Barriers, drivers and decision-making process for industrial energy efficiency: A broad study among manufacturing small and medium-sized enterprises ☆

Andrea Trianni [a,*], Enrico Cagno [a], Stefano Farné [b]

[a] *Politecnico di Milano, Dept. Management, Economics and Industrial Engineering, Piazza Leonardo da Vinci 32, 20133 Milan, Italy*
[b] *Università degli Studi di Pavia, Dept. Industrial Engineering and Information Technology, Via A. Ferrata 5, 27100 Pavia, Italy*

Energy efficiency has been recognized as a primary means to increase the competitiveness of the indus-trial sector, and in particular for small and medium-sized enterprises (SMEs), in which energy efficiency measures (EEMs) are scarcely implemented. For this reason, future policies should carefully address such issue. Hence, it is really crucial to have a precise and punctual knowledge of the barriers to be tackled in the decision-making process of adopting an EEM and the drivers to be promoted. This study discussed the findings from a broad investigation within 222 manufacturing SMEs located in a Northern Italy region. Beside economic issues particularly affecting SMEs, awareness and behavioural issues emerge as critical, affecting the very first steps of the decision-making process, related to the punctual identification and evaluation of plausible EEMs. The support from manufacturers, technology suppliers, installers and ESCOs supporting SMEs through vocational training drivers (e.g. technical support) is really important to tackle such issues. More generally, beside financial institutions, the supply chain of technologies is recognized as particularly useful for supporting enterprises in the adoption of EEMs. Additionally, having previously conducted energy audit and implemented EEMs are critical factors able to highlight non-economic barriers and drivers. Therefore, the promotion of EEMs will necessarily imply a further effort in pointing out the so-called non-energy benefits (NEBs) from the implementation of EEMs. Finally, our study reveals that smaller and non-energy intensive emerge as most critical and therefore deserve greater attention from policy-makers.

Keywords:
Industrial energy efficiency
Barriers
Drivers
Decision-making
Small and medium-sized enterprises

1. Introduction and background of the study

According to recent estimates in Italy, industrial energy efficiency is considered as the best cost-effective means of reducing fossil fuel consumption, thus with consequent benefits in terms of mitigating greenhouse gas emissions [1]. Moreover, we should take into account that Italy is one of the European countries with the largest energy dependence (more than 80%) compared with

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* Corresponding author.
E-mail addresses: andrea.trianni@polimi.it (A. Trianni), enrico.cagno@polimi.it (E. Cagno), stefano.farne@unipv.it (S. Farné).

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an EU-28 average of 53.4% [2]. Therefore, increased energy efficiency means also improved energy supply security, which is crucial to ensure a sustainable industrial development.

Industrial energy efficiency measures (EEMs) are widely known, both in case of process-specific industries and for cross-cutting technologies. Recent contributions in literature are trying to provide a structured classification of their characteristics (see, e.g.[3]), so to highlight the effective benefits from their implementation for both industrial decision-makers as well as policy-makers [4]. Nonetheless, the low implementation rate of such measures in the industrial context (see, e.g. [5]; and, more recently, [6]) represents a clear warning of the existence of an ''en-ergy efficiency gap'' [7] due to several barriers [8].

Barriers to industrial energy efficiency represent a consolidated stream in literature, with several theoretical contributions (from various perspectives: for a summary, see, e.g. [9]) and empirical investigations at all levels. In particular, just referring to the last fifteen years, several transnational, national, regional, and local studies can be found, exploring different sectors and firm sizes, as summarized in Table 1. In such studies pieces of evidence shed light on the existence of barriers of various nature (e.g. economic, behavioural, organisational), within and outside an enterprise. Indeed, it can be inferred by the literature review that enterprises are obstructed from implementing EEMs by a combination of such barriers. According to recent research [42], barriers can be categorised as: (i) economic; (ii) information-related; (iii) organisational; (iv) behavioural; (v) competence-related; (vi) technology-related; and (vii) awareness. In addition, studies have highlighted the relevance of several firm characteristics (e.g. sector, firm size) affecting the enterprises' barriers to EEMs' implementation (e.g. [34]). Recently, as pointed out by Cagno and Trianni [13], it has also been possible to observe that barriers may considerably vary according to EEMs' characteristics, such as ease of implementation, specific technical requirements, produc-tion disruption, etc.

In turn, the existence of barriers at various levels offers justification for continuous efforts in developing the most effective means (i.e. drivers) within enterprises to tackle the energy efficiency gap, so to promote EEMs. In this regard, some contributions have been provided mainly at empirical level, with investigations in different industrial contexts, as shown in Table 2.

Similarly to what observed for barriers, studies are pointing out that drivers of various natures may stimulate enterprises in the adoption of EEMs (see, e.g. [12,44]). In particular, scholars have recently highlighted the existence of drivers within a company (e.g. management commitment, or cost reduction due to lower energy use), acting in combination with external ones (e.g. public incentives, threat of rising of energy prices). Nonetheless, the theoretical background for drivers has received little attention by scholars, as few contributions have attempted categorising them (see, e.g. [44,45]) and just recently scholars have started linking barriers and drivers in the decision-making process [31,46]. In particular, Trianni et al. [47], based on a recent taxonomy of barriers to industrial energy efficiency (reported in Table 3), have developed a structured list of drivers (see Table 4). In doing so, taking inspiration from previous literature contributions, they have divided drivers according to several categories, as follows: regulatory, economic, information, and vocational training. They have additionally suggested to distinguish between external and internal drivers (according to their origin with respect to an enterprise). Moreover, they have modelled the possible relationships between barriers and drivers in the decision-making process (Fig. 1). Specifically, the modelled steps of the decision-making process are as follows: (i) generation of awareness, (ii) identification of needs and opportunities, (iii) technology identification, (iv) planning of the intervention, (v) financial and economic analysis, (vi) implementation, start-up and training. Finally, taking inspiration from the approach of Hirst and Brown [48], they have pointed out some relevant stakeholders that could best promote drivers to energy efficiency, namely: Governmental authorities (A1), Energy suppliers, (A2), Manufacturers (A3), Technology suppliers (A4), Installers (A5), Financial institutions (A6), ESCOs (A7), Industrial Associations and Groupings (IAGs, A8), Clients (A9), Competitors (A10), Allies (A11), and the Firm itself (A12).

Nevertheless, despite the existence of such theoretical frame, for the success of any particular action by policy-makers to pro-mote industrial energy efficiency, a sound empirical understanding of the barriers and the drivers is needed. Here, literature approaches have so far been limited in evaluating barriers and driving forces in general terms (for a recent contribution see, e.g.[12]), thus without a specific zoom on understanding which is the role of drivers and barriers in the decision-making process of adopting an EEM, and how they may vary accordingly. Moreover, studies have paid scarce attention in providing empirical knowl-edge to highlight the stakeholders that would best promote the drivers for increased industrial energy efficiency. In this respect, in the present study we aim at providing a broad picture of barriers and drivers to industrial energy efficiency in the decision-making process, by conducting a broad empirical investigation of the Italian largest industrial area and exploring some firm characteris-tics (i.e. size and energy intensity) that influence, either positively or negatively, the value of barriers and drivers.

The paper's novelty relies on some crucial elements. First, no study has so far looked at which are the most relevant barriers in the steps of the decision-making process of adopting an EEM, and which are consequently the drivers to tackle such barriers. This would result quite relevant for e.g. policy-making purposes, as it may clearly point out if and how specific drivers are able to tackle the most relevant barriers. This would represent, in turn, a solid basis for the development of most effective policies on the ground. Second, to the authors' awareness, no study has so far presented simultaneously results on barriers and drivers for industrial energy efficiency in Italy (i.e. investigating barriers and drivers). Indeed, obtaining a snapshot of barriers and drivers is crucial in order to link them for policy-making purposes, also considering that barriers and drivers evolve over time. Third, in doing so, we are also interested if previous experience with energy efficiency issues (e.g. having recently conducted an energy audit, or having implemented a measure specifically for energy efficiency purposes) may affect barriers and drivers, as well as the decision-making process. This offers a unique opportunity to provide empirical evidence of the importance of some specific policy measures, thus for the promotion of future energy policies for manufacturing SMEs. Fourth, this study represents a first empirical contribution highlighting the role of stakeholders in promoting the drivers in different steps of the decision-making process, and possibly varying their role according to several firm characteristics. This is quite interesting for industrial decision-makers, as well as for policy-makers, revealing the most effective stakeholders able to support enterprises (through specific actions, i.e. drivers) in tackling their barriers to increased energy efficiency. Even though we acknowledge that the results of this study cannot be generalised for all European countries and industrial contexts, the findings represent a good basis for further investiga-tion and research in industry.

The remaining of the paper has been structured as follows: in Section 2 we will describe the research methods and the sample involved in the investigation. Section 3 will be devoted to present and discuss the results, leaving in Section 4 conclusions and further research.

Table 1
Overview of empirical studies on barriers to industrial energy efficiency, integrating the contributions from recent reviews [10–13].

