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The need for a new approach in NEBs classification

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Abstract

Industrial energy efficiency has been widely recognized as a major contributor for the reduction of green-house gases emissions and the improvement of industrial competitiveness. Nevertheless, a broad set of studies have pointed out the existence of barriers limiting the adoption of promising Energy Efficiency Measures (EEMs). Recently, authors have shown the relevance of the so-called "non-energy benefits" (NEBs) coming from the adoption of EEMs. Still, the existence of such benefits has been pointed out from specific studies and manuals for practitioners, but an overall framework describing them in terms of savings and benefits, as well as technical and management implications, cannot be found yet. Furthermore, the focus on an industrial decision-making perspective seems to be lacking. Hence, starting from a thorough literature review of scientific as well as practitioners studies, the present study aims at sheding the light on NEBs features, implementation issues and management implications coming from the adoption of EEMs. In summary, the study reveals major elements to be taken into consideration for a novel framework to properly address NEBs (and losses) in the implementation and service phases of an EEM from an industrial decision-making perspective, with consequent implications and suggestions for the stakeholders involved into an EEM supply chain. Additionally, the study sketches several opportunities for further researches into the topic for both industrial decision-making as well as policy-making purposes.

Introduction

According to the International Energy Outlook 2014 from EIA (2014), by 2035 the world energy consumption is expected to increase by more than 50%, overcoming the value of 791.000 PJ, because of the robust economic progression and the sensible population growth. The sectors considered responsible for this situation are mainly four: the major one is the industrial (52% of the overall energy consumption), that includes agriculture, mining, manufacturing and construction, followed by the transportation sector (27%), the residential (accounting for the 14%) and, finally, the commercial sector (7%). On the other hand, green-house gases emissions (GHG) in general terms are generated for the 65% by the production and use of energy. When considering CO_2 emissions, the production and use of energy is responsible for 84% of the emissions, and 40% are generated from the industrial sector, with sensible increases along with the energy consumption (EIA 2011), in particular in developing countries.

Based on those evidences, the European policy makers developed multiple agreements and, among these, in more recent years the Europe 20-20-20 program (European Council 2012). It is a long-term European strategy to deal with energy and environmental issues, aiming by 2020 at reducing GHG emissions by 20% or more, increasing the energy efficiency at least by 20% and, finally, increasing the share of renewable energy in final energy consumption to 20%. The revision of Directive in 2012 has shown a worrying perspective: indeed, despite the targets of increase of renewable energy and GHG emissions level are going to be reached, the 20% increase in energy efficiency is far to be achieved. Therefore, much additional efforts should be paid in the near future towards this objective. For this reason, it is apparent that attention should be devoted to the industrial sector, due to its relevant energy consumption. To increase industrial energy efficiency, it is really crucial to foster the adoption of the so-called Energy Efficiency Measures (EEMs). Indeed, as Palm and Thollander (2010) note, EEMs must be diffused to reduce the existing energy efficiency gap, in combination with other policy instruments such as proper thresholds on the emissions level and adequate incentives, in a proper blend of engineering and social sciences approaches.

However, existence of an energy efficiency gap reflects that the implementation rate of EEMs is low because of the existence of several barriers that prevent the decision makers to accomplish such measures. In the field of barriers to industrial energy efficiency, scholars and practitioners have offered contributions at multiple levels. Indeed, as for example, empirical studies have distinguished between market-related or behavioral and organizational-related barriers (Thollander and Ottosson 2008). Sorrell et al. (2004; 2010) have offered a thorough review of studies on barriers to industrial efficiency, coming up with a classification of six barriers, namely: *i)* risk; *ii)* imperfect information; *iii)* hidden costs; *iv)* access to capital; *v)* split incentives; and *vi)* and bounded rationality. More recently, Cagno et al. (2013) in their taxonomy have classified barriers according to seven categories, namely: *i)* technology-related; *ii)* informative; *iii)* economic; *iv)* behavioral; *v)* organizational; *vi)* competence-related; and *vii)* awareness. Additionally, they have paid attention to characterize barriers according either to the most affected phase of the decision-making process or the specificity of a barrier (thus making a distinction between general barriers from intervention-dependent ones).

Nevertheless, empirical studies have revealed that EEMs are perceived as not relevant for the core process of industrial activities (Fleiter et al. 2012), thus being considered as marginal or with low priority (Trianni et al. 2013). Other relevant contribution in the discussion have been recently offered by Cooremans (2007; 2011), that has pointed out the need to go beyond a “mere” investment logic, thus considering EEMs possibly as strategic.

A quick overview of the literature contributions on barriers to energy efficiency allows gathering an interesting picture: scholars and industry have so far paid little attention to increase the knowledge on how to overcome such barriers and, in particular, there is a little discourse on the so-called Non-Energy Benefits (NEBs), that have been presented to the industrial decision makers as positive effects arisen because of the EEMs in the service phase of the measure. Heffner and Campbell (2011) recognized that they are able to modify the perception of the decision maker about the EEMs. Nevertheless, they have been so far considered with scattered examples almost exclusively focused on the service phase of an EEM, without really considering the huge amount of possible positive and negative implications either at the implementation and service phases. In short, a structured framework to thoroughly describe and analyze NEBs is missing.

