roles like health and safety manager or facility manager. This makes senior management buy-in difficult for energy efficiency upgrades decisions. However, most participant SMEs agreed that having energy efficiency upgrades will enhance their green image and would be helpful to win new businesses.

Participant SMEs agreed that as they lack in-house expertise, there is a need of external energy consultant to recommend and implement ECMs. They also agreed that external energy consultant will be more effective for building and developing energy culture within their organisation than their own employees. SMEs also stated that they are not aware about available government scheme to support energy efficiency improvement at SMEs, and they agreed that these support schemes are not publicised and promoted enough.

Moreover, the participants in the focus groups were asked to comment on the differences between engaging with large organisations and with SMEs. The key finding was that gaining senior management buy-in from SME owners could be more difficult than from large organisations senior managers because they are busy running their business. They need hassle-free solutions to manage energy which do not impact on the daily business operation and to see the value added to the business of energy efficiency. This finding contributes to explain the fact that SMEs do not effectively follow energy-saving activities, including energy-saving guidelines and energy management standards, which was attributed to the scarcity of their resources in Prashar (2017b).

SMEmPower Efficiency

The objective of the SMEmPower Efficiency project is to design and deliver integrated Education & Training (E&T) programmes and training tools, targeting energy related SME staff. The trainees will collaborate with at least 160 SMEs as pilot installations of

Does your business have dedicated funds for investing in Energy Efficiency improvements

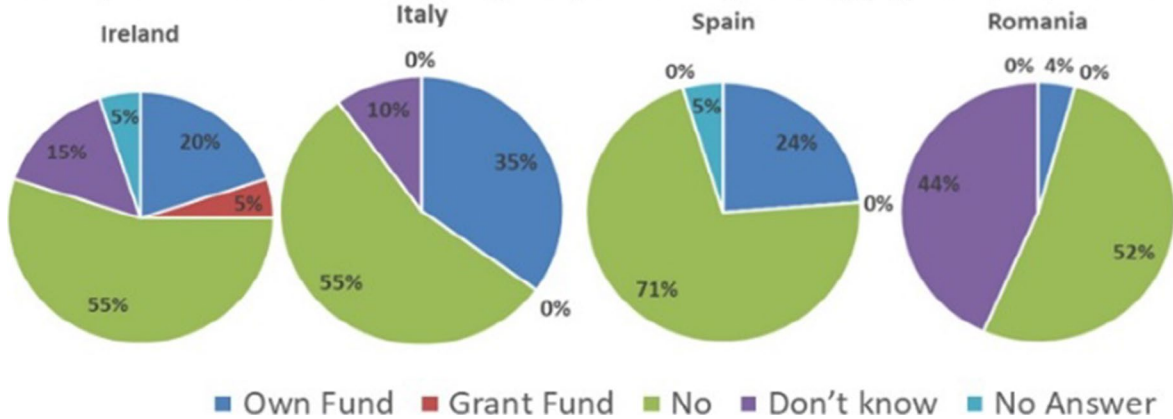


Fig. 2 Survey results about funds for investing in energy efficiency improvements for the SMEs of four pilot countries

Has your business ever received any government support or incentives to help you to implement Energy Conservation Measures?

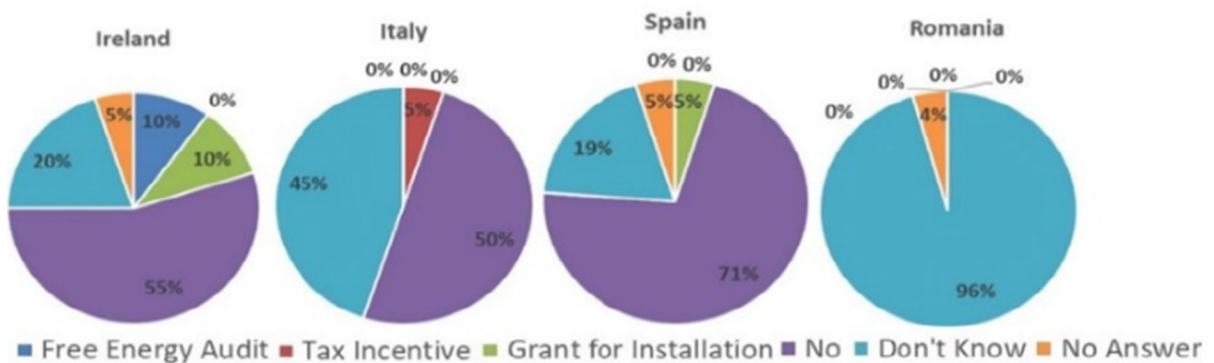


Fig. 3 Survey results about the support or incentives received from the Government for implementing energy efficiency measures for the SMEs of four pilot countries

energy efficiency measures. Both partners and trainees will deliver in-house specially designed short trainings for at least 800 decision-makers and staff members of grouped SMEs. Finally, targeted workshops where both SME decision-makers and stakeholders from financial entities will come together and interact on the experiences and the real data resulted from the pilot SMEs will be delivered.

