Energy Efficiency

Challenges and Opportunities for Improving Energy Efficiency in SMEs: Learnings by seven European projects

--Manuscript Draft--

Manuscript Number:	ENEF-D-22-00195
Full Title:	Challenges and Opportunities for Improving Energy Efficiency in SMEs: Learnings by seven European projects
Article Type:	Original Research
Keywords:	Energy Efficiency, SMEs, Energy Conservation Measures, Energy Audit
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Challenges and Opportunities for Improving Energy Efficiency in SMEs: Learnings by seven European projects

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Abstract

This paper analyses challenges and opportunities for improving energy efficiency in Small and Medium Enterprises 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 the awareness of small and medium enterprises (SMEs) and support an effective decision-making oriented to improving energy efficiency. These projects conducted research by means of surveys, focused group discussions and interviews to gain knowledge from the stakeholders about the drivers and the barriers to energy efficiency improvements in SMEs in several European countries and various industrial sectors. Results of the performed research showed that staff trainings, facilitation of energy audits, development of corporate policy measures and collaboration between SMEs involved in the same supply chain, are key methods to succeed in improving the uptake of energy efficiency measures in SMEs, thereby unlocking the large potential of achieving higher energy savings and energy cost reductions.

1 Introduction

The 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. SMEs account for 99.98% of European enterprises (Muller et al, 2017) and are responsible for approximately 13% of 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 European 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 European target, under the EED, of 32.5% improvement in energy efficiency by 2030.

Energy consumption breakdown in SMEs depends on the specific type of industry. Typical energy consumers are the facilities, steam production, motor driven systems, process cooling, fire heater, boilers (Hasanbeigi and Price, 2012). Electric motors are the most important type of electric load consuming 60-80% of the electricity used in the industrial sector and about 35% of the electricity used in the commercial sector. They are used in all the industrial sectors and in a wide range of applications such as fans, compressors, pumps, mills, winders, elevators, transports, home appliances, office equipment and others. 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 the 62% and 83% in the industrial and in the services sectors in the EU (de Almeida et al., 2003). Compressed air is used in various industries such as Food, Textiles, Apparel Conveying, Lumber and wood, Furniture, Pulp and paper, Chemicals, Petroleum, Rubber and plastics, Stone-clay-glass, Primary metals, Metals fabrication. Energy efficiency measures applicable to compressed air systems other than adoption of high efficiency motors are: leak prevention, use of outside intake air, reducing pressure drop, recovering waste heat, use of efficient nozzle, and use of variable displacement compressor (Saidur et al. 2010). Other energy efficiency measures are associated with heating system. The efficiency of boilers may be kept close to the optimum by cleaning and adjust burners such that fuel and air are mixed to minimize excess air for the specific firing rate. Too much air will cool the furnace and carry away useful heat, whereas with too little air the combustion will be incomplete, and unburned fuel will be wasted causing smoke production. Moreover, the firing rate has significant impact on boiler efficiency and the highest efficiency is achieved by utilising the maximum number of boilers possible for the given load. In (Naik

and Mallur, 2018) it was reported 30% energy savings obtained by controlling the discharge oxygen concentration of the boiler and prevent the discharge temperature from exceeding the designed specification. Energy savings achievable using Energy management system (EMS), building energy management system (BEMS), industrial, company and factory energy management system (I/C/F/EMS); and EMS for heating, ventilation, air conditioning (HVAC) and refrigerating equipment, artificial lighting systems, motors and others (EMS for equipment) were analysed in (Lee and Cheng, 2016). Energy savings from BEMS increased from 11.39% to 16.22% yearly from 1976 to 2014, whereas savings provided by I/C/F EMS decreased from 18.89% to 10.35% in the same period. Artificial lighting systems may 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%. Several other energy efficiency measures apply to production processes in the diverse sectors of SMEs whose detailed discussion goes beyond the scope of this paper.

The challenges associated with barriers to the implementation of energy efficiency measures in SMEs are complex and depend on multiple factors. Research on drivers is in many cases still at early stages and will benefit from a better understanding of the current barriers with respect different types of SMEs. This paper will contribute to the research in the field analysing results from seven European research projects regarding implementation of energy efficiency measures in SMEs.

The European Commission is committed to improve energy efficiency of SMEs and have granted funds to various projects under Horizon 2020 program. SPEEDIER, SMEmPower 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 on energy efficiency and its benefits. With the aim to achieve the EED target, the seven projects considered in this paper are addressing the challenges and the barriers identified by previous studies, to enable the SMEs to undertake energy audits and to implement recommended energy saving measures. The remaining part of the paper is structured as follows. Section 2 provides some background information on energy efficiency in SMEs and the barriers related to implementation of energy efficiency measures as available from the literature. Section 3 introduces the research framework for energy efficiency improvement in SMEs used in this paper. Section 4 (and its subsections) discusses the seven projects, the survey they conducted with the participant SMEs and the related key learnings. Section 5 is the discussion of the findings previously introduced, whereas section 6 concludes the paper. In addition, the appendix includes a description of focus, participants, research hypothesis, methods, results of the analysed projects.

2 Background

An analysis performed by EUROSTAT revealed that the first ten most energy intensive industrial sectors are: Electricity, gas, steam and air conditioning supply, Manufacture of chemicals and chemical products, Land transport and transport via pipelines, Manufacture of basic metals, Manufacture of coke and refined petroleum products, Air transport, Manufacture of other non-metallic mineral products, Water transport, Manufacture of paper and paper products, Manufacture of food products, beverage and tobacco products. These sectors consume the 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. Some of the SMEs considered in the seven EU projects of this paper belong to manufacturing energy intensive sectors whereas some others belong to non-energy intensive sectors such as services, commerce or hospitality. However, it is fairer to compare the energy savings 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 may be significant if compared against them, e.g. 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. In addition, 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 and Catarino, 2016). SMEs consume more than 13% of total global energy according to the International Energy Agency, while accounting for more than half the energy in the industrial and commercial sectors in some countries such as the UK.

Challenges in improving energy efficiency in SMEs are mainly related to the existence of barriers which prevent the process of implementing effective energy efficiency measures to be successful. Barriers to energy efficiency have been classified into three main groups: economic, behavioural and organizational (Sorrell et al, 2000; Rohdin et al, 2007). The economic barriers are usually the most important ones, such as the access to capital, the risk of production disruptions when implementing efficiency measures and the lack of budget funding.

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 et al, 1997). However, that idealized behaviour is in many cases not the observed one. Herbert A. Simon pointed out that the decision-making is not a fully rational process, because of unavoidable limitations in the access to information and computational capacities available, therefore rationality of humans is bounded (Simon et al, 1990). The issue of the bounded rationality of the consumer in the context of energy efficiency was discussed in (Linares and Labandeira, 2010). Bounded rationality may lead to give more importance to upfront costs, and more value to costs than benefits of an increased efficiency. These behaviours can be corrected with different measures such as education and information. Moreover, it is expected that all the individual barriers to energy efficiency must be removed for allowing the organisations to assume a 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 energy saving measures are cost effective, and if individual consumers behave in an appropriately rational manner, such a gap should not exist (Shove, 1998).

Behavioural barriers have been defined as the barriers inside individuals (Weber et al, 1990). 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 are the main individual barriers preventing implementation of energy efficiency measures (Trianni et al, 2012).

Other possible barriers are related to the organization, its culture and the power of individuals working in the organization (Sorrell et al, 2000). To overcome lack of power of employees, the involvement of operational top-managers was found very effective. They can reallocate resources and therefore it is more likely that they implement audit recommendations involving equipment and process changes than other employees (Blass et al, 2014).