For this reason, in the present study we aim at offering a contribution to fulfill this research gap, by identifying some major features for a new framework through which analyze EEMs defining their impact. In addition, a new classification for the benefits should be developed with a top-down approach and proposed in order to provide a higher level of knowledge to the industrial decision makers as well as to the policy makers, who can really benefit from the novel approach proposed in the present study.

Literature Review

Non-Energy benefits (NEBs) from the adoption of EEMs have been mostly presented and described without any structured analysis of their characteristics, but just with the inclusion of a few properties. In addition, despite in some cases attempts to evaluate the impact on the payback time have been provided, the considerations have been offered without a comprehensive approach, thus resulting inadequate for a structured analysis needed for generalization purposes.

An example able to provide the perspective so far adopted on the NEBs is the study by Lung et al. (2005). In that case, the authors presented a model for the evaluation of the magnitude of the benefits, in monetary units. The approach also includes the existence of additional benefits to be considered when deciding to perform an investment in a EEM. Indeed, authors have pointed out the capability of EEMs to offer an opportunity to gain a competitive advantage in the long-term. In this regard, Bunse et al (2011) offer an interesting contribution, defining three macro-categories of benefits based on the aspects involved: economic, environmental and societal. For each of these classes of impact, a list of benefits has been defined. Nevertheless, they tend to recognize all positive consequences occurring in the plant and including the production, or core process, as well as other ancillary processes with limited interest for the negative ones. This may happen because highlighting the potential of such type of investments and the wide range of positive effects for the organization undertaking an investment in EEMs was deemed as most important. A further confirmation has been provided by Mills and Rosenfeld (1996), who concluded their study with the indication of a higher interest, from an industrial manager perspective, for several non-energy benefits, thus pointing out the need to go beyond energy savings.

In the past, NEBs have been considered as benefits perceived as a consequence to the adoption of an EEM, but that cannot always easily be quantified in monetary terms. Indeed, as authors note, “a benefit may be deemed ‘non-quantifiable’. For example, adopting a technology may enhance a firm’s reputation as an innovator and leader, but this is too intangible to quantify” (Worrell et al. 2003). Nevertheless, regardless of the capability to quantify benefits (and monetize them), the interest for describing NEBs has been differentiated. In fact, the focus from scholars and practitioners was directed toward the indication of possible areas within an organization where the benefit was going to be experienced or, alternatively, towards the definition of their nature indicating e.g., whether the benefit is internal or not, direct or not, economic or not.

Contemporary to the increasing knowledge about their existence, the level of detail used for the description of NEBs has been enriched with further attributes. Here Elliott et al. (1997) have offered an interesting contribution to the discussion. In particular, even if benefits are considered just based on the area where they can be experienced, some additional progresses have been reached. In particular, it has been highlighted the need to add a "project" or intervention-related perspective. For this reason, benefits in their study are defined as project benefits (stemming from the label used for the EEMs, i.e. Energy Efficiency Projects). With regard to this, the areas used for clustering the benefits have been defined considering the areas of a company where the benefits could be appreciated, including: *i)* reduced costs of environmental compliance; *ii)* improved worker safety; *iii)* reduced production costs; *iv)* improved product quality; *v)* improved capacity utilization; and *vi)* improved reliability. Hence, it has been possible to overcome the idea of almost exclusively considering energy savings, thus admitting that those benefits may go over the energy savings provided through the EEMs analyzed. Furthermore, Lilly and Pearson (1999), who have proposed an economical evaluation of the benefits deriving from the implementation of the EEMs in the industrial context, pointed out the need to evaluate such impacts in the decision-making process. This first attempt reveals the need to encompass (in some way) NEBs into the decision-making process of adopting an EEM.

Piette and Nordman (1996) propose several areas where to experience a benefit, such as: *i)* improved indoor environmental quality and comfort; *ii)* improved controls and zoning; *iii)* reduced operations and maintenance costs; *iv)* improved equipment life; and *v)* reduced EEM dollars. Additionally, the benefits accounted into such areas tend to reduce the total costs paid for adopting an EEM. As a consequence, the authors offer an approach to evaluate the cost-effectiveness for the measures taken into account, by comparing the energy costs savings with the total costs paid for an EEM commissioning. Furthermore, the study by Piette and Norman (1996) is notable for their first attempt of considering in the investment analysis also the so-called "deficiencies", intended as operational problems existing in the plant before the EEM completion. Such deficiencies could be directly related to the EEM, indirectly related to the EEM – as in case of a deficiency that could have been found even without the implementation of the measure considered – and, finally, unrelated to EEM.

