Barriers to energy efficiency measures and the role of industrial sustainability

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Abstract

Energy efficiency is largely recognized as a major contributor for industrial sustainability. In order to improve their energy efficiency and thus industrial sustainability performances firms should implement energy efficiency measures (EEMs) that are not largely diffused yet. Hitherto, EEMs have been evaluated exclusively by looking at barriers from an energy efficiency decision maker's viewpoint, thus not accounting for a broader sustainability perspective. When considering the latter, the Triple Bottom Line could be taken: within an industrial context, it can be identified with the areas of Occupational Health and Safety (OHS) and Eco-efficiency (in which energy efficiency is gaining increasing relevance). For this reason, the present work is aimed at better understanding barriers to EEMs adoption, by analyzing them through different perspectives and insights offered by several responsible of single areas of industrial sustainability within a firm.

To address this research gap, we have investigated through explorative case studies some firms within Northern Italy with a specific model on barriers to industrial sustainability measures,. The results seem to show that an EEM should be analyzed under different perspectives. New with respect to previous literature, a more proper perspective for analyzing an EEM should be that of industrial sustainability, and not just that of energy-efficiency, since it may result limited. Energy and Environmental managers may have a different perspective on barriers than the OHS's one, highlighting barriers not perceived by just one area's responsible. Moreover, an EEM may be stopped by reasons not knowledgeable to energy efficiency, rather to other areas, such as, e.g. OHS. Lastly, an EEM may have positive effects (co-benefits) on other areas of industrial sustainability, that may be perceived only by such areas. The study concludes with some remarks for policy and industrial decision- makers, and advice for further research.

Introduction

The Brundtland Report in 1997 first defined Sustainability as the "meet the needs of the present generation without compromising the ability of future generations to meet their own needs" (WCED, 1987). Since then, numerous action plans and agreements have been studied and developed by national and international organizations, committees and governments, in order to increase sustainability at different levels of society. Examples of these are the Rio de Janeiro UN Conference, the Kyoto Climate Change Protocol, the Johannesburg World Summit, and the COP21 Paris Agreement.

Energy efficiency is a fundamental area of sustainability, as it can be inferred also using the Triple Bottom Line (TBL) proposed by Elkington (1998), according to which Sustainability can be defined as the intersection of three different issues, that are identified as "pillars" and are namely Environment, Economic and Safety. Energy use is not only necessary for economic and industrial activities, but it also causes different environmental impacts, primarily greenhouse gas emissions, but also air and water pollution (European Commission 2011). Moreover, by looking at the aforementioned plans and agreements, it is possible to observe that energy efficiency represents one of the main objectives (see, e.g., EU

Energy Efficiency Plan, 2011; EU Energy Efficiency Directive, 2012).

In the industrial sector, when addressing sustainability, we refer to industrial sustainability, that is represented by Occupational Health and Safety (OHS) and Eco-efficiency, in which energy efficiency is gaining increasing importance and it is very often considered as an area of industrial sustainability per se. These areas refer respectively to the Social and Economic and to the Environmental and Economic pillars of the TBL [see also (Pagell and Gobeli 2009; Gimenez et al. 2012)]. The industrial context would represent a primary area for improving sustainability and energy efficiency, since it covers about one third of the EU primary energy consumption and has still ample room for improvement, as authors note (Calogirou et al. 2010; European Commission 2011; Energy Information Administratio, 2013; Eurostat 2013; Eurostat 2014). In order to achieve their energy efficiency goals, firms should implement numerous energy efficiency measures (EEMs). Nevertheless, even though such measures have been proven to be very effective and profitable, they are often not implemented. Indeed, this is due to the presence of several barriers that affect the decision-making process or can even prevent the possible willingness of implementing a measure, as deeply studied in literature. The debate over the existence of the so-called "energy efficiency gap" started in the early 80's with the contribution by Blumstein et al. (1980), who underlined the existence of an hidden potential for energy efficiency, followed by other authors such as Stern (1984), Hirst and Brown (1990), De Canio,(1993) and Jaffe and Stavins (1994). Until this point, literature considered three main typologies of barriers: market failures, non-market failure and behavioural. A taxonomy comprehensive of all these perspectives has been developed by (Sorrell et al. 2000). The taxonomy has been then modified in (Sorrell et al., 2004) and in (Sorrell et al., 2010) in order to obtain a neater one, and it became the basis of several empirical contributions that lay on the three perspectives and/or use them as a theoretical starting point (Rohdin and Thollander 2006; Schleich and Gruber 2008; Fleiter et al. 2012; Trianni and Cagno 2012; Venmans 2014). Thollander and Palm, (2012) underlined the importance of considering the socio-technical perspective when addressing barriers to the implementation of EEMs. More in detail, they highlighted that promoting the energy efficiency improvement in firms is related to deeply understand which is the perception of energy use and efficiency within a firm, considering that actors' organizational position and social network may play an important role. A new perspective on barriers to EEMs has been given by Cagno et al. (2013), who studied barriers from an industrial decision maker point of view, taking inspiration by the taxonomy proposed by (Sorrell et al. 2000). This new proposed taxonomy has been used as a basis for other contributions, such as (Brunke et al. 2014; Johansson 2015; Catarino et al. 2015).