Additional barriers being faced by SMEs that prevent them from implementing energy efficiency measures have been identified in (IEA, 2017). As per IEA's report there is lower level of energy efficiency improvements implementation within SMEs as compared to large organizations. Some of the reasons for this lagging nature of SMEs towards energy efficiency upgrades, are lack of time and resources to find out energy efficiency implementation opportunities, lack of information about how

and where energy is being used in their organization, lack of technical expertise to develop any internal energy efficiency implementation program on their own and lack of funding to invest in energy efficiency implementation. Energy costs are frequently a very small proportion of many SME's cash outflow hence they are very much focused on their day-to-day business activities rather than managing their energy efficiency.

The European Energy Efficiency Directive has highlighted that one powerful measure to overcome barriers and drive the adoption of energy-efficiency measures are the energy services. Most known energy services are the Energy Performance Contracting (EPC) and the Third-Party Financing (TPF) (Thollander et al, 2013). Energy management can be effectively outsourced contracting with an Energy Service Company (ESCO). That way, the risk of an energy efficiency project can be shared with the ESCO through an EPC, and a TPF can be put in place in case there are capital shortages.

Many energy saving measures are not being implemented by SMEs because of financial and non-financial problems (Fresner et al., 2017). The financial problems include 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; Painuly, 2009; Nigohosyan et al. 2021; Viesi et al., 2017; Lee, 2015; Meath et al., 2013). Non-financial problems include 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).

In analogous way, a list of barrier and challenges to energy efficiency implementation for SMEs were also identified in the project CHANGE (Chambers Promoting Intelligent Energy for SMEs). Small businesses lack resources to assign energy management responsibility to any staff member (Eurochambres, 2010; Sorrell et al., 2000; Henriques and Catarino, 2016). Financial factors are then the main barrier to invest in energy efficiency upgrades (Trianni et al, 2016). Lack of knowledge and awareness is another barrier which prevents SMEs to benefit by accessing 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).

2.1 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)[1].

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 16247: 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.

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.

[1] Similar outcomes have been referenced by all the projects.

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.
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 16247, which requires the commitment of economic resources which not all the SMEs can afford though. In Spain, there are no significant differences between audits in SMEs and non-SMEs, however differences 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. 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.

3 Research Framework for Energy Efficiency Improvement in SMEs

The main hypothesis behind the research described in this paper is that there exist cost effective measures which can be installed 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. The new aspects of the research are related to the comparison of recent data gathered from SMEs located in different countries and the comparison of findings from different EU projects which also focus on SMEs from diverse sectors.

With respect to the research framework for energy efficiency improvements in SMEs considered in this paper, it is acknowledged that (i) the classic barriers and drivers' approach is convenient to analyse in a structured way the energy efficiency improvement processes in SMEs and can facilitate the design of energy policies; (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 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 et al., 2021).

The empirical research which was conducted by the seven projects use an enhanced framework extending the barriers and drivers framework with the other factors influencing the energy management practice in SMEs (Fig. 1). Following the methodology introduced in the SMEmPower Efficiency project and (König et al, 2020), the influencing factors were grouped in three dimensions: the institutional, the 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 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. 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 and Hampton, 2020). When focussing uniquely on the investment decision the influence of material, cultural, social and regulatory domains on the decision itself are not fully taken into account (Banks et al., 2012).

The proposed research framework 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 need of training 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.

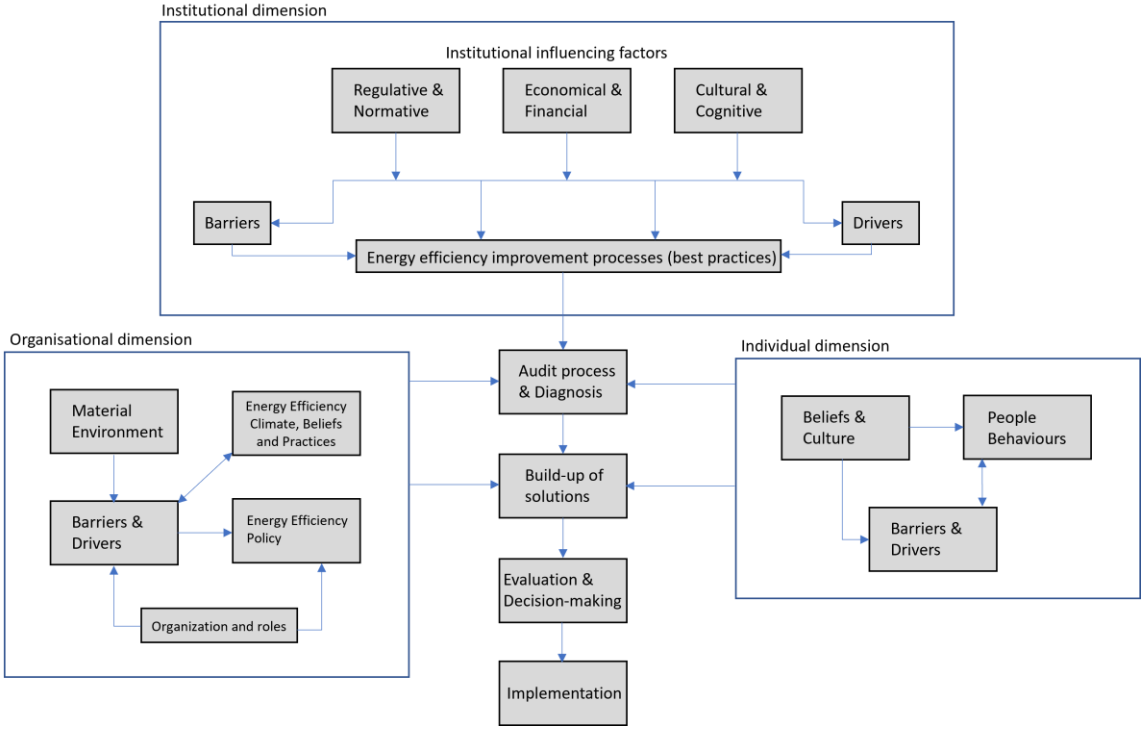

Figure 1: Research framework for energy efficiency improvements in SMEs

4 Projects and their Surveys

The seven projects considered in this paper have conducted initial research work (literature review/online survey /face-to-face discussion/interviews) to understand the current market of energy audit within their pilot countries. These surveys addressed SMEs of various sectors, such as Construction, Manufacturing, Food industry, Services, Chemicals and chemical products, Hospitality, Commercial and trade, Heavy industry, Education, Energy and Automotive industry, and several European countries (Cyprus, France, Germany, Greece, Ireland, Italy, Poland, Romania, Slovenia, Spain, and UK).

In the following subsections each project is introduced, and their research and survey summarized, comparing the results against other works found in the literature.

4.1 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. The core innovation of SPEEDIER is a novel self-financing 'ring fencing mechanism', which enables SMEs to implement energy efficiency upgrades without initial capital investment. The self-financing mechanism works by implementing simple no-cost Energy Conservation Measures (ECMs) first, 'ring fencing' the savings to pay for low-cost ECMs implementations and then continuing the 'ring fencing' cycle for medium-cost and high-cost ECMs, thus eliminating the need of initial capital investment (Figure 2). This service to SMEs will be delivered via Energy Experts who will receive free training from SPEEDIER team and will work as SPEEDIER Experts for SMEs.

