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ORIGINAL ARTICLE

Classification of drivers for industrial energy efficiency and their effect on the barriers affecting the investment decision-making process

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Abstract Industrial energy efficiency represents a priority for European industrial competitiveness. Many studies offer contributions providing evidence of the existence of driving forces supporting the adoption of energy efficiency measures, but a structured approach to drivers for industrial energy efficiency is still lacking. Therefore, in the present study, we propose a definition of drivers, making emphasis on the industrial decision-maker perspective, that is needed for their classification here proposed. Focus is given to point out the difference between internal and external drivers, highlighting the major stakeholders responsible for their promotion. Drivers are further categorized into: regulatory, economic, informative, and vocational training. Moreover, we propose a framework describing the effect of drivers on barriers in the decision-making process, as well as a preliminary identification of the major stakeholders to promote drivers. The study opens several opportunities for further research in the area of industrial energy efficiency.

Keywords Energy efficiency · Drivers · Classification · Barriers · Decision-making · Energy efficiency measure

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Introduction

Improved energy efficiency has become a strategic issue for Europe, and much greater efforts are needed in all countries and sectors. In this regard, industry surely represents a key player, as increased energy efficiency may be a relevant driver for improved competitiveness of the industrial sector (European Council 2012).

Research has revealed that, despite the existence of a wide range of energy efficiency measures (EEMs), their implementation rate is still very low (Anderson and Newell 2004; Cagno and Trianni 2012), due to several barriers (e.g., Sorrell et al. 2010a, b). Taking inspiration from Sorrell et al. (2000; 2010a, b), Cagno et al. (2013) have recently defined a barrier as "a postulated mechanism that inhibits investment in technologies that are both energy efficient and (apparently) economically efficient," without the necessity that one or more other barriers occur." The issue of barriers has been widely covered by scholars (Palm 2009). Regarding theoretical studies, recent literature reviews have been conducted (Sorrell et al. 2010a, b) and taxonomies proposed (Cagno et al. 2013). The body of literature concerning empirical studies on barriers is vast, with contributions at all levels, ranging from regional—see, e.g., Trianni et al. (2013a, b)—to domestic or even local level—see, e.g., Thollander and Ottosson 2008; Hasanbeigi et al. 2010; Fleiter et al. 2012; Trianni et al. 2013b; Kostka et al. 2013; Catarino et al. 2015). Many useful approaches may be adopted, but one of the most effective would be to study the decision-making process of adopting an EEM taking the perspective of the final user

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ABSTRACT

Industrial energy efficiency represents a priority for European industrial competitiveness. Many studies offer contributions providing evidence of the existence of driving forces supporting the adoption of energy efficiency measures, but a structured approach to drivers for industrial energy efficiency is still lacking. Therefore, in the present study we propose a definition of drivers, making emphasis on the industrial decision-maker perspective, that is needed for their classification here proposed. Focus is given to point out the difference between internal and external drivers, highlighting the major stakeholders responsible for their promotion. Drivers are further categorized into: regulatory, economic, informative and vocational training. Moreover, we propose a framework describing the effect of drivers on barriers in the decision-making process, as well as a preliminary identification of the major stakeholders to promote drivers. The study opens several opportunities for further research in the area of industrial energy efficiency.

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1 INTRODUCTION

Improved energy efficiency has become a strategic issue for Europe, and much greater efforts are needed in all countries and sectors. In this regard, industry surely represents a key player, as increased energy efficiency may be a relevant driver for improved competitiveness of the industrial sector (European Council, 2012).

Research has revealed that, despite the existence of a wide range of Energy Efficiency Measures (EEMs), their implementation rate is still very low (Anderson and Newell, 2004; Cagno and Trianni, 2012), due to several barriers (e.g., Sorrell et al., 2010). Taking inspiration from Sorrell et al. (2000; 2010), Cagno et al., (2013) have recently defined a barrier as “a postulated mechanism that inhibits investment in technologies that are both energy efficient and (apparently) economically efficient”, without the necessity that one or more other barriers occur”. The issue of barriers has been widely covered by scholars (Palm, 2009). Regarding theoretical studies, recent literature reviews have been conducted (Sorrell et al., 2010), and taxonomies proposed (Cagno et al., 2013). The body of literature concerning empirical studies on barriers is vast, with contributions at all levels, ranging from regional – see, e.g., Trianni et al. (2013; a) –, to domestic or even local level – see, e.g., Thollander and Ottosson, 2008; Hasanbeigi et al., 2010; Fleiter et al., 2012; Trianni et al., 2013b; Kostka et al., 2013; Catarino et al., 2015). Many useful approaches may be adopted, but one of the most effective would be to study the decision-making process of adopting an EEM taking the perspective of the final user as, on the basis of its perceived barriers, he/she will take the decision to adopt or not an EEM. In this regard, some scholars have conducted a work to identify, characterize and model barriers within the decision-making process (Cooremans, 2012; Cagno et al., 2013) and a very few empirical studies can be found (Hasanbeigi et al., 2010; Trianni et al., 2013b).

Likewise, it seems particularly interesting – in order to understand the problem and boost the adoption of EEMs by industrial end-users – to focus on the factors removing the barriers affecting the end-user within the different steps of his/her decision-making process. Here too little work has been conducted. In fact, despite the existence of a huge body of literature on the policy activities to favor industrial energy efficiency, as well as empirical studies trying to highlight some factors driving enterprises to adopt EEMs (since ’80, see, e.g., from Blumstein et al., 1980, to more recently, Brunke et al., 2014 and Cui and Li, 2015), a comprehensive, exhaustive and, at the same time, effectively operative approach to understand how to overcome barriers to industrial energy efficiency seems so far missing.

It is clear that the comprehension of the drivers and the mechanisms linking drivers to barriers in the decision-making process looks really interesting also in a policy-making perspective – and in general for the whole energy efficiency market – because, without a proper understanding of the mechanisms to tackle existing barriers affecting enterprises’ decision-makers, policies in their support could be surprisingly ineffective. In fact, policy-makers, understanding drivers, could also identify the stakeholders able to best promote such drivers. Moreover, industrial decision-makers could clearly identify the most acknowledged and effective partners supporting them to increase their energy efficiency. For the whole energy efficiency market, such enhanced knowledge could on the one hand allow to better understand enterprises’ needs, on the other hand possibly open new market opportunities (in terms of e.g., new services).

Nevertheless, to properly define the boundaries of the present work, we acknowledge that the study of how policies should be developed and shaped according to drivers and firm’s characteristics does not fall within the scope of the paper. Likewise, we understand the strong need to have empirical evidence on which drivers can act in different context (e.g., industrial sectors, different energy intensity, firm size, or additional firm’s characteristics, or even context in which firms operate). Nevertheless, we believe that, to fully exploit the empirical evidence, it is crucial to first develop a framework through which the pieces of evidence may be read, in order to better define and shape the most promising opportunities to be deployed in order to support enterprises increasing their efficiency.

