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Energy-efficiency investments and the concepts of non-energy benefits and investment behaviour

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Abstract
Despite the attention for energy efficiency today, the industry does not seem to adopt energy-efficient technology to the extent necessary. A reason which has been stressed is that not all benefits are included in the evaluation of energy-related investments, leading to an underestimation of their potential. Previous findings suggest that quantifying non-energy benefits can help showing the financial possibilities of energy-efficient technologies and increase the probability of adopting these investments. However, the literature today lacks a distinct definition of this type of benefits, even though they clearly are of high importance for evaluating investments in energy efficiency. The aim of this paper is thus to define and categorise the benefits related to industrial energy-efficiency investments by reviewing the existing literature within the field, definitions which until now have been scarce in the literature. The paper also aims at covering the investment behaviour for energy-efficiency investments, including evaluation methods and the decision-making process, thereby assessing on what basis investment decisions are made. Closely related to this is the aspect(s) of strategy; there are findings also emphasising the importance of an investment's strategic character as well as corporate energy strategy for investments in energy efficiency. This paper contributes to the field of industrial energy efficiency in two ways. Firstly, by reviewing the literature on both non-energy benefits and the investment behaviour within the energy field and secondly, by clarifying the concept of non-energy benefits.

Introduction
Industrial energy efficiency is an important topic today and in addition to direct energy savings, improving energy efficiency may yield other benefits as well. The use of these so-called non-energy benefits as a motivation for energy-efficient technologies has been stated previously in the literature. For energy-efficient improvements to appeal to the industry it is necessary that the financial opportunities are highlighted. This in turn creates a need for quantifying non-energy benefits, which is acknowledged by Pye and McKane (2000) who describe this as "making business sense of energy efficiency" (Pye and McKane 2000, p. 182). In general, energy efficiency on its own is not a driving factor for investments and the value of the energy savings related to an investment is mostly less than the non-energy benefits. Therefore, quantifying non-energy benefits can show the financial possibilities of energy-efficient technologies and increase the probability of adopting these investments. (Pye and McKane 2000) The link between energy-efficient investments and productivity is also established by Worrell et al. (2003) who show that there are possible productivity benefits to gain for the industry if investments in energy-efficient technology are made. They apply cost evaluated non-energy benefits to bottom-up energy conservation supply curves, so-called CSCs[1]. Using data for the iron and steel industry in the US, the including of productivity benefits in the cost calculations doubles the potential for cost-effective energy savings. (Worrell et al. 2003) The same methodology is later applied by Lung et al. (2005) in an analysis of 54 case studies with quantifiable

1. CSCs give the amount of supplied energy conservation for a given price. Bottom-up CSCs are constructed based on technology and cost data for each energy conserving technology. (Worrell et al. 2003)

ancillary and production benefits. They conclude that if ancillary and productions benefits are included in the analysis, the payback period is shorter. Hence, there are great incentives for studying industrial energy efficiency and non-energy benefits.

In addition to non-energy benefits, there are several other concepts used for describing benefits stemming from energy-efficiency investments; multiple benefits (IEA 2012), co-benefits (Jakob 2006) and productivity benefits (Worrell et al. 2003) are a few examples. Since no clear distinction between these concepts is to the author's knowledge available today, a review of the benefit concepts is necessary. A categorisation that meets the need for quantifiability can simplify the procedure that follows, which is confirmed in the literature as well; Worrell et al. (2003) propose a framework for evaluating productivity benefits related to energy-efficiency technologies where the first step is to identify and describe the productivity benefits. The second step is to quantify the previously identified benefits to the extent possible. The third step is to identify all necessary assumptions required for calculating the cost impacts of the productivity benefits, which is the fourth and final step. (Worrell et al. 2003) This implies that a first step in the process of quantifying non-energy benefits is to identify and categorise them in a way that enables the quantification itself.