Study	Sector	Area	Main barriers
[14]	All sectors	India	Lack of awareness and high initial costs
[15]	All sectors	Australia	Low rates of return; long payback periods; auditors assessment inaccurate
[16]	Industrial sector	UK	Other priorities for capital investments; lack of time and technology not appropriate
[17]	Chemical, Basic Metals, Metal products, Horticulture, Food, Paper	The Netherlands	Other investments more important; technology can only be implemented after existing technology has been replaced; energy costs are not sufficiently important
[18]	Electric motor market	Germany	Split incentives; lack of information; hidden costs
[5]	Manufacturing SMEs	USA	Too expensive initially; lack of staff for analysis/implementation; cash flow prevents implementation
[19]	Mechanical engineering industry	Ireland	Other priorities for capital investments
[20]	Non-energy-intensive manufacturing	Sweden	Cost of production disruption/hassle/inconvenience; lack of time or other priorities; cost of obtaining information about the energy consumption of purchased equipment
[21]	Foundry, Brick	Karnataka, India	Financial and economic barrier; behaviour and personal barrier; awareness and information barrier
[22]	Manufacturing SMEs	Sweden	Lack of time or other priorities; other priorities for capital investment; access to capital
[23]	Foundry	Sweden	Access to capital; technical risks such as risk of production disruptions; lack of budget funding
[24]	Commerce – services	Germany	Split incentives; lack of information about energy consumption patterns
[25]	Pulp and paper	Sweden	Technical risks such as risk of production disruptions; cost of production disruption/hassle/inconvenience; technology is inappropriate at the mill
[26]	SMEs	China	High initial capital cost; absence of economic incentives policies; lack environmental enforcement
[27]	Metals, Machinery, Food/Drink, Chemicals, Paper, Textiles	Greece	Bureaucratic procedures to get governmental financial support; limited access to capital; increased perceived cost of ECM
[28]	Commerce – services	Germany	Lack of information about energy consumption patterns; lack of time; low status of energy efficiency
[29]	Petrochemicals	OECD	Shortage of staff and time; competition from other prioritised projects; unfavorable economic conditions
[30]	Energy-intensive chemical industry	The Netherlands	Budget restrictions and investment priorities; rules of investment decision making; technology fitting in actual process
[31]	Manufacturing industry	Thailand	Other priorities; cost of production disruption; lack of financial incentives
[58]	Manufacturing industries	USA	High investment costs
[32]	ISI	Japan	Other priority for financial investment; inadequate national policies and regulations; technology not applicable to process
[33]	Electricity-intensive commercial and industrial sectors	Switzerland	Lack of interest in energy-efficiency interventions; other priorities for capital investments
[10,11]	SMEs	Germany	Investment costs too high; other investments have higher priority; measure not profitable
[34]	Non-energy-intensive manufacturing SMEs	Northern Italy	Access to capital; scarce information regarding energy efficiency opportunities and winning solutions; poor information for the energy efficiency decisions
[35]	Process industries with a focus on a low grade heat utilisation	UK	Availability of appropriate infrastructure; utilisation of low grade heat; high capital costs
[36]	SMEs	China	Lack of interest in energy efficiency; information and other priorities
[37]	Foundry	Finland, France, Germany, Italy, Poland, Spain, and Sweden	Lack of budget funding; other priorities for capital investments; lack of time or other priorities
[38]	Primary metal manufacturing SMEs	Northern Italy	Information issues on energy contracts; lack of interest in energy-efficiency interventions; hidden costs
[39]	Manufacturing SMEs	Northern Italy	Investment costs; information issues on energy contracts; hidden costs
[40]	Selected industries (Iron and Steel, Aluminium, Food, Plastcs, Chemicals)	Ghana	Lack of budget funding; access to capital; other priorities for capital investment
[41]	Ceramice, Cement, Lime	Belgium	Other priorities for capital investments; hidden costs; technical feasibility was not studied before
[12]	Iron and steel industry	Sweden	Internal economic and behavioural barriers
[13]	Primary metals manufacturing SMEs	Italy	Other priorities and lack of competences in implementing the interventions; barriers vary significantly according to the intervention considered
[15]	All sectors	Australia	Low rates of return, long payback periods, auditors assessment inaccurate

2. Research methods

The research has focused on manufacturing SMEs[1] located in Lombardy region, Northern Italy. In particular, the investigation takes place in the richest and most industrialized Italian region, with about 800,000 enterprises and 3.77 million employees [49]. Lombardy generates 22.4% of the whole Italian gross domestic product (GDP), and has a GDP per capita 33% higher than that of the EU27 in 2010 [50]. Moreover, our focus on manufacturing SMEs is due to the following reasons:

- manufacturing sector is the largest and prevalent industrial activity in Lombardy;
- manufacturing SMEs represent the industrial backbone of the region and crucial for the whole region's competitiveness (in terms of number of enterprises, employees, value added, etc.);

[1] A SME is here intended an enterprise according to the 2003 recommendation of the European Council [57].

Table 2
Overview of recent empirical studies on drivers to industrial energy efficiency, extending the approach of Brunke et al. [12].

Study	Sector	Area	Main drivers
[17]	Chemical, Basic Metals, Metal products, Horticulture, Food, Paper	The Netherlands	Green image for the firm
[5]	Manufacturing SMEs	USA	Publicly financed energy audits
[20]	Non-energy intensive manufacturing	Sweden	Long-term energy strategy, increasing energy prices, people with real ambition
[22]	Manufacturing SMEs	Sweden	Long-term strategy; people with real ambition; environmental company profile and/or EMS
[23]	Foundry	Sweden	Long-term strategy; people with real ambition; environmental company profile
[43]	Printing SMEs	The Netherlands	Improved working conditions
[25]	Pulp and Paper	Sweden	Cost reductions resulting from lower energy use; people with real ambition; long-term energy strategy
[29]	Petrochemicals	OECD	Process energy costs savings; tight supply of gas feedstock; personal commitment of individuals
[31]	Manufacturing industries	Thailand	Production cost reductions from lowered energy use; staff health and safety; and improvements in product quality
[44]	Manufacturing SMEs	Italy	Allowances or public financing; external pressures; long-term benefits
[45]	Foundry	Finland, France, Germany, Italy, Poland, Spain, and Sweden	Cost reductions; threat of rise in energy prices and energy taxes; commitment by top management
[40]	Selected industries (steel, aluminium, food, plastics, chemicals)	Ghana	Cost reduction resulting from lowered energy use; threat of rising energy prices; energy efficiency requirements by government
[41]	Ceramic, cement, lime	Belgium	Increasing energy prices; commitment by top management; environmental image
[12]	Iron and steel	Sweden	Commitment from top management; cost reduction resulting from lowered energy use; long-term energy strategy

– manufacturing SMEs are widely considered as less energy-efficient, compared to larger enterprises [51].

Therefore, given that the focus was on manufacturing SMEs in Lombardy region, enterprises meeting these three requirements were chosen for the research. The preliminary list of potentially suitable case studies has been created from company databases available from several sources and a market research institute (AIDA, a database of Italian enterprises) that have been integrated, leading to a total list of 1467 SMEs. The final selection was made by contacting the companies through either e-mail or telephone to discuss with them their availability as well as getting confirmation of their suitability, leading to a total of 222 companies, distributed as follows in terms of firm size and energy intensity (see Fig. 2). In particular, SMEs were divided into three size clusters (small, medium-small and medium-large), taking inspiration from previous research that highlighted possible differences among barriers [34]. Energy intensity has been measured considering the ratio between energy expenditures and production costs, with a thresh-old of 5%, as suggested from previous literature [39]. About 46% of the involved SMEs had conducted an energy audit in the previous 3 years, and about 58% had recently (i.e. within the last 3 years) implemented EEMs.

The interviews with the firms' respondents were audio-recorded (whenever received the availability by respondents for privacy reasons, even if the confidentiality of the information was assured) and transcribed for analysis (so to obtain *construct validity*). The interviews, using a questionnaire as a guide, have been carried out in 3 main phases: in the first respondents have provided a general description of their enterprise, the processes in place, the type of manufactured products, specifying their role within the company (through a combination of close and open questions). In fact, we have asked specifically to discuss with peo-ple responsible for energy efficiency investments, but the profile could vary from firm's owners (almost exclusively, considering that we investigated SMEs), operations managers, maintenance managers, etc. The second phase was devoted to provide his/her view about barriers, grouped in categories (for time limitation, as from Table 3), providing a synthetic value for the whole company, followed by an indication of the two decision-making process steps most affected by the identified barrier. The third phase was devoted to drivers for energy efficiency, that have been asked in general terms grouped by categories (for time limitation, as from Table 4), followed by an indication on which barriers they can best

Table 3
Taxonomy of barriers adopted for empirical investigation. *Source*: [42].

Categories	Barriers
Technology-related	Technologies not adequate Technologies not available
Information-related	Lack of information on costs and benefits Information not clear by technology providers Trustworthiness of the information source Information issues on energy contracts
Economic	Low capital availability Investment costs External risks Intervention not sufficiently profitable Intervention-related risks Hidden costs
Behavioural	Other priorities Lack of sharing the objectives Lack of interest in energy-efficiency interventions Imperfect evaluation criteria Inertia
Organizational	Lack of time Divergent interests Lack of internal control Complex decision chain Low status of energy efficiency
Competence-related	Implementing the interventions Identifying the inefficiencies Identifying the opportunities Difficulty in gathering external skills
Awareness	Lack of awareness

Table 4
Taxonomy of drivers for empirical investigation. Adapted from [39].

Categories	Drivers
Regulatory Internal	Long-term energy strategy Willingness to compete Green image Voluntary agreements
Regulatory External	Clarity of information External energy audit/submetering Increasing energy tariffs Efficiency due to legal restrictions Technological appeal Trustworthiness of information
Economic Internal	Cost reduction from lower energy use Information about real costs
Economic External	Management support Public investment subsidies Private financing
Informative Internal	Management with ambitions Staff with real ambitions Knowledge of non-energy benefits
Informative External	External cooperation Availability of information Awareness
Vocational training Internal Vocational training External	Programs of education and training Technical support

tackle in each decision-making step. In case of external drivers, respondents have been also asked to indicate the two most responsible stakeholders for driver's promotion. The case study database has been integrated incorporating additional information (secondary data) from company website, with detailed reports drafted to aid analysis [52,53]. This step allowed us to achieve data triangulation, which is a critical issue for results' *reliability* [54].