Another important contribution has been provided by Worrell et al. (2003) and Laitner et al. (2001), who focus their attention on the definition of the productivity benefits, highlighting the possible distance from the core process of the benefits arisen and indicating the areas where the impact is perceived. The six areas for the productivity benefits are as follows: *i)* waste reduction; *ii)* emissions reduction; *iii)* operation and maintenance; *iv)* production; *v)* working environment; and *vi)* other. In addition, the definition of such productivity benefits points out the possibility to include them in strategic evaluations and, consequently, trying to suggest the industrial decision makers that EEMs themselves can be perceived as further possibilities to build a competitive advantage. Notably, to evaluate the cost-effectiveness of EEMs complemented with additional benefits, the authors propose the Conservation Supply Curves (CSCs). CSCs represent a useful tool based on discounted cash flow techniques where all benefits (energy and non-energy) and costs related to the service phase of an EEM, being aware of different capital recovery factors as well as EEM lifetime, have to be accounted and compared to a given energy cost threshold (typically, the current average energy price). Based on the approach proposed by Worrell et al. (2003) and Laitner et al. (2001), Finman and Laitner (2001) have conducted a study of the impacts of NEBs through 77 different case studies available in literature, even if only 52 of them have been thoroughly evaluated, because of missing information.

Considering, in addition, the contribution by Pye and McKane (2000), the definition of the profitability of the benefits has been pointed out through the introduction of a different perspective. In fact, a stronger interest towards the NEBs is demonstrated with the indication of the impacts attributable to a certain measure accomplished in order to increase the *efficiency*, and not merely the *energy efficiency*. This shift shows indeed the need to identify and characterize the benefits as able to increase and build (or strengthen) the firm's competitive advantage on the long-term. Again, other scholars have offered an attempt to look at other than energy-related performance affected by the adoption of EEMs. In the study proposed by Finster and Hernke (2014), the perspective adopted changes sensibly, moving the focus from the quantification in monetary units to the consideration of gaining a competitive advantage from the implementation of the EEMs. Seven domains have been identified, namely: *i)* markets and products; *ii)* reputation; *iii)* risk; *iv)* human resources; *v)* sourcing; *vi)* collaboration; and *vii)* strategic direction. In addition, for each of them, there is the proposal of different benefits.

More recently, an interesting proposal has been offered by Ryan and Campbell (2012); in particular, there is a wider analysis of the socio-economic outcomes arising from an EEM different from the energy savings. Even in this case, it has been taken into account on the one hand that different perspectives on NEBs exist; on the other hand, that benefits from the adoption of EEMs may be either direct or indirect. In particular, they are defined as direct if they are a consequence of the having implemented an EEM, while they are indirect if they can be experienced as consequences (or evolutions) of the direct benefits. In addition, the categorization of the benefits has been accomplished considering the economic level (individual, sectorial, national and international levels), even if other hints are provided. Among these, they have proposed to look at the beneficiary, the nature of the impact, the temporal scale and the character of the impact.

Scholars have stressed the need to consider multiple perspectives on benefits for energy efficiency, moving beyond those experienced exclusively by a single company. In particular, Skumatz and Gardner (2005) define several co-existing perspectives when considering the EEMs, individuating three opportunities: the utility, the societal and the participant benefits. For each benefit, in order to provide satisfying estimates, the evaluation of the net effect has to be accomplished considering the type of impact (positive or negative), defined in relation to the non-efficient equipment available, instead of that included in the EEM and accomplished exclusively considering the benefits attributable to an energy efficiency program, and not to the technology. According to the authors, a deeper knowledge of the NEBs – relevant for the stakeholders where the efficiency program has to be implemented – reduces the existing barriers and improves the awareness of a company regarding the EEM that suits the most its needs. In short, a thorough knowledge of NEBs allows a more accurate choice of the EEMs, e.g., thus understanding which of them is closer with respect to a company energy strategy or which one is most effective. This represents a driver for improved energy efficiency. Indeed, combining this enhanced opportunity with the need for a more detailed EEMs description, the benefits have been initially indicated as Net Non-Energy Benefits. The "net" concept here seems to underline the existence of both positive and negative impacts, as previously mentioned.

In 2014, the IEA (2014) has published a report on capturing the multiple benefits of energy efficiency, where the benefits are analyzed to demonstrate the correlation existing between EEMs and strategy as well as core processes of the organization, contrary to what happens to policy makers. Nevertheless, the report is pretty vague in describing how to account for both the full costs and benefits of the EEMs and to the way known aspects are communicated to the decision maker. The first aspect provided relates to the area where benefits can be experienced, similarly to what proposed from other authors (see, e.g., (Worrell et al. 2003) and (Lung et al. 2005)). Consequently, the time axis is considered, in order to distinguish the benefits easy to be quantified and defined, so to give them a higher priority, with consideration expressed on the base of previous studies, interviews and collaborations. In a recent publication on policy pathways for energy efficiency in Small and Medium-Sized Enterprises (SMEs) by IEA (2015), benefits are presented as opportunities to improve the profitability of the EEM in SMEs. Nevertheless, the considerations of the extension of the real impact of the measure is not proposed. In addition, the classification and characterization of the benefits, in this phase, is something not considered. This happens because the interest at this stage is still focused on the definition of the advantages proper of the EEMs for strengthening their diffusion.