Starting from these research gaps, in the present study we address drivers for industrial energy efficiency, looked as stimuli either within a single enterprise or at the hands of the stakeholders directly dealing with enterprises. Therefore, stemming from the literature review, we aim at providing a novel definition of drivers to industrial energy efficiency better fitting the perspective of the industrial decision-maker, followed by a drivers' classification, discussing their most relevant characteristics. Furthermore, we propose a framework describing the mechanisms relating drivers and barriers in the decision-making process to adopt an EEM and a preliminary identification of the major stakeholders promoting EEMs for industrial energy efficiency. The final section provides concluding remarks and suggestions for further research.

2 LITERATURE BACKGROUND ON DRIVERS FOR INDUSTRIAL ENERGY EFFICIENCY

2.1 Review of definitions of drivers for industrial energy efficiency

The definition of drivers itself seems debatable. In fact, Worrell et al. (2003) and Reddy et al. (2013) have given different definitions of drivers, which nonetheless seem both to be partial. The former have analyzed the problem exclusively on technologies, while the second has focused exclusively on investments. Hence, they do not seem to take into account organizational and behavioral issues, which may be insurmountable barriers to adopt some EEMs. Additionally, none of them has pointed out that some EEMs may not require a direct investment. Other authors, see, e.g., Thollander and Ottosson (2008), have instead considered drivers as the opposite of a barrier. The authors make a step forward, acknowledging that, alike barriers, drivers may be of various nature. Although the work is remarkable and opens interesting research paths, however, it does not seem fully appropriate to describe a driver as the negative of a barrier. Indeed, it is apparent that a driver can be useful to overcome several barriers, even with various nature. For instance, economic incentives are widely used not just as tools for tackling economic-related or financial barriers, rather also for increasing interest, generating awareness, etc.

Again, in a recent empirical work on resource use and material productivity, Steger and Bleischwitz (2011), confirmed that: activities are influenced by a number of inconsistent forces; people respond to a variety of incentives; and drivers are related to many other aspects which have an impact on them.

Another point of criticism is the lack of focus on the level at which drivers for industrial energy efficiency have an impact. Notably, Vine et al. (2003) have tried to separate the concept of driver, called "program" by the authors, from the policy one, called "mechanism". "Programs are targeted at energy end users, as distinct from mechanisms that are targeted at the developers and implementers of programs". In particular, with mechanisms they refer to governmental policies. The work provides here a quite interesting contribution, but the authors then exclusively focus on the policies and how they can diminish selected barriers. To summarize, in literature the definition of drivers does not look as shared and agreed, as many levels and different perspectives may be adopted. Still, it is crucial to point out a perspective able to focus on the industrial decision-maker.

2.2 Empirical studies regarding drivers for industrial energy efficiency

The willingness of scholars to understand which factors could support industry increasing its performance has apparently deep roots. In particular, when dealing with industry, we can note that drivers for energy efficiency have been investigated so far mostly in empirical studies, through broad surveys and interviews. Referring to the most recent contributions (but, as aforementioned, some publications on the topic could be found since '80s), almost a decade ago, de Groot et al. (2001) have performed an empirical study within Dutch firms, trying to identify the most relevant factors affecting the investment behavior of enterprises. The authors have divided driving forces into two categories: market-related and policy-related. The former includes: direct installation of equipment by public utilities, green image of corporation, cost reductions resulting from lower energy use. On the other hand, policy-related driving forces include: fiscal arrangements, investment subsidies, special financing possibilities for investments, and long-range plans within sector. In addition to that, the authors have tried to understand the attitude of enterprises towards environmental policies, namely: voluntary agreements, investment subsidies, energy standards in terms of technology standard, energy standards in terms of maximum energy use, and energy taxes. Swedish scholars in the last decade have performed several case studies in different contexts so to provide empirical evidence of the driving forces leading to increased industrial energy efficiency. Rohdin and Thollander (2006) and Rohdin et al. (2007) have conducted case-studies among respectively Swedish non-energy intensive and foundry industries, highlighting the relevance of people with real ambition and long-term strategies as major drivers for the success of energy efficiency initiatives at site level. Rohdin et al. (2007), in particular, have discussed a selection of the aforementioned drivers, namely: people with real ambitions, long-term strategies, third party financing, environmental management systems, international competition, and environmental company profile. More recently, Brunke et al. (2014) have investigated the Swedish iron and steel sector regarding its barriers, drivers, energy management practices and energy services for increased energy efficiency, highlighting that increased energy management within a company represents the most relevant driver. Thollander and Ottosson (2008) have discussed some driving forces for energy efficiency through a case study in a Swedish paper mill industry, dividing them into market-related driving forces, potential energy policies, as well as organizational and behavioral factors. Market-related driving forces include: cost reductions resulting from lowered energy use, threat of rising energy prices and international competition, support from energy service companies (ESCOs), and third party financing, investment subsidies for EEMs, offering detailed support from energy experts, publicly financed energy audits by energy consultant/sector organizations, beneficial loans for energy efficiency investments, networks within the sector, and information and support through sector organization. Additionally, the authors identify behavioral and organizational-related driving forces as follows: green image of corporation, long-term energy strategy, people with real ambition, environmental management systems, and improved working conditions. Hasanbeigi et al. (2010), in their empirical investigation among Thai industries, have focused their attention towards industry and analyzed the several key drivers, taking the useful suggestions coming from industry and experts. In detail, they have found that the main drivers in Thailand are: reducing final product cost by reducing energy cost, rise of energy prices, improving staff health and quality and products' quality, improving compliance with enterprises environmental targets and long-term strategy, improving reputation and recognition, and management vision and understanding about energy efficiency. Aflaki et al. (2013) have dealt with drivers for energy efficiency projects in several German industries identifying three major value drivers: savings intensity, green image, and project complexity. Their study is interestingly supplied by a preliminary and unstructured analysis of the impact of drivers on the decision-making process and on the perceived risk giving some interesting hints. In particular, four factors are evaluated to be essential to the effective management of industrial energy efficiency projects: reliable measurement, management systems, tested and reliable technologies and financial and technical expertise. A recent exploratory investigation among Italian SMEs (Cagno and Trianni, 2013) revealed, beside public financing, the importance of external pressures, as well as the relevance of several contextual factors and firm's characteristics (e.g., size, complexity of the production), leading to a different perception of drivers. Market factors related to cost reductions resulting from lowered energy use and threats of rising energy prices represent the major driving forces for the Ghana's largest industrial area, as shown by recent research (Apeaning and Thollander, 2013). Increasing energy prices, commitment by top management and environmental image resulted as major drivers in a

Belgian cross-sectoral study by Venmans (2014). Brunke et al. (2014) studied the Swedish iron and steel industry, finding that cost reduction from lowered energy use, long-term energy strategy and again commitment from top management were the most relevant drivers. More recently, Lee (2015) has conducted an investigation among Korean steel industry, finding that "market-based factors, as well as organizational/individual behavioral factors, play important roles in energy efficiency investment towards sustainable development". Sathitbun-anan et al. (2015) used bottom-up conservation supply curves to investigate the factors affecting the implementation of EEMs in the Thai sugar industry, finding that the major driving forces were represented by the potential to reduce energy costs and creating a good "green" image for the company. Table 1 summarizes the literature of recent empirical studies on drivers to industrial energy efficiency.