3. Results and discussion

3.1. Analysis of the whole sample

3.1.1. Barriers to energy efficiency

Fig. 3(a) clearly shows three areas: (i) economic barriers, with a value higher than 3; (ii) five categories of barriers in the range 2–2.5; (iii) technology-related barriers, perceived as very low (around 1.70). As recently pointed out by Brunke et al. [12], authors have widely discussed the major relevance of economic issues. To mention some recent studies, Trianni et al. [39], in a very detailed investigation among 48 Italian SMEs, highlighted the relevance of several economic issues, such as: high investment costs, hidden costs, low returns from investments, and lack of access to capital (either public or private). It is worth noting that, according to such investigation, enterprises may have so far adopted a "defensive" approach in their production strategies, trying to keep their market share (64% of the SMEs, and 69.4% of large enterprises), claiming to suffer a lack of financial resources to counterbalance the crisis and reverse the recent trends of decreased competitiveness of the Italian industrial system. Hence, we can conclude that here

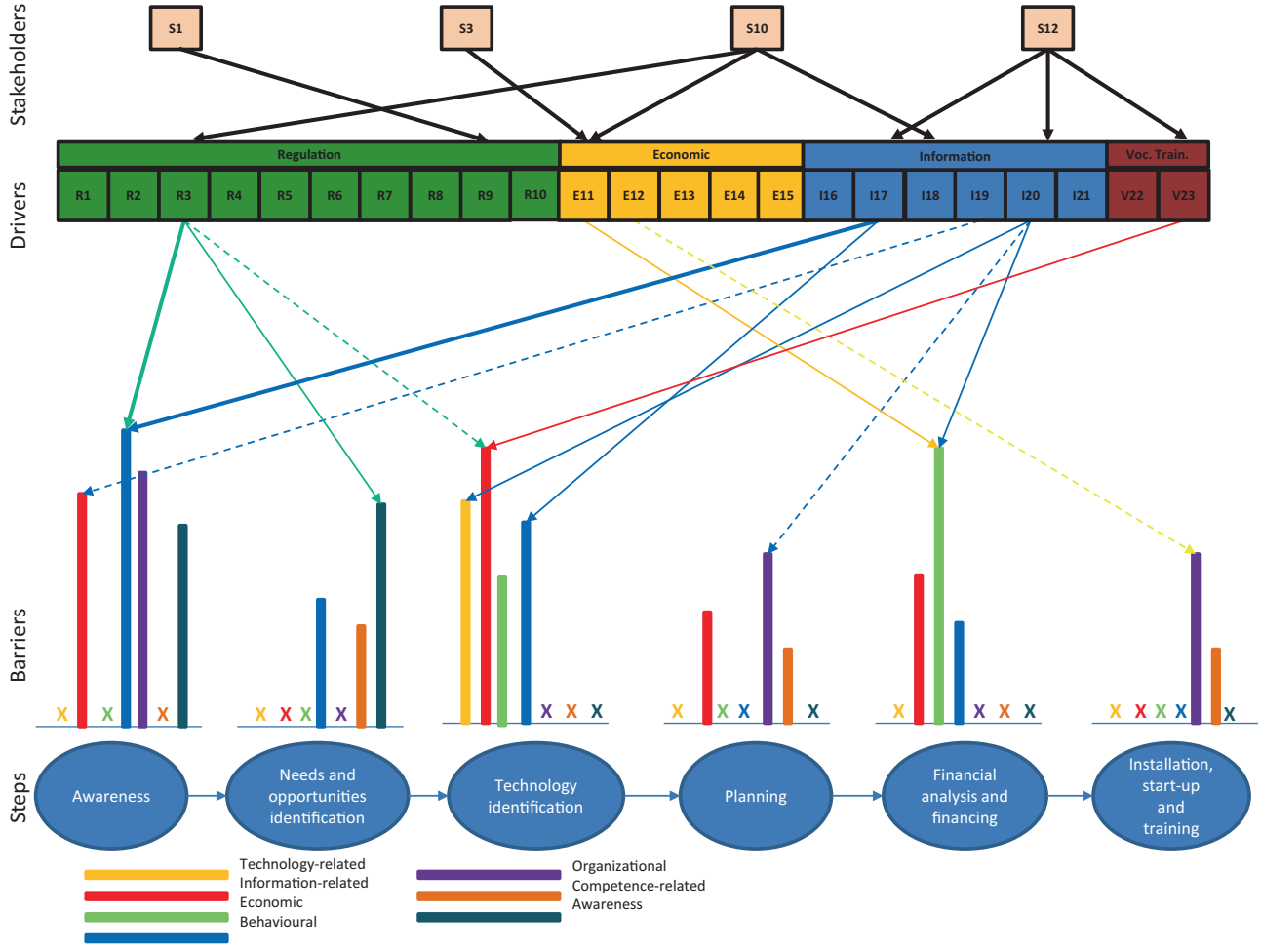
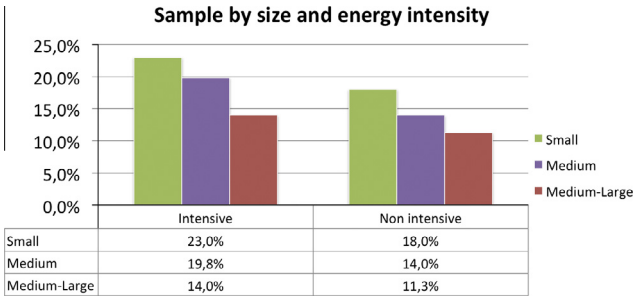


Fig. 1. The framework to describe the mechanisms connecting barriers, drivers and stakeholders in the decision-making process to undertake an investment in an EEM. (*Source*: [37]).



	Intensive	Non intensive
Small	23,0%	18,0%
Medium	19,8%	14,0%
Medium-Large	14,0%	11,3%

Fig. 2. Distribution of the sample by firm size and energy intensity.

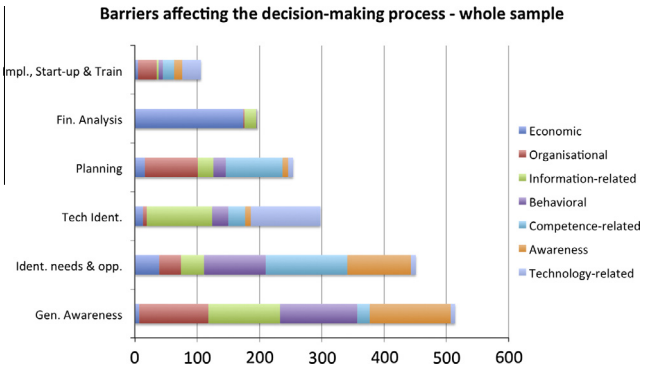


Fig. 4. Effect of barriers on the decision-making process of investing in an EEM – whole sample. The bars report the total summated scores given to a barrier (by category) with respect to the specific decision-making step.

enterprises have started looking as energy efficiency as an effective means for their competitiveness. Slight differences can be observed in Rohdin and Thollander [20], who highlighted the production disruption issues (a form of hidden costs) as major barrier to implementing EEMs. Considering that such studies have been specifically focused on barriers, with greater detail than here, and that economic issues almost always emerged as the primary issue, we can say that the results seem aligned with previous literature.

By considering the "middle-ranked" barriers, despite a homogenous result on average, some differences can be indeed appreciated by looking at the analysis of frequencies, see Fig. 3(b).

Firstly, the lack of awareness, within the two thirds of enterprises evaluating it with some importance, is almost equally distributed. Secondly, more than half of the interviewed enterprises have evaluated their behaviours towards energy efficiency issues as somehow appropriate (i.e. those evaluating behavioural barriers as important or very important is less than 50%). Moreover, a relevant share of enterprises (about 40%) has evaluated the lack of awareness on energy efficiency as a primary issue for implementing EEMs. Such shares may result even more critical for policy-making purposes if we consider the limitation of our approach. In fact, we should note that the investigation reports a self-assessment of the barriers. Therefore, results could be biased by the unwillingness to reveal personal lacks or faults (in a "defensive" approach) in managing energy efficiency issues, therefore leading to a much greater importance of behavioural and awareness barriers, as pointed out by other studies (e.g. [39]).

3.1.2. How barriers affect the decision-making process

Fig. 4 allows understanding (i) the decision-making steps mostly affected by the barriers; and (ii) for each decision-making step, which is the most critical barrier. At a first look, two com-ments appear as apparent. Firstly, we can observe a general trend: the highest resistance is found in the first steps, as the total rele-vance of barriers is decreasing from the generation of awareness to the installation of the equipment, start-up and training. Secondly, limiting the analysis of barriers in general terms, as lar-gely done by previous literature, seems somehow weak. In fact, although economic barriers are ranked highest, their effect is almost exclusively limited to the fifth step (financial analysis and evaluation), with very little role in the identification of needs and opportunities (cost for energy audits, etc.). Therefore, and to some extent new with respect to previous literature, our findings reveal that several other barriers have greater effect than economic ones in the very beginning of the decision-making process. In fact, the *lack of awareness* and *behavioural* barriers, although present a

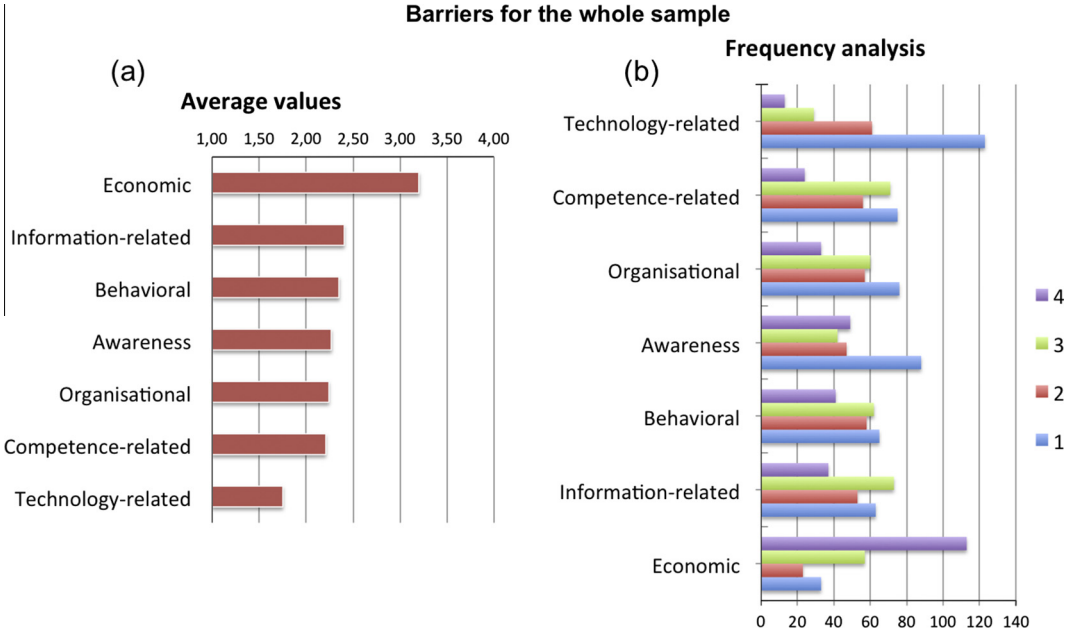


Fig. 3. Barriers to energy efficiency for the whole sample. (a) Average values. (b) Frequency analysis of the responses. Barriers have been asked on a even Likert scale ranging from 1 – not important to 4 – very important.

lower value on average, play the lion's share for the generation of awareness and identification of needs and opportunities, whilst they decrease their relevance at the final steps.