General considerations on the existing classifications

What emerges from the literature review is the existence of a narrow interest focused almost exclusively on the benefits with a positive impact that arise in the service phase, i.e. after the adoption of the measure has been completed. However, as some authors pointed out, the effects are not all positive – considering, for example, negative benefits (Skumatz e Gardner 2005), (IEA 2005), or deficiencies) – and do not manifest just in the service phase (as for the deficiencies encountered in the implementation phase (Piette and Nordman 1996)). A full set of literature review has been reported in Table A.1 (in Appendix). To summarize the main information analyzed, in *Figure 1* we have exploited a graph characterized from two axes: on the one hand, we have reported the time, which covers all the EEM lifetime, thus with a clear distinction between implementation phase (installation, start up, etc.) from the service phase of an EEM. On the other hand, we have distinguished between the type of impact of the benefit.

The picture clearly shows that almost the whole literature has been focused on benefits (25 out of 38 studies considered on the topic) for the service phase: this is reasonably due to the fact that a strong boost has come from EEMs manufacturers, suppliers and policy-makers, thus tending to show as much positive impacts as possible in the description of the EEMs, so to improve the diffusion of such measures. However, according to the perspective of an industrial decision maker, it is important to perform a frank and complete analysis of the EEMs, including the effects of each phase in the previously mentioned description as well as possible negative impacts (here called "losses") both in the implementation as well as in the service phase. The need to highlight both negative as well as positive impacts is related to the need of overcoming the informational barriers related to the lack of knowledge (as briefly reported in the introduction), mostly about the interaction of the EEMs with the context where they are applied, and also regarding the impact that the adoption of an EEM has on the organization's strategy. Last, but not least, it is really interesting that no study has been so far focused on addressing losses in the implementation phase: indeed, the so-called "disturbance" has been recognized as a possible crucial element when dealing with implementation of EEMs, and assumes great relevance especially in case of EEMs with possible effect on core production activities.

Consequently, in order to address the viewpoint of an industrial decision maker, it is important to provide first a new framework to describe the attributes of the impacts proper of each EEM and, consequently, a new characterization of the benefits, in order to precisely define the dynamics within a plant where EEMs are implemented, the core process and the ancillary ones. The characterization of the benefits would for sure take advantage from the previous literature contributions, thus aiming at including the most relevant properties proposed by previous scholars.