Numerous contributions have studied barriers empirically, with contributions in different context such as: firm sector, (Nagesha and Balachandra 2006; Blass et al. 2014; Rohdin et al. 2007; Trianni et al. 2013), country (Anderson and Newell 2004; Walsh and Thornley 2012; Liu et al. 2014) or firm size (Thollander et al. 2007; Fleiter et al. 2012; Trianni et al. 2012; Kostka et al. 2013). But, to fully understand why firms do not adopt EEMs, some additional considerations should be done.

Firstly, as aforementioned, energy efficiency is a part of industrial sustainability, and it might be analyzed in this broader context, in order to evaluate possible interdependencies among the different areas of industrial sustainability (Trianni et al. 2015). Secondly, as Cagno and Trianni (2014) noted, the relevance of a barrier with reference to a specific measure might vary according to the level at which it is investigated (e.g., company level, technology area level and energy management level). Therefore, we could reasonably infer that, as energy efficiency decision makers within the firm, at different levels, may perceive different barriers' relevance, similarly different people acknowledgeable for industrial sustainability areas might have different perspectives on barriers related to a specific measure of industrial sustainability, including, of course, EEMs. In this way, technology/service suppliers and policy makers, in order to promote EEMs needed by firms, must evaluate the barriers to the implementation of EEMs not exclusively from an "energy efficiency" perspective, but also broadening the perspective and analyzing the different viewpoints related to industrial sustainability.

Thus, the most effective way to evaluate EEMs is to evaluate them as an industrial sustainability measure.

Hence, this paper aims at empirically investigating the following research questions:

- What are the differences among the perspectives of different responsible accountable for industrial sustainability areas within the same firm, with reference to the same EEM?
- What is the impact of this different perspectives related to the different responsible accountable for industrial sustainability areas within the same firm on the implementation of EEMs? Can an EEM be supported or prevented by issues related to the other areas of industrial sustainability?

The paper is organized as follows: after the presentation of the theoretical framework used for the evaluation of barriers to EEMs implementation, the research method, i.e. the case study methodology and the data collection and administration, is discussed. Further, results are presented and discussed in a specific section, and concluding remarks and suggestions for further research are provided in the final section.

Theoretical Framework

In order to study barriers to EEMs under an industrial sustainability hat, it was decided to investigate such barriers using a model specifically developed for barriers to industrial sustainability (Trianni et al., 2015). This model has been studied for the improvement of industrial sustainability, i.e. the unit of analysis is an Industrial Sustainability measure.

The model has been developed starting from a thorough review of literature regarding industrial sustainability. Indeed, the authors have created a model able to provide a comprehensive understanding on barriers to industrial sustainability measures' implementation, with both the capability to point out general barriers to sustainability, as well as the ability to evaluate barriers to specific measures in the areas of OHS, eco-efficiency and energy efficiency. In this study the model will be used for the analysis of EEMs from the different perspectives related to the different responsible accountable for the areas of industrial sustainability within a firm.

Table 1. The theoretical model of barriers to industrial sustainability proposed by Trianni et al. (2015). Origin (within or outside the firm), Categories and related Barriers are reported, for each Category and each Barrier, definition is provided. In the last three columns is indicated the stream of literature in which the barrier was identified (EE: Energy Efficiency, Eco-E: Eco-efficiency, OHS).