By looking at barriers by categories, *organizational* issues mainly affect two steps, namely the generation of awareness (step 1) and planning (step 4). Additionally, some sort of relevance could be also appreciated in the phase of implementation, start-up and training (step 6). The characteristics of the investigated sample could at least partially provide explanation of this result. The lim-ited size of such enterprises may deeply affect the lack of time, jeopardizing on the one hand the comprehension of how energy efficiency issues may be relevant; on the other hand, they inhibit the development of an energy efficiency culture and awareness. Additionally, SMEs may not have people knowledgeable of energy efficiency issue at their site, therefore not being able to manage the whole process of effectively planning the intervention, with the needed modifications to the layout, setting of new procedures, etc. *Information-related* issues result reasonably most relevant when the information to make advances in the decision-making process is more important, i.e. generation of awareness and tech-nology identification. *Competence-related* barriers play instead a greater role for the identification of needs and opportunities, as well as planning. To conclude, *technology-related* barriers have a primary role only for the third step, i.e. the technology identification.

3.1.3. Drivers to energy efficiency

As reported in Fig. 4(a), economic drivers have been perceived as most important, with a value of about 3.30. The other categories of drivers have been ranked with similar values, slightly higher than 2.5. The figure also allows noting that enterprises have pointed out an interesting difference, still not large, between external and internal drivers, with a slightly greater relevance of external drivers. Such difference clearly emerges considering the economic drivers (with a difference of about 0.2).

The analysis by frequencies (Fig. 2(b)) makes clear that a limited set of enterprises consider either vocational training or informative drivers as "very relevant" (from 14% to 22%), whilst economic ones range from 38.9% (internal) to 61.1% (external). Through bundling external and internal drivers by category (economic, regulatory, informative, vocational training) some additional insights can be obtained. In fact, just 5% of the sample has evaluated them as not important, whilst more than 84% deemed them as at least important (and 50% very important). It is notable that similar values are found for regulatory drivers (79% as important or very important), but 45% of them considered them as just important. Nonetheless, it is notable that about 24% of the sample deems internal regulatory drivers as very important (e.g. adopting a long-term energy strategy). Informative drivers are still considered as with lower power (only about 16% evaluated them as very important), whilst the vocational ones are evaluated as important in about 40% of the sample, and equally distributed among the remaining clusters (about 20% each) (see Fig. 5).

The major relevance of economic drivers was, somehow, expected, due to the current economic crisis that is particularly affecting the Italian industry almost exclusively composed by SMEs. Moreover, public financing (e.g. through fiscal subsidies) is found as quite relevant in previous research [44,17]). In particular, authors have also highlighted the relevance of economic internal drivers such as energy cost reductions or reduced product costs [25,31]. Interestingly, external regulatory drivers as threat of rising energy prices and legal restrictions are found to be the highest group of drivers after economic ones: in this regard, previous literature is conflicting, as in some cases such drivers were considered as not a priority [31,55], whilst for other studies they represent a major driving force (e.g. [40,44]). Informative drivers are still perceived as with lower relevance, similarly to what found by Wentemi Apeaning and Thollander [40] in Ghana. In our sample we can conclude that enterprises do not seem to have yet acknowledged the relevance of quantifying the existence of additional benefits from the implementation of EEMs, as improved product quality, improved staff health and safety [31]. It nonetheless represents a very interesting issue to be addressed: research here is performing huge efforts, with recent contributions aimed at evaluating EEMs not merely for their energy benefits, but also for the so-called "non-energy benefits" (see [10,11,3,4]).

3.1.4. How drivers affect barriers

Considering the framework presented in the introduction (Fig. 1), it was clear that drivers and barriers may have different values, and drivers may act with a different strength in tackling various barriers within the decision-making process. The framework brings here a relevant novelty in the study of barriers and drivers to industrial energy efficiency, as scholars have so far not

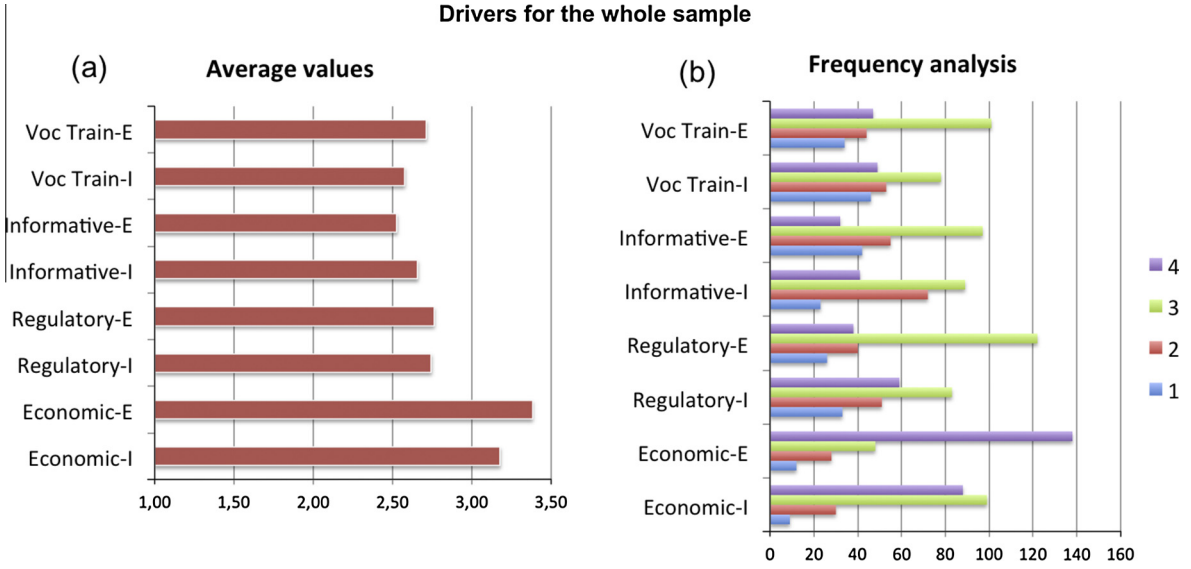


Fig. 5. Drivers to energy efficiency for the whole sample. (a) Average values. (b) Frequency analysis of the responses. Drivers have been asked on a even Likert scale ranging from 1 – not important to 4 – very important.

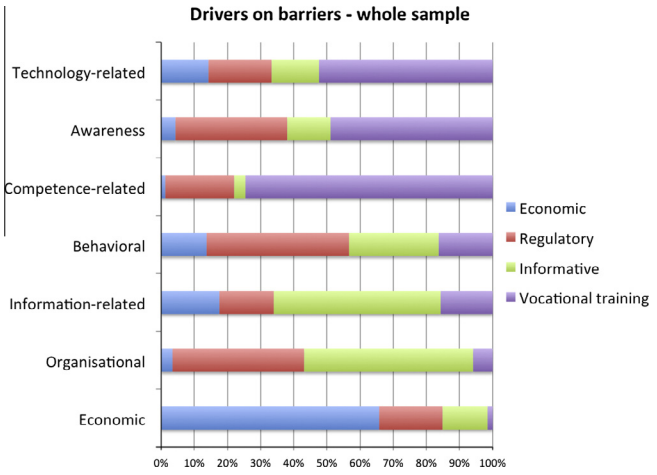


Fig. 6. Effect of drivers on barriers for the whole sample. Given 100% the relevance of a barrier (by category), the power of a driver to tackle such barrier has been evaluated.

related the role of a driver in tackling a barrier (as shown in Fig. 6). In particular, we can firstly see the effect of economic drivers on economic barriers. Such result was somehow expected, due to the current economic crisis that is largely inhibiting any type of investment, especially in case of SMEs. Therefore, economic drivers seem to represent a crucial instrument to be put in place, but we should remark here that their spectrum of influence appears as limited to the last steps of the decision-making process (financial analysis), and particularly focused on economic barriers.

The analysis reported in Fig. 6 also casts light on a very interesting result, which is the role of vocational training drivers. Firstly, and mostly expected, we can note that are judged as able to tackle about 60% of the competence-related barriers. Secondly, and not previously highlighted by scholars, they are deemed as able to tackle about 50% of the technology-related barrier, thus e.g. supporting enterprises perceived more precisely whether a technology is effectively inadequate to be installed in a specific context. Thirdly, the role of vocational training is large for the abatement of awareness barrier (more than 50%). Hence, putting together such findings with the role of barriers in the decision-making process, the priority to promote vocational-training drivers appears as apparent. In fact, vocational training plays the lion's part in tackling the most relevant barriers at the very beginning of the decision-making process, thus releasing enterprises from the status of being unaware of either the relevance of energy efficiency or its viable opportunities.

