BROADENING TO SUSTAINABILITY THE PERSPECTIVE OF INDUSTRIAL DECISION-MAKERS ON THE ENERGY EFFICIENCY MEASURES ADOPTION: SOME EMPIRICAL EVIDENCE

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Abstract

The industry should take further efforts towards increased energy efficiency, that is a major contributor to improve industrial sustainability performance, by implementing energy efficiency measures (EEMs). However, the rate of adoption of these measures is still quite low. Hitherto, EEMs and barriers to their adoption have been evaluated almost exclusively from the viewpoint of energy efficiency decision-makers, not accounting for the broader sustainability perspective. This work aims at understanding whether an industrial sustainability perspective can better address issues related to EEMs adoption, analyzing the question through different viewpoints and insights offered by industrial decision-makers of different industrial sustainability areas within a firm. By doing this, we aim at offering a contribution in the understanding of the low rate of adoption of EEMs. As case studies, we investigated 12 firms from Northern Italy. In comparison to previous literature, results show that an industrial sustainability perspective can better explain the real decision-making process of adopting an EEM. Indeed, people knowledgeable about different industrial sustainability areas may perceive different barriers about the same EEM. EEMs may be negatively affected by reasons related to other areas of industrial sustainability, while positive reciprocal impacts may exist among areas of industrial sustainability; thus, EEMs may have effects on areas other than energy efficiency, and these effects may be perceived only by such areas. The study concludes with some remarks for policy and industrial decision-makers and advice for further research.

Keywords

Energy efficiency measure · Industrial decision-maker · Industrial sustainability · Barriers

Introduction and background of the study

The relevance of environmental and social issues in the society—and especially in industrial activities—is calling national and international organizations, committees, and governments to develop a number of action plans and agreements aimed to increase sustainability at different levels (e.g., Kyoto Climate Change Protocol in 1997; COP21 Paris Agreement in 2015). Sustainability has been conceptualized by Elkington (1998) using the triple bottom line (TBL) model, as the intersection of three different pillars, namely, environmental, economic, and social. Focusing on an industrial context, we refer to industrial sustainability (Trianni et al. 2017), that it is related to all those actions that can be undertaken in a production plant level (and not just with reference to a production line) and that are referred to the levels of material, product, process, plant, and systems of production (Tonelli et al. 2013), and integrated into normal operations (Evans et al. 2009). Industrial sustainability has been often identified in literature with the areas of occupational health and safety (OHS) (Pagell and Gobeli 2009), and eco-efficiency (Gimenez et al. 2012), with a growing relevance of energy efficiency issue within eco- efficiency (Pehlken et al. 2015). Using the TBL model, we can identify these areas as the intersections of social and economic pillars (OHS), and environmental and economic pillars (eco-efficiency) (Pagell and Gobeli 2009; Gimenez et al. 2012).

To improve energy efficiency-related performance, it is necessary for firms to adopt energy efficiency measures (EEMs) (Rademaekers et al. 2011). Although there is good evidence that such measures are effective and have a positive impact on firms' performance (Fleiter et al. 2012a), less than 50% of manufacturing firms have adopted EEMs (Anderson and Newell 2004; Cagno and Trianni 2012). Scholars have underlined the existence of barriers to energy efficiency improvement (Chiaroni et al. 2017). These barriers have been largely addressed in the literature, with both theoretical (Sorrell et al. 2000; Cagno et al. 2013) and empirical contributions. Regarding the former ones, scholars have studied barriers in different contexts such as firm sector (Henriques and Catarino 2016), country (Hassan et al. 2017), and firm size (Fresner et al. 2017); for a recent review of empirical studies, see, e.g., Brunke et al. (2014). Despite the deep investigation of barriers to EEMs, their adoption rate is still very low (Rasmussen 2014).

Cooremans (2011) suggested that EEMs are not adopted because they are not considered as strategic, i.e., able to create sustainable competitive advantages, and because no link is perceived between EEMs and firm's core business. According to Cooremans (2012b), indeed, the mere increase in profitability, i.e., a financial analysis, is not enough to explain the low level of adoption, since several profitable measures are actually not adopted.

Nevertheless, literature has largely proven that adopting measures in the different areas of industrial sustainability, and in particular in the energy efficiency one, can improve competiveness and influence firm's core business. Indeed, Lucato et al. (2017) affirmed that a pro-environmental attitude can increase competitiveness, while Das et al. (2008) stated that OHS-related measures lead to good quality management that in turn is linked to improvements in competitiveness (Gill 2009), as also confirmed in EASHW (2007). Regarding energy efficiency, Svensson and Paramonova (2017) purported that increasing energy efficiency is considered to be an important mean for increasing competitiveness, and the same is confirmed in McKinsey and Company (2012). According to other authors (Fleiter et al. 2012a), the strategic character of a specific EEM can be given in particular by non-energy benefits (NEBs). Indeed, according to IEA (2014), the multiple benefits can reveal the strategic value of energy efficiency, in terms of cost reduction, value increasing, and risk reduction (see also Cooremans 2011).

Several authors have suggested also considering the NEBs associated with the adoption of EEMs, i.e., those benefits related to the implementation of an EEM other than energy savings. NEBs can be looked as empirical evidence showing the impact of EEMs on other areas within the firm, and they can even amount to more than the energy savings (Pye and McKane 2000). A first categorization of NEBs was provided by Worrell et al. (2003) (the proposed categories are reduction of emission, material use, waste, time for maintenance; improvement of product quality, productivity, workers' safety). Even if NEBs are well known, the authors underlined that firms lack the necessary knowledge to properly quantify them (Nehler and Ottosson 2014), and models for the quantification have been proposed (Ouyang and Ju 2017). An example of NEBs is provided, for instance by Trianni et al. (2014), according to whom an

EEM related to the lighting may have also an impact on the working conditions, i.e., on safety issues. Nevertheless, on the one hand these relationships have been evaluated from an empirical viewpoint, and on the other hand, the different perspectives on the same EEM related to the different areas on which it may impact have not been studied, hitherto, in a holistic manner.