Origin	Category	Category definition	Barrier	Barrier definition	Found in Literature
External	Regulatory	Government's actions can be ineffective or can hinder interventions	Legal requirements	Legal requirements are excessive or not effective with respect to the real needs of the company related to sustainability.	EE, Eco-E, OHS
			Bureaucracy	Excessive amount of paperwork necessary to be compliant with legal requirements, which is not tailored with respect to the capabilities of the company.	EE, Eco-E, OHS
			Lack of incentives	No economic incentives such as tax exemptions and grants for the implementation of interventions.	EE, Eco-E
			Policy distortion	Taxes, subsides or other policy interventions that discourage the implementation of interventions.	EE
	Support	Inability of technical experts, support agencies or institutions to provide the firm with the support and advice needed	Lack of external technical support	Firm does not receive a technical support suitable to its needs.	EE, Eco-E, OHS
			Lack of consultancy	There is not an adequate consultancy (from services, insurance companies, accounts, public authorities) that can help firm in the different phases of the decision making.	Eco-E, OHS
	Market	Barriers related to this group have their origin in the economic system in which the firm is located	Customer not ready/Lack of demand	Customers are not sensible to the issue thus not requiring a minimum level of performance e.g. not demanding green products/not demanding specific safety requirements.	EE, Eco-E
			Uncertainty of future trend	Without guidance on the future trend e.g. the prices of energy, natural resources or fines lower of sustainability, interventions may be avoided.	EE, Eco-E
			Distortion of price	Prices do not reflect all the externalities (that can be related for example to environment or to social costs).	EE, Eco-E
Internal	Organization	Barriers related to this group arise within the enterprises and are related to resources, behavior, values and culture, attitude of the firm towards sustainability	Lack of time	Firm has not enough time for the implementation of the intervention.	EE, Eco-E, OHS
			Lack of staff	Firm has not enough staff for the implementation of the intervention.	EE, Eco-E, OHS
			Resistance to change/Inertia	Organization can be against the change since it leads to a modification in ways of working and in habits.	EE, Eco-E, OHS
			Attitude/Other priorities	The culture and the values of the firm inhibit the implementation of the interventions. Moreover the decision making might be focus almost uniquely on core the business activity, thus focused mainly on productivity related interventions.	EE, Eco-E, OHS
			Communication	Lack of communication or the inadequacy of communication between management and workers or between the workers themselves.	EE, Eco-E, OHS
			Workplace and task	Not taking into account the workplace (analysis of the workplace, like hazard exposures) and the tasks (design, pace, repetition, pressure and psychosocial issues) during the implementation of an intervention may have inhibitory consequences.	OHS
			Organizational system	The firm is a social system influenced by goals, routine, organizational structure and dominated by the decision making. There are several factors related to the company's structure that can hinder interventions.	EE, Eco-E, OHS
	Management behaviour	Hindrance of interventions that derive from a management not aware or expert of the issue	Commitment/ Awareness	Manager has no awareness and/or commitment.	EE, Eco-E, OHS
			Expertise	Manager lacks of adequate management skills with respect to the issue or has limited expertise.	EE, Eco-E, OHS
	Workers behaviour	Role of workers during the implementation of interventions, both for what it is about their training and awareness, and for what concerns their proper involvement	Not trained/ skilled	Lack of adequate skill or training of the personnel, with respect to a specific intervention area, can hinder the implementation of intervention.	EE, Eco-E, OHS
			Awareness	Staff lacks of awareness on the issue and ignores which are the criticalities of the firm with respect to the issue.	EE, Eco-E, OHS
			Not involved	Employees not involved are given a fair opportunity to take an active part in the decision-making and realization process.	EE, Eco-E, OHS
			Incorrect behaviour	The adoption of wrong behaviours by the personnel can hinder the implementation of sustainability interventions in case in which an active participation of the personnel is required.	OHS
	Information	Refer to all the types of information that the firm may need for the implementation of interventions	Lack of information	Lack of information or inadequacy of the information owned by the firm with reference to all the aspects related to intervention implementation.	EE, Eco-E, OHS
			Trustworthiness of information	Problems with trustworthiness of the information sources, the sources are not adequate.	EE
	Technology/ Service	Refer to the technology or the service needed by the firm for the implementation of intervention	Lock in	Solution is incompatible with the current status of the system.	EE, Eco-E
	Economic	Role of the economic factor in the implementation of interventions	Limited access to capital	Firm does not have sufficient capital for the implementation.	EE, Eco-E, OHS
			Hidden costs	Investment entails extra costs or loss of benefits that are no properly estimate in investments analysis.	EE
			Risk	Risk related to the success of the interventions e.g. interruption of production, losses in quality.	EE, Eco-E
			Investment cost	High investments costs prevent firms from implementing sustainability interventions.	EE, Eco-E, OHS
			Pay back time	Intervention not sufficiently profitable such as low returns and long period of time required.	EE, Eco-E, OHS

Table 2. The model for empirical investigation proposed by Trianni et al. (2015). To each barrier is assigned a code, which will be used during the empirical investigation of the model.