Fig. 6 allows evaluating the role of informative and regulatory drivers, which look more distributed among the barriers, although playing a greater role to tackle respectively information-related and organizational issues (informative drivers), as well as awareness and behavioural barriers (regulatory). Here we should remark that regulatory drivers include the implementation of a long-term energy strategy, as well as external energy audits and submetering, thus beside a "mere" imposition of regulatory standards. Therefore, such means may effectively represent a relevant boost to increase the interest of SMEs towards energy efficiency issues, removing the existing inertia (resistance to change and risk) and making energy-efficient behaviours as a priority.

3.1.5. Stakeholders promoting drivers for energy efficiency

Fig. 7 shows the most relevant stakeholders. In particular, we can note that Governmental bodies – either national or local –are deemed as responsible for economic drivers (45.1%), followed by generic financial institutions (29.3%), as well as ESCOs (20.9%). Regarding vocational training instead, the picture looks differently, with much more similar proportions between technology manufacturers (23.1%), suppliers (34.1%), as well as installers (27.5%). Additionally, a minor role (9.0%) has been attributed by the investigated sample to ESCOs. It is also worth remarking that energy and technology suppliers, as well as Governmental bodies and manufacturers, could effectively play a relevant role in promoting

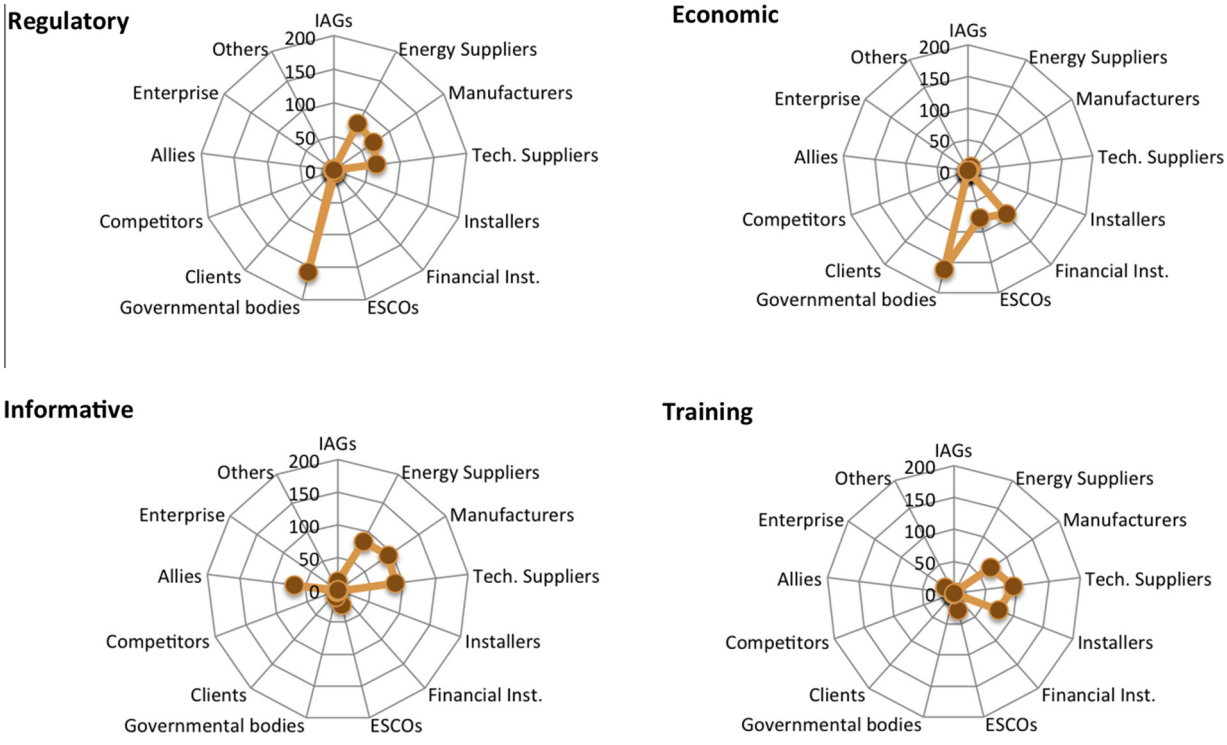


Fig. 7. Stakeholders and drivers for energy efficiency. Each radar reports the times a stakeholder has been indicated as most responsible for promoting the categories of drivers, namely: regulatory, economic, informative, and vocational training.

regulatory drivers. Moreover, suppliers of energy and technology, with manufacturers and allies, could be interesting players for the promotion of informative drivers.

3.2. Analysis by clusters of enterprises

In the following sub-sections we have conducted several analyses by clusters of enterprises. Primarily, enterprises have been clustered according to firm size (3.2.1) and energy intensity (3.2.2). Then, we have also looked either at the effect of having recently conducted an energy audit or having recently imple-mented EEMs for specific energy efficiency purposes (3.2.3). Finally, we have considered clusters of enterprises considering simultaneously firm size and energy intensity (3.2.4).

3.2.1. Firm size

The analysis by firm size has allowed observing several differences among barriers and drivers. In particular, regarding barriers (Fig. 8(a)), such differences emerge for medium-larger enterprises (MLEs), presenting in general lower barriers than smaller enterprises (SEs). On the contrary, SEs perceive technology either as more adequate or available: this could be related to the usual stronger relationship and trust SEs have with their technology suppliers, and in particular with installers.

Moreover, some variations can be appreciated also by firm size in how barriers affect the decision-making process (Fig. 9). In fact, we can note that economic barriers are more relevant for SEs also in the second decision-making step (identifying needs and opportunities), whilst for medium enterprises (MEs) and MLEs their effect is marginal. Interestingly, the effect of organizational barriers in the planning step as well as in the implementation, start-up, and training is quite limited for SEs, whilst organizational barriers have a primary role in case of MLEs. This could be explained by considering the need of integrating an EEM into a much more complex organisational structure (typical of larger enterprises), with consequences in terms of ways of managing
e.g. a new technology, adapting routines, procedures, etc.

In Fig. 10(a) we can note that SEs are more focused toward external drivers, and particularly towards economic, regulatory and vocational training. This finding could provide interesting insights for policy-making purposes, as it is worth noting that external vocational training represents more technical support, and regulatory includes e.g. prescriptive energy audits from independent sources. Additionally, SEs remark the support given by external economic drivers in different forms (public subsidies as well as credit from financial institutions). Briefly, such enter-prises highlight the need of either greater "external" pressures or support in order to implement EEMs. Contrarily, in case of MEs and MLEs, the role of internal drivers appears as more prevalent. This finding seems to suggest that such enterprises have started acknowledging that crucial means to overcome barriers to energy efficiency rely in internal activities such as long-term energy strategy, greater willingness to compete (internal regulatory drivers), or internal programs of education and training (internal vocational training drivers).

Analysing the effect of drivers on barriers (Fig. 11) by firm size, we can interestingly note the greater role played by regulatory drivers for SEs: indeed, they are deemed to tackle with greater effect awareness and competence-related barriers. Moreover, we can note two major differences concerning vocational training drivers. First, if for MEs and MLEs their role is limited to tackle technology-related, awareness and competence-related barriers, in case of SEs they are also relevant for behavioural and information-related barriers. Such finding could indeed be crucial for policy-making purposes: a wider training can effectively increase the capability to process information, to look at energy efficiency as an opportunity to increase firm competitiveness, to change internal routines, to increase enterprises' awareness. A wider and complete training, in conclusion, could lead to increased attention towards a produc-tion resource, i.e. energy, which is acquiring greater and greater relevance over time, in terms of production costs, environmental impact, and public concern. Second, in case of SEs, awareness and competence-related barriers are not primarily tackled by vocational training activities, rather through a proper mix of drivers, consequently increasing the difficulty in promoting effective actions by policy-makers.

In this regard it is really interesting to note that SEs look at technology suppliers, installers and ESCOs as major stakeholders able to most effectively promote vocational training drivers. Here we can note the difference with the whole sample (Fig. 6), for instead highlighted the relevance of manufacturers (and not ESCOs). In conclusion, this finding suggest that vocational training drivers are best promoted by stakeholders having a tighter and closer relationships with enterprises, i.e. those supplying SEs with

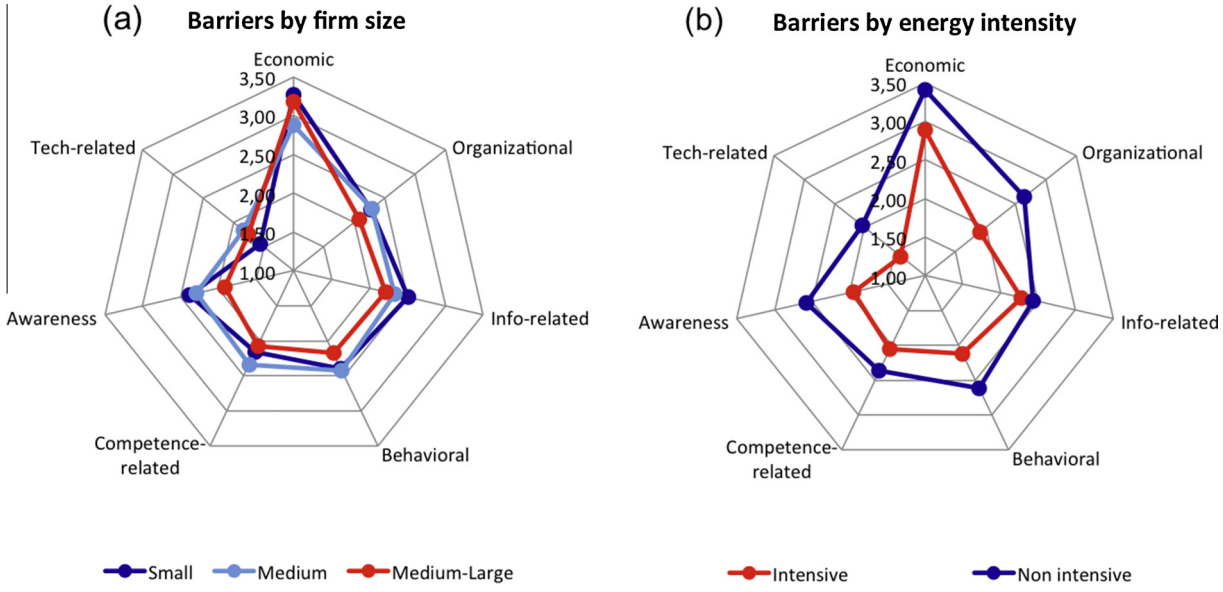


Fig. 8. Barriers to energy efficiency by clusters of enterprises. (a) firm size; and (b) energy intensity.