Hence, looking at EEMs and their barriers adopting an industrial sustainability point of view may help in better understanding all mechanisms lying behind the adoption of an EEM. Indeed, the presence of different perspectives (see also Cooremans 2012a; Thollander and Palm 2012) could provide added value to the comprehension of the problems related to adoption of EEMs, showing those so far hidden and helping in a more effective deployment of EEMs. Indeed, since the impact of the EEMs on the operations and on the other areas of industrial sustainability has been largely recognized, it would be interesting to broaden our perspective and understand if the issues related to the non-adoption of the measures can be related to industrial sustainability areas other than energy efficiency. For this specific purpose, the authors recently developed an integrated model for the evaluation of barriers to the adoption of measures to improve industrial sustainability performance (Trianni et al. 2017). Among those, for sure EEMs can be considered. Therefore, this model can be used by industrial decision-makers (IDMs) to evaluate barriers to the adoption of EEMs, pointing out possible sustainability issues hampering their adoption. Indeed, the model can identify general barriers to sustainability, as well as evaluate barriers to specific measures in the different areas of industrial sustainability (OHS, eco-efficiency, energy efficiency) and, therefore, could be very useful to understand problems related to the adoption of EEMs. In Table 1, we report the model with all barriers and their definition.

Category	Barrier	Definition
Organization	Lack of time	The firm does not have enough time for the implementation of the intervention
	Lack of staff	The firm does not have enough staff for the implementation of the intervention
	Resistance to change/ Inertia	The organization can be against the change because it leads to a modification in ways of working and in habits
	Attitude/Other priorities	The culture and the values of the firm inhibit the implementation of the interventions. Moreover, the decision making might be focused almost exclusively on core the business activity, thereby focusing mainly on productivity-related interventions.
	Communication	There is a lack of communication or inadequacy of communication between management and workers or between the workers themselves
	Workplace and task	Not considering the workplace (analysis of the workplace, such as hazard exposures) and the tasks (design, pace, repetition, pressure and psychosocial issues) during the implementation of an intervention may have inhibitory consequences
	Organizational system	The firm is a social system influenced by goals, routines, and the organizational structure and is dominated by the decision making. There are several factors related to the company's structure that can hinder interventions.
Management behaviour	Commitment/ Awareness	The manager has no awareness and/or commitment.
	Expertise	The manager lacks adequate management skills with respect to the issue or has limited expertise.
Workers behaviour	Not trained/skilled	A lack of adequate skill or training of the personnel, with respect to a specific intervention area, can hinder the implementation of the intervention.
	Awareness	The staff lacks awareness on the issue and ignores it, which are criticalities of the firm with respect to the issue.
	Involvement	Employees not involved are not given a fair opportunity to take active part in the decision-making and realization process.
	Incorrect behaviour	The adoption of wrong behaviours by the personnel can hinder the implementation of sustainability interventions in cases in which an active participation of the personnel is required
Information	Lack of information	There is a lack of information or inadequacy of the information owned by the firm regarding all the aspects related to intervention implementation.
	Trustworthiness of information sources	There are problems with the trustworthiness of the information sources, and the sources are not adequate.
Technology/ Service	Lock in	The solution is incompatible with the status quo of the system.
Economic	Limited access to capital	The firm does not have sufficient capital for the implementation
	Hidden cost	Investment entails extra costs or the loss of benefits, which are not properly estimated in the investments analysis.
	Risk	There are risks related to the success of the interventions e.g., interruption of production and losses in quality.
	Investments cost	High investments costs prevent firms from implementing sustainability interventions.
	PBT	The intervention is not sufficiently profitable, e.g., with low returns and a long period of time required.

Table 1. The model on barriers to industrial sustainability. Source: Trianni et al. (2017). For each barrier, a definition is provided.

Starting from this theoretical contribution, we aim to empirically investigate, on the one hand, the barriers to EEMs adoption from an industrial sustainability perspective and, on the other hand, the perspectives of the different IDMs knowledgeable about sustainability on the same

EEM. Indeed, since an EEM affects several areas of the operations, multiple IDMs may influence its adoption. Hence, in our exploratory investigation, firstly, we are interested to understand whether different IDMs with different decision-making responsibilities in the different areas of industrial sustainability have different perceptions of barriers related to a specific EEM; secondly, beyond investigating whether possible positive reciprocal impacts among the different areas may support the implementation of an EEM, we would like to see whether and how the adoption of an EEM can be hindered by an IDM related to an area other than energy efficiency. Our analysis has been carried out through case studies conducted in 12 manufacturing firms located in Northern Italy.

The remainder of the paper is organized as follows: in the Research methods section, we present the theoretical framework used for the evaluation of barriers to EEM adoption and the research methods used for the empirical investigation (i.e., the case study methodology and the data collection and administration). In the Results and discussion section, we present and discuss our findings. Finally, conclusions are drawn and further research is suggested in the Conclusions and further research section.

Research methods

We have focused our exploratory empirical investigation on EEMs considered for implementation among manufacturing firms of Lombardy region (in Northern Italy), given its relevance for the Italian manufacturing sector and the still wide room for improvement in energy efficiency (ENEA 2016).