Online survey and its key learnings

A questionnaire was developed to conduct a survey about SMEs energy cost and energy efficiency (SMEmPower Efficiency, 2020). The sample of SMEs which responded to the survey comprises 213

SMEs from the 8 participating countries of which the 41% employ between 50 and 249 people, 29% employ between 10 and 49, and 27% employ less than 10 people. In addition, there was 3% which employ over 250 (non-SMEs) of which 1% from Germany with less than 500 employees and 2% from Cyprus. Most of the SMEs participating in the survey have low energy consumption (49%), followed by companies with an energy consumption between 100 and 500 toe/year (23%) and companies with a consumption greater than 1000 toe/year (16%). The companies with a consumption between 500 and 1000 were the least numerous in the survey (12%). Moreover, targeted workshops were organised in order to identify which are the main barriers (legislative, institutional,

Of the barriers you identified above, please select the ONE that you consider to be the MAIN barrier to implementing energy conservation measures

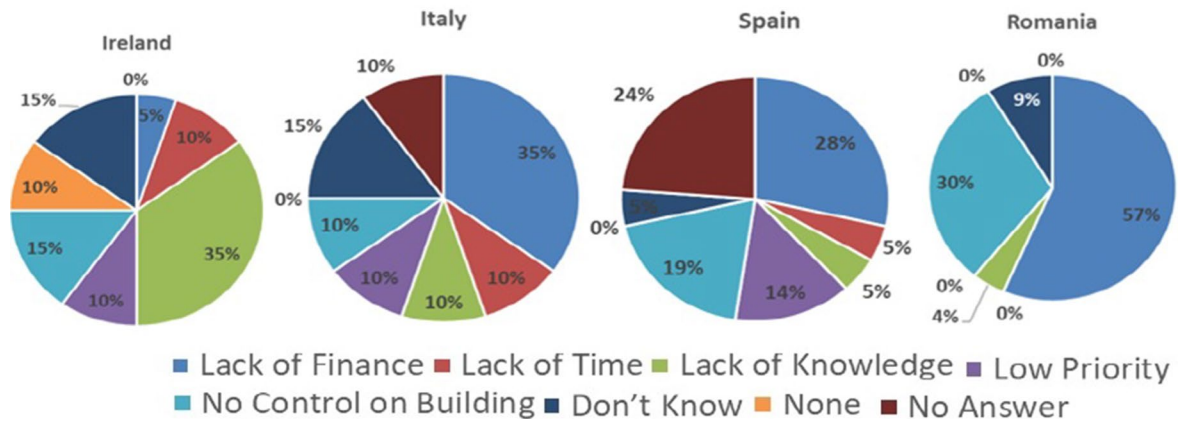


Fig. 4 Survey results about the main barrier to the implementation of energy efficiency measures for the SMEs of four pilot countries

technical, financial and communication) that prohibit the implementation of energy efficiency measures in SMEs and to propose solutions.

The survey's results highlighted that most of the SMEs have not appointed an energy manager; they have not implemented environmental/energy standards and energy audits have never been carried out in the 50% of the SMEs that participated in the survey. The results confirm that SMEs do not consider energy efficiency in high priority and that there is a need for training to increase the skills and qualifications of SMEs personnel. Since in most countries SMEs are not obliged to assign an energy manager or to carry out energy audits, a lack of interest and motivation on energy efficiency issues was recorded.

The survey results show that SMEs use their own resources to fund energy efficiency investments and that the majority of SMEs are not well informed about the funding opportunities in their countries, including EU grants, loans, national support schemes etc. SMEs participated in the survey consider it bureaucratic and complex to apply for grants or bank loans.

The energy efficiency measures already implemented in some SMEs participating in the survey are those with a quick payback time, e.g. LED lighting, ventilation, heating/cooling and automation especially in buildings, showing that these types of investment have lower risk and do not affect production processes and product quality. However, the investments in heating, ventilation and air conditioning systems

(HVACs) could be further increased whether the barriers related to lack of information and bounded rationality could be lowered. The lack of knowledge about how much energy is consumed by the HVACs and about their running costs may affect the decision to purchase a HVAC. The existing energy labels are often unclear and not clearly linked to monetary information (López-Bernabé et al., 2021). In some cases, SMEs are reluctant to implement energy efficiency measures as it is believed that these can affect the daily business routines and the profitability. All the above have been identified as the main technical barriers in Germany, Romania and Spain.