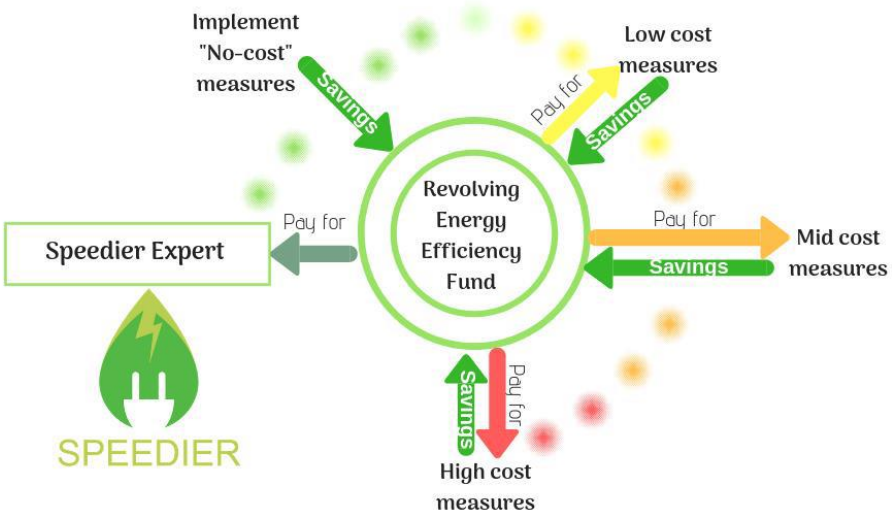

Figure 2: SPEEDIER project: financing of energy efficiency measures

SPEEDIER was designed to address the barriers to energy efficiency upgrades implementation by SMEs as identified by previous research. In order to validate its design concept, the SPEEDIER project carried out 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). The objective of the survey was to understand SME's attitude including barriers and drivers towards energy management and energy efficiency of their organization.

4.1.1 Online Survey

To achieve the above stated objectives, first an online survey was conducted using Google Forms as the hosting platform (SPEEDIER, 2020a). To encourage the participation with honest answers and to make survey anonymous personal details and IP address of respondents were not collected. In order to make the survey easy to complete, all the questions in the survey were not mandatory to answer. All the questions were provided with options to choose either one or multiple answers. Restricting the choice of answer allowed easy analysis of the survey response. The survey was available in the languages of the four SPEEDIER pilot regions: English (Ireland), Spanish (Spain), Italian (Italy) and Romanian (Romania). 84 (20 - Ireland, 20 - Italy, 21 - Spain and 23 - Romania) responses to the survey were received against the set target of 80 responses (20 from each pilot country).

4.1.2 Survey Participants

Below Figure 3 presents the business sector of the participating SMEs from all the pilot countries. It is clear from the picture that in Ireland SMEs form manufacturing sector, in Romania SMEs from hospitality sector, in Spain SMEs from Service and other business sector and in Italy mixed of all sector (i.e. more general approach) participated in the survey. This trend follows the SPEEDIER's target sector in each of the pilot country.

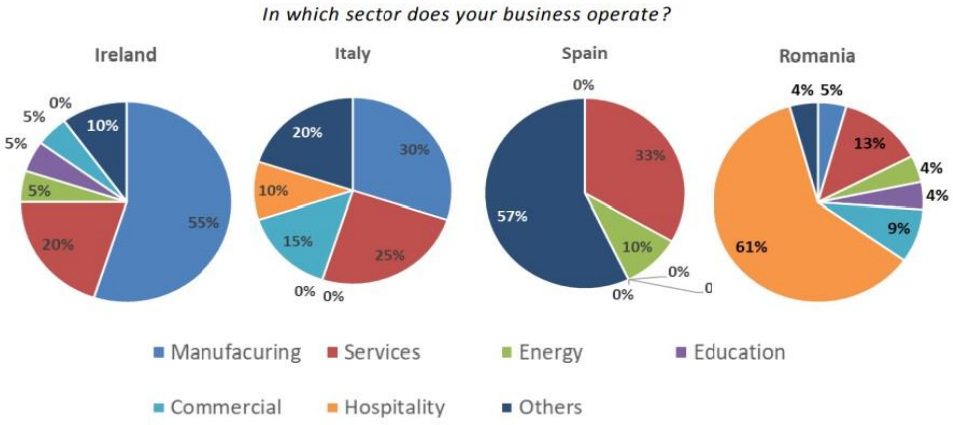

Figure 3: Business sector of participating SMEs

Figure 4 shows the average number of employees in each of the participating SMEs from all the four pilot countries. Majority of the SMEs in all pilot countries have employed less than 25 employees except Italy where survey responses were almost equally spread between all size of SMEs. In Italy a significant number of participants (25%) have more than 250 employees, which means they represent large enterprises.

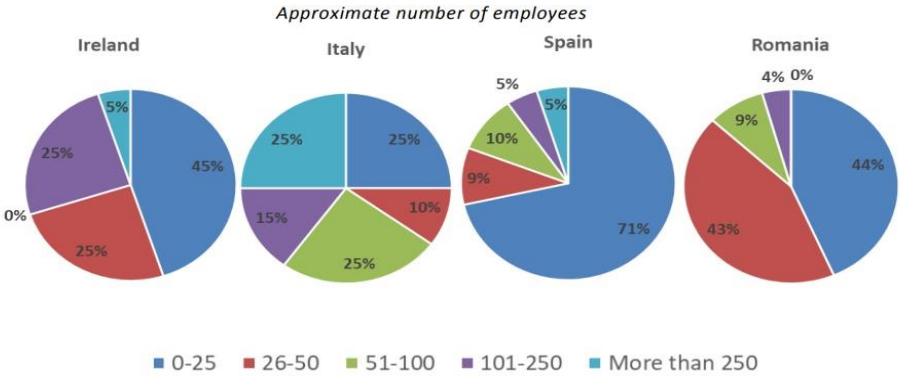

Figure 4: No. of employees of the participating SMEs

From below Figure 5 which shows annual turnover of the participating SMEs, it can be seen that distribution of turnover is different in each country. Majority of the SMEs from all the countries have average annual turnover less than €10million except Italy with majority (35%) of the participants have average annual turnover more than €50million. This is in sync with the size of SMEs.

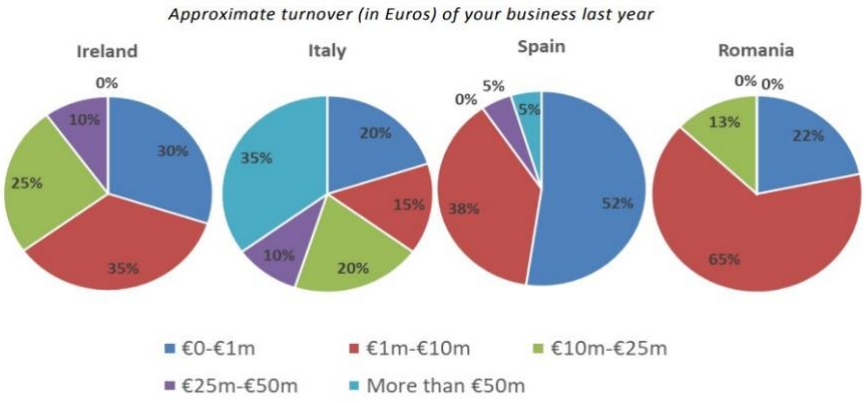

Figure 5: Average annual turnover of participating SMEs

4.1.3 Key Learnings

The survey results provided insights into the level of energy awareness and energy management activities in SMEs in 4 countries of the Europe. Between these four countries there exist some similarities and some differences regarding SME's energy management practices.

Below Figure 6 and Figure 7 represents the level of awareness among participating SMEs of all four pilot countries regarding unit price of electricity and gas compared to their annual spend for electricity and gas.