The empirical investigation is based on case study research methodology. This study fulfills the criteria for case study research identified by Yin (2009). We conducted the investigation through confirmatory case studies with semi-structured interviews, questionnaires, and secondary material. Twelve manufacturing firms differing in sector, size, and turnover were investigated (as shown in Table 2), following previous research pointing out that investigating a heterogeneous sample of firms provides evidence for the generalizability of an emerging theory (Eisenhardt 1989). Considering the need to judge the theoretical generalizability of the research (Hillebrand et al. 2001; Stuart et al. 2002) rather than its statistical generalizability, our number of selected case studies is deemed to be enough to provide valid support for the initial set of propositions (Eisenhardt 1989; Pagell and Wu 2009), allowing also depth of observation (Zorzini et al. 2008). To ensure that we collected appropriate data, with the aim of predicting similar results from the case studies (Shakir 2002), we identified interviewees able to provide specific information regarding EEMs and their impact on the operations and firm sustainability (Voss et al. 2002). Therefore, we selected in each firm people knowledgeable and responsible for energy issues (i.e., energy efficiency), environmental issues (i.e., eco-efficiency), and safety issues (i.e., OHS). We interviewed 24 people in charge of energy efficiency, eco-efficiency, and OHS within the sampled firms, ensuring to have at least two managers in each firm, so to compare different perspectives, e.g., interviewees from energy and environmental area, and from OHS area. We interviewed each manager separately to better capture the personal judgments and frank opinions, thus limiting as much as possible any bias due to, e.g., different power within the firm (for further detail see (Eisenhardt and Zbaracki 1992)). We developed a case study protocol for helping us standardize the sequence in which the questions were asked and minimize the impact of contextual effects (Patton, 1990). Each face-to-face interview lasted approximately 2 h.

Firm	Sector	Main activity	Employees	Turnover (million €/year)	Certifications	Managers interviewed
A	Metalworking	Manufacturing and assembly of high precision machine tools accessories	113	20	ISO 9001	OHS; Energy and Environment
B	Plastic	Manufacturing and assembly of products for apparel and engineering thermoplastics applications (e.g. electronic and automotive sector)	62	40	-	OHS; Energy, Maintenance and Environment
C	Metalworking	Designing and manufacturing of machineries for agriculture and greens maintenance, and machines for producing autonomous electricity and welding units	400	105	ISO 9001	OHS; Production and Energy
D	Metalworking	Designing and manufacturing of high-precision blanking dies with shearing parts in both steel and carbide	229	50	ISO 9001, ISO 14001, IT 16949	OHS; Energy and Environment
E	Metalworking	Designing and manufacturing of custom loudspeakers based on each client's individual applications	136	30	ISO 9001, ISO 14001, IT 16949	OHS; Energy and Environment
F	Food	Production of milk based products	536	290	-	OHS; Energy and Environment
G	Metalworking	Manufacturing of flow control products and systems for critical applications	146	35	ISO 9001, OHSAS 18001	OHS; Energy and quality
H	Wood	Manufacturing of doors and furniture	75	20	ISO 9001	OHS; Energy
I	Plastic	Manufacturing of chrome plating of plastic parts for automotive and industrial trucks industries	90	35	ISO 9001, IPPC-IED, IEA	OHS; Energy and Quality
J	Wood	Manufacturing of wood panels	243	60	ISO 9001, ISO 14001, OHSAS 18001	OHS; Energy
K	Textile	Manufacturing of fabric components and adhesives for footwear industry and furniture industry	80	20	-	Health, Safety and Environment; Energy
L	Metalworking	Manufacturing of drinking systems for broilers, pullets, breeders, turkeys and layers	47	15	ISO 9001	OHS; Energy

Table 2. Data of the investigated firms. For each firm, the sector, a short description of the activity, the number of employees, turnover, certifications owned and managers interviewed are reported.

The data collection has been organized in three parts. The first corresponded to the identification of the research sample using a database (AIDA 2017) containing relevant industrial information. Firms were selected basing on sector, number of employees, turnover, and geographical location. Firms were contacted by e-mail or performed adopting semi-structured interviews, audio-recorded and transcribed for analysis, with a questionnaire used as a guide, so to standardize the sequence in which the questions were asked and minimize the impact of contextual effects (Patton 1990). We based the interviews around a series of open-ended questions, which were supplemented by questions emerging from the dialog between the interviewer and interviewees, and probes (Remler and Van Ryzin 2014). We also collected free comments, in line with the procedure described by Dicicco-Bloom and Crabtree (2006). To start, each interviewee was asked to introduce the firm to the interviewer (i.e., sector, production process, number of employees, turnover, and attitude towards sustainability). This allowed to have a first corroboration of the data found in the web and to ask interviewee to explain performed adopting semi-structured interviews, audio-recorded and transcribed for analysis, with a questionnaire used as a guide, so to standardize the sequence in which the questions were asked and minimize the impact of contextual effects (Patton 1990). We based the interviews around a series of open-ended questions, which were supplemented by questions emerging from the dialog between the interviewer and interviewees, and probes (Remler and Van Ryzin 2014). We also collected free comments, in line with the procedure described by Dicicco-Bloom and Crabtree (2006). To start, each interviewee was asked to introduce the firm to the interviewer (i.e., sector, production process, number of employees, turnover, and attitude towards sustainability). This allowed to have a first corroboration of the data found in the web and to ask interviewee to explain possible misalignments, in particular regarding their attitude towards sustainability. The first manager interviewed in each firm was asked to arrange a tour of the plant for the interviewer. This allowed the interviewer to directly observe and evaluate how the plant worked and to identify possible problems related to industrial sustainability areas. After the tour, the interview took place. We presented the model of barriers to each interviewee, describing every single barrier. Interviewee was provided with a list of industrial sustainability measures (we adopted the one proposed by Trianni et al. 2017) and asked to identify, among the measures, those that were considered for adoption within their firm. For these measures, the interviewee was asked to evaluate, using the model proposed, the main barriers faced for their adoption and to discuss possible additional measures missing from the list. For each measure considered for adoption, the interviewee was asked to recount the whole decision-making steps followed, contextualizing the situation in which the adoption took place and to explain in detail the impact of that barrier in the specific situation. Main insights and issues that emerged from the evaluation of barriers were further investigated. The interviewee was then asked to rate the relevance of barriers using a four-point Likert scale, where 1 is not relevant, 2 is low-medium relevance, 3 is medium- high relevance, and 4 is high-very high relevance. Using a Likert scale to collect data on the relevance of barriers enabled us to synthesize the data from all interviewees and provide a quantitative measure, thus supplementing the comments and evaluations. An even four-point Likert-like was chosen, so as to push the respondents into taking a position, as done by previous research (Massoud et al. 2010; Fleiter et al. 2012b).