<< Table 1 >>

Table 1 – Overview of recent empirical studies on drivers to industrial energy efficiency, extending the approach of Brunke et al. (2014).

Nonetheless, scholars have done very little in providing comprehensive theoretical approaches on drivers for industrial energy efficiency. Most recently, Reddy et al. (2013) have offered an interesting contribution distinguishing three different perspectives for the analysis of energy efficiency barriers and drivers: micro (project/end user), meso (organization), and macro (state, market, civil society). The developed framework nevertheless does not provide a structured classification for drivers, rather discussing some examples such as awareness, decrease in technology price levels, increase in energy prices, technology appeal, non-energy benefits, environmental regulations. Similarly, the actor-barrier linkage is discussed by examples, but not exhaustively. Cagno and Trianni (2013) started providing a outlook of characteristics of driving forces, in particular highlighting the relevance of distinguishing between internal and external, as well as from regulatory to economic or informative drivers, but their work presents some issues: the authors had neither tried to provide a comprehensive extensive classification, nor to model the effect of drivers on barriers in the decision-making process. Furthermore, the same definition of drivers was unclear, as well as the nature of the drivers. Finally, Thollander et al. (2013) sketched the distinction between financial, informational or organizational driving forces, to be distinguished from external ones, but even the rationale behind the distinction among them was missing.

Additionally, always in the eyes of an industrial decision-maker, pointing out the relevance of possible stakeholders promoting driver to energy efficiency (Hasanbeigi et al., 2010) is crucial for a further promotion of most effective energy efficiency policies. In particular, drivers should not only be modelled in order to punctually understand which are the major stakeholders to promote drivers within the decision-making process of adopting EEMs, but it should also be understood the role of the stakeholders (e.g. financial institutions, energy suppliers, industrial associations and groupings, manufacturers, suppliers, installers, ESCOs) of the so-called energy efficiency supply chain (Hirst and Brown 1990; Vidil and Marvillet, 2005; Liu et al., 2012; Abdelaziz et al. 2011).

To summarize, in terms of modelling, the literature review points out several research gaps to be addressed. Firstly, a new definition is indeed needed according to the perspective of the industrial decision-maker, as, on the basis of his/her perception of internal and external barriers, the decision of adopting an EEM will be taken. Secondly, in the perspective of an industrial decision-maker, the effect of the drivers on the decision-making process to adopt an EEM has to be described in full: this should also encompass the description of the mechanisms relating barriers tackled and correspondent drivers in the different decision-making process steps. Thirdly, drivers should be clearly identified and described. Then, some additional features should be highlighted: it is important to clarify which is the main nature of each driver, i.e. which type of action the driver represents. Fourthly, to properly characterize them, it is also relevant to point out which are the internal versus external drivers. In particular, it would be appropriate to categorize drivers with respect to their stakeholders, as it would more effectively point out the most suitable stakeholders able to support enterprises in the adoption of EEMs. Finally, an identification of the possible major stakeholders promoting drivers should be proposed. The present paper aims at giving a contribution to fulfil those research gaps.

3 A NOVEL DEFINITION AND CLASSIFICATION

It is apparent that the efforts so far paid in defining and describing drivers to industrial energy efficiency have been devoted to gain an understanding of the problem, but still the approach looks too vague, and, more critically, does neither sufficiently focus on the final industrial decision-maker, nor it is able to identify and characterize the relationships between drivers and barriers throughout the decision-making process. Hence, in the wake of Worrell et al. (2003), drivers are effectively factors promoting EEM. But, as other authors note (Cagno and Trianni, 2013; Thollander et al., 2013), they may be originated internally or externally (with respect to an organization), and they have a different nature (e.g., economic, regulatory) (Thollander et al., 2013). Indeed, looking at EEMs, drivers to support their implementation could be defined as *factors promoted by one or more stakeholders, stimulating the sustainable adoption of energy-efficient technologies, practices and services, influencing a portion of the organization and a part of the decision-making process in order to tackle existing barriers*, so to provide a thrust towards increased energy efficiency in a perspective of industrial sustainability. We would like here to point out that the sustainability evaluation (related to the adoption) could be undertaken exclusively at an industrial decision-making level, thus depending on the peculiar context and firm's situation, as at this level the sustainability of an EEM is established. Furthermore, a sustainability evaluation goes beyond the cost-effective measure concept (Sorrell et al., 2010), rather showing that we need to perform a holistic evaluation of the EEM, thus including additional (with respect to energy efficiency) benefits and implications (IEA, 2014).

The current perspective and subsequent definition offer us the opportunity to point out the set of relationships linking drivers to barriers within the industrial decision-making process, i.e. the mechanisms. Fig. 1 helps understand this definition. In particular, a driver D_j could act on a barrier (e.g. B_i) with a certain strength (bold line) in an *k-th* step of the decision-making process, whilst acting on the same barrier, but on a different decision-making step (*k+1-th*), with a different strength (dotted line). Moreover, the same driver could act simultaneously on a barrier B_{i+1} in a *k-th* step (continuous line), and on a different barrier in another *k+1-th* step of the decision-making process. To complete the description, it should be noted that the driver could be promoted by one or more A_m stakeholders.

<< Figure 1 >>

Figure 1. The framework to describe the effect of drivers on barriers in the decision-making process to undertake an EEM. Drivers are promoted by one of more stakeholders.

3.1 Classification of drivers for industrial energy efficiency

Once defined our framework, it is here relevant to identify and describe the set of drivers, taking inspiration from the aforementioned literature contributions, operating a clear distinction among them (so to limit their overlapping) and reaching a homogeneous level of detail.

Clarity of information: all types of information related to energy efficiency should be widely disseminated in an appropriate form, e.g., through particular standards. This information must be sufficient to properly design and implement energy efficiency improvement programs, as well as for promoting and monitoring energy services and other energy efficiency improvement measures (European Council, 2012).

Efficiency due to legal restrictions (regulations and standards): strict environmental regulations or standards application – such as mandatory energy saving obligations (Waide and Buchner, 2008), and associated costs to their compliance, could force industry to adopt EEMs. Although it should be acknowledged that this type of activity does not necessarily imply an effective improvement in the awareness towards energy efficiency of the industrial decision-makers, it is widely recognized that such a type of obligation represents a strong driver for industrial energy efficiency.

External energy audits/sub metering: according to Abdelaziz et al. (2011), this driver helps any organization analyze its energy flows and discover areas where energy use can be reduced. Once these data are clear, feasible energy conservation methods that will enhance firm's energy efficiency improvements can be structured and scheduled.

Green image: as mentioned by Hasanbeigi et al. (2010) in the Thai textile industry and later by Sathitbun-anan et al. (2015), this could be an important driver for energy efficiency. Having a good image and a recognized good energy-efficient reputation is very important for many enterprises. The driver includes all the pressures deriving from non-governmental organizations (NGOs), community groups, environmental organizations, other potential lobbies that can mobilize public opinion in favor of or against a firm's environmental policy, and the media with the capability to influence society's perception over a firm. Most importantly, such pressures can be absorbed by customers directly transferring them to an enterprise. As more customers become willing to pay a premium for green products, enterprises can look at green image as a way to derive business opportunities from reputation management (Aflaki et al. 2013).