In some countries, e.g. Germany, Romania, Slovenia and Spain, the SMEs have not developed an energy strategy for the next 3 years. The lack of proper communication channels among the staff and management have been identified as the main barrier in this aspect. Survey results show a strong desire of SMEs for case studies and examples of projects to shape ideas, for activities that could facilitate the networking between professionals and SMEs and in general for events which can support them in tackling these barriers and gain the opportunity and confidence to implement energy efficiency solutions. Literature has identified some important factors which may contribute to overcome the existing barriers: future regulations, public support, cost saving and environmental awareness (Segarra-Blasco & Jove-Llopis, 2019). Another finding of the survey results analysis is that the staff of SMEs is generally

motivated to attend further training to improve skills and competences. This is a gap that the SMEmPower Efficiency project aims to bridge.

A positive outcome from the survey is that the level of awareness of SMEs regarding environmental issues is high and this has been taken properly into consideration in the design of the contents of the SMEmPower Efficiency training courses. However, previous studies have highlighted that, despite their awareness of environmental issues, business owners and managers not always can put into place formal environmental management systems or market their goods or services following environmental practices; hence, the importance of well-designed training courses (Gadenne et al., 2009).

Other highlighted main barriers that might limit SME investments in energy efficiency are the payback period, which is usually too long, and the difficulties in accessing financing/grants. It can be concluded that some of the respondents are willing to invest in energy efficiency measures, only if the investment has a short payback period (Palm, 2009), and most of the respondents are expecting to see an energy bill reduction in a short time. More details on the survey results and responses are available in SMEmPower, D3.4.

E2DRIVER

The European automotive industry⁵ ranks among the largest energy consumers worldwide. Manufacturers of the automotive sector are seeking to improve energy efficiency and sustainability of the whole manufacturing process optimising energy sources utilization (especially in the paint shop, that is responsible for the highest energy consumption in the vehicle manufacturing process) and adopting heat recovery strategies (Giampieri et al., 2020). The total energy consumption of a manufacturing plant of the automotive sector is determined by the operation system, energy efficiency management, HVAC system and other loads (Katchasuwannanee et al., 2017). E2DRIVER project aims to train SMEs in the automotive sector on energy auditing and energy saving measures for cost-effective energy efficiency

improvements. The project also aims to boost capacity-building programmes on energy auditing by establishing an innovative learning platform.

The sector comprises the production of several products ranging from hard metal parts to tiny plastic components; therefore, an adapted training methodology is required for each participating company to provide appropriate skills that they can use to self-promote ‘best practices’ in energy efficiency. The goal of the E2DRIVER project is to provide the companies (12 pilot and 28 replication companies)⁶ with an adaptive training path that adapts the competencies in energy efficiency to specific needs of each organisation.

Before the actual training, the E2DRIVER project conducted a survey to define target groups that will benefit from a customised training plan in future training sessions and to identify current gaps in energy management and energy auditing procedures in the participating SMEs as well as best opportunities and main barriers for the implementation of energy efficiency improvements can be identified. To conduct the survey, 12 SMEs (3 from each country—Germany, France, Spain and Italy) were selected from the project partners in the pilot phase. The SMEs were selected to ensure each company involved in a different activity within the automotive supply chain. Two types of surveys were conducted with each of 12 SMEs: staff questionnaire and energy assessment interview.

The staff questionnaire and its key learnings

A sample of trainee’s representative of each company was selected to undergo a written form staff questionnaire. The first part of the questionnaire focuses on organisational aspects and individual trainee’s characteristics regarding role in the company, academic background, years of experience, etc. The second part of the questionnaire seeks to understand individual trainee preferences in regard to training methods and procedures as well as to assess trainee’s past training experiences and his/her expectations to be achieved through the involvement into the E2DRIVER project.

Forty-five questionnaires from 12 SMEs within four participant countries were received. The questionnaire was structured as a sequence of multiple choice and open

⁵ The scope of the automotive industry comprises all the activities involved in the manufacture of motor vehicles, including most of their components, such as engines and bodies, but excluding batteries, fuel and tires.

⁶ The results presented in this paper refer to the 12 SMEs from the pilot phase.

questions trying to investigate trainee's characteristics from both organisation and energy knowledge point of view.