Category	Barrier	Barrier's Code
Organization	Lack of time	O1
	Lack of staff	O2
	Resistance to change/Inertia	O3
	Attitude/Other priorities	O4
	Communication	O5
	Workplace and task	O6
	Organizational system	O7
Management behavior	Commitment/Awareness	M1
	Expertise	M2
Workers behavior	Not trained/skilled	W1
	Awareness	W2
	Involvement	W3
	Incorrect behavior	W4
Information	Lack of information	I1
	Trustworthiness of the information sources	I2
Technology/Service	Lock in	T1
Economic	Limited access to capital	E1
	Hidden cost	E2
	Risk	E3
	Investments cost	E4
	PBT	E5

The theoretical model is structured as follows (Table 1): firstly, the origin of barriers has been identified, that can be external or internal with reference to the firm; secondly, categories, that is where the barriers stem from, have been modelled. In particular, nine categories could be observed, three external (Government, Support, Market) and six internal (Organization, Management behaviour, Workers behaviour, Information, Technology, Economic). Lastly, each Category is then detailed in one or more barriers. The theoretical framework has been then adapted for empirical investigation by the authors, and the final framework for the empirical investigation is reported in Table 2. In performing this adjustment, the authors tried to identify how external barriers are perceived by internal stakeholders as an internal barrier. For further detail, please see (Trianni et al. 2015).

Research method

CASE STUDY METHODOLOGY

A first exploratory empirical investigation has been focused on EEMs implemented, rejected or considered for implementation among Lombardy's (Northern Italy) manufacturing firms. This choice was based both on the importance of the Lombardy region in Italy both for the importance of the manufacturing sector in the Country and the still wide room for improvement in energy efficiency (Calogirou et al. 2010; European Commission 2011; Lombardy Region, 2013). Companies have ben sampled according to some major characteristics (summarized in Table 3).

We decided to use the case study as research method, since this study meets the characteristics of case study research identified by Yin (2009), as well as by Meredith (1998), Voss et al. (2002) and Zorzini et al. (2008): case study corresponds to a situation in which "why", "how" and "what" questions are asked, there is any or little control by the investigator over events and contemporary events are investigated. The primary sources for the analysis was a semi-structured interview. This allows researchers to structure the interview and keep a logical order. We have organised the interview by open-ended question, as well as other questions emerging from the dialogue between interviewer and interviewee/s, in order to collect also open comments and secondary data, according to Dicicco-Bloom & Crabtree, (2006). Through the interviews qualitative data were collected. The use of a Likert-like scale for the identification of each barrier's relevance was used in order to synthetize the perspective of the persons interviewed, and it is meant as a quantitative transformation of comments and evaluations, with which it was also triangulated.

In addition, as suggested by Voss et al. (2002) and Yin (2013), multiple sources of evidence both qualitative and quantitative (i.e. behaviour observations, documents, quantitative data …) were used in order to triangulate the findings and further increase the validity of the analysis (e.g. face to face interviews, observations, phone interviews, official documents etc.).

According to Yin, (2009), a good case study research must meet four essential requirements: external validity, internal validity, construct validity, and reliability. External validity refers to the extent of generalization of results, and in this study it was assessed by defining the domain, defined at the beginning of the paragraph, to which study findings can be generalized; internal validity was assessed through pattern matching during data collection; construct validity was achieved through the use of multiple sources of evidence; reliability of the results was obtained with the use of a case study protocol (Yin, 2009).

DATA COLLECTION AND ADMINISTRATION

A case study protocol was developed and thorough face-to-face interviews of approximately 1.30–2.30 hours with personnel acknowledgeable and responsible of industrial sustainability areas were conducted.

In particular, interviews consisted of four parts:

1. Descriptive information about the firm were collected.

Table 3. Data of the firms interviewed

Data of the firm	Firm A	Firm B	Firm C
Ateco Sector	28	25	25
Size	Small	Medium	Large
Form of business	S.r.l	S.p.A	S.p.A
Turnover	€18,000–20,000 (Medium)	€20,000–25,000 (Medium)	€70,000,000–90,000,000 (Large)

2. The model as a whole and individual barriers were explained.
3. The persons interviewed were asked to list the main barriers faced by the firm when implementing measures related to energy efficiency improvement in general.
4. The method for the evaluation of single measures implemented within the firm was explained. For each measure, it was asked to indicate the relevance of each barrier during its implementation, or the main barriers that have prevented its implementation. Relevance has been assessed it using an even 4 points Likert-like scale, where 1 is "no relevance", 2 "low-medium relevance", 3 "high-medium relevance", 4 "high/very high relevance". As authors note, an even-number Likert-like scale forces the person interviewed to take position, thus avoiding a neutral one by placing in the middle (Cagno and Trianni, 2014). On the basis of previous research conducted by the authors, measures with an impact on the energy efficiency area of industrial sustainability were selected (Trianni et al. 2015) and a list of measures was provided to the person interviewed. The rationale behind the choice of measures of the given list has been two-fold: firstly, to identify the most implemented measures in the area of energy efficiency; secondly, to have a short list of measures with a certain impact on energy efficiency and different impact on other areas of industrial sustainability. In particular, for each measure, impact on the different area was taken in consideration [see (Trianni et al. 2015)].

During each interview, we asked to Energy, Environment and OHS responsible if the firm had implemented or had evaluated the implementation of other possible EEMs not considered in the given list.