Increasing energy tariffs: when enterprises face higher energy prices, they first look at the share of energy cost in the total production cost. In case of large shares, enterprises are likely willing to act in reducing energy expenditures. According to Streimikiene et al. (2008), such a regulatory driver might be due to an harmonization of e.g. excise tariffs, and may also include the threat of rising energy prices.

Long-term energy strategy: as many authors note (Ramirez et al., 2005; Hasanbeigi et al., 2010; Diabat and Govindan, 2011; Azevedo et al., 2011), involving long-term energy strategy is very important to pose considerable challenges for the management of the firms. With this type of strategies, energy and environmental management systems are more likely to be successful, as they grow in the list of priorities; hence, energy efficiency investments are encouraged.

Technological appeal: taking suggestion from Reddy et al. (2013), *"if the energy-efficient equipment gives an impression that it looks 'modern', 'appealing', and 'fashionable', there is a higher probability of consumers purchasing the technology"*. For this reason, technological appeal may represent an interesting driver for equipment manufacturers in effectively promoting energy efficiency solutions.

Trustworthiness of information: information is quite often available to enterprises. Nevertheless, it is disregarded, being considered as unreliable (Thollander et al., 2007). This is the problem of credibility and trust. Concerning the industrial sector, Industrial Associations and Groupings (IAGs) or similar external stakeholders may play an important role, being regarded as a trustworthy source by enterprises (Ramirez et al., 2005).

Voluntary agreements: it results directly from the government's public policies, or collaboration between different companies that enter into a contract bringing benefits in terms of energy efficiency. It also stimulates the adoption of new technologies in contrast to less efficient ones – see, e.g., Stenqvist and Nilsson (2011).

Willingness to compete: enterprises often make most of their investments in accordance with their core business and prefer those that improve their market position. When a company views EEMs as competitive tools, such topics are no longer treated as marginal, rather as of primary importance to achieve business targets (Bleischwitz et al., 2009).

Cost reduction from lower energy use: with this driver, an enterprise is pushed to consume less energy, as immediately related to a cost reduction. According to Thollander and Ottosson (2008), it is a market related driver, but the implementation strictly depends on the decision undertaken by a single enterprise.

Information about real energy costs: according to Hasanbeigi et al. (2010), if the energy price represents its real price with neither subsidies nor distortions, thus covering all externalities, the market would work towards energy efficiency improvement and even less intervention from the government would be necessary.

Management support: often profitable EEMs are not undertaken due to a lack of capability of enterprises in managing the complexity of the whole project, from its design to its implementation. Research has shown that this type of support can be derived, e.g., from ESCOs, able to provide the technical, commercial and financial services related to energy efficiency projects (Painuly et al., 2003). Moreover, within the management support, also actions related to the so-called “change management”, that revolves around the management the impact of energy-efficient investments on human involved. This aspect seems particularly crucial for the continued success of any energy efficiency improvement.

Public investments subsidies: the creation of funds to facilitate the implementation of energy efficiency programs and to promote the development of a market for energy services has been widely recognized as an appropriate tool for the provision of start-up funding in such a market. Subsidies may be made available to enterprises through government policies and may therefore be supportive in steering investments towards higher energy efficiency (European Council, 2012).

Private financing: this driver might represent monetary support, e.g., loans that an enterprise can obtain from financial institutions, and it also includes the so-called third party financing (Thollander et al., 2007).

Availability of information: to make better-informed decisions concerning their individual energy consumption, final consumers should be provided with a reasonable amount of relevant information. Policy-makers should establish appropriate conditions and incentives for market operators to provide more information and advices to final customers on energy end-use efficiency (European Council, 2012).

Awareness: increased awareness represents one clear driver able to bring long-term benefits for energy efficiency within a company (Thollander and Ottosson, 2008).

External cooperation: the collaboration with the industrial sector in which an enterprise operates can generate the exchange of information and the ongoing discussion, through which enterprises remain active in their field and well-informed. According to Azevedo et al. (2011) and Duggan (1996), enterprises may lever on the collaboration with suppliers, working with designers to reduce and eliminate product environmental impact and working with customers to change product specifications. Recently, learning experience networks in Switzerland and Germany offered successful empirical evidence of external cooperation (Jochem and Gruber, 2007; Koewener et al., 2011).

Knowledge of non-energy benefits: empirical research has shown the relevance of this driver, that includes benefits as: (1) improved indoor environment, comfort, health, quality, safety, and productivity; (2) reduced noise; (3) labor and time savings; (4) improved process control; (5) increased reliability, amenity or convenience; and (6) direct and indirect economic benefits from downsizing or elimination of equipment (Worrell et al., 2003; Trianni et al., 2014; IEA, 2014). As a result, incorporating benefits in EEMs' profitability evaluation will help accelerate the uptake of EEMs.

Management with real ambition and commitment: having people with real ambitions as members of the management could be also beneficial for the adoption of EEMs. Indeed, greater power of ambitious people managing energy efficiency issues could transform them into a priority for a company, as many authors note (Worrell et al., 2001; Diabat and Govindan, 2011; Qi et al., 2010).

Staff with real ambition: this driver creates a culture in which employees are genuinely empowered and focused on the customer; in fact, according to Worrell et al. (2001), the implementation of energy efficiency technologies and practices depends also on the motivation of personnel.

Programs of education and training: without a proper knowledge on the use of EEMs, the potential efficiency will not be fully exploited, even after the implementation of EEMs. Therefore, implementing internal programs of education and training on energy efficiency would stimulate a proper use and management of the equipment, and also increase the energy efficiency awareness and culture (Cagno and Trianni, 2013).

Technical support: this driver is particularly useful to overcome barriers that involve technical risks, such as production disruption, particularly critical when facing long disruptions, such as in the case of the installation of some specific EEMs, in which the consequences might be partially unknown. In this case, support can be obtained from technologies suppliers, installers, ESCOs, etc. (Rohdin et al., 2007).

3.2 Nature and distinction between external and internal drivers

Once drivers are identified and described, for industrial decision-makers as well as policy-makers, it is crucial to characterize them in order to classify them. Our classification has been conceived according to two main elements, basically following an industrial decision-maker perspective. Indeed, the first element is the nature, i.e. the type of action implied by making leverage on the driver. The second element is if a company itself can propose a driver, or rather if it is originated by an external actor. In fact, according to an industrial decision-making perspective, it is quite relevant to understand whether a company can itself promote such drivers, or if they are somehow handled by external stakeholders.