The third part of the data collection corresponded to the transcription and coding of the interviews and to the identification of possible misalignments that emerged, identified through the corroboration of the data obtained from the different sources (i.e., semi-structured interview, tours of plants, Likert-like scale, secondary data). In case of misalignments, we called back the interviewees, asking for a second face-to-face meeting or a phone- arranged one, in order to clarify these misalignments.

According to Yin (2009), four requirements must be met to guarantee the methodological rigor of case study research.

First, construct validity is the establishment of operational measures, obtained with triangulation of multiple source of evidence and with the development of a chain of evidence. Regarding triangulation of multiple sources of evidence (Voss et al. 2002; Beverland and Lindgreen 2010), in our investigation, we corroborated the data obtained using semi-structured interviews, direct observations, and secondary material, i.e., company's report and websites (Baškarada 2014). Concerning the chain of evidence, this is considered necessary to understand how the researchers arrived at their research outcomes from the data that was collected (Benbasat et al. 1987); basing on Rowley (2002) for every firm investigated, we create an electronic folder containing secondary data with related notes, interview transcript, notes taken during the interview and during the tour of the plant, and coding of the interview. Regarding the coding, we used structural coding since it is considered appropriate for exploratory semi-structured investigation in which multiple participants are involved (Saldaña 2009), and the main themes used were strictly related to the research questions of the study, i.e., barriers to the adoption of EEMs and different perspectives on them according to the different IDMs.

Second, internal validity is the extent to which casual relationships can be established: according to Yin (2009), Beverland and Lindgreen (2010), and Baškarada (2014), it only applies to explanatory and not to descriptive or exploratory case studies.

Third, external validity is the extent to which results can be generalized; this was assessed by defining the domain to which study findings can be generalized, i.e., the specification of population, replication logic, and the use of multiple case studies (Beverland and Lindgreen 2010).

Fourth, reliability is concerned with demonstrating that same results can be obtained by repeating the data collection procedure; it was addressed with the use of a case study protocol (Beverland and Lindgreen 2010) that standardizes the investigation and with the creation of a case study database.

In order to eliminate possible researcher bias, on the one hand, multiple case studies were conducted (Barratt et al. 2011), and on the other hand, more than one interviewers were involved in each interview and each interview was tape recording, as suggested by Voss et al. (2002).

Results and discussion

The investigated EEMs for each firm have been reported in Table 4. Each EEM has been categorized according to its main impact on the different areas of industrial sustainability. For each measure, we reported, where present, barriers with a value equal to or greater than 3 of the Likert-like scale. We also provided further comments regarding the implementation of the EEM. In the following, the discussion is structured according to the main research issues addressed in the study.

Existence of multiple perspectives on barriers to energy efficiency measures

During our exploratory investigation, we observed that the different IDMs of the industrial sustainability areas may have different perspectives on the same EEM, as well as perceive different barriers on their adoption, as can be inferred from Table 4. In particular, the existence of multiple perspectives on barriers to EEMs has been observed in all the firms investigated. In eight firms out of 12, this has been observed even in most of the EEMs discussed. The second column of Table 3 summarizes the findings for this point.

Firm	Existence of multiple perspectives on barriers to EEMs	EEM adoption can be affected by other areas of sustainability
A	✓	✓ (-)
B	✓	✓ (-)
C	✓	✓ (+)
D	✓	×
E	✓	✓ (-/+)
F	✓	✓ (-)
G	✓	✓ (+)
H	✓	×
I	✓	✓ (+)
J	✓	✓ (-)
K	✓	✓ (+)
L	✓	✓(+)

Table 3. Result. The table reports the summary of findings in each investigated firm.
Legend: ✓: the issue has been observed.
+: positively affected
-: negatively affected

×: the issue has not been observed.

In firm A, OHS manager was totally underestimating barriers to the adoption of EEMs, with respect to energy and environmental manager. For each EEM proposed, the first identified almost no barriers for its implementation, stating that, in general, EEMs were implemented without any problem. In contrast, the latter identified several barriers, particularly related to a general attitude of the organization (because of other priorities and lack of awareness), to a lack of proper information, to a lack of time, and to economic barriers. Moreover, the investigation showed, beside a different view on the barriers, a different knowledge of IDMs regarding the implementation of EEMs. The OHS manager stated that, e.g., preventive maintenance was not carried out, as he asserted they do not have specific weekly or monthly commitment for preventive maintenance, and maintenance activities were implemented only after a machine failure; on the contrary, the energy and environment manager pointed out that a maintenance team should have periodically controlled the machines and that, although these activities were scheduled, very often they were not implemented due to lack of time and the costs related to the production disruption. Moreover, workers should have implemented preventive maintenance during their working hours, but, as energy and environment manager stated, Bin this way they have to interrupt their normal activities, postponing them, or have to stay at work after the normal working hours, adding that preventive maintenance Bis perceived by workers as a waste of time.

In several other cases, we detected that OHS managers were often unaware of barriers related to the adoption of EEMs. For example, firm D implemented the EEM energy efficiency training once per year after the achievement of ISO 14001 certification. Managers tried to further involve workers in energy efficiency issues by asking them to provide suggestions and advice, as energy efficiency manager said workers can suggest possible actions to be undertaken so to improve energy efficiency: there is a PO box in the industrial building and everyone can write a mail with suggestions. OHS manager did not pinpoint any relevant barrier, underlining that training was strongly supported by top management, whereas energy and environment manager pointed that, in daily activities, possible positive effects of training on production were nullified by incorrect behavior of workers. Another example is the substitution of existing lamps with more efficient ones in firm E. Both managers recognized the investment costs as a main barrier, and they highlighted that, for this reason, the EEM was only partially implemented. The energy and environment manager however further explained that this barrier was related to the management's inability to see future benefits from the implementation of that EEM (e.g., savings) and thus a lack of a long-term vision. He also related this situation to a resistance to change.