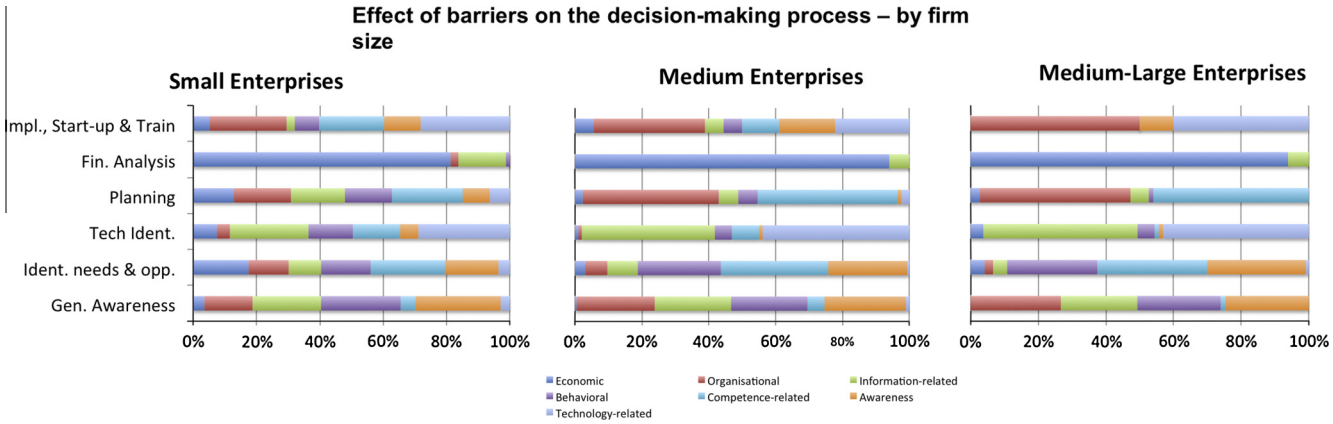


Fig. 9. Effect of barriers on the decision-making process of investing in an EEM – firms clustered according to firm size. The bars report (on percentage the relevance of a barrier in affecting a specific decision-making step).

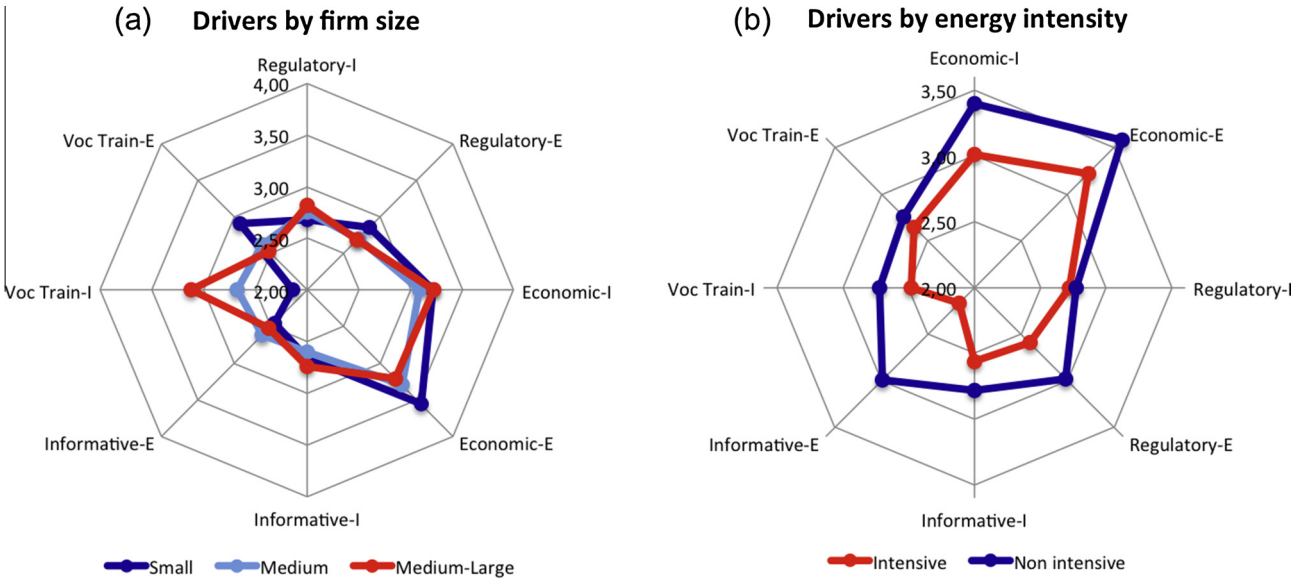


Fig. 10. Drivers to energy efficiency by clusters of enterprises. (a) firm size; and (b) energy intensity.

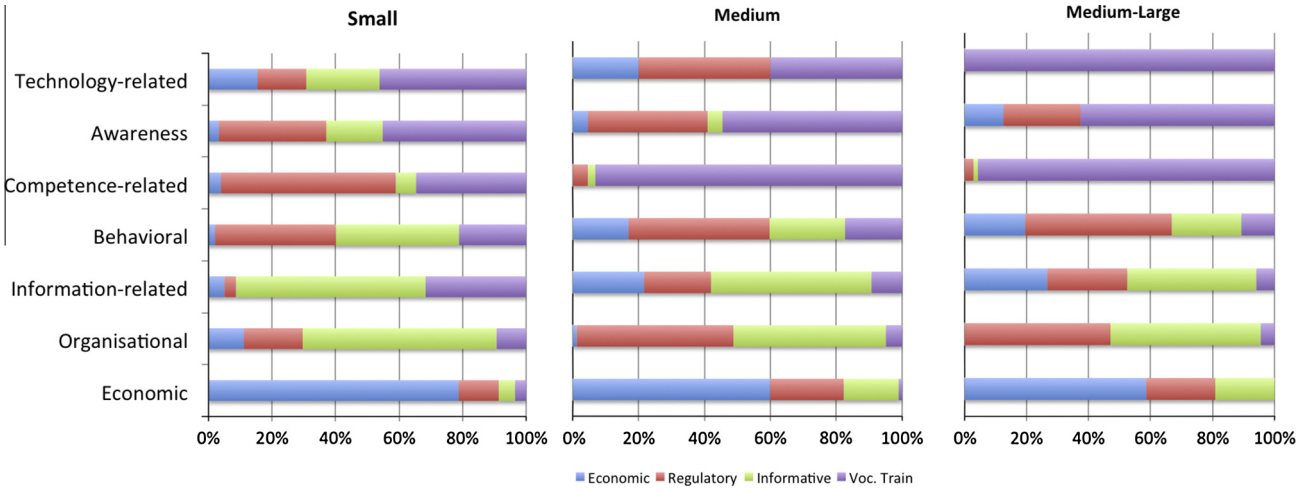


Fig. 11. Effect of drivers on barriers – enterprises clustered according to firm size. Given 100% the relevance of a barrier, the bars report the power of a driver to tackle such barrier.

technologies and services (such as distributors and installers, who may differ from manufacturers).

3.2.2. Energy intensity

When dealing with differences related to energy intensity, the analysis of barriers (Fig. 8(b)) provides an interesting finding: non-energy intensive enterprises (NEIs) present higher values of barriers for all the categories with respect to energy intensive (EIs) ones. This could be partially explained looking at the intrinsic relevance that energy expenditures have on EIs: enterprises with higher share of energy costs on production costs tend to look at energy efficiency with much greater attention and usually have started moving towards a more efficient production [34]. In particular, largest differences are observed for technology-related barriers as well as organisational ones: here, EIs seem to suggest that technology is available and adequate and, e.g. the organisation has given a higher status to energy efficiency. Additionally, it is interesting that larger behavioural as well as awareness barriers can be appreciated for NEIs.

Moreover, the effect of barriers in the decision-making process (Fig. 12) is slightly different: in particular, behavioural barriers have a greater relevance (e.g. imperfect evaluation criteria) for the NEIs. This role seems indeed crucial in the financial analysis (5th step). Similarly, the analysis of the drivers (Fig. 10(b)) provides two interesting findings for NEIs: firstly, they present higher dri-vers for all categories; secondly, they tend to give much greater weight to economic drivers than regulatory, informative and voca-tional training compared to EIs.

3.2.3. Analysis by energy audit and EEMs' implementation

The analysis has also delved at highlighting possible differences in the perception of barriers (Fig. 13) and drivers (Fig. 14) to energy efficiency with respect to the following firm's characteristics, namely: (i) having recently conducted an energy audit; and (ii) having recently implemented EEMs.

At a first look (Fig. 13), having conducted energy audit represents a useful means in order to reduce some barriers: lower values can be indeed observed for behavioural, information-related and organizational (and, moderately, also economic ones). Nonetheless, only enterprises having implemented EEMs experi-ence lower barriers at all categories. Additionally, interesting find-ings can be observed with respect to drivers (Fig. 14): on the one hand, enterprises that recently have not conducted an energy audit tend to give much greater importance to regulatory (internal and external), informative (internal), and, to some extent, also vocational training drivers. On the other hand, those having recently implemented EEMs tend to give similar scores to all the categories, but slightly reducing the economic one.