From the below figure we can see that, SMEs are more aware about annual spend of electricity and gas as compared to unit price of electricity and gas. SMEs are more aware about unit of price and annual spend of electricity as compared to gas. Further we can also note that there is clear difference in the knowledge of energy pricing among pilot countries SMEs. One highlighted difference can be Romania, where a considerable number of SMEs lack knowledge on unit price of electricity and gas whereas they are more aware about annual spend on electricity and gas.

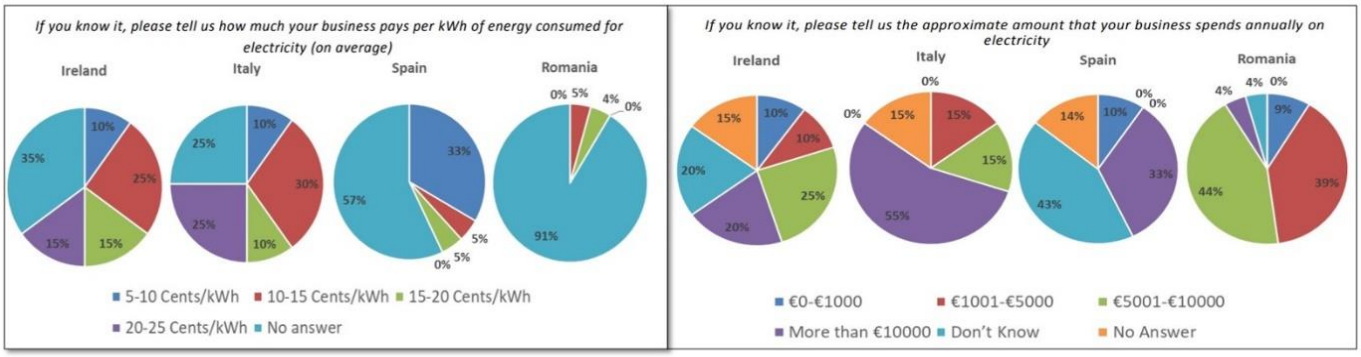

Figure 6: Survey results about awareness of unit electricity price v/s annual electricity spend

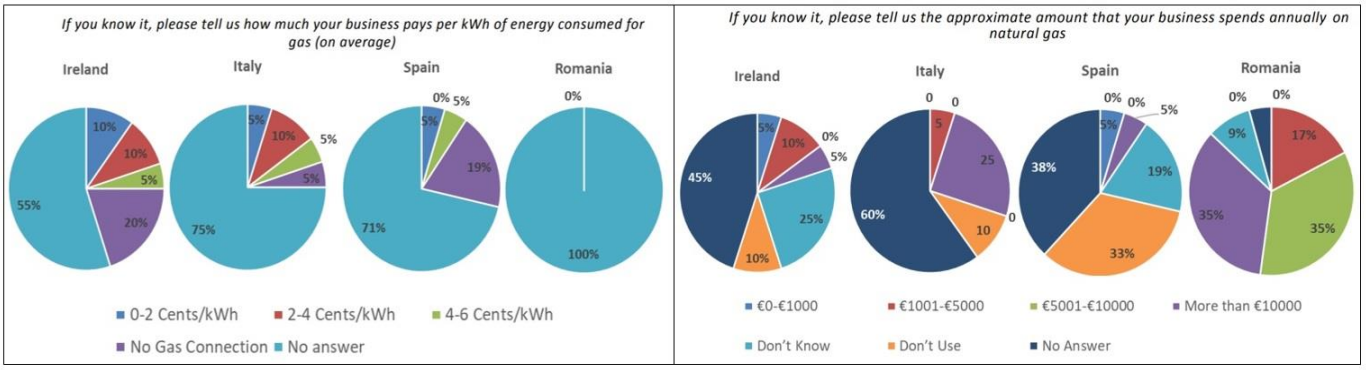

Figure 7: Survey results about awareness of unit gas price v/s annual gas spend

The most significant and notable similarity between SMEs of Ireland, Spain, Italy and Romania is that the majority of the answering organizations don't have an energy manager (Figure 8), energy policy (Figure 9), or energy reduction target (Figure 10) and they have not undertaken an energy audit in the last five years (Figure 11).

Figure 8: survey results about the energy manager of SMEs in four pilot countries

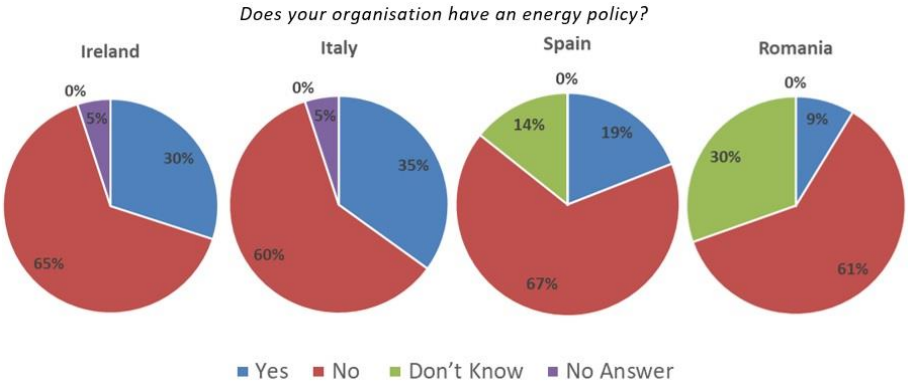

Figure 9: survey results about energy policy for the SMEs of four pilot countries

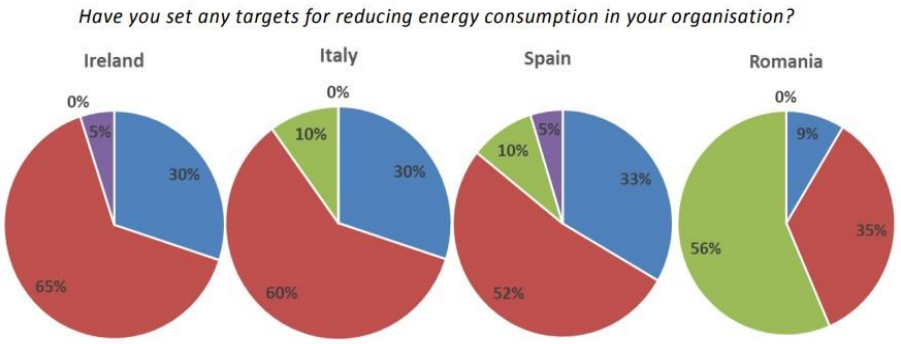

Figure 10: survey results about energy reduction target for the SMEs of four pilot countries

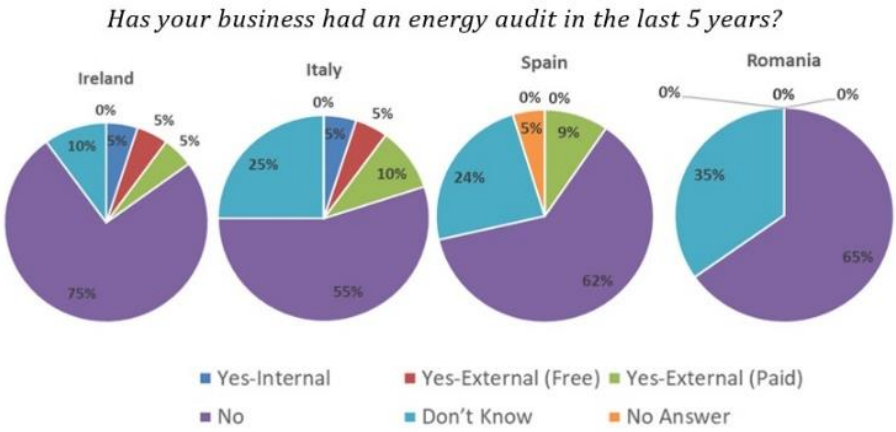

Figure 11: survey results about energy auditing in the last five years for the SMEs of four pilot countries

Furthermore, most of the participant organizations don't have dedicated funds available to invest in energy efficiency upgrades of their organization (Figure 12). These responses indicate lack of interest of respondent organization towards energy management and energy efficiency as compared to their other day to day business activities and business needs.