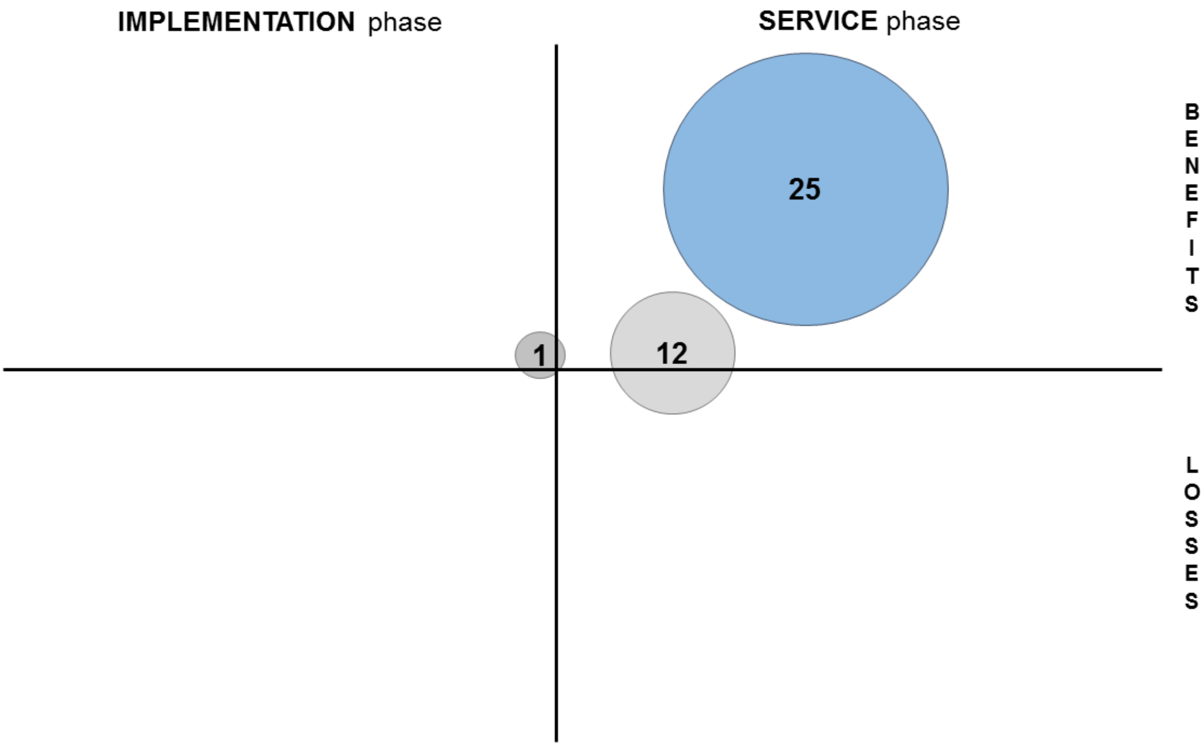

Figure 1 - Focus of the existing literature studies on Non-Energy Benefits

The need of a novel model for NEBs

Considering the previous literature review and keeping the perspective of an industrial decision maker, it is really crucial to re-design the set of attributes needed to entirely describe the impact that EEMs have on the whole organization. This indeed calls for a brand novel approach much more oriented towards investment decision support from a manager perspective, as Sandeberg and Söderström (2003) note. To do so, on the one hand it is important to encompass a set of characteristics so far missing, or barely integrated; on the other hand, it would be needed to develop a tool able to measure (with appropriate scales) both benefits and losses of EEMs.

Having a proper instrument for decision-making purposes has been recognized as important since the whole supply chain where the organization is placed may have different performance, technologies, demand and regulations, that may also vary over time (e.g. due to regulatory issues). The industrial decision makers responsible for the investments must therefore be able to understand the widest spectrum of consequences of each decision accomplished, in order to establish the investment chain that supports the most the company strategy and enables an enterprise to build a long-lasting competitive advantage.

As it can be noticed from *Figure 1*, the focus has some missing attributes that relates both the phase in which the benefit can be appreciated and the type of impact of the benefit itself, i.e. positive or negative. The first terminological aspect must relate to the definition of a new framework that should account for the type of impact, defining how the benefits and the organization relate one with the others. This is partially what can be observed from the extant literature, where a distinction among positive and negative impacts has been considered to some extent (although unclear). For this reason, it is important to modify the terminology adopted: the indication of the benefits must suit the different perspectives about the perception of the positivity of the benefits themselves, defining the NEBs and other categories of benefits.

According to Sandeberg and Söderström (2003), an investment is the consequence of a trade-off between quality and time; consequently, many effects must be considered in the decision making process regarding the impact of the investment itself on several aspects of the company. These include environmental and quality issues but, mostly, it is important that even an EEM has advantages and opportunities, disadvantages and alternatives pointed out in the early decision-making phase, that, without being clearly identified, may jeopardize the whole EEM implementation. Indeed, the need to account for several alternatives calls for a more detailed evaluation of the phases that define the lifetime of an EEM, as happened in case of a detailed *feasibility study*. In fact, in a feasibility study it is really important to properly define and respect the boundary conditions and thresholds (both technical and environmental ones), and to evaluate the possible change in some performance due to the implementation of the measures. In short, industrial decision makers need a detailed objective picture of the EEM to be undertaken with a broader perspective according to its lifetime, including possible implications in terms of relevant economic and environmental performance. In doing so, a crucial element is to offer fair and unbiased information about the real performance, so to limit as much as possible the inertia of decision makers.

Therefore, and quite new with respect to previous literature, it would be important to include in a framework of NEBs the time window in which the impact is going to be perceived and, thus, defining the implementation phase and the service one, including a detailed analysis of the EEMs and their impacts on the plant. These are important if considering the perspective of the industrial decision maker, who is strongly interested in the definition of the effects deriving from the adoption of the EEM considered in both phases. In particular, these effects are so important since they strongly influence the opinion of a decision maker about the measures since they include, among the other effects, production disruption and discomfort in production departments. The possible benefits and, mostly, the losses perceived in the implementation phase should be objectively described and remarked, as well as evaluated in an unbiased manner. What is reputed as a fundamental aspect to be considered is the dynamic evolution of the conditions inside the plant during the intervention, defining possible consequences of this specific phase on the surrounding environment. Considering all these aspects, the first of the two phases proposed, that is the implementation one, is defined as the time interval that includes the decommissioning of the existing non-efficient equipment, the installation, the testing and the start up of the efficient one. The second phase, i.e. the service one, is the time window in which the best energy-efficient equipment installed is exploited and the energy savings forecasted occur. Combining both the phases, the whole lifetime of the measure is obtained.

With respect to the above mentioned opportunities, it would be interesting to identify those impacts (not necessarily positive benefits, but a general impact involving the organization) that may be obtained in cooperation with the considered EEM. Following Ryan and Campbell (2012), this means that the focus should not be just given towards the identification of the impacts directly related to the EEMs, but also on the indirect ones, i.e. of the set of events and consequences triggered by the implementation of the EEM itself (as an effect from direct benefits or losses).