Besides highlighting the financial opportunities with energy-efficiency investments, there are others who suggest that the economic and financial aspects of the investments only play a secondary role in the decision-making process and that other factors, especially those of a strategic character, are of higher importance. Examples mentioned as important strategic characteristics are the link between an investment and the firm's core business and the connection to competitive advantage. (Cooremans 2011) The strategic character of energy-efficiency investments and other related concepts, such as investment behaviour and the decision-making process, have during the past decade been given very limited attention. But since there are findings emphasising an existing energy-efficiency gap (e.g. DeCanio 1998, Backlund and Thollander 2011), i.e. that there is a difference between the actual energy-efficiency level and the potential one, this subject needs to be explored further. The need for combining non-energy benefits and strategy for energy-efficiency investments have been stressed recently (Cooremans 2011), which suggests that non-energy benefits and investment behaviour should be studied in parallel in order to find possible ways to incorporate energy efficiency into firms' strategies and business models.

This paper aims to define the benefits related to industrial energy efficiency and propose a methodology for categorising these benefits in a way that can meet the need for quantifiability. An additional perspective is applied to this categorisation by incorporating findings from another field of research, IT investments. The paper also aims to review the previous findings on investment behaviour regarding energy efficiency and an attempt to integrate these two areas.

Methodological approach

This paper covers two fields of research; benefit concepts related to energy efficiency and investment behaviour. It is based on a literature review of both of these areas. Starting with the benefit concepts, a systematic search of the concepts was made using the database Scopus[2] and sorting the hits by number of citations. The benefit concepts used as search strings were non-energy benefits, co-benefits, ancillary benefits and multiple benefits, both in unrestricted search strings and restricted to only cover the subject area "Energy". In addition, search strings such as "non-energy benefits of energy efficiency", "co-benefits of energy efficiency" and so on, were applied in order to capture any possible relevant findings accidently excluded by the restriction. Also, "indirect benefits" and "productivity benefits" were used as search strings since these terms occasionally are used as synonyms to non-energy benefits (e.g. Worrell et al. 2003, Cooremans 2011). The number of hits varied greatly for each concept. For example, an unrestricted search on "co-benefits" resulted in 497 hits and 116 hits when the search was restricted to the energy area, whereas the corresponding searches for "non-energy benefits" yielded 41 (unrestricted) and 29 (restricted) hits. By studying the abstracts, a final selection was made. Especially for the concepts "co-benefits" and "ancillary benefits", a number of the first results (i.e. most cited) were irrelevant for the purpose of this paper.

A similar approach was applied when reviewing the investment behaviour field. In this case, "investment behaviour", "decision-making", "investment evaluation", "investment characteristics" and similar search strings were applied and both unrestricted and restricted searches were made. Finding relevant hits from these search strings is complicated by the fact that these are very broad terms that occur in various fields of research and limiting the search to only include findings within energy is not enough; for "decision-making", the result is still over 7,000 hits. Therefore, additional searches of previous citations from relevant articles were carried through and yielded additional articles that would have been difficult to find otherwise. No restriction on what type of papers to include was applied. Nevertheless, the majority of the included papers are articles from scientific journals; there are only three conference papers (Lilly and Pearson 1999, Lung et al. 2005, Skumatz and Dickerson 1997) and two reports (IEA 2012, Sauter and Volkery 2013).

Non-energy benefits and similar concepts

Non-energy benefits, henceforth NEBs, represent the potential benefits related to energy investments other than those related to the direct energy savings. It could for example include increased productivity, reduced production costs, higher product quality or improved worker safety (Pye and McKane 2000). Other, similar concepts discussed in the literature are productivity benefits (Finman and Laitner 2001, Worrell et al. 2003), indirect benefits (Cooremans 2011), ancillary benefits (Lung et al. 2005) and multiple benefits (IEA 2012). IEA use the term "multiple benefits" to cover NEBs, ancillary benefits and co-benefits, whereas Lung et al. use ancillary benefits as a synonym to NEBs. Clear definitions and distinctions of these concepts are hard to find today, it seems to be a confusion regarding these concepts and they are occasionally used interchangeably.