Another similarity among respondent participants from four countries is that many organizations don't have knowledge on available government's financial scheme to support their energy efficiency upgrade, for which they might be eligible to avail (Figure 13).

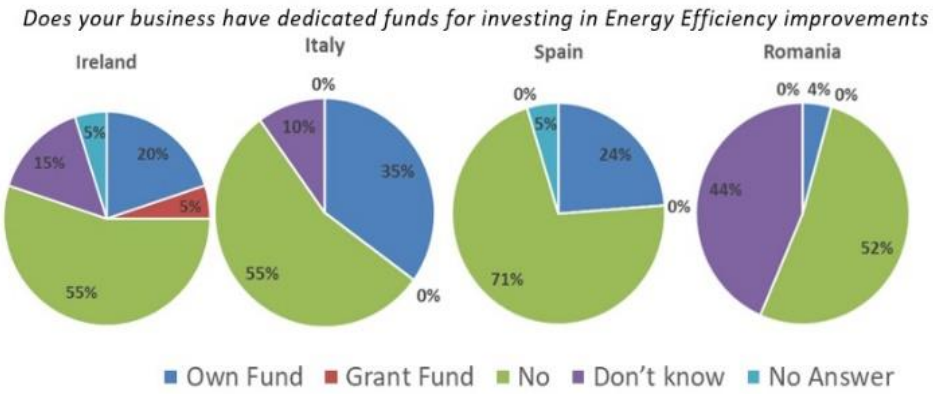

Figure 12: survey results about funds for investing in energy efficiency improvements for the SMEs of four pilot countries

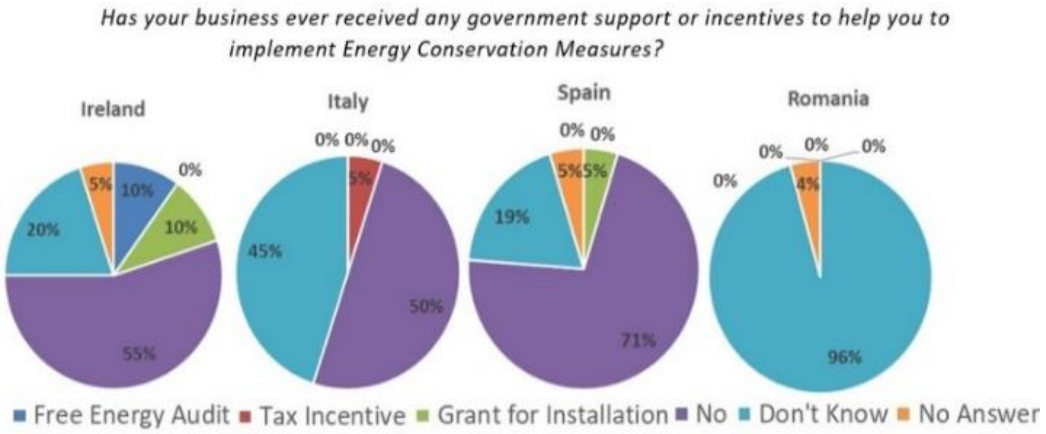

Figure 13: survey results about the support or incentives received from the Government for implementing energy conservation measures for the SMEs of four pilot countries

Most of the answers from Ireland, Italy and Romania would be happy to outsource their energy management whereas most of the replies from Spain would like to keep energy management their in-house activity (Figure 14). This indicates lack of awareness for available support but their willingness to implement energy efficiency within their organization. And another similarity is that majority of organizations have already implemented ECMs that are easy to implement with no complex technical expertise required for example, installing LEDs and lighting controls followed by HVAC controls. This points to SME's need of assistance for more complex ECMs implementation as they might lack time and specific knowledge within their organization.

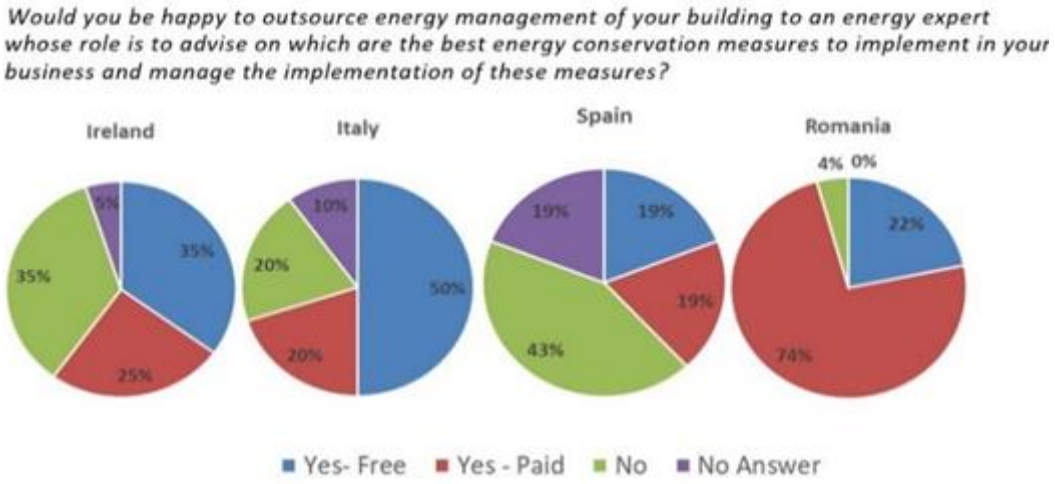

Figure 14: survey results about the outsourcing of energy management activities to an external consultant for the SMEs of four pilot countries

Most important differences among the pilot countries is the main barriers which is preventing them for implementing recommended ECMs (Figure 15). For Ireland the main barrier is lack of knowledge on which ECMs to implement and how to procure them. For 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 (Trianni and Cagno, 2012; Sorrell et al, 2000). 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 is one of the well-known split incentive effects arising when those who pay for the ECM implementation are not whose who eventually enjoy the benefits.

A recent study highlighted that this barrier exists also in the Netherlands, Germany and Belgium (Nie et al, 2020).

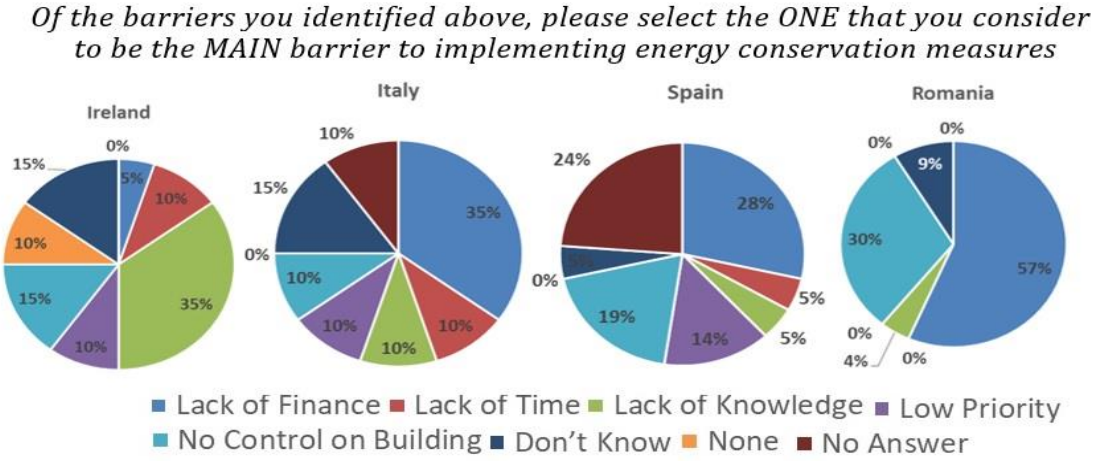

Figure 15: survey results about the main barrier to the implementation of energy conservation measures for the SMEs of four pilot countries

There are some differences between the opinion of SMEs and Stakeholders regarding the main barrier to energy efficiency for SMEs. According to majority of the respondent stakeholders lack of finance to invest in ECM implementation is major barrier for SMEs based in Ireland, Italy and Romania, whereas for Spanish SMEs energy efficiency is low priority. These different perception of barrier to energy efficiency is critical and very important to consider for the success of the project. These difference needs to be addressed by offering tailored SPEEDIER Service for each pilot country as per their specific challenges.