Finally, in some cases, different IDMs of industrial sustainability areas not only agreed on the relevance of barriers to the adoption of a specific measures but also recognized the existence of an additional perspective (i.e., the top manager's one) hindering the adoption of the EEM. Installation of extractor fans, indeed, was strongly supported by both managers in firm L. Born as a measure for improving workers' comfort, both managers recognized it as being able to bring energy savings to installed equipment. Despite the existence of a feasibility study showing the opportunity to have energy savings and improved working conditions, as well as the positive evaluations from both managers, the management decided to perform a test by installing only two extractors out of the six proposed and to evaluate the positive effects deriving from this installation. By limiting the scope of the EEM, the management was not able to effectively experience the full set of expected benefits after the installation, so he decided to stop a further investment in the EEM. In this case, the management, indeed, showed to be unable to properly assess benefits derived from the EEM adoption. The OHS manager in particular pointed out that: the benefit deriving from the control of the temperature related to the installation of the fans would have been twofold. Indeed, when there are more than 25°C in the production department, on the one hand, workers start to feel tired more easily and their level of attention is low; on the other hand, machines go into crisis, the process becomes longer and the energy consumption increases.

Our exploratory investigation preliminarily shows that, for different IDMs related to the different areas of industrial sustainability, different perspectives on the relevance of the barriers to the implementation of an EEM may exist. This finding is in line with the research by Langley et al. (1995) that emphasizes the individual rather than the organizational level of analysis of the decision-making process, underlying how the process is mainly driven by personal insights and emotions. As a consequence, in order to have a more thorough comprehension of the barriers affecting EEMs, it seems quite beneficial to broaden the perspective, thus enlarging from an energy efficiency to an industrial sustainability one. Indeed, during the analysis of barriers to EEMs, our study revealed that considerable other information can be inferred from other IDMs' perspectives beyond the energy-related one. This is even more interesting for giving a proper boost to the adoption of EEMs. In fact, if IDMs referring to other areas of sustainability are unaware of existing barriers to EEMs, they could not provide a valuable support for its effective implementation. For this reason, considerations regarding the involvement of energy managers at top level of a company's organizational chart (see, e.g., Sorrell et al. 2010; Thollander and Palm 2015) are really crucial for the promotion of energy efficiency and sustainability in industrial activities, as it has been largely recognized that the characteristics of the management (including beliefs, theories, and propositions based on managers' personal experience) are critical for explaining the performance of a firm (Prahalad and Bettis 1986; Bettis and Prahalad 1995). Indeed, it is important to give energy manager power influence, i.e., provide them with formal authority, control of scarce resources (i.e., skills and money), and information and knowledge: indeed, basing on the assumption that firms are coalitions of people with competing goals coming from their positions within the firm and personal ambitions and interests (Eisenhardt and Zbaracki 1992), the project champions very often do not succeed because they struggle in overcoming barriers created by divisional structure (Sorrell et al. 2000; Masi et al. 2014). In particular, the complexity of the decision-making process for sustainability-related decision has been largely underlined (Gibson 2006; Arvai et al. 2012), and it has been related to the presence of trade-offs among the performances concerning different pillars of sustainability, the time span considered (short, medium, long), and the different stakeholder requirements (Nicolăescu et al. 2015; Gong et al. 2016; Frini and Benamor 2017).

Energy efficiency measure adoption can be negatively affected by other areas of sustainability

In our exploratory investigation, frequently, the implementation of an EEM was positively or negatively affected by reasons related to other industrial sustainability areas within the firm, as can be inferred from Table 4. Regarding EEM adoption affected by other areas of sustainability, in 6 cases out of 12, it was possible to observe that EEM adoption was positively affected by other areas of industrial sustainability, but more relevant was to observe that in 5 firms out of 12, EEM adoption was negatively affected by other areas of sustainability. The third column of Table 3 summarizes the findings for this point.

We detected that positive reciprocal impacts may exist between energy efficiency area and the other industrial sustainability areas of the firms. In particular, EEMs may have positive effects on other areas, and measures originally related to other areas, such as safety, may have positive effects on energy efficiency. For instance, the substitution of existing lamps with more efficient ones proved to bring safety-related benefits in more than one firm. Such benefits can be as in, e.g., firm C, improvement of workers' comfort and the reduction of power, and, as a consequence, the reduction of absorption, dissipated power, voltage drops, and danger. Furthermore, the installation of combined heat and power system in firm I for substituting the previous heating system allowed to reduce the energy consumption and costs associated with heating and to eliminate the electrical resistances needed by the previous system, thus avoiding the concrete possibility of risk of a fire: indeed, as the environmental and safety manager said, they Bused to have a heating system with resistances inside, that, for an error, went in shortcircuit and caused an initial fire. Finally, the installation of glass roofing in some parts of the production plant in firm L to reduce the need for artificial illumination and use daylight as much as possible also brought benefits related to working conditions, in particular to comfort.

Interestingly, we also ascertained new with respect to previous literature that safety-related measure brought energy efficiency-related benefits. This occurred in firm K, in which original brick walls of the production departments were painted white to make the space brighter and improve workers' comfort. Even if this measure was primarily aimed at increased safety, the firm also experienced energy benefits. Indeed, with a brighter space, the need for lighting was reduced, with positive impact in terms of energy and economic savings, as health, safety, and environmental manager said: we implement this measure for reasons not related to lighting [...] but it turned out to benefit lighting and so energy consumption.

We detected that EEM adoption may be hindered by reasons related to other areas of industrial sustainability. As from our investigation, this negative impact can be observed according to factors as follows. Firstly, workers' comfort prevailed over energy firm performance. For instance, firm A moved a machine to a place in which fewer workers operate and with a higher ceiling, in order to more easily disperse the noise. Despite the change and the low use of the machine (about only 1 day every 2 weeks), some processing parameters were lowered to reduce the perceived still loud noise, with negative impact on production performances of the machine, and increased energy consumption. In this case, as energy and environment manager revealed, workers were properly equipped with ear protections, but they did not use them. Nevertheless, they complained about the noise and, to guarantee a comfortable place for workers to work in, it was decided to lower the parameters.