Firstly, as reported in Table 2 the nature of drivers represents a crucial feature: in fact, the stimulus towards the adoption of EEMs could come through different means. Indeed, a driver calls primarily for a different type of action. Taking inspiration from the extant literature – see, e.g., Brunke et al. (2014) and Cagno and Trianni (2013) –, we have identified four categories: regulatory, economic, informative and vocational training. *Regulatory drivers* involve all norms and standards aimed at stimulating enterprises towards energy efficiency. This is the case, e.g., of: mandatory external energy audits and sub metering, standards for increased the clarity and trustworthiness of information, as well as efficiency due to legal restrictions. Additionally, regulatory drivers include pressures from increasing energy tariffs and technological appeal, but also long-term energy strategy, voluntary agreements, green image and willingness to compete. *Economic drivers* involve the monetary aspect, and are also widely recognized as one of the strongest drivers. Public investment subsidies and private financing are among them, as well as management support. Additionally, economic drivers include cost reduction from lower energy use and information about real energy costs. *Informative drivers* involve all aspects related to both the information content and its flow to the company. In particular, we could find increased awareness, external cooperation and information availability, but also knowledge of non-energy benefits as well as management and staff with a real ambition. *Vocational training drivers* encompass aspects connected with technological problems and education of technicians and workforce in general. This would include programs of education, training and technical support, aimed at a proper use of the incoming EEM.

We acknowledge that in drivers several natures may coexist (informative, economic, etc.). We have conducted our characterization looking at the main nature of each driver. For instance, considering the drivers “clarity of information” and “trustworthiness of information”, indeed they refer to information, but they rather point out that making leverage on them means adopting some kind of standard for diffusing information (i.e. substantially, a regulatory driver). On the contrary, “availability of information” clearly refers to the need of developing an action aimed at increasing the information brought to enterprises on EEMs, thus being an informative driver.

Secondly, it is relevant to make a distinction between internal and external drivers, as it allows understanding whether a driver might be promoted internally or an external support should be required. At present, the number and type of stakeholders are really increasing, the market is under strong evolution, and several drivers may be handled by multiple stakeholders. Hence, although acknowledging that this is a first attempt and further research is surely needed, a preliminary identification of the possible major stakeholders and their attribution to the drivers is offered in Section 3.3. Regarding the distinction between internal versus external drivers, *internal drivers* refer to forces within an enterprise moving it to implement EEMs, such as: willingness to compete, cost reduction from lower energy use, long-term energy strategy, people with real ambition and management with real ambition and commitment. For example, if a company were empowered on energy efficiency issues by special policies to increase the awareness, the research of internal staff could be targeted to ambitious people. It is here interesting to note the difference with *external drivers*, i.e. drivers on which external stakeholders make leverage in order to promote energy efficiency within organizations. In this case, enterprises do not generally have the strength to change or influence such actions. Examples of external drivers are: clarity or trustworthiness of information, increasing energy tariffs, legal restrictions forcing enterprises to the adoption of EEMs, public investment subsidies, availability of information and technical support.

3.3 Possible role of major stakeholders promoting drivers for industrial energy efficiency

When dealing with the stakeholders able to promote drivers for industrial energy efficiency, the picture becomes really complex. Indeed, a large number of stakeholders deals with EEMs at various levels, including end-user equipment manufacturers and suppliers, energy suppliers, local and national financial institutions, governments and financial institutions, etc. To achieve improvements in energy consumption, energy efficiency should be promoted at all levels, from the lowest one of the consumer, up to the highest levels of global agencies (Reddy, 1991). Stakeholders in different industrial sectors highlight distinctive barriers to energy efficiency, and the EEMs in a particular socio-cultural domain may be useless into another, due to unique attitudes, norms and routines (Palm and Thollander, 2010). For these reasons, the analysis of factors influencing the firm’s decision to adopt EEMs requires a dynamic approach, taking into account external stakeholders’ interests and strategies, which strongly influence the decision-making process. Therefore, according to del Rio Gonzalez (2005), EEMs adoption is a response of firms to the stimulus from the external context, involving a wide array of stakeholders and factors. Suppliers, public administrations, trade associations, consulting firms and other stakeholders such as local communities, investors and teaching institutions may play a relevant role in building networks of collaboration. Research shows that suppliers – either technology or energy – seem to be the main sources of information on environmental issues in pulp and paper firms in Spain (del Rio Gonzalez, 2005). According to Reddy et al. (2013), EEMs may not succeed unless there is an interface between stakeholders operating in the energy efficiency field. Indeed, investors, utilities, governmental agencies, financial institutions, local authorities, research and development organizations, equipment manufacturers, market institutions, ESCOs and international institutions can play a vital role. It is thus important to try enlarging as much as possible the perspective, identifying which stakeholders may have the power or the responsibility to develop and stimulate drivers for industrial energy efficiency.

Since an enterprise is the most relevant stakeholder for endorsing internal drivers, external drivers must be linked to their promoting stakeholders. Taking benefits from a vast set of evidence in scientific and industrial literature (partially presented above), a list of major stakeholders is provided. *Governmental bodies (at various level)* are the stakeholders from which most of the policies originate, but mainly responsible for regulatory external drivers, such as clarity and trustworthiness of the information, increasing energy tariffs and setting legal restrictions. Additionally, governmental bodies may be responsible for informative external drivers such as diffusing information on EEMs as well as awareness campaigns. *Technology suppliers* could indeed result crucial for clarity and trustworthiness of the information, as well as external energy audits and submetering, but also offering management support. *Technology Manufacturers (M)* can offer clear and trustworthy information and crucial technical support, but also awareness campaigns to promote energy efficiency. *Installers* may play a major role for some regulatory external drivers, as well as for external informative ones, but also for external vocational training. The role of *Energy Suppliers* could be relevant either for regulatory as well as informative drivers, but some examples of private financing could also be found. *ESCOs* can offer similar economical support, but also management as well as technical support, external energy audits, programs of education and training, knowledge of non-energy benefits and a reliable source from which enterprises could obtain complete and accurate information. *Financial Institutions (F)*, such as e.g. banks, may offer valuable support generate private financing for supporting enterprises' investments. *Industrial Associations and Groupings (IAGs)* can help enterprises find information as well as setting regulatory standards related to information, but also promote awareness campaigns and offering programs of education and training. *Clients* may also influence companies' behavior towards energy efficiency through external cooperation and stimulating companies in technological appeal from implementing EEMs, whilst *Competitors* may be responsible of external cooperation, as well as increasing a company awareness toward energy efficiency opportunities. Finally, *Partners* may be relevant for external informative drivers such external cooperation and awareness.

Nevertheless, as said before, it is worth noting that the energy efficiency market is quite dynamic, and consequently the set of possible drivers promoted from the aforementioned stakeholders is under evolution: indeed, several innovative business models can be found and may coexist. Limiting our identification of the stakeholders just for external drives, Table 2 reports the list of drivers according to the novel framework proposed and its aforementioned features, including possible major external stakeholders.

<< Table 2 >>

Table 2 – Classification of drivers according to their nature (regulatory (R), economic (E), informative (I), and vocational training (V)) and distinction between internal vs external drivers. For external drivers only, indication of possible major external stakeholders for drivers' promotion: A1= Governmental bodies; A2=Technology suppliers; A3=Technology manufacturers; A4=Installers; A5=Energy suppliers; A6=Energy Service Companies (ESCOs); A7=Financial Institutions; A8=Industrial Associations and Groupings (IAGs); A9=Clients; A10=Competitors; A11=Partners. The order in which external stakeholders are presented does not necessarily refer to a specific priority.