Secondary data regarding firms' information, strategy and sustainable actions undertaken were collected and used to triangulate the information obtained during the interviews. To improve the reliability of the empirical research, structured procedures for the interviews analysis were used and interviews were organized in a common framework, in order to have a better outline of each case study.

Results

In this section the results from the case studies are illustrated. Each sub-section is structured as follows: a description of the firm is given; a presentation of the main barriers (with different perspectives on that, if any) to the implementation of EEMs is provided, followed by the presentation of interesting consideration pointed out in the analysis of single EEM; lastly, emerged issues are discussed.

FIRM A

Description of the firm

Firm A was found in 1983 and since then it has been growing steadily and rapidly. Firm A manufactures numerous types of products. The production process in organized in six parts and the firm deals with different technologies: design lab, toolmaker division, extrusion division, injection division, lathes division and the robotic division. The firm operates 24 h and it is run by qualified people who adhere to a Quality Assurance Service program in addition to being certified ISO 9001.

We interviewed the people in charge of Energy and Environment issues and the one in charge of OHS ones. We interviewed the two responsible separately so to better catch the personal point of view each of them. They both were asked to underline the main barriers faced in the implementation of EEMs in general, and then with reference to specific ones.

At the end of the interview it was possible to interview a representative of the Administration Department, recently hired by the firm. It was asked him to evaluate the barriers to the implementation of EEMs in the firm in general terms.

Different perception of barriers relevance within the firm

General level of barriers to EEMs

As shown in Table 4, the Energy and Environment responsible tended to relate barriers to Workers behaviour and Economic aspects, thus not perceiving possible problems related to firm's Organization or Management. The OHS Responsible appeared more critical with respect to the internal Organization of the firm; he also recognized the importance of Workers' wrong behaviour related barrier and of technological Lock in problems. Lastly, the Administration Representative identified as fundamental barriers the one related to Organization, Management and Economic problems. In summary, each person interviewed had a different perception on the barriers to EEMs.

Extractor fans (Not Implemented)

The implementation of this measure was strongly supported by both the responsible. It was born as a measure for improving workers' comfort, but it was recognized by both the responsible as able to bring energy savings to installed equipment. A feasibility analysis was conducted by an external company that underlined the need of installing six extractor fans in order to improve the working and operating conditions for workers and for machines. The responsible did not perceive or identify any barrier for the implementation of this measure: the Energy and Environment responsible just underlined the importance of considering possible Lock in barrier during the feasibility study. During the interview, both responsible agreed on the positive results that the implementation of this measure could have brought, underlying, however, the fact that the top management was not particularly convinced. The management decided to install only two extractors out of the six and to evaluate the positive effects deriving from this installation. Of course, since all six extractors were needed to have positive effects, the management was not able to perceive benefits after the installation, so that it was decided to stop the implementation of the measure. The management was not able to properly assess the benefits deriving from the installation, i.e. he identified some barriers in the pay back time of the measure.

Preventive Maintenance (Implemented)

Both the responsible agreed that the amount of Preventive Maintenance practices implemented within the firm was very low compared to the amount of maintenance practices currently in place.

The Energy and Environment responsible affirmed the main barriers were related to Lack of Time, Lack of Staff and to Risk

of possible production losses, as he stated: "We are strictly tied to the available workforce" and "And then, you have to ask, which is the reverse of the coin I get? Does all this translate into a positive result?"

The OHS responsible identified as main barrier the Attitude/ Other priorities of the firm, deriving the other relevant barriers from this, i.e. Lack of time, Lack of staff, Resistance to Change/ Inertia and Organizational system). He stated: "Attitude, I think this [Attitude/Other priorities] is the main barrier […] I think that the pulling should derived directly from the attitude as a philosophy".

Detection/ Elimination of Compressed Air Leaks (Not Implemented)

The two responsible recognized that firm had problem with compressed air leaks, in particular OHS responsible stated: "You can come here on Saturday or Sunday and easily have an idea on how many vents we have". The firm had the chance to get in touch with a company able to help them during the implementation of this measure, but then the project was never undertook.

According to Energy and Environment responsible the main problem was related to the management of the firm that would have needed to be pushed for the implementation of the measure, as he stated "We started to make an analysis […] but then we have inevitably to cope with a property that needs to be pushed for".

The OHS responsible instead identified as main barrier the Lack of time, that, as can be easily inferred by its words, has its roots in the attitude of the firm: "Lack of time… yes, also because this would have been a project of those that we would have liked to follow within the firm. In order to reduce or eliminate the Lack of time barrier, it would be possible to hire some external consultants, but this is not part of the management's attitude, and, as far I am concerned, neither mine."