Secondly, similarly to what was shown by Trianni et al. (2013), other priorities may lower the urgency of EEMs, such as interventions that guarantee compliance with safety regulations and allow a firm to continue its production activity. For example, in firm B, the substitution of existing lamps with more efficient ones was recognized as particularly critical by both managers. Firm B had asbestos in the roof that should have been removed years before. Nevertheless, top management had so far postponed the decision, because of the extant opportunity to move to another plant. Eight years later, on the one hand, the firm had not moved yet; on the other hand, so far, no interventions had been implemented on the roof. But, at the time of the interview, the firm experienced several structural problems in the roof and had to remove the asbestos due to regulatory issues. In a nutshell, despite the positive evaluation of both OHS and energy, maintenance and environment managers (the first even stating Bit has been ten years since I proposed to change the lighting), now, the priority of regulatory (safety) issues emerged, stopping any further investment in energy efficiency. In particular, the energy, maintenance, and environment manager clearly stated: Bat this moment, all those interventions that are not included in the building revamping are not considered and we privilege those interventions that keep us alive, rather than those that give us an economic benefit.

The aforementioned considerations seem to point out that the set of performances of an EEM to be taken into account when adopting it goes beyond the energy efficiency ones. In fact, our empirical evidence shows that firms cannot avoid safety and comfort issues when implementing EEMs. Positive reciprocal impacts among the different areas, indeed, may support the implementation of an EEM. EEMs can be positively affected by reasons related to other areas of industrial sustainability, in particular, findings underlined strong relationships with OHS area. In this way, NEBs may foster the implementation of EEMs, confirming previous literature that pointed out possible benefits stemming from the adoption of EEMs (Morrow et al. 2014; Nehler and Rasmussen 2016). It has also emerged that energy efficiency reasons may positively affect the adoption of measures related to other areas of industrial sustainability, so that energy benefits may foster the implementation of non-energy measures. In the same way, EEMs can be hindered by an IDM related to an area other than energy efficiency. From the investigation, a strong relationship with the OHS area emerged. Indeed, EEMs can be stopped for reasons related to safety that concern, e.g., workers' safety and comfort or the need to be compliant with safety regulations. Firms cannot avoid such aspects when implementing EEMs. Nevertheless, too little attention has been so paid hitherto to analyze the negative consequences that may arise from the implementation of an EEM (Trianni et al. 2017), thus extending the perspective on industrial sustainability beyond energy efficiency performance

Firm	EEM	Impact	Manager	Main barrier (Likert-like scale value ≥3)	Further Comments
A	More efficient type of motors	EnEff EcoEff	OHS	-	OHS manager identified no barriers for the substitution of motors. Energy and environment manager said motors were changed only in case of break, and not for energy efficiency reason, because of several barriers.
			Energy and Environment	Lack of time, Investment cost, Lack of Information, Attitude/Other priorities	
	More efficient lamps/ light source	EnEff	OHS		OHS manager did not remember in the specific, he affirmed that maybe they have LEDs. Energy and environment manager said they have no LEDs but had high-efficiency neon lamps.
			Energy and Environment	Attitude/Other priorities, Lack of time	
	Detection Compressed Air Leaks	EnEff	OHS	-	OHS manager said he did not know. Energy and environment manager said compressors have already been placed outside the production plant, in the coolest possible place for them.
			Energy and Environment	-	
	Preventive Maintenance	OHS EnEff	OHS		According to OHS manager, preventive maintenance was not implemented. Energy and environment manager said there was a dedicated team for it, but that it was not always properly implemented due to a lack of time and risks related to production disruption.
			Energy and Environment	Lack of time, Risk	
	Detection Compressed Air Leaks	EnEff	OHS	-	OHS manager identified no barriers. Energy and environment manager said the measure was not properly implemented because of a lack of time.
			Energy and Environment	Lack of time	
	Solar panels	EnEff EcoEff	OHS	-	OHS manager recognized no barriers. Energy and environment manager said the firm faced economic barriers.
			Energy and Environment	Economic	
	Noise reduction	OHS	OHS	-	The firm lowered the functional parameters of a machine to reduce the noise. Energy and environment manager stated this increased the energy consumption.
			Energy and Environment	-	
B	More efficient type of motors	EnEff EcoEff	OHS	-	OHS manager thought motors were substituted with new and more efficient ones. Energy, maintenance and environment manager said motors were changed only in case of break, due to lock in and high cost.
			Energy, Maintenance and Environment	Lock in, PBT, Investment cost	
	Preventive Maintenance	OHS EnEff	OHS	Investment cost	Safety manager did not think it was implemented, due to high related costs. Energy, maintenance and environment manager said they did not have enough and properly trained staff for the implementation of preventive maintenance.
			Energy, Maintenance and Environment	Lack of staff, Not trained/skilled staff	
	Presence sensors	EnEff	OHS	Attitude/ Other priorities	According to OHS manager, the measure was not implemented because of other priorities. Energy, maintenance and environment manager explained it was related to a lock in barrier with reference to the existent lamps.
			Energy, Maintenance and Environment	PBT, Lock in	
	More efficient lamps/ light source	EnEff	OHS	PBT	The substitution of the lamps was not even taken in consideration due to the presence of asbestos in the roof, which had to be removed before implementing any other measure on roof/ceiling.
			Energy, Maintenance and Environment	PBT	