2. Database of peer-reviewed literature from several research fields. (Elsevier 2014)

In their report on benefits stemming from energy efficiency improvements, IEA use the term "multiple benefits" where NEBs, co-benefits and ancillary benefits are included (IEA 2012). The benefits are divided according to their societal level. The levels used are individual, sectoral, national and international, where the individual level refers to individuals, households and firms, and the sectoral level refers to economic sectors such as the industrial, for example. On a national level, benefits such as employment creation, energy security and other macroeconomic impacts are mentioned. The mitigation of greenhouse gas emissions and lower energy prices are in turn two examples of benefits occurring on an international level. (IEA 2012) The level's perspective is also applied by Sauter and Volkery for reviewing the costs and benefits related to energy efficiency, although their focus is on sectoral, national and international benefits (Sauter and Volkery 2013). However, "multiple benefits" is not used here; instead both NEBs and co-benefits are mentioned, as well as indirect benefits.

In the literature of energy efficiency, "multiple benefits" is applied in several contexts, such as bioenergy (Abou Kheira and Atta 2009, Kraxner et al. 2003), biogas (Katuwal and Bohara 2009), sustainable development in industry clusters (Nagesha 2008) and building renovation (Martinaitis et al. 2007). Since there is such dispersion, the three concepts included in multiple benefits by IEA (2012) are reviewed individually in order to establish where the difference (if any) lies between them.

NEBS

Reviewing the literature on NEBs reveals that the term is mainly used in two areas within the field of energy efficiency; the building (and residential) sector and the industry, respectively. NEBs for the building sector and especially for weatherisation programs for low-income households are frequently explored in the literature (e.g. Tonn and Peretz 2007, Schweitzer and Tonn 2003, Skumatz and Dickerson 1997). Attempts to categorise NEBs for this sector have been made, for example the three categories of utility and ratepayer benefits, societal benefits and participant benefits (Skumatz and Dickerson 1997), or the similar categorisation of ratepayer benefits, household benefits and societal benefits (Schweitzer and Tonn 2003). When evaluating the potentials and costs of CO_2 emissions mitigation for the building sector, NEBs are instead divided into five categories; health effects, ecological effects, economic effects, service provision benefits and social effects (Ürge-Vorsatz et al. 2009). However, even though the names of the categories differ to some extent, the included NEBs are very similar. Some of these benefits are applicable on the industrial sector as well, such as health effects (fewer illnesses, better work environment etc.), reduced waste and productivity gains.

NEBs from a consumer perspective have also been considered (Mills and Rosenfeld 1996). The benefits stemming from energy efficient technologies, such as energy efficient lighting and windows, are defined according to seven categories. The first category is improved indoor environment, comfort, health and safety followed by reduced noise, labour and time savings, improved process control, increased amenity or convenience, water savings and waste minimisation, and finally, direct and indirect economic benefits from downsizing of equipment (Mills and Rosenfeld 1996).

For the industrial sector, several types of NEBs have been identified, such as reduced costs for maintenance and operations, together with reduced emissions (e.g. Lilly and Pearson 1999). Other NEBs include reduced waste, improved product quality, increased reliability, improved worker safety and improved productivity (Pye and McKane 2000, Mills et al. 2008, Finman and Laitner 2001, Worrell et al. 2003). Few attempts to classify the industrial NEBs have been made, but one example is Finman and Laitner (2001) and Worrell et al. (2003) who divided them into six categories; waste, emissions, operation and maintenance, production, working environment and other. The included benefits have recently been reorganised into the three categories cost, value and risk (Cooremans 2011), in order to explore the connection between NEBs and competitive advantage, since these three variables are described as "the three dimensions of competitive advantage" (Cooremans 2011, p. 485–486). Reduced product waste and lowered cooling requirements are examples of benefits categorised as cost benefits while improved product quality and improved public image are examples of value benefits. In the risk category, benefits such as reduced emissions and decreased liability are found (Cooremans 2011). In addition to the NEBs stated by Worrell et al. (2003), Cooremans also adds four benefits to the risk category, namely legal risks, carbon and energy price risks, disruption of energy supply and commercial risk (Cooremans 2011).