3.2.4. Firm size and energy intensity

The analysis has also explored a combination of the firm characteristics previously described, seeking to point out the existence of particular trends. Enterprises have been clustered according to firm size and energy intensity. As the four resulting clusters are little populated, only major pieces of evidence have been presented and discussed. In particular, we have observed that interesting differences emerge by looking at small non energy intensive enterprises (SNEIs) compared with medium-large intensive (MLEIs) ones. Regarding barriers, Fig. 15a shows that all barriers result higher for SNEIs. In particular, larger barriers of awareness can be appreciated, followed by behavioural and organisational ones. This means that those enterprises tend to give little attention to the energy efficiency issues, they are neither aware of being ineffi-cient nor give proper resources (i.e. time, staff, and budget) for increasing their energy efficiency. Among them, the positive effect of having conducted an energy audit and implemented EEMs (Fig. 15b) is twofold: on the one hand, awareness barriers are reduced; on the other hand, organisational and competence-related barriers assume greater relevance, showing that energy efficiency activities really require a proper status (e.g. through staff, budget, time dedicated).

When looking at the effect of barriers in the decision-making process by clusters, SNEIs present larger barriers in Step 6 (Implementation, start up and training), whilst lower barriers in terms of generation of awareness (Step 1). Again, they feel themselves as interested in the energy efficiency issues and aware of its importance, but, in reality, they do not give proper resources (as shown by Trianni et al. [39]).

Among SNEIs, having conducted energy audit and implemented EEMs is able to show a greater relevance of step 3 and 6, respectively the specific selection of the technology as well as implementation, start up and training. Again, having somehow experienced energy efficiency issues make enterprises aware that a specific knowledge of issues, technologies etc. could be much more critical than expected.

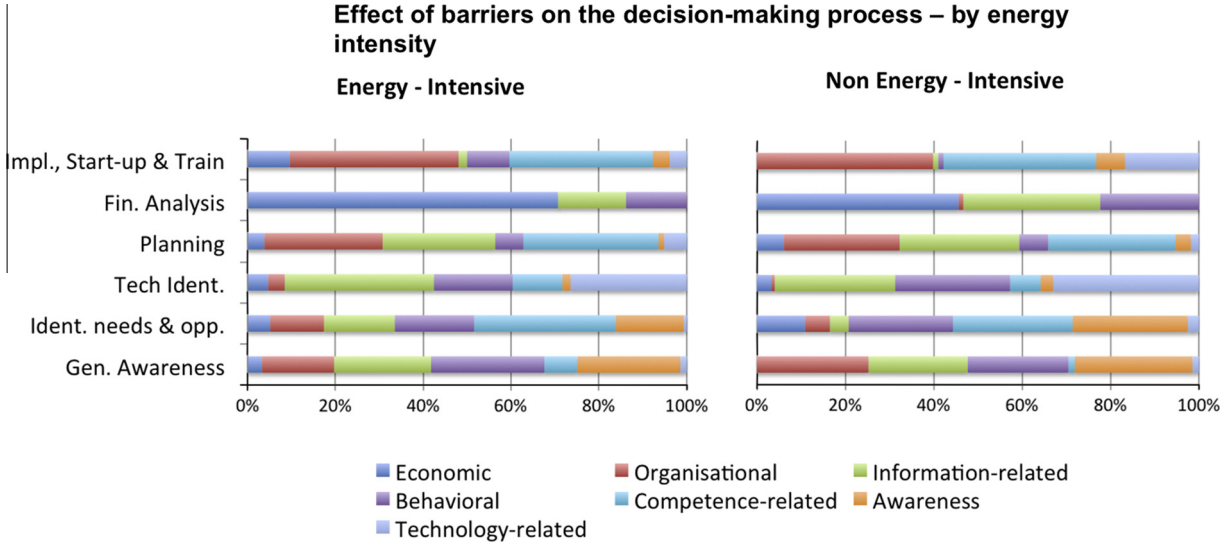


Fig. 12. Effect of barriers on the decision-making process of investing in an EEM – firms clustered according to energy intensity. The bars report (on percentage) the relevance of a barrier in affecting a specific decision-making step.

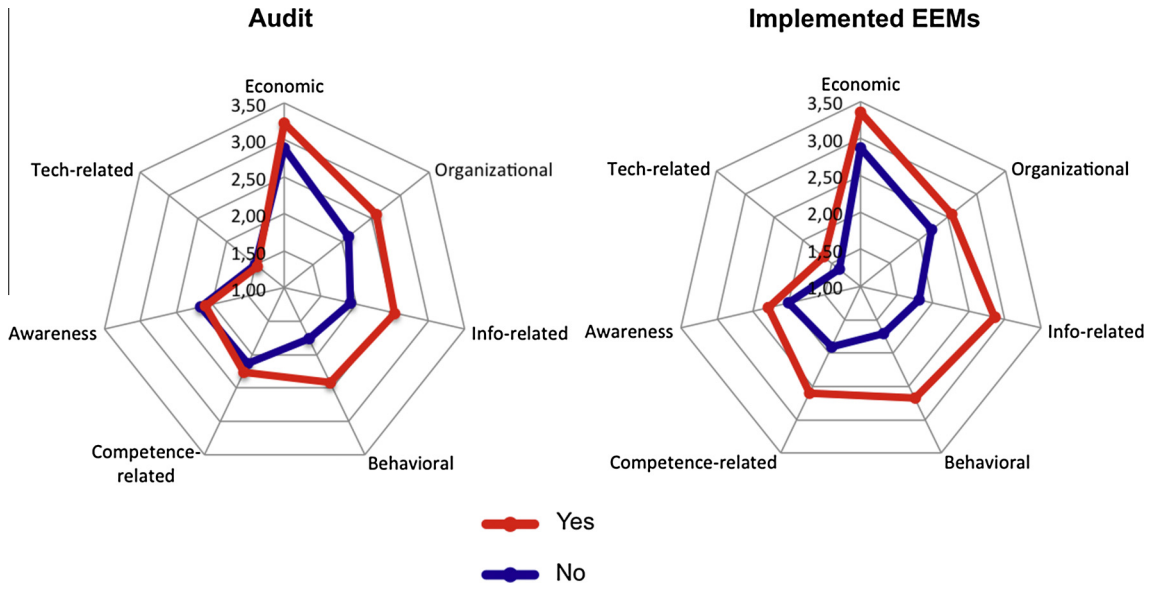


Fig. 13. Barriers to energy efficiency by clusters of enterprises according to having recently (i.e. within 3 years) conducted an energy audit or implemented an EEM.

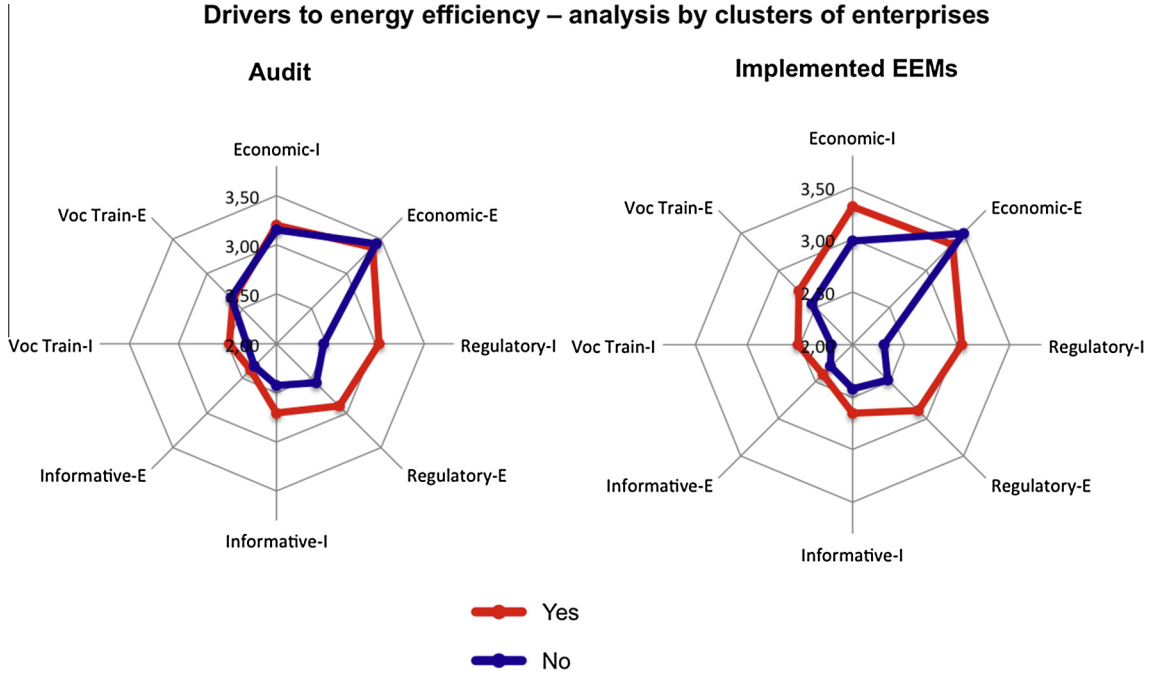


Fig. 14. Drivers to energy efficiency by clusters of enterprises according to having recently (i.e. within 3 years) conducted an energy audit or implemented an EEM.

Regarding drivers (Fig. 16a), SNEIs present a higher relevance of external drivers, not only in economic terms, but also informative and regulatory ones. On the contrary, MLEIs higlighted a major relevance of internal vocational training drivers, able to increase technical competences and awareness. Among SNEIs, having conducted an energy audit and implemented EEMs allows highlighting a greater relevance of non-economic drivers, as shown in Fig. 16b. Indeed, such companies (that, as aforementioned, present greater barriers than LEs) have started recognizing that, beside economic support, also information, regulation and vocational training drivers may play a crucial role for boosting their energy efficiency.

Finally, despite the analysis of stakeholders promoting drivers has not pointed out major differences among clusters, the analysis of how drivers affect barriers by clusters has revealed that SNEIs have pointed out a greater relevance of regulatory drivers for reducing behavioural barriers: the finding seems to show that interviewees would modify their "routines" and behaviours mostly if they would be forced to do so. This is quite different from MLEIs ones, for which behavioural issues are mostly tackled by vocational training drivers. Moreover, in SNEIs vocational training plays a greater role in reducing information-related barriers: indeed, increased technical competences are able to increase the capability to process information (in accordance to [34]). In particular, vocational training activities are more relevant for tackling information-related drivers in enterprises having implemented energy efficiency measures and conducted energy audits. Therefore, we have an additional confirmation of the relevance of training activities.