Detailed report on the survey results and responses is available in SPEEDIER website[1].

4.1.4 Focus Group Discussion

To supplement the results of online survey, focus group discussions with SMEs and energy experts were organized 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. To maintain the consistent discussion in all four pilot regions a questionnaire template was prepared for the use of moderator during the focus group discussion. The conversation was audio recorded and then anonymized transcript was prepared for each pilot region. In Spain separate focus group discussion was organized for SMEs and energy experts, whereas, in other pilot regions SMEs and energy experts participated in the same focus discussion.

[1] https://speedierproject.eu/it/

Breakdown of participants in Irish focus group by size and sector

Stakeholder Group	Size and Sector				
	Micro	Small	Medium	Large	Sector
SMEs	0	1	2	0	Manufacturing
Experts	3	0	2	0	Energy

Breakdown of participants in Romanian focus group by size and sector

Stakeholder Group	Size and Sector				
	Micro	Small	Medium	Large	Sector
SMEs	2	0	4	0	Hospitality
Experts	2 x Experts, unknown size				Energy agency and energy auditor

Breakdown of participants in Spanish focus group by size and sector

Stakeholder Group	Size and Sector				
	Micro	Small	Medium	Large	Sector
SMEs	1	2	0	1	Services
Experts	1	5	6	0	Energy auditors

Figure 16: Details of focus group attendees in Ireland, Spain and Romania

Figure 16 shows size and number of SMEs and Energy Experts who attended focus group discussion in Ireland, Spain and Romania. 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.

4.1.5 Key Learnings of the focus group discussion

The focus group discussions provided important and interesting insights regarding uptake of energy efficiency upgrades in SMEs of pilot region. There are differences in the opinion of SMEs and energy experts. As per SMEs, low priority of energy management and energy efficiency is major barrier for them, however 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 and 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 increase the level of engagement of SMEs with energy efficiency issues (Redmond and 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 and Revoltella, 2019). One of the significant findings of the SPEEDIER project is that not only lack of finance to implement ECMs is 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, high cost helps to determine the measures that can be prioritized 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 group 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 don't have in-house expertise dedicated to energy management, sometimes it is combined with other organizational 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 organization 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 publicized 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). More details are available in (SPEEDIER, 2020b).

4.2 SMEmPower Efficiency

The objective of the SMEmPower Efficiency project is to "Empower" SMEs to undergo energy audits and implement their proposals, addressing different barriers related to three dimensions: the Individual, the Organizational and the Institutional. The design and delivery of integrated Education & Training (E&T) programs, targeting energy related SME staff, of 5 ECTS/EQF 6 for at least 720 experts, is addressing the first dimension. The E&T programs will focus on the financial and technical data required to support the implementation of cost-effective energy efficiency improvement measures, while the trainees will collaborate with at least 160 SMEs as pilot installations for the practical action. This relates to the second dimension, targeting the SME decision makers. In-house specially designed short trainings for at least 800 decision makers and staff members of grouped SMEs will be delivered, by both partners and trainees. Finally, the third dimension includes 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, aiming to bridge the gap between energy audits and the actual financing of measures.

In addition, 4 long lasting training tools will be developed, namely advanced training handbooks in 7 languages, a web platform for energy analytics, a tool for Monitoring & Targeting and a tool for Measurement & Verification.

4.2.1 Online Survey

At the early stage of SMEmPower Efficiency, the consortium developed a methodology to gather data on SMEs energy cost, energy efficiency and other important parameters. Thus, a questionnaire was developed to conduct a survey. The information about the actual number of respondents is provided in (SMEmPowerEfficiency, 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, 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 1,000 toe/year (16%). The companies with a consumption between 500 and 1,000 were the least numerous in the survey (12%).

Moreover, targeted workshops were organized in order to identify which are the main barriers (Legislative, Institutional, Technical, Financial, Communication) that prohibit the implementation of energy efficiency measures in SMEs and to propose solutions.

The survey was focused on the seven objectives shown in Fig. 10, and it was based on a questionnaire, designed to contain closed-ended questions. The questionnaire included a combination of multiple selection questions, accepting several answers and multiple-choice questions, with single selections. Such closed-ended questions facilitated the data collection, made easier the data analysis and finally provided comparable results. The questionnaire also contained some open-ended questions. To ensure the success of the survey, the questionnaire was translated to all partner's local languages.

4.2.2 Key Learnings of the online survey

The survey's results highlighted that there are many similarities among the SMEs from different European regions. For example, 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 (Fig. 11). 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, 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 has 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, 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 SMEs investments in energy efficiency are: the pay-back period, which is usually too long; 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 pay-back period (Palm, 2009), and most of the respondents are expecting to see an energy bill reduction in a short time.

The above survey took place before the first COVID-19 pandemic outbreak. The pandemic definitely added new barriers in promoting energy efficiency for SMEs, because most of them are facing serious financial problems, severe curtailments in their turnovers and potential staff reductions. Improving the energy efficiency is currently considered a low priority. However, energy efficiency is a key factor to consider in the economic recovery plans to respond to COVID-19 of various countries, in order to prevent retaliatory, rebound of carbon emissions following the sharp drop in carbon emissions in 2020 (Wang and Wang, 2020). Detailed report on the survey results and responses is available in SMEmPower website (SMEmPower, D3.4).