EEMs with positive effect on safety

Use daylight when possible (Implemented)

Firm A has three different types of places: those where artificial light is hardly needed; those where artificial light is necessary, also for safety reasons; and those in which, given certain external weather conditions, artificial light may be unneeded, thanks to the installation of glass roofing (where possible).

The Energy and Environment responsible did not identify any barrier during the implementation and the service of the EEM On the contrary the OHS responsible underlined that quite often, since the turning on or off of the artificial lights is not automated, workers turn on the light according to their discretion, thus identifying a workers' incorrect behaviour related barrier. After the interview it was possible to have a look at the production plant, once arrived in on of the spaces under investigation for this measure, the OHS responsible said: "Look, it is a very sunny day, the spaces are properly illuminated also solely with the daylight, but, as you can see, lights are turned on"

Even if this EEM faced an incorrect workers' behaviour barrier during its service, it is undoubtedly that it has brought also some benefits related to workers' working condition. As a matter of fact, the OHS responsible said: "Of course a daylight illuminated space positively impacts on the comfort of the workers and they prefer to work in such a space instead of in one illuminated only by artificial light."

EEMs not implemented for safety reason

The OHS responsible was asked to discuss about EEMs that he stopped for safety reasons. He stated that the firm would never result well disposed to implement measures that could compromise workers' safety. He made the example of a system for the aspiration of particulate. Indeed, even if from an energy efficiency perspective it would be better to have an higher aspiration speed, OHS responsible would never allow that, as, in the specific context, it would compromise workers' comfort. To summarize, it was quite clear that safety issues are always considered when deciding about possible EEMs' adoption.

Emerged issues

The evidence from Firm A seems to suggest that Energy and Environment responsible is not aware of, or not able to address properly the barriers related to the organization of the firm and to the awareness of the firm in general on energy efficiency issues.

The different perspectives on barriers' relevance related to the two responsible was underlined also between the responsible perspectives and the management's one. This is a very interesting point, since very often the final decision whether to implement a measure or not is taken, ultimately, by the top management.

Proof of evidence proved also that EEMs can be stopped for safety reasons, that is, they are recognized to possibly decrease the safety and the comfort level of the workers, but they can also bring positive affects on other areas of industrial sustainability, such as on OHS.

FIRM B

Description of the firm

Firm B operates in the metal sector since 1951. It is a world leader in the manufacture of high precision machine tool accessories and it is worldwide known for the quality of its products, which are developed basing on the one hand on the changes in the customers' needs, on the other hand on the technological progress of the precision engineering industry. Indeed, 70 % of the products are sold all over the world and 30 % in Italy. The firm has two separate and independent production plants, one in Lombardy and the other one in another Italian area. For this research the Lombardy's plant was considered.

For Firm B, workers are a very valued asset, and several actions are undertaken in order to assure them a safe, comfortable and enjoyable workplace, e.g. plants and flowers in the production area, smokers' area, flexible working hour as well as warning signs and safety instructions not only on each machine, but also in several different places of the production area.

We interviewed the people in charge of Energy and Environment issues and the one in charge of OHS issues. We interviewed the two responsible separately so to better catch the personal point of view each of them. They both were asked to underline the main barriers faced in the implementation of EEMs in general, and then with reference to specific ones.

Different perception of barriers relevance within the firm

General level of barriers to EEMs

As it can be inferred from Table 4, the OHS responsible identified nearly any barriers related to the implementation of EEMs, stating that, in general, EEMs were implemented without any problem. On the contrary, the Energy and Environment responsible, considered as extremely important the Organizational barriers, as well as the Economic ones. He also highlighted barriers related to Workers and Information.

Substitution of motors with more efficient one (Not implemented)

Regarding the possible substitution of motors with more efficient ones, the OHS responsible affirmed that the motors used by the firm are small and are not particularly energy consuming. He added they substituted two motors for wear in the last years, without facing any particular barrier. The Energy and Environment responsible gave a total different view on the issue. In particular he said the firm has several motors. The Energy and Environment responsible asked to an external consultancy company to evaluate possible measures to improve the energy efficiency performance of the firms, and motors were identified as one of the main areas of intervention. The responsible highlighted Lack of Information and Lack of Awareness of the overall organization as two of the causes that made him contact the consultancy company. Although the conducted study, Lack of time and High cost of investment are the main barriers for which they have not substituted the motors yet.