On the other hand, it would be interesting to have a thorough definition of the indirect effects during the implementation phase, in the sake of what proposed by Ryan and Campbell (2012), although having a slightly different meaning. Indeed, the definition of the indirect benefits should be done in order to define the dynamic behavior of an EEM in a plant, positioning it into an industrial context and considering the possible existence of either several operators, production systems and other investments (or measures in general) under accomplishment in the same time window, not necessarily specifically addressed for increased energy efficiency.

Considering the scheme reported in *Figure 1*, it is possible to notice how the contents introduced and suggested in this section would improve the knowledge of the benefits, properly defining the way they are obtained and can be perceived, other than the need to describe the impact of the benefits and defining when they arise in the organization. A description obtained in this way could suit the perspective of an industrial decision maker: in fact, as first objective, we aim at defining a novel approach to consider and analyze EEMs and their consequences on the whole organization. As second objective, we would like to offer a new perspective also for policy making purposes, so to increase the effectiveness of their choices and actions.

Additionally, a crucial element that has been partially suggested from previous literature is the distinction between benefits stemming from a reduced energy flow, with respect to those depending on the implementation of the given EEMs. Indeed, in many cases, authors seemed to have mixed up between these two categories of benefits, that should be kept separate, in particular related to GHG emissions (that are typically energy-flow related).

Moreover, based on the empirical evidence as well as existing contributions, it would be really useful to include in a framework describing Non-Energy Benefits (NEBs) Losses (negative impacts deriving from the adoption of such measures) who, within a company, is going to experience a benefit, as well as whether a benefit could be persistent over time and how long it would be possible to experience it. Finally, in a proper framework to describe the effects, it would be interesting to describe which effects may have a relevant effect in the relationship with external company's stakeholders, from those that may be appreciated exclusively within the company. This enhanced knowledge on NEBs would support on the one hand industrial decision makers to properly give a higher priority to selected EEMs on the basis of those with most interesting effects. On the other hand, it would support the set of stakeholders in promoting EEMs, since it would be clearer who (and to what extent) is going to effectively benefit from the adoption of the considered EEMs within and outside a company.

Concluding remarks and further research

In conclusion, the present study has offered a thorough review of the set of studies concerning the whole set of effects, both benefits and losses, deriving from the EEMs adopted in the industrial sector, in production plants. In particular, we have highlighted the need to develop a novel approach to characterize and analyze such effects, based on an industrial decision-making perspective. If yet most of the work has been accomplished to point out benefits in the service phase for an EEM, much greater attention should be paid to clearly point out the existence of benefits since the implementation phase of an EEM as well as to describe the negative consequences (losses) brought by the adoption of EEMs. Additionally, several attributes would still need to be described in detail, getting benefits from the extant literature. Furthermore, in detailing attributes, proper attention should be paid in offering adequate scales for measuring the characteristics. Finally, to validate the novel approach and guarantee to have developed a really useful tool for industrial decision-making purposes, a thorough investigation of the framework with respect to different EEMs would be needed. This phase would be really crucial to test the capability of the framework to thoroughly describe the set of relevant attributes of an EEM as well as its benefits (and losses) according to the implementation as well as the service phase.

As further research opportunities, the development of such framework could be exploited for additional empirical research through the following research streams: firstly, it would be interesting to apply the framework in selected cluster of enterprises, so to understand common needs and opportunities (as well as difficulties and barriers to the adoption of EEMs). Secondly, it would be possible to apply the framework in analyzing several stakeholders within the same supply chain of an EEM, so to point out different perspectives and analyze existing mismatches (that lead an EEM to not being implemented by a final user). Thirdly, it would be possible to analyze a single company with respect to several different EEMs, so to understand which might be the possible existing synergies (either positive or negative) coming from the adoption of a set of EEMs. Fourthly, it would be quite interesting and challenging to seek whether the framework would perform out of the context for which it has been specifically developed, i.e. industrial energy efficiency. Indeed, it would be quite relevant to point out existing energy efficiency benefits from the adoption of measures not designed for energy efficiency purposes. Finally, from a policy making perspective, it would be possible to use the developed framework to describe a set of different companies with respect to the same EEM, so to develop the most appropriate means to foster the adoption of such measures.

References

Bunse, K. et al., 2011. Integrating energy efficiency performance in production management–gap analysis between industrial needs and scientific literature. Journal of Cleaner Production, 19(6), 667-679.

Cagno, E., Worrell, E., Trianni, A. & Pugliese, G., 2013. A novel approach for barriers to industrial energy efficiency. Renewable and Sustainable Energy Reviews, 19, 290-308.

Cooremans, C., 2007. Strategic fit of energy efficiency (Strategic and cultural dimensions of energy-efficiency investments). Proceedings of ECEEE summer study, La Colle sur Loup, France. ISBN: 978-91-633-0899-4.