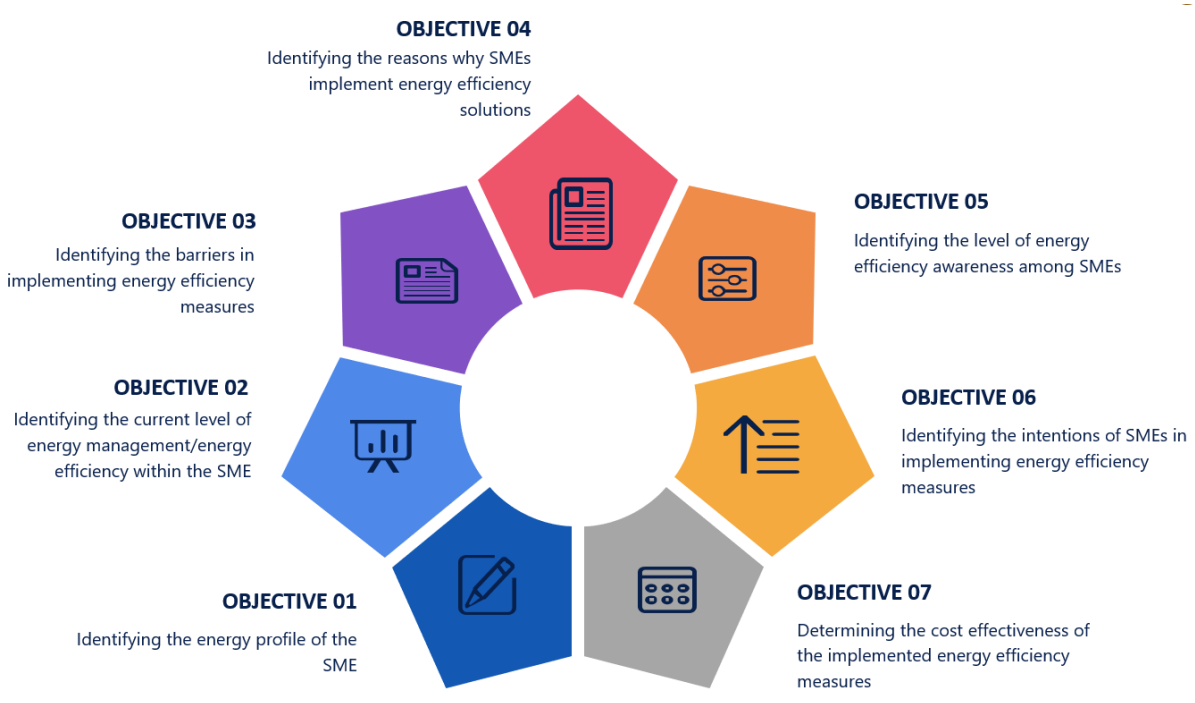

Figure 17: SMEmPower efficiency project: objectives of the survey

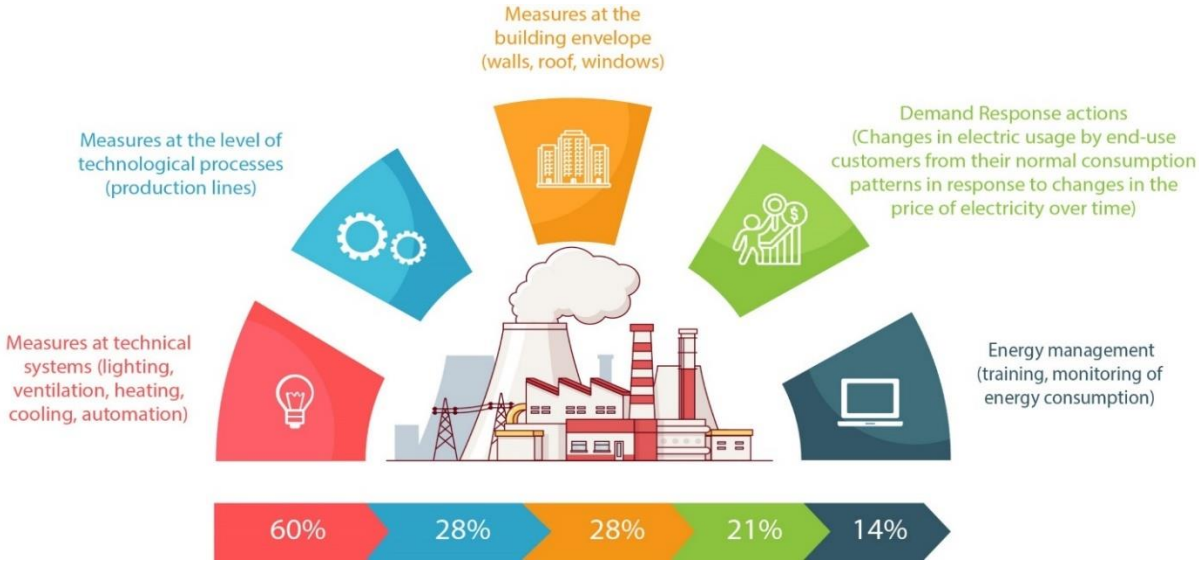

Figure 18: SMEmPower efficiency project: implemented energy efficiency improvements

4.3 E2DRIVER

E2DRIVER project aims to create awareness regarding benefits of energy auditing and energy efficiency within SMEs in the automotive sector. The European automotive industry ranks among the largest energy consumers worldwide. In the industry's complex manufacturing supply chains, small and medium scale auto parts suppliers consume about 90% of the total energy in production processes (Azevedo et al, 2013). 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 (Katchasuwanmanee et al, 2017).

The goal of E2DRIVER is to train SMEs in the automotive sector on energy auditing and energy saving measures for cost-effective energy efficiency improvements. To overcome the lack of knowledge, skills and awareness diffused in the industry, the project's integrative approach aims to boost capacity-building programs 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. Moreover, the development of the capacity-building program must be customized, considering the specific characteristics of the staff (academic background, position involved, years of experience, current energy skills, etc.). The goal of the E2DRIVER project is to provide the companies (12 pilot and 28 replication companies)[1] with an adaptive training path that adapts the competencies in energy efficiency to specific needs of each organization.

E2Driver aims at providing targeted training not only for the key decision makers and energy managers but also for other categories of employees such as Science and Engineering Professionals, Technician and Change agents. In principle all the employee of a SME might benefit from receiving knowledge about technical and non-technical aspects of energy efficiency, as well as their applications to the specific state of their company and their workplace. The E2DRIVER training covers the behavioural,

[1] The results presented in this paper refer to the 12 SMEs from the pilot phase.

cultural and organizational perspectives of energy efficiency. The method used by E2DRIVER trainers include an online training to transfer general and technical knowledge about energy efficiency and a face-to-face practical and interactive training session to discuss more specific aspects about achieving energy efficiency in their company (such as the most effective changes and energy measures to be implemented and the role that each employee must play in order to improve energy efficiency), to improve communication skills of employees and to generate motivation in assuming the right behaviours and attitudes toward energy efficiency. In addition, a consultancy service is provided after the training, in which possible energy efficiency measures for the company's own facility are worked out together with the company and the benefits in terms of energy and economic savings are calculated.

Before the actual training the E2DRIVER project conducted a survey to define target groups that will benefit from a customized 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 survey were conducted with each of 12 SMEs: staff questionnaire and energy assessment interview.

4.3.1 The Staff Questionnaire

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 organizational aspects and individual trainee's characteristics regarding role in the company, academic background, years of experience, etc. Through further questions, the degree of involvement of the trainee in the company's energy management planning and actions as well as his/her specific knowledge and skills regarding energy efficiency improvements is assessed (e.g., "Are you involved in the calculation of the potential for energy savings in your daily job?"). The second part of the questionnaire seeks to understand individual trainee preferences in regard to training methods and procedures (e.g., "What are your preferences about the formats of training material on energy audit?") as well as to assess trainee's past training experiences and his/her expectations to be achieved through the involvement into the E2DRIVER project.

45 questionnaires from 12 SMEs within four participant countries were received. The questionnaire was structured as a sequence of multiple choice and open questions trying to investigate trainee's characteristics from both organization and energy knowledge point of view. Organizational aspects are crucial to highlight personal characteristics of the trainee (the role in the company, academic background, years of experience, etc.) as well as training methodology preferences. Current knowledge about energy efficiency topics is investigated so that it is possible to understand how energy management is perceived in the daily work activities.

4.3.2 Key Learnings from the staff survey

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 organized 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. Most respondents are not familiar with the capabilities offered by new technological means and technologies such as augmented reality (AR) and virtual reality (VR) as only a very small number of them (mostly managers) has previously participated in other non-typical/non-traditional educational initiatives.