4 THE EFFECT OF DRIVERS ON THE BARRIERS AFFECTING THE INVESTMENT DECISION-MAKING PROCESS

We can now analyze the effect of the identified drivers on the barriers affecting the decision-making process of adopting EEMs. Previous literature has started to build a framework about decision-making process in energy efficiency investments or the energy efficiency state obtained by a single enterprise when adopting an EEM. Indeed, Tonn and Martin (2000) have focused on the state reached from the enterprise out of each step rather than on the decision making process. Cooremans (2011) and Elliot and Pye (2010) have considered a seven-steps decision-making process. Hasanbeigi et al. (2010) and Cagno et al. (2013) have developed a three-steps decision-making process, grouping some activities. After a re-categorization of the literature, we propose a decision-making process composed by six steps. The six steps are as follows: *i)* awareness; *ii)* needs and opportunity identification; *iii)* technology identification; *iv)* planning; *v)* sustainability analysis; and *vi)* installation, start-up and training. In addition, and new with respect to previous literature, we have described the effect of drivers on the main barriers affecting each step.

Awareness: if people in industry are more aware of the importance of energy efficiency and the achievable benefits by improving EEMs, new technologies and practice for energy efficiency will be more likely to be taken into consideration (Hasanbeigi et al., 2010).

Needs and opportunity identification: problems need to be analyzed and understood, in order to find potential solutions for energy efficiency, and sought the existing opportunities (Tonn and Martin, 2000).

Technology identification: once opportunities have been identified, it is necessary to punctually seek the suitable technologies available on the market.

Planning: the technologies must be placed in the context of the company, taking into account several factors such as e.g., the physical layout. The compatibility between existing and new technologies should be verified, to simplify as much as possible their integration.

Sustainability analysis: we need to perform a broad evaluation, thus not merely economic, in which all the costs needed for the implementation of an EEM should be analyzed, and an enterprise must find the adequate funds to bear the investments (Elliott and Pye, 2010). Indeed, the full sustainability of the

EEM should be assessed, understanding the full set of indirect (not energy efficiency specific) benefits and implications deriving from its adoption (IEA, 2014).

Installation, start-up and training: after purchasing a technology, the installation, set-up (following appropriate routines) and training of personnel (e.g., to properly use the new equipment) need to be developed. This can be the most critical phase in order to maximize the long-term saving potentials (Elliott and Pye, 2010).

As aforementioned, we have made some adjustments with respect to previous literature. For instance, we have combined and included into a single step (Sustainability analysis) two elements (i.e., financial analysis and financing) considered as separate by Elliott and Pye (2010), since in industry they are quite often combined. Nevertheless, e.g. differently from Elliott and Pye (2010), we have clearly separated the very first steps of the decision-making process, as a thorough comprehension is really crucial. Indeed, without awareness, the overall decision-making process of adopting an EEM would not start. Furthermore, it is crucial to clearly distinguish between needs and opportunity identification, as well as from punctual technology identification: in fact, only through a specific identification of needs and opportunities, the most adequate technology would be properly selected.

Beside the description of the decision-making steps to adopt EEMs, it is relevant to point out which barriers are tackled by drivers in the decision-making process, and which are the relevant stakeholders for their promotion. Regarding barriers to energy efficiency, we have adopted a very recent literature contribution (Cagno et al., 2013). In their taxonomy, the authors present a list of 27 independent barriers, grouped in the following categories, as shown in Table 3: Technology-related (T), Information-related (I), Economic (E), Behavioral (B), Organizational (O), Competence-related (C), and Awareness (A).

<< Table 3 >>

Table 3 – Taxonomy of barriers adopted for the present study (Source: Cagno et al., 2013).

In the following we describe some relevant relationships between drivers and barriers in the decision-making steps. A full picture of the complexity of existing relationships has been sketched in Figure 2 (for the correspondence between drivers and codes reported, please refer to Table 2).

<< Figure 2 >>

Figure 2. The framework describing the relationship between drivers, barriers in the decision-making process, as well as major stakeholders responsible for the promotion of drivers.

Without the first step of the decision-making, i.e. generation of awareness, energy efficiency would not even be seen as an opportunity. People with real ambition could create a corporate culture able to face energy efficiency problems. Also ambitious management is very important in this moment since it may be a relevant promoter of values and routines within the firm. Increased awareness is surely crucial for overcoming barriers in this step. External energy audits are a valuable driver to fill the gap regarding lack of knowledge on energy efficiency. In fact, the knowledge of the energy consumption of specific departments is widely recognized as a preliminary step for adopting further and more effective EEMs. External cooperation generates the opportunity to exchange information and experiences, so that companies are well informed with limited additional costs. Firms can also make benchmarks in order to compare their performance to those of competitors in the same sector. The third phase may be effectively tackled by information availability, coupled with technical support. These factors, together with knowledge of non-energy benefits may support companies to make a step forward to the decision of purchase. If the awareness of energy efficiency is not deeply rooted in the enterprise, the knowledge of these ancillary benefits could help in EEMs' implementation. In the fourth step, the decision maker must understand how EEMs could be inserted within a company taking into account all tangible and intangible boundaries. Technical support may help, as well as clear and reliable information. In fact, some of these projects are not considered because they are too difficult to deal with. Such obstacles could certainly be addressed by the presence of clearer and understandable information and by the assistance of experienced people. Sustainability analysis is quite a delicate step since it involves many economic aspects. It is important to note that each firm adopts a specific criterion for investment decisions that depends on many factors, such as size and availability of resources, both linked to financial exposure. But should not be limited to direct investment expenditures, rather an increased knowledge about the real performance of an EEM (thus with all its operating costs during the entire life) could overcome or reduce barriers in this phase. Private financing and public investment subsidies could meet the financing needs, providing sufficient capital to a company, with e.g. soft loans. When a measure succeeds in the sustainability analysis, it can be purchased and installed in the plant. As a consequence, staff must be well trained. Programs of education and training are needed in order to successfully implement an EEM. Also technical support could be important, since technology suppliers may follow the early stages of the introduction of new equipment to avoid its improper use.

5 CONCLUSIONS AND FUTURE RESEARCH

Research and empirical evidence have clearly shown that the full comprehension of the obstacles, but also the ways to overcome them, are crucial to achieve a higher level of industrial energy efficiency.

One of the most effective approaches would be to investigate the decision-making process of adopting an EEM from the final user's perspective, as, on the basis of its perceived barriers, he/she will take the decision to adopt or not an EEM. Such perspective would result particularly interesting both for policy as well as industrial decision makers and energy efficiency market as a whole. Likewise, the approach of the present study is based on a focus on the factors acting within the different steps of the decision-making process on the barriers affecting an industrial end-user.

If on the one hand the paper has provided a definition and a structured classification of drivers, on the other hand it has proposed a framework to describe the mechanisms between drivers and barriers in the decision-making process. Additionally, the paper has tried to outline the major possible stakeholders to most effectively promote external drivers.