Cooremans, C., 2011. Make it strategic! Financial investment logic is not enough. Energy Efficiency, 4, 473–492.

[EIA], Energy Information Administration, 2014. International Energy Outlook 2014. U.S. Energy Information Administration Office of Integrated and International Energy Analysis U.S. Department of Energy, Washington, DC 20585, report no. DOE/EIA0484(2014), available at: http://www.eia.gov/ieo

Elliot, N. R., Laitner, S. & Pye, M., 1997. Considerations in the estimation of costs and benefits of industrial energy efficiency projects. In Energy Conversion Engineering Conference, 1997. IECEC-97., Proceedings of the 32nd Intersociety (Vol. 3, pp. 2143-2147). IEEE.

[EC], European Council, 2012, Directive 2012/27/EU on energy efficiency, amending Directives 2009/125/EC and 2010/30/EC, and repealing Directives 2004/8/EC and 2006/32/EC.

Finman, H. & Laitner, J. A., 2001. Industry, Energy Efficiency and Productivity Improvements. Proceedings of the 2001 ACEEE Summer Study on Energy Efficiency in Industry. Washington DC, United States.

Finster, M. P. & Hernke, M. T., 2014. Benefits organizations pursue when seeking competitive advantage by improving environmental performance. Journal of Industrial Ecology, 18(5), 652-662.

Fleiter, T., Schleich, J. & Ravivanpong, P., 2012. Adoption of energy-efficiency measures in SMEs—An empirical analysis based on energy audit data from Germany. Energy Policy 51 (2012): 863-875.

Fleiter, T., Worrell, E. & Wolfgang, E., 2011. Barriers to energy efficiency in industrial bottom-up energy demand models - a review. Renewable and Sustainable Energy Reviews, 15(6), 3099-3111.

Heffner, G. & Campbell, N., 2011. Evaluating the co-benefits of low-income energy-efficiency programmes. Workshop Report, OECD/IEA, Paris, available at: https://www.iea.org/publications/freepublications/publication/low_income_energy_efficiency.pdf .

[IEA], International Energy Agency, 2014. Capturing the multiple benefits of energy efficiency. Paris, France; 2014, ISBN 978-92-64-22072-0, p. 232.

[IEA], International Energy Agency, 2015. Accelerating Energy Efficiency in Small and Medium-sized Enterprises. OCED/EIA, Paris, available at: https://www.iea.org/publications/freepublications/publication/SME_2015.pdf .

Laitner, J. A., Ruth, M. B. & Worrell, E., 2001. Incorporating the productivity benefits into the assessment of cost effective energy savings potential using conservation supply curves. Lawrence Berkeley National Laboratory. Available at: http://escholarship.org/uc/item/49g4p179 .

Lilly, P. & Pearson , D., 1999. Determining the full value of industrial efficiency programs. Proceedings from the 1999 ACEEE Summer Study on Energy Efficiency in Industry, Saratoga Springs, NY, June 15-18 (pp. 349-362).

Lung, R. B., McKane, A., Leach, R. & Marsh, D., 2005. Ancillary savings and production benefits in the evaluation of industrial energy efficiency measures. Proceedings of the 2005 American Council for an Energy-Efficient Economy Summer Study on Energy Efficiency in Industry. Washington, DC: ACEEE.

Mills, E. & Rosenfeld, A., 1996. Consumer non-energy benefits as a motivation for making energy-efficiency improvements. Energy, 21(7), 707-720.

Palm, J. & Thollander, P., 2010. An interdisciplinary perspective on industrial energy efficiency. Applied Energy, 87(10), 3255-3261.

Piette, M. A. & Nordman, B., 1996. Costs and benefits from utility-funded commissioning of energy-efficiency measures in 16 buildings. (No. CONF-960254--). American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, GA (United States).

Pye, M. & McKane, A., 2000. Making a stronger case for industrial energy efficiency by quantifying non-energy benefits. Resources, Conservation and Recycling, 28(3), 171-183.

Ryan, L. & Campbell, N., 2012. Spreading the net: the multiple benefits of energy efficiency improvements. OECD/IEA, Paris, France, available at: https://www.iea.org/publications/insights/insightpublications/Spreading_the_Net.pdf .

Sandberg, P. & Söderström, M., 2003. Industrial energy efficiency: the need for investment decision support from a manager perspective. Energy policy, 31(15), 1623-1634.

Schleich, J., 2009. Barriers to energy efficiency: a comparison across the German commercial and services sector. Ecological Economics, 68(7), 2150-2159.

Skumatz, L. A. & Gardner, J., 2005. Methods and results for measuring non-energy benefits in the commercial and industrial sectors. Proceedings of ACEEE Summer Study on Energy Efficiency in Industry: Cutting the High Cost of Energy. West Point, New York, 163-176.