Preventive Maintenance (Not implemented)

Regarding the implementation of preventive maintenance, some interesting issues emerged. Indeed not only the two responsible saw different barriers but they also have different view on the implementation of the measure. The OHS responsible stated that preventive maintenance is not considered and maintenance is implemented only after a machine break, thus neglecting the implementation of preventive maintenance. On the contrary, the Energy and Environment responsible stated that there is a maintenance team that periodically should control the machines; but, even if these activities are scheduled, very often they are not implemented for Lack of Time and the Cost related to the production disruption. Moreover, workers should implement preventive maintenance during their working hours, but, as the Energy and Environment Responsible stated: "In this way they have to interrupt their normal activities, postponing them, or have to stay at work after the normal working hours" and added that preventive maintenance "is perceived by workers as a waste of time".

Energy efficiency performances overcome by safety reason

Processing parameters lowered for safety reason

We asked the responsible whether or not, in the potential change of a machine for noise reduction, they would have considered to buy to a more energy efficient one than the previous. Both of them, in answering, referred to a machine that was not substituted but just moved from the original place to another one, where there are less workers and higher ceiling (so that the noise is more easily dispersed). Although the transfer and the fact that the machine was used one day every two weeks, since the noise was still loud, some processing parameters were lowered in order to reduce the noise. OHS responsible stated that there was any barrier in the implementation of this measure. Also the Energy and Environmental responsible said that were no barriers, underlying that they "just change the processing parameters". It was logical to ask him whether this change had somehow reduced the performances of the machine, increasing its energy consumption. He answered in the affirmative, adding that "workers were properly equipped with ear protection, but they did not use them. Nevertheless, they complained about the noise and, in order to guarantee a comfortable place for workers to work in, it was decided to lower the parameters".

Emerged issues

The OHS responsible has completely no vision of the possible problems related to the implementation of an EEM. This situation is well underlined by the fact that he identified no barriers for all the EEMs proposed, stating they were implemented without any problem, while the Energy and Environment responsible stated he had a lot of problem in promoting EEMs within the firm and above all he underlined barriers related to Organization and Economic issues.

The firm pays for sure a lot of attention to safety related issues, in order to provide workers "a workplace where you are happy to go to work in when you wake up in the morning", as the OHS responsible said. This vision had lead, as in the case of the noisy machine, to the reduction of the optimal processing parameters of the machine in order to increase the comfort of the workers who, nevertheless, were equipped with ear protection and decided autonomously not to wear them. It is possible to affirm that energy consumption optimization was overcome by comfort related (although unneeded) reason.

FIRM C

Description of the firm

Firm C is a market leader in the ammunition sector. It was founded in the 19th century and, since then, it has always invested in technology research. Firm B invests in new technology not only to be always up-to-date but also for the research of appropriate solutions to meet the needs of environmental sustainability. The company turnover has been growing during the last years and the 60 % of it is attributable to export.

As the firm pays particular attention to customer satisfaction, scrupulous controls during all the production phases and the attention that commercial department gives to every order are fundamental. As evidence of this commitment, the company achieved numerous certifications. On the one hand, Firm B has certification related to its sector of activity, on the other hand it has international technical standard's certifications such as ISO 14001, ISO 9001 and OHSAS 18001.

The firm has a Health Safety and Environment (HSE) responsible, who was the person interviewed as the only one in charge of the issues related to this study.

A Table 4 shows, responsible reported few barriers for the implementation of EEMs, and they are referred mainly to technological Lock in, Other priorities of the firm and Cost of

investment, reasonably related to the huge efforts paid in the Environmental and Energy related issues (as also certifications obtained seem to show).

EEMs that have not been implemented for safety reason

Substitution of lamps/light sources with more efficient ones (Not Implemented)
The responsible recognized the importance of the installation of energy efficient lamps. The measure was, at the time of the interview, under evaluation, and was suffering mostly for Investment cost barrier. However, given the economic feasibility of the measure, there were some places in the plant that would have never been equipped with more efficient lamps. Indeed, given the fact that in these areas explosive material is stocked, the implementation of this measure would be quite dangerous.

EEMs sponsored from the safety viewpoint too

Detection/Elimination of Compressed Air Leaks (Implemented)
The measure of detection and elimination of leaks of compressed air is implemented regularly by the firm. It origins from the energy efficiency area, since it allows a great reduction in energy consumption, but the firm also recognized the considerable improvement in working conditions and, among others, the noise reduction. The economic benefits deriving from the elimination of the leaks are seen as an important and positive implication for the implementation of the measure, but they are not deemed as the first reason for implementing the EEM. In this regard, the HSE pointed out "[The detection and elimination of risk] is also money that we save".

Emerged issues

Proof of evidence proved that EEMs could be stopped for safety reasons, i.e. when their implementation is recognized to be possibly dangerous for safety. Moreover, it was underlined how an EEM can be implemented for reasons related both to energy efficiency and to other areas of industrial sustainability, such as OHS.

Concluding remarks

In order to investigate the barriers to EEMs in the context of sustainability and under different perspectives related to industrial sustainability, three case studies in manufacturing firms located in Northern Italy (one of the European wealthiest and most industrialized regions) were conducted, through semi-structured interviews with the responsible of the industrial sustainability areas' in the firms.