Regarding stakeholders, it is apparent that what has been done so far should be improved and further opportunities of refinement should be pursued: for instance, the detail (and nature) of the involved stakeholders could be strongly increased. Moreover, a thorough classification of stakeholders might be tailored according to different contexts in which the novel approach would be applied. Nevertheless, at present, we have still kept a lower detail as the study aimed at describing the mechanisms and the type of stakeholders involved, rather than punctually describing the peculiarity of the large number of active stakeholders in the market of energy efficiency solutions (in terms of technologies, practices, and services), since the whole market is under deep evolution. In conclusion, a detailed stakeholders' classification may represent a further extension of the categorization approach developed in the current study.

Finally, having developed here a framework, it is now possible to conduct an extensive empirical activity of application of the taxonomy is needed, so to provide empirical evidence able to shed the light on the mechanisms relating barriers, drivers and stakeholders in the decision-making process. Such empirical activity would be needed looking at different contexts (in terms of e.g., sectors and firm size). This activity would lead to offer firm-driven and/or context-driven pieces of evidence as useful suggestions in order to develop and tailor the most effective actions to be undertaken, both at enterprise level as well as system level (regional or sectorial). Indeed, the relevance of drivers in different groups of industrial companies may be quite different: hence, investigating drivers by clusters of enterprises could lead to more detailed and specific suggestions for industrial decision-makers and policy-makers. In this regard, particular attention should be paid in analyzing the strength of specific stakeholders active in different contexts, so to understand their effective role, but also the status quo with respect to energy efficiency, the existing difficulties and the effective opportunities and ways for increased energy efficiency.

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Study	Sector	Area	Main drivers
deGroot et al., 2001	Chemical, Basic Metals, Metal products, Horticulture, Food, Paper	The Netherlands	Green image for the firm.
Anderson and Newell, 2004;	Manufacturing SMEs	USA	Publicly financed energy audits.
Rohdin and Tholander, 2006	Non-energy intensive manufacturing	Sweden	Long-term energy strategy, increasing energy prices, people with real ambition.
Thollander et al., 2007	Manufacturing SMEs	Sweden	Long-term strategy; people with real ambition; environmental company profile and/or EMS.
Rohdin et al., 2007	Foundry	Sweden	Long-term strategy; people with real ambition; environmental company profile.
Masurel, 2007	Printing SMEs	The Netherlands	Improved working conditions.
Thollander and Ottosson, 2008	Pulp and Paper	Sweden	Cost reductions resulting from lower energy use; people with real ambition; long-term energy strategy.
Ren, 2009	Petrochemicals	OECD	Process energy costs savings; tight supply of gas feedstock; personal commitment of individuals.
Hasanbeigi et al, 2010	Manufacturing industries	Thailand	Production cost reductions from lowered energy use; staff health and safety; and improvements in product quality.
Cagno and Trianni, 2013	Manufacturing SMEs	Italy	Allowances or public financing; external pressures; long-term benefits.
Thollander et al., 2013	Foundry	Finland, France, Germany, Italy, Poland, Spain, and Sweden	Cost reductions; threat of rise in energy prices and energy taxes; commitment by top management.
Wentemi Apeaning and Thollander, 2013	Selected industries (steel, aluminium, food, plastics, chemicals)	Ghana	Cost reduction resulting from lowered energy use; threat of rising energy prices; energy efficiency requirements by government.
Venmans, 2014	Ceramic, cement, lime	Belgium	Increasing energy prices; commitment by top management; environmental image.

Brunke et al., 2014	Iron and steel	Sweden	Commitment from top management; cost reduction resulting from lowered energy use; long-term energy strategy.
Sathitbun-anan et al., 2015	Sugar industry	Thailand	Potential to reduce energy costs, green image,
Lee, 2015	Steel industry	Korea	Cost savings resulting from lowered energy use, Demand from owner, Energy tax, Threat of rising energy prices.

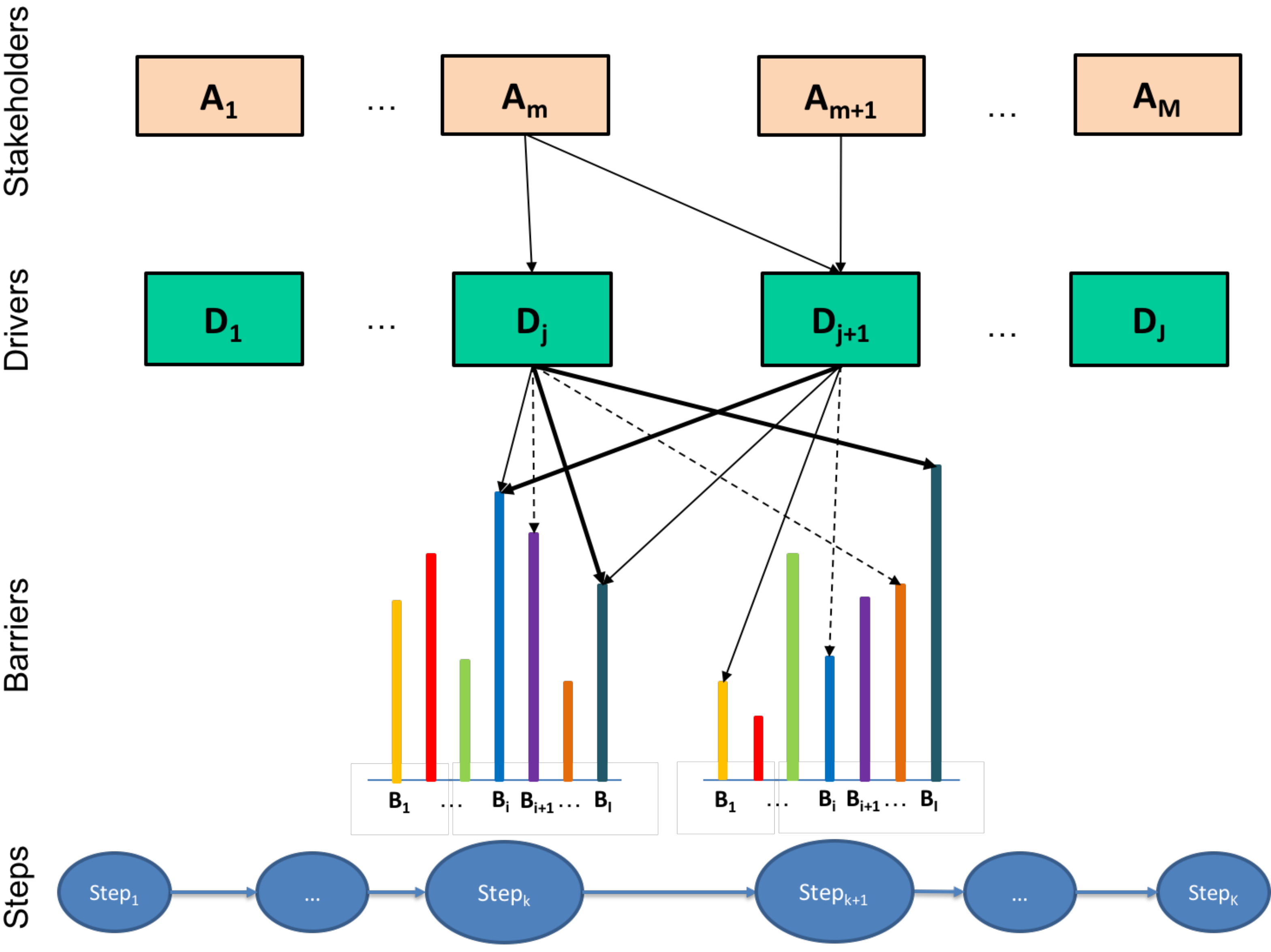
Table 1 – Overview of recent empirical studies on drivers to industrial energy efficiency, extending the approach of (Brunke et al., 2014).