Sorrell, S., Mallett, A. & Nye, S., 2010. Barriers to industrial energy efficiency: a literature review. Brighton: SPRU, University of Sussex (UK): In: Background study for the UNIDO Industrial Development Report (IDR) 'Industrial energy efficiency pays, why is it not happening?'.

Sorrell, S., O'Malley, . E., Schleich, J. & Scott, S., 2004. The economics of energy efficiency. Cheltenham, UK: Edward Elgar Publishing p. 349.

Thollander, P. & Ottosson, M., 2008. An energy efficient Swedish pulp and paper industry–exploring barriers to and driving forces for cost-effective energy efficiency investments. Energy Efficiency, 1(1), 21-34.

Trianni, A., Cagno, E., Worrell, E. & Pugliese, G., 2013. Empirical investigation of energy efficiency barriers in Italian manufacturing SMEs. Energy. Vol. 49, 444–458.

Worrell, E., Laitner, J. A., Ruth, M. & Finman, H., 2003. Productivity benefits of industrial energy efficiency measures. Energy, 28(11), 1081-1098.

Appendix

Table A.1 Overview of literature contribution on Non-Energy Benefits for industrial energy efficiency measures

Authors	Year	Type	Focus	Implementation/Service phase	Benefits/Losses
Benemnt and Skumatz	2007	Conference proceedings	Commercial and Industrial sector	Service phase	Benefits and Losses
Boyd and Pang	2000	Journal - Energy policy	Industrial sector	Service phase	Benefits
Bozorgi	2015	Journal - Energy Efficiency	Real estate	Service phase	Benefits and Losses
Bunse et al.	2011	Journal of Cleaner Production	Industrial sector	Service phase	Benefits
Cooremans	2011	Journal - Energy efficiency	Industrial sector	Service phase	Benefits
Elliott et al.	1997	Conference proceedings	Industrial sector	Service phase	Benefits
Finman and Laitner	2001	Conference proceedings	Industrial sector	Service phase	Benefits
Finster and Hernke	2014	Journal of Industrial Ecology	Industrial sector	Service phase	Benefits
Fleiter et al.	2012	Journal - Energy policy	Industrial sector and policy makers	Service phase	Benefits and Losses
Giannantoni	2009	Conference proceedings	Policy makers	Service phase	Benefits and Losses
Gillingham et al.	2004	Report	Policy makers	Service phase	Benefits
Hall and Roth	2004	Conference proceedings	Commercial and Industrial sector	Service phase	Benefits
Hall and Roth	2003	Report	Policy makers	Service phase	Benefits
Heffner and Campbell	2012	Report	Policy makers	Service phase	Benefits and Losses
IEA	2015	Report	Policy makers	Service phase	Benefits
IEA	2014	Report	Policy makers	Service phase	Benefits
Imbierowicz and Skumatz	2004	Conference proceedings	Policy makers	Service phase	Benefits and Losses
Laitner et al.	2001	Conference proceedings	Industrial sector	Service phase	Benefits
Lilly and Pearson	1999	Report	Industrial sector	Service phase	Benefits
Lung et al.	2005	Conference proceedings	Industrial sector	Service phase	Benefits
Worrell et al.	2002	Report	Industrial sector	Service phase	Benefits
Mills and Rosenfelds	1996	Journal - Energy	Industrial sector	Service phase	Benefits
Pearson and Skumatz	2002	Report	Commercial sector	Service phase	Benefits and Losses
Piette and Nordman	1996	Conference proceedings	Commercial and Industrial sector	Service phase / Implementation phase	Benefits and Losses
Pye and McKane	1999	Conference proceedings	Industrial sector	Service phase	Benefits

Pye and McKane	2000	Journal - Resources, Conservation and Recycling	Industrial sector	Service phase	Benefits
Ryan and Campbell	2012	Report	Policy makers	Service phase	Benefits and Losses
Skumatz and Gardner	1997	Report	Industrial sector	Service phase	Benefits and Losses
Skumatz and Dickerson	1998	Conference proceedings	Industrial sector	Service phase	Benefits
Skumatz and Gardner	2005	Conference proceedings	Commercial and Industrial sector	Service phase	Benefits and Losses
Skumatz et al.	2000	Conference proceedings	Residential sector	Service phase	Benefits
Smith-McClain et al.	2006	Conference proceedings	Residential and commercial sector	Service phase	Benefits and Losses
Trianni et al.	2014	Journal	Industrial sector	Service phase	Benefits and Losses
Vine	2011	Report	Policy makers	Service phase	Benefits
Vine et al.	2000	Journal - Energy	Insurance, industrial sector, policy makers	Service phase	Benefits
Worrell et al.	2003	Journal - Energy	Industrial sector	Service phase	Benefits
Zhang et al.	2015	Journal - Applied Energy	Industrial sector	Service phase	Benefits
Zhang et al.	2014	Journal - Energy	Industrial sector	Service phase	Benefits