Despite that the sample is for sure limited and further investigation is needed, still the findings offer good preliminary insights drawing some considerations for industry and policy-makers:

1. Different responsible have different perspectives on the relevance of the barriers in the implementation of an EEM. It resulted in that actually, every responsible has his own perspective. In this way, the most effective way to evaluate EEMs and the problems related to their implementation is to evaluate them under the umbrella of industrial sustainability. Indeed, during the analysis of barriers to EEMs the Energy responsible is not the only person to be considered for the investigation, because a lot of other information can be inferred from other responsible' perspectives. It was also underlined the one who takes the last decision, i.e. the top management, may be not fully aware of barriers and benefits related to and that can derive from the implementation of measure. Of course, in this case, position in the organizational chart could play a very important role.
2. EEMs can be stopped for safety reason. As a matter of fact, workers' safety and comfort turned out to be something from which firms cannot prevent when implementing EEMs, in order to avoid problems (different kind of, with different impacts) in the ongoing of the measure.
3. EEMs can also bring safety benefits. Evidences underlined that EEMs can be linked also to an improvement in performance related to other areas of industrial sustainability, i.e. for example OHS. These improvements may have not been considered or assessed before the implementation. This finding can be related to the stream of research regarding the non-energy benefits of EEMs (Nehler and Ottosson 2014).

What can be inferred is that, in order to adopt an EEM, it is necessary to consider not only the energy/energy efficiency department within the firms, but also all those areas that, one way or another, may be involved in the implementation of an EEM. These areas are typically those related to industrial sustainability, as well as all those managers/responsible that may be involved in the decision making process or in the operation of the EEM. Industrial decision makers and policy makers should not overlook the perspectives that responsible of all industrial sustainability areas may have on the EEM and should understand which are the barriers perceived by them. In addition, for an effective implementation of an EEM, it is not possible to avoid taking in consideration the impact of the measure on the other areas of industrial sustainability, which, as it can be inferred from our study of specific EEMs, , can be either positive or negative.

This study has some limitations that derive from the little sample investigated. Of course the extension of the study to a broader sample would allows appreciating possible common patterns. It would be interesting, for example, to investigate these patterns according to firms' cluster related to their geographical area, sector, dimension, firms' characteristics (e.g. if they are energy intensive or not, the different types of processes etc.), organizational characteristics (e.g. different configuration of organograms and related division of responsibilities in the industrial sustainability areas). Moreover, with an even larger sample, it would be possible to make some statistical analyses.

These all could be further development of the study. Parallel, it could be also very interesting to understand which could be the role of energy efficiency in preventing or supporting the implementation of measures related to the other areas of industrial sustainability, that is, sharing the view of Trianni et al. (2015), mainly related to Eco-efficiency and OHS. Once addressed the barriers, would be is important to understand which are the drivers that may act on these barriers, both at an industrial sustainability and at an energy efficiency level. In this regard, it would be of great interest to study drivers with respect to the multiple perspectives related to industrial sustainability.

Table 4. For each firm the relevance assigned to each barriers of the model to the implementation of EEMs by each responsible interviewed is reported.

			Firm A			Firm B		Firm C
Category	Barrier	Barrier's code	Energy and Environment Responsible	OHS Responsible	Administration Representative	Energy and Environment Responsible	OHS Responsible	HSE Responsible
Organization	Lack of time	O1	1	2	2	3	1	1
	Lack of staff	O2	1	2	1	2	1	1
	Resistance to change/ Inertia	O3	1	3	3	1	1	1
	Attitude/Other priorities	O4	1	3	3	1	1	2
	Communication	O5	1	1	4	1	1	1
	Workplace and task	O6	2	1	1	1	1	1
	Organizational system	O7	1	2	3	2	1	1
Management behaviour	Commitment/ Awareness	M1	1	1	4	1	1	1
	Expertise	M2	1	1	4	1	1	1
Workers behaviour	Not trained/skilled	W1	1	2	1	1	1	1
	Awareness	W2	1	2	2	1	1	1
	Involvement	W3	3	2	2	1	1	1
	Incorrect behaviour	W4	1	2	1	2	1	1
Information	Lack of information	I1	1	1	1	1	1	1
	Trustworthiness of the information sources	I2	2	2	1	2	1	1
Technology/ Service	Lock in	T1	2	3	1	1	1	3
Economic	Limited access to capital	E1	1	1	1	2	1	1
	Hidden cost	E2	2	2	2	1	1	1
	Risk	E3	3	2	1	1	1	1
	Investments cost	E4	3	2	4	4	2	2
	PBT	E5	3	2	3	3	1	1

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