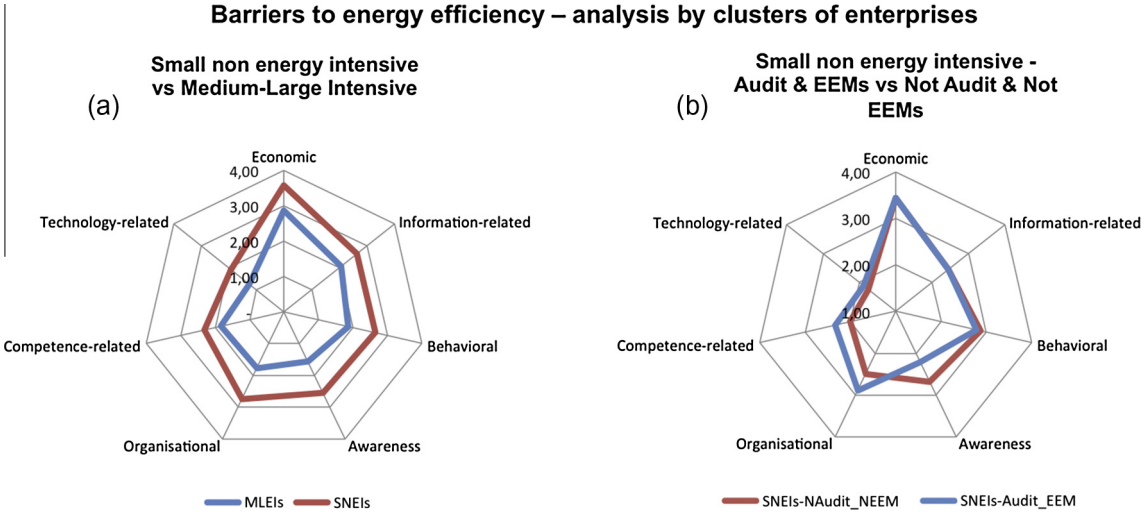


Fig. 15. Barriers to energy efficiency by clusters of enterprises: (a) small non-energy intensive enterprises (SNEIs) versus medium-large energy intensive enterprises (MLEIs); and (b) among SNEIs, enterprises having conducted energy audit and implemented EEMs (SNEIs-Audit_EEM) versus enterprises neither having conducted energy audit nor implemented EEMs (SNEIs-NAudit_NEEM).

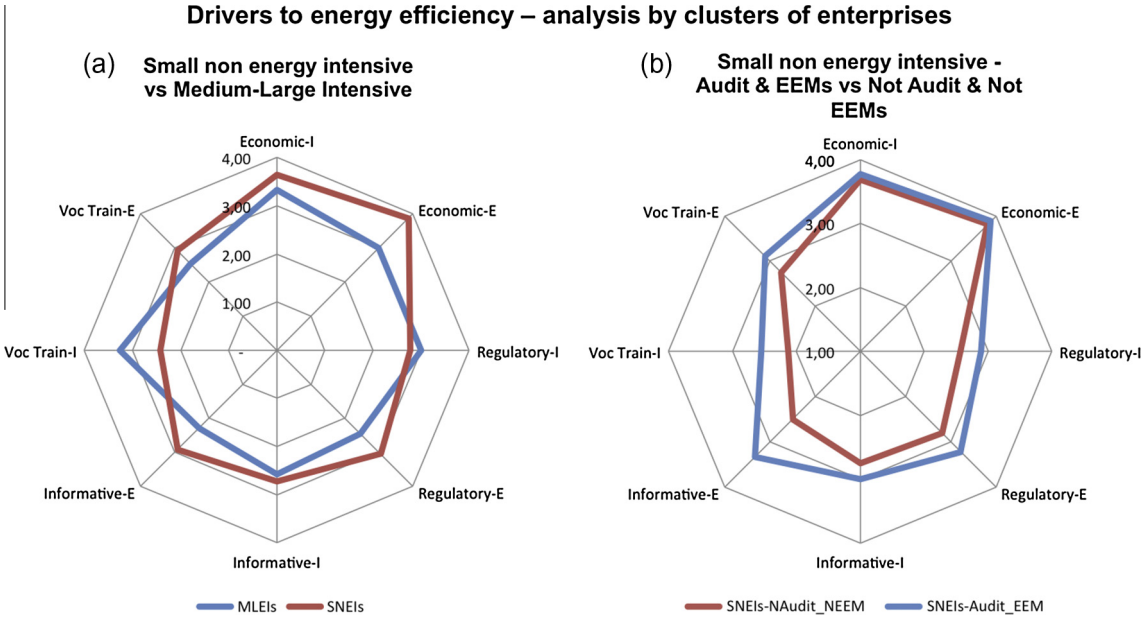


Fig. 16. Drivers to energy efficiency by clusters of enterprises: (a) small non-energy intensive enterprises (SNEIs) versus medium-large energy intensive enterprises (MLEIs); and (b) among SNEIs, enterprises having conducted energy audit and implemented EEMs (SNEIs-Audit_EEM) versus enterprises neither having conducted energy audit nor implemented EEMs (SNEIs-NAudit_NEEM).

4. Conclusions and further research

Considering that future efforts in Europe will be directed towards increased energy efficiency, with particular focus on industry, it is thus crucial, for policy-making purposes, that the support for the adoption of EEMs should be shaped using the most appropriate leverages, in order to most effectively tackle the barriers affecting the decision-making process.

This very first broad investigation among Italian manufacturing SMEs has allowed gaining a first look into the mechanisms relating barriers and drivers in the decision-making process of adopting an EEM. In particular, some key messages can be summarized. Firstly, we can note the relevance of economic barriers, particularly affecting the world of SMEs, which represent the backbone of the industrial European structure, are less efficient than larger enterprises, and are strategic for the European competitiveness. Monetary and financial support provided in different forms and through different channels (e.g. from Governmental bodies, either European, national or local, but also financial institutions as well as ESCOs), is perceived as the largest priority for increasing SMEs' energy efficiency. Secondly, beside economic issues, awareness and behavioural issues are crucial to be tackled. In fact, despite they might not be perceived as particularly critical for SMEs, they affect the very first steps of the decision-making process, thus inhibiting enterprises from evaluating or even recognizing possible energy-efficient solutions to be implemented, whilst economic barriers act almost exclusively in the financial evaluation step. In particular, having conducted an energy audit and implemented

EEMs shows even more apparently the need of vocational training activities as major drivers, especially in SNEIs. In this regard, the role of stakeholders such as manufacturers, technology suppliers, installers and ESCOs that support SMEs through providing them vocational training drivers (e.g. technical support) is really crucial, as they can most effectively remove the barriers affecting the awareness and knowledge of needs and opportunities. This finding means that, beside financial institutions, the supply chain of technologies is recognized as very critical for supporting enterprises in the adoption of EEMs. Many efforts in the future will be needed to highlight the so-called NEBs and support the technology transfer of EEMs (thus, not just technologies, but also information and competences) towards SMEs. Thirdly, the findings of the present study point out the importance to shape course of action according to several firm characteristics, taking into account that smaller and non-energy intensive users are most critical. Additionally, findings seem to show that enterprises having implemented EEMs present lower barriers in all categories, whilst the "mere" conduction of energy audit is able itself to lower just some barriers (related to behaviour, organisation and information).

The study had some limitations and offers opportunities for further research. Firstly, we should acknowledge that has been conducted to the world of SMEs in a delimited Italian region. Owing to such considerations, the research findings reflected a particular situation. In this regard, further research is needed. In fact, future studies could on the one hand extend towards the world of micro enterprises, which cover the largest share (by number) of European industrial activities. On the other hand, the geographical context could represent a very interesting variable: in particular, future research could focus on different Italian regions as well as other European regions. In fact, such additional investigations, using both qualitative and quantitative research approaches, could allow researchers to compare the findings and investigate the possible socio-economic factors leading to commonalities and differences. Secondly, research has been focused investigating barriers and drivers in the decision-making process in general terms, thus not looking at commonalities and differences according to specific EEMs, due to limited time for the interview. Nonetheless, recent contributions in the literature have started highlighting the importance of pointing out specific barriers according to specific EEMs. Hence, further research here appears as necessary. Third, our findings suggest that external drivers are more relevant than internal ones, especially for smaller enterprises. In this regard, the response was, to some extent, expected. Hence, further research should more deeply investigate this issue, gathering a much larger amount of information about how people involved in energy efficiency issue effectively operate (understanding routines, how they man-age the operations, etc.), so to understand to which extent SMEs (and specifically, smaller ones) have the need to develop "internal drivers" to promote EEMs. Moreover, we should acknowledge that data contains some uncertainty and possible inaccuracy as exclusively being reported by enterprises, thus without the opportunity to obtain a precise and effective knowledge of the energy efficiency status from the company. Researchers had not the opportunity to verify the set of information provided on the ground (e.g. regarding energy consumption). Moreover, evaluating qualitative data could leave some room for mistakes and misinterpretation, although the interview has been reviewed and thoroughly analysed.

Furthermore, the study has not analysed some relevant factors that could be quite relevant for policy-making purposes. Enterprises have reported if they had implemented EEMs for specific energy efficiency purposes, but additional information has been required neither regarding the type of intervention implemented nor what has effectively driven such implementation. The same holds for the conduction of energy audit: enterprises have reported if they had recently conducted an energy audit, but a greater detail of the type of energy audit conducted – according to ASHRAE's definition [56] – has not been provided. Additionally, respondents could have different culture, education, and experience, etc., thus biasing the responses to perceived barriers, drivers, decision-making steps, and stakeholders as well. Future research should carefully consider such limitations and see if differences according to those factors may arise.

Acknowledgement

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