4.3.3 Energy Assessment Interview

Energy assessment interview was conducted with the energy manager/maintenance or staff responsible for energy management in each of the 12 companies. The interview was conducted in two parts. In the first part, the proposed questions concern the companies' energy consumption, energy management and auditing procedures, Key Performance Indicators (KPIs), energy policy and, more generally, the as-is state of their energy framework (e. g. "Do you manage energy consumption in your company?" or " Do you know the regulation that apply in your country and region about energy efficiency?"). In the second part, a general assessment of available technologies and past/future energy efficiency measures is conducted for each pilot company (e. g. "What kind of energy efficiency measures were considered or implemented during the last 2 years?" or "Expected potential for improvement in the next 2 years"), so that initial insight can be gained into which technology area is most likely to be improved from an energy perspective.

4.3.4 Key Learnings of the energy assessment interviews

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 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 two years prior to the project (n = 48) or that are planned for the upcoming two 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.

Table 1: Energy efficiency measures of E2DRIVER (implemented prior to the project or planned within the project).

Area	Sector	Measures
Supply technologies	Electric drives	• High efficiency motors • Inverters installation
	Compressed air systems	• More efficient equipment • Inverters installation (VSD) • Leakage detection on regular basis
	Pump systems	Variable Speed Drive (inverter)
	Process cooling	• Heat recovery from cooling circuit • AHU substitution • Set point temperature optimization
	Process heating	• Heat pipes insulation • AHU substitution • Installation of condensing boiler
	Logistics	• Low-emission/electric vehicle fleet • Substitution of gasoline forklifts with electric ones
Building technologies	Building heating/cooling	• Boiler substitution • Compressors exhaust heat recovery • Heat recovery from process • Heat pumps
	Building envelope	• Building insulation • Heat recovery from process
	Lighting	• LED installation • Light and presence detection sensors
	ICT	Server and machinery substitution
	Air supply and climatization	• HVAC optimization • Free coolers adoption
Production processes	Processes	New efficient process equipment

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 facts, 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 organizations 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.

Summarising the key leanings from and taking into account the information deficit of some companies, the E2DRIVER project seeks to generate a solution to increase the collective intelligence of the automotive sector regarding energy efficiency and energy auditing. The novelty of the E2DRIVER methodology compared to other EU projects is a solution design based on personalised capacity building programmes tailored to the needs and interests of companies (with a focus on SMEs) and their worker, which can be also transferred to other sectors. On one hand, the cornerstone is the customisation of the trainings, based on the scheme of classifying the trainees in four groups to allow for personalized learning. On the other hand, it must be emphasised that the E2DRIVER trainings follow the Ontological Flip Teaching as pedagogical approach, with blended learning and academic works as the key points of this approach. Finally, these capacity building programmes offer a high level of interactivity thanks to the platform and new technologies such as the virtual reality.

Detailed report on the results are available in E2DRIVER website (E2DRIVER, Deliverable D2.2).

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

This paper thoroughly analysed the methodologies and findings of the projects: Innoveas[1], Triple-A[2], DEESME[3] and ICCEE[4], 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 of 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 in this paper due to lack of space. Results of the performed analysis are available in synthetic for in tables 2 and 3.

5 Discussion

Each project identified attitude of SMEs towards importance of energy management and energy efficiency and a set of barriers to uptake of energy efficiency upgrades. These attitude 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.

The barriers, drivers and other influencing factors have been studied using the research framework in Figure 1 and identified within the three dimensions: Institutional, Organisational and Individual. The

[1] https://innoveas.eu/
[2] https://www.aaa-h2020.eu/
[3] https://www.deesme.eu/
[4] https://iccee.eu/

comparative analysis of the projects is reported in table I. The research framework introduced in section 3 enabled to analyse the results obtained from the empirical research conducted in the seven projects through the surveys.

Table 2: Comparative analysis of the seven projects (B: Barrier, D: Driver)

Project	Institutional dimension	Organisational 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 payback 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 technical knowledge, need for training (B)	Low risk propension 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

		Lack of awareness (B) Sufficient financial availability for energy efficiency improvements (D)			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.
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 organizations, 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 contribution of this paper to the overall scientific knowledge in the field is to reassess 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. In fact, it is unrealistic to assume that the barriers and drivers faced by the SMEs with respect to energy efficiency can be discovered once for all by the scientific research. Several experts in the field agree upon the fact that the regulations, technologies and markets relevant with the energy efficiency in SMEs may be significantly changing every five years. Excellent papers such as (Trianni and Cagno, 2012) and (Thollander et al., 2007) might be considered outdated by experts and therefore most of their findings need to be reassessed. In addition, other papers developed narrower research than this paper. (Catarino et al., 2015) focused only on Portuguese SMEs. (Hampton, 2019) considered only three SMEs in 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., 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. Many more examples could be added to this list of focused research papers about energy efficiency in SMEs. The reader of such publications may doubt about the generality of those findings and think how the differences between the countries and the industrial sectors could lead to different conclusions. The analysis reported in this paper covers instead SMEs from the sectors: manufacturing, services, energy, education, commercial, hospitality, automotive, industrial, building sector, food supply chain (with refrigeration) from several countries: Ireland, Spain, Italy, Romania, Cyprus, Germany, Greece, Slovenia, United Kingdom, 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, but it does not tackle the challenges associated to lack of financial resources, lack of information, and limited in-house skills. Focusing only on the auditing process, the authors do not elaborate on aspects such as 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 were addressed in this paper.

6 Conclusion

This paper has contributed to analyse the decision-making of SMEs with respect to energy audit and energy efficiency implementation by tying together the results of seven currently running European projects (Speedier, SMEmPower Efficiency, E2Driver, Innoveas, Triple-A, DEESME and ICCEE). It adopted a research framework which assumes barriers and drivers and other influencing factors within the three dimensions 1) institutional, 2) organisational 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 audit and energy efficiency implementation vary as per the SME's country of operation, business sector, size, building ownership (a summary was presented in table II).

This paper has investigated energy efficiency in European SMEs using very recent data collected through surveys, in a much wider 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 (see previous section for a thorough discussion).

The lessons learned from the projects concern 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 adapted to the various professional roles to be effective. SMEs need training actions which can help them to appoint an energy manager, to develop an energy efficiency strategy and a policy, 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 may play a significant role in whole supply chains, like in the food and beverage sector. 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 win the reluctance of SMEs in undertaking energy audits and implementing energy management systems and energy efficient retrofits. Energy audits are recommended to determine the specific needs and requirements of each SME and their attitude towards energy efficiency. Experts of energy efficiency and auditors should guide the SMEs through a gradual implementation of energy efficiency measures, starting with the no-cost ones and those low-cost ones which can be financed; and then letting the energy cost savings accumulate such that more powerful measures can be purchased. The implementation of the seven projects' recommendations will contribute 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.

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 behavior, 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 organizations (Lopes et al, 2018).

Acknowledgement

The projects Speedier, SMEmPower Efficiency, E2Driver, Innoveas, Triple-A, DEESME and ICCEE have been funded by the European Commission under the H2020 programme.

Appendix

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 on 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. This is illustrated in Fig. 2 and will be the subject of a forthcoming publication.
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, Organizational, and Institutional.
Participants	**213** SMEs engaged in **8** countries (Cyprus, Germany, Greece, Italy, Romania, Slovenia, Spain and the UK) with a minimum **4,973** 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, national support schemes etc. 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.
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 replications 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.
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 prioritize in the short-term low risk energy efficiency measures such as lighting, electric drives, compressed air systems, 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.
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 realize 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.
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, policy makers, 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.
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, production efficiency, etc.
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 11 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 on energy efficiency opportunities.
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 organizations struggle with EEMs implementation because of the high investment costs and might find interesting opportunities for a cooperation with other companies of their CSCs.

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