Categories	ID	Drivers	Possible major external stakeholders
Regulatory Internal	R1	Green image	
	R2	Long-term energy strategy	
	R3	Voluntary agreements	
	R4	Willingness to compete	
Regulatory External	R5	Clarity of information	A1, A2, A3, A4, A5, A8
	R6	Efficiency due to legal restrictions	A1
	R7	External energy audit/submetering	A1, A2, A5, A6
	R8	Increasing energy tariffs	A1, A5
	R9	Technological appeal	A2, A4, A6, A9, A10
	R10	Trustworthiness of information	A1, A2, A3, A4, A5, A6, A8
Economic Internal	E11	Cost reduction from lower energy use	
	E12	Information about real costs	
Economic External	E13	Management support	A2, A3, A4, A6
	E14	Public investment subsidies	A1
	E15	Private financing	A3, A5, A6, A7
Informative Internal	I16	Knowledge of non-energy benefits	
	I17	Management with ambitions	
	I18	Staff with real ambitions	
Informative External	I19	Availability of information	A1, A2, A3, A5, A6, A8, A11
	I20	Awareness	A1, A3, A4, A5, A6, A8, A10
	I21	External cooperation	A2, A3, A4, A7, A8 A9, A10, A11
Vocational training Internal	V22	Programs of education and training	
Vocational training External	V23	Technical support	A2, A3, A4, A6, A8

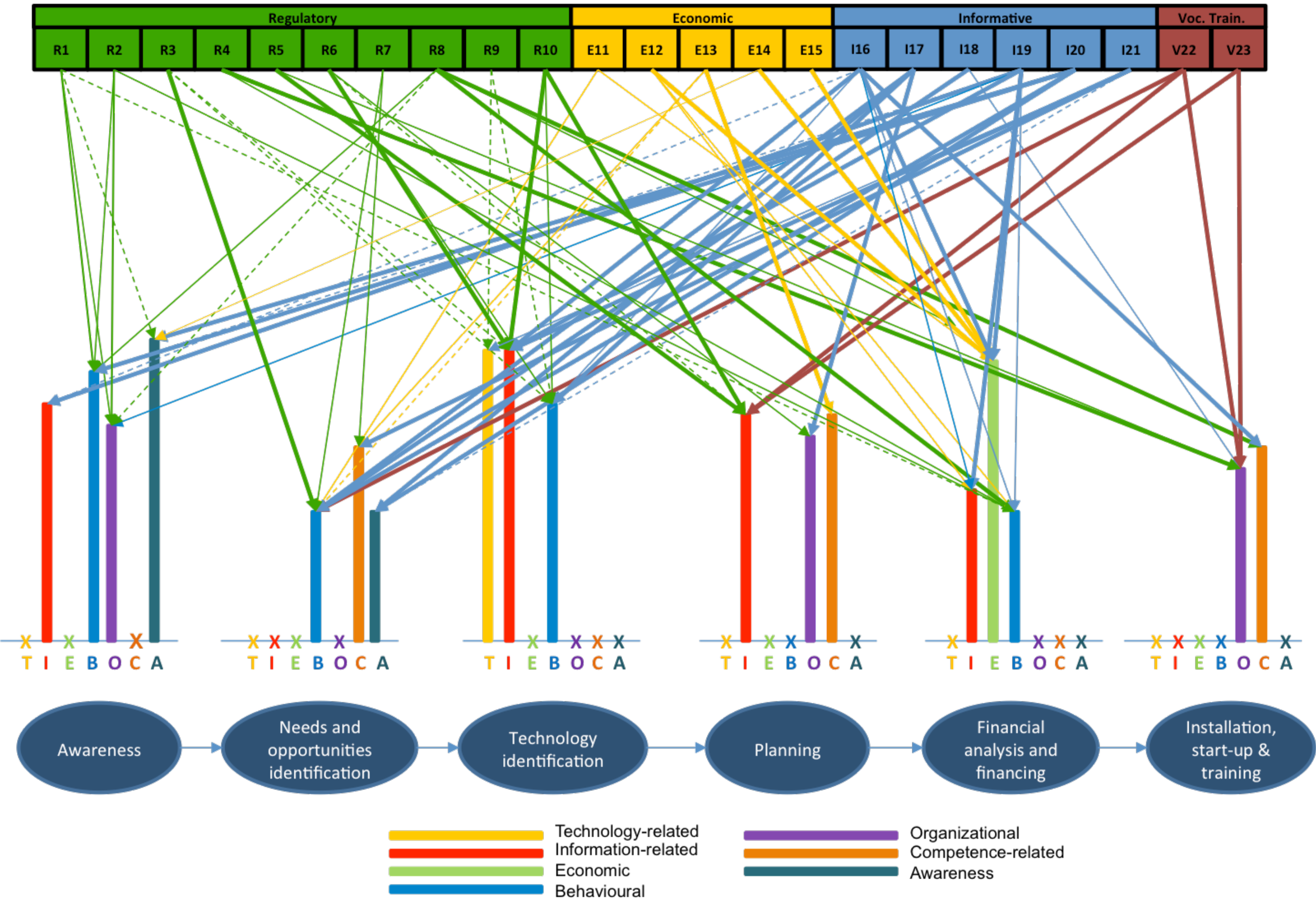
Table 2 – Classification of drivers according to their nature (regulatory (R), economic (E), informative (I), and vocational training (V)) and distinction between internal vs external drivers. For external drivers only, indication of possible major external stakeholders for drivers' promotion: A1= Governmental bodies; A2=Technology suppliers; A3=Technology manufacturers; A4=Installers; A5=Energy suppliers; A6=Energy Service Companies (ESCOs); A7=Financial Institutions; A8=Industrial Associations and Groupings (IAGs); A9=Clients; A10=Competitors; A11=Partners. The order in which external stakeholders are presented does not necessarily refer to a specific priority.

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

Table 3 – Taxonomy of barriers adopted for the present study (Source: Cagno et al., 2013).



Stakeholders
Drivers
Barriers
Steps
A1
…
Am
Am+1
…
AM
D1
…
Dj
Dj+1
…
DJ
B1 … Bi Bi+1 … BI
B1 … Bi Bi+1 … BI
Step1
…
Stepk
Stepk+1
…
StepK


Regulatory
Economic
Informative
Voc. Train.
R1
R2
R3
R4
R5
R6
R7
R8
R9
R10
E11
E12
E13
E14
E15
I16
I17
I18
I19
I20
I21
V22
V23
T I E B O C A
Awareness
Needs and opportunities identification
Technology identification
Planning
Financial analysis and financing
Installation, start-up & training
Technology-related
Information-related
Economic
Behavioural
Organizational
Competence-related
Awareness