Occupation of the responders was reported using the ESCO classification: managers, science and engineering professionals, technical managers and technicians. Despite the above classification, the collected responses indicate homogeneous trends. One out of three staff answering the questionnaire was not familiar in a professional level with energy efficiency and energy management topics and generally they also report not being aware of any energy measuring procedures in their company. Half of the participants further reported that there is no policy/procedure in place for the identification and promotion of interventions to improve the operation, maintenance or energy efficiency of process systems. In this context, less than 20% of the participants reported being involved in the calculation of the potential for energy savings in their daily job. When present, energy management in the 12 companies is either implemented independently from any certified management system or is integrated into other quality management systems such as the ISO 9001 and/or ISO 14001. Training and awareness of employees regarding energy efficiency topics is usually not included in the established management systems and as a result almost none of them has ever participated in a course or seminar organised by the company about measures to increase energy efficiency. Regarding the preferred training formats, traditional workshops were indicated as the most preferred approach as more modern digital training methods are considered less effective.

The energy assessment interview and its key learnings

An energy assessment interview was conducted with the energy manager/maintenance or staff responsible for energy management in each of the 12 companies.

Although energy consumption is perceived as an important topic by almost all 12 SMEs, many of them are still lacking concrete energy management measures like the implementation of KPIs. However, there is large interest in improving this situation either by the implementation of additional ISO certifications or by the implementation of energy audits.

Literature has reported that a large number of cost-effective energy efficiency measures are not eventually

implemented in manufacturing SMEs, because of financial reasons, lack of information and limited in-house competencies (Trianni et al., 2013). The results of the energy assessment reveal that there are some areas where particular actions are needed: one point is the lack of knowledge regarding energy efficiency regulations in the respective country. In addition, although all participating companies collect energy data and many of them monitor their energy consumptions, support seems to be needed in the implementation of processes and management structures to deal with the monitored energy use and in the consistent implementation of energy efficiency measures. Therefore, methods to gather up-to-date energy data and to monitor areas of significant energy use and benchmarking approaches can be fostered. This consideration comes along with the need for a common agreement on how energy issues are communicated and the need for a regular exchange—especially regarding a regular reporting at executive and board level. One of the most important points, where action is required, is the training and education of employees about energy efficiency, since many of the SMEs indicate a lack of knowledge and clear instructions of their staff.

A list of measures already in place or planned in the immediate future is determined for the 12 companies participating in the project. Table 1 gives an overview of all energy efficiency measures that have either been implemented during the past 2 years prior to the project ($n=48$) or that are planned for the upcoming 2 years according to the energy assessment interviews ($n=28$). They are grouped into three areas, supply technologies (A), building technologies (B) and production processes (C) and subdivided by different sectors.

The lack of awareness in energy efficiency topics is reflected into companies' attitude towards energy efficiency measures and especially on the ones they are willing to implement. In fact, most of the energy saving measures which have been implemented/considered in past 2 years and planned over 2 years are directed towards low-risk areas which are the ones that also lead to smaller economic revenues (lighting, electric drives, compressed air systems, logistics). Measures to be implemented in process specific technologies seem to be considered over a wider period (i.e. higher than 4 years): this may be due to the required higher investment and/or long-term stop of productive lines. The latter issue

represents a strong technical barrier for production-oriented organisations such as automotive sector ones. However, more innovative SMEs generally have a lower perception of technological-related barriers, and similar finding applies to the SMEs with a greater production variability (Trianni et al., 2013). Moreover, the performed assessment reveals that most of the companies declare to have sufficient financial availability to sustain energy efficiency improvements; however, they are hindered by missing a proper knowledge about energy efficiency regulations. There is also an insufficient knowledge of incentive schemes and subsidies, which are fundamental to the implementation of expensive measures. More details are available in (E2DRIVER, Deliverable D2.2).

Other projects: Innoveas, Triple-A, DEESME and ICCEE

The methodologies and findings of the Innoveas,⁷ Triple-A,⁸ DEESME⁹ and ICCEE¹⁰ projects were also systematically analysed, in addition to those previously presented. The Innoveas project intends to address the issues regarding the low uptake of energy auditing practices by European SMEs. The Triple-A project aims at enhancing at an early stage the investment value chain of energy efficiency projects. The DEESME project enables the SMEs to profit from multiple benefits from energy management and audit approaches and provides national authorities with guidelines to empower their schemes under the Article 8 of the Energy Efficiency Directive (EED). The ICCEE (Improving Cold Chain Energy Efficiency) project aims to facilitate SMEs belonging to supply chains in the food and beverage sector to undertake energy efficiency measures after carrying out overall supply chain energy audits (Zanoni et al., 2020). Detailed descriptions of the findings are omitted from this paper due to lack of space. Results of the performed analysis are available in synthetic form in the tables of the ‘Methodology and research framework’ section.

⁷ <https://innoveas.eu/>

⁸ <https://www.aaa-h2020.eu/>

⁹ <https://www.deesme.eu/>

¹⁰ <https://iccee.eu/>

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Declarations

Conflict of interest The authors declare no competing interests.

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