C	More efficient lamps/ light source	EnEff	OHS	Economic	According to both managers, the substitution of existent lamps had a positive effect on workers' comfort. Moreover, production and energy manager said they had no economic barriers, because the investment was repaid by the savings obtained.
			Production and Energy	-	
D	Detection Compressed Air Leaks	EnEff	OHS	-	This measure was implemented during weekends or in summer, so as not to interrupt the production. OHS manager identified no barriers, whereas according to energy and environment manager workers were unhappy to work during weekends or holidays.
			Energy and Environment	Attitude/Other priorities, Risk	
	More efficient type of motors	EnEff EcoEff	OHS	-	Both managers said motors were substituted after a failure. OHS manager identified no barriers, whereas energy and environment manager affirmed this was related to a lock in and the high investment cost of the substitution.
			Energy and Environment	Lock in, Investment cost	
	Energy Efficiency Training	EnEff EcoE	OHS	-	Once per year, the firm implemented training. OHS manager identified no barriers, whereas according to energy and environment manager, in daily activities, possible positive effects on production were nullified by incorrect workers' behaviour.
			Energy and Environment	Wrong Behaviour of Workers	
	Solar panels	EnEff EcoEff	OHS	-	The implementation of this measure was stopped due to safety reasons related the risk roof structural failure because of to the weight of the panels.
			Energy and Environment	Lock in	
	More efficient lamps/ light source	EnEff	OHS	Lack of time	OHS manager recognized a lack of time as the only barrier for the implementation of the measure. Energy and environment manager considered a lack of staff also to be relevant.
			Energy and Environment	Lack of time, Lack of staff	
	Preventive Maintenance	OHS EnEff	OHS	Economic, Lack of time	Both managers recognized economic barriers and a lack of time as relevant ones. Energy and environment manager also affirmed that risk and costs related to the interruption of production had an important role.
			Energy and Environment	Economic, Lack of time, Risk, Hidden costs	
E	More efficient lamps/ light source	EnEff	OHS	Investment cost	Both managers recognized the cost of investment as a main barrier. Energy and environment manager however, affirmed this was related to the management's inability to see future benefits related to the measure (coming from savings), the lack of a long-term vision, as well as resistance to change.
			Energy and Environment	Investment cost, PBT, Commitment/Awareness of the management, Resistance to change/Inertia	
	Presence sensors	EnEff	OHS	-	Measure was not implemented for safety reasons. The project was related to outdoor illumination and it was found that, during night time, in the case of an emergency, the night watchman would have been unable to gather a complete view of the area.
			Energy and Environment	-	
	Insulation of the roof	EnEff EcoEff	OHS	-	Firm decided to insulate the roof to reduce the energy consumption for heating. While implementing this measure, the firm discovered some safety irregularities. They adjusted irregularities, and benefitted from them, e.g. when conducting maintenance activities.
			Energy and Environment	-	
F	More efficient type of motors	EnEff EcoEff	OHS	-	According to both managers, motors were substituted only when necessary. OHS manager identified no barrier. Energy and environment said technology and innovation were not a priority, because the main objective was to guarantee production.
			Energy and Environment	Attitude/Other priorities	
	Detection Compressed Air Leaks	EnEff	OHS	-	OHS manager affirmed they implemented the measures. Energy and environment denied, underlining that this was an improvement measure and thus not urgent.
			Energy and Environment	Lack of time, Lack of staff, Attitude/Other priorities	
	Energy Efficiency Training	EnEff EcoEff	OHS	Attitude/Other priorities	According to energy and environment manager, they tried to implement this training, but they stopped because they decided to focus only on what was strictly necessary.
			Energy and Environment	Attitude/Other priorities, Lack of time	

	Solar panels	EnEff EcoEff	OHS	-	Firm thought about the installation of solar panels on the roof of the ageing cheese warehouse, but the installation would have made the warehouse not accessible to firemen in the case of a fire. Therefore, for safety reasons and to prevent the loss of all the cheese in the case of an emergency, the firm decided not to implement the measure.
			Energy and Environment	-	
G	Preventive Maintenance	OHS EnEff	OHS	-	Preventive maintenance was implemented by an external firm. OHS manager identified no barriers. Energy and quality manager said this decision was due to the impossibility of implementing it internally, due to incorrect behaviour of workers.
			Energy and Quality	Wrong Behaviour of Workers	
	Remake of the roof	OHS	OHS	-	Original roof contained asbestos, so the firm remade it. Managers agreed the new roof reduced the need for heating, thereby reducing consumption of natural gas.
			Energy and Quality	-	
	More efficient lamps/ light source	EnEff	OHS	Economic	Both managers recognized the economic barrier as the main one. OHS manager explained this measure received a relevant boost from the safety area. Indeed, to comply with safety regulation, they conducted studies on luminance of different areas, according to the different types of activities, and they found it was necessary to improve lighting.
			Energy and Quality	Economic	
H	Preventive Maintenance	OHS EnEff	OHS	Attitude/Other priorities, Lack of time	Firm did not implement preventive maintenance. OHS manager did not deem it as a relevant problem, because, he stated, it was very difficult to implement in every firm.
			Energy	Lack of staff	
	More efficient lamps/ light source	EnEff	OHS	Attitude/Other priorities	According to OHS manager, years before the firm had neon lamps but that he did not know the current situation, adding he did not think that lighting was a priority. Energy manager said they had a programme to change lamps, because the neon was becoming obsolete.
			Energy	-	
I	More efficient lamps/ light source	EnEff	OHS	Workplace and Task	OHS manager said substitution of lighting in areas such as quality control might have been critical because of the characteristics of the required light. Energy and quality manager said they postponed the implementation of this measure because it was not a priority.
			Energy and Quality	Attitude/ Other priorities	
	Energy Efficiency Training	EnEff EcoEff	OHS	Investment cost	Both managers affirmed this training was done at the management level. OHS manager said the main barrier for the extension of training to workers was economic, whereas energy and quality manager said it was because workers did not have enough competences and would not have been able to understand the topic properly.
			Energy and Quality	Not trained/skilled Workers	
	Cogeneration	EnEff EcoEff	OHS		Managers explained the measure was implemented first for energy efficiency reasons, but it also had safety-related benefits. Specific manufacturing processes needed electrical resistance; cogeneration allowed them to substitute them with coils, which were safer. Energy and quality manager stated economic barriers were easily overcome because the measure was strongly supported by energy and safety reasons. He, however, thought the firm lacked of competences for the ongoing maintenance.
			Energy and Quality	Lack of Workers Awareness, Not trained/skilled Workers	
J	More efficient type of motors	EnEff EcoEff	OHS	Lock in, Investment cost	Both the managers recognized economic barriers as critical ones. Nevertheless, OHS one stated there was also a problem related to technological lock in.
			Energy	Investment cost, PBT	
	More efficient lamps/ light source	EnEff	OHS	Investment cost, Lack of time, Lack of staff	OHS manager said before implementing this measure was necessary to have an evaluation of risk related the possibility of not proper optical radiation. He added this was not really a problem, but just something *burdensome*. Energy manager added it was quite risky to substitute lighting in the painting department, for the types of activities performed in it.
			Energy	Investment cost, Lock in	
K	More efficient type of motors	EnEff EcoEff	Health, Safety and Environment	Investment cost, PBT	Health, safety and environment manager said they were not able to properly and precisely evaluate each machine's consumption, so they only estimated it.

			Energy	Investment cost, Lock in	
	White wall painting	OHS	Health, Safety and Environment	-	Both managers said some years ago they decided to paint the walls of the productive department white. This small change brought both safety benefits: the workplace appeared more comfortable, and for the energy manager, because the place became brighter, less artificial lighting was needed.
			Energy	-	
L	Preventive Maintenance	OHS EnEff	OHS	Attitude/other priorities	OHS manager said preventive maintenance was not implemented because not considered a priority. Energy one stated it was because they did not have enough time and staff, and because of the risk of interrupt the production.
			Energy	Lack of time, Lack of staff, Risk	
	Detection Compressed Air Leaks	EnEff	OHS	Lack of time	OHS manager said the measure was not implemented because of a lack of time. Energy manager affirmed it was because the management did not care about the measure.
			Energy	Commitment/Awareness of Management	
	Extractor fans	OHS EnEff	OHS	Commitment/Awareness of Management	Both agreed that barriers to this measure were related to the management commitment and referred the lack of implementation of the measure to an inability of the management to properly address barriers.
			Energy	Commitment/Awareness of Management	
	Use daylight when possible	OHS EnEff	OHS	-	Firm installed glass roofing so to reduce energy consumption related to lighting. OHS manager added that this measure positively impacted workers' comfort.
			Energy	Incorrect behaviour of Workers	

Table 4. The EEMs discussed during the interviews. For each firm investigated, we listed the EEMs considered during the interviews. Each measure is categorized according to the impact on the different areas of industrial sustainability (EnEff: energy efficiency; EcoEff: eco efficiency; OHS: occupational health and safety), according to Trianni et al. (2017). Managers interviewed and main barriers identified by each of them (Likert-like scale value ≥3) are reported and further comments regarding the specific EEM are provided.

Conclusions and further research

There is a growing concern (Omer 2008; Dincer and Rosen 2012) regarding the adoption of EEMs as relevant contributors to industrial sustainability. Through our exploratory investigation, we have empirically shown that looking at EEMs and their barriers adopting an industrial sustainability point of view may help in better understanding all those mechanisms lying behind the adoption of an EEM, hinting that the presence of different perspectives is able to provide added value to the comprehension of the problems related to adoption of EEMs. Indeed, our investigation revealed that different IDMs seem to have different perspectives on the relevance of the barriers in the adoption of a specific EEM. This, of course, impacts on the adoption itself and a more proper evaluation of all the issues related to the adoption seem possible broadening the perspective, from an energy efficiency to an industrial sustainability one. Furthermore, our sample pointed out that, if in some cases the EEM adoption may have positive reciprocal impacts with other areas of industrial sustainability, in other cases, EEMs can be negatively affected by reasons related to areas others than the energy efficiency one. Stemming from the obtained findings, it is possible to conclude that, when adopting an EEM, it is necessary to consider not only the energy area but also all those areas that may be involved in the implementation of an EEM, i.e., to broaden the perspective towards an industrial sustainability one, so as to have a more complete and proper view on all those factors that may hinder or foster the adoption of an EEM. It becomes clear, indeed, that if we really want to increase the rate of adoption of EEMs, it is necessary to consider all their impacts and thus all the different perspectives related to them. On the one hand, the perspectives that IDMs related to of all industrial sustainability areas may have about the EEM should not be overlooked; on the other hand, for the effective implementation of an EEM, it is important to take into consideration the impact of the EEMs on other areas of industrial sustainability.

Our findings may offer relevant suggestions to IDMs as well as policy makers in order to, on the one hand, point out the best drivers to tackle existing barriers and, on the other hand, identify the most suitable stakeholders within the firm (or outside) to promote such drivers. The results obtained would also be useful for technology/service suppliers, i.e., properly identifying in the firm their right counterparts for the promotion of their products/services within the firm.

Despite that the study provides a good empirical validation of the initial set of propositions, it presents some limitations, that howbeit has offered the opportunity to sketch some future research. First, we were not able to interview people in exactly the same leadership position among the different firms. Moreover, the results obtained provide only a theoretical generalizability of the results. Further research may, for sure, enlarge the sample. This would allow having a statistical generalizability too, investigating possible common patterns, i.e., according to firms' clusters related to their characteristics and contextual factors, such as, e.g., geographical area, sector, dimension, energy intensity, types of processes, organizational structure.

In addition, further research could understand the role of energy efficiency in preventing or supporting the implementation of measures related to the other areas of industrial sustainability. Both for EEMs and for measures related to other areas of industrial sustainability, it would be interesting to analyze together main barriers and main drivers related to their adoption and to evaluate their relevance according to multiple perspectives related to different IDMs knowledgeable about industrial sustainability. Furthermore, to offer a valuable support to IDMs as well as policy makers in the promotion of sustainability measures, it would be quite important to link the adoption of EEMs to the broad set of sustainability performance. For this reason, further research could explore the relationships that, with respect to a specific measure, exist among barriers, drivers, level of adoption of the measure, and sustainability performance reached. Such type of analysis should not be necessarily limited with the boundaries of a single firm. Indeed, future research could analyze such relationships according to the different perspectives of different firms belonging to, e.g., the same supply chain and industrial district.

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