CO-BENEFITS

Another common concept is co-benefits. It is for instance acknowledged as a factor that should be taken into account when discussing the so-called rebound effect (Hertwich 2005). It has also been used for describing benefits related to energy efficiency investments in the buildings sector (Jakob 2006), as well as for describing the benefits stemming from CO_2 reduction for this sector (Ürge-Vorsatz et al. 2007, Ürge-Vorsatz et al. 2009). The benefits mentioned by Jakob (2006) are similar to the NEBs stated by Mills and Rosenfeld (1996) above; for example thermal comfort and improved indoor air quality. Tradable White Certificate schemes on an EU level and their co-benefits are also mentioned in the literature (Mundaca 2008). The benefits stated are improved competitiveness, increased employment, technological market transformation, air pollution, increased comfort level for households and energy security, among others (Mundaca 2008). These are similar to the NEBs mentioned above.

However, the term "co-benefits" is most frequently used to describe environmental and health benefits, which can be related to reduced CO_2 emissions (van Vuuren et al. 2003, van Vuuren et al. 2006, Changhong et al. 2006, He et al. 2010, Malla 2009), climate policy (Aunan et al. 2004, Rypdal et al. 2005), Tradable White Certificate schemes (Mundaca 2008),cleaner production (Mestl et al. 2005), Life Cycle Assessment and environmental impacts (Koornneef et al. 2008, Singh et al. 2012) or bioenergy (Brown et al. 2007, Gan and Yu 2008). That is, with a few exceptions, the concept of co-benefits seems to be closely related to the mitigation of CO_2 emissions and other environmental impacts. The environmental co-benefits most often mentioned in the literature are reduced air pollution, improved local air quality and reduced corrosion of materials, together with the environmental related health benefits (see for example Aunan et al. 2004, Mestl et al. 2005, Koornneef et al. 2008).

ANCILLARY BENEFITS

Ancillary benefits are not applied as often as co-benefits but when they are used, they are mostly discussed in the same contexts as co-benefits and the two concepts are used as equivalents (for example Mundaca 2008, Jakob 2006, van Vuuren et al. 2006). Stated benefits are reduced air pollution (van Vuuren et al. 2006, Rafaj and Kypreos 2007, Xu and Masui 2009), (environmental) health benefits (Nishioka et al. 2002), employment creation and improved waste control (Bilgen et al. 2007). When evaluating different energy-efficient initiatives, welfare improvements and positive effects on other resources, such as water supply, are also mentioned as ancillary benefits, in addition to employment creation (Neves et al. 2008).

CATEGORISING THE CONCEPTS

There are both similarities and differences between NEBs, co-benefits and ancillary benefits. Benefits such as improvements in air quality and its health effects, waste control and/or reduction and competitiveness are examples that the three concepts have in common. However, NEBs are to a larger extent used in the context of industrial energy efficiency whereas both co- and ancillary benefits more frequently describe environmental impacts. This leads to the second difference between these concepts; on which level they occur. Following the typology used by IEA (2012), energy efficiency benefits can appear on an individual, sectoral, national and international level. The benefits which are categorised as co- and ancillary often appear on a national or even international level. That is, they are benefits that affect the economy as a whole and not just a specific industry or sector (e.g. air pollution, environmental health benefits, employment creation and energy security). On the contrary, NEBs can often be considered as sectoral benefits, or as individual when the consumers' or households' perspective is applied (Mills and Rosenfeld 1996). There are of course exceptions; energy efficiency programs aimed at, for example, the residential sector will not only provide NEBs for the individual households, but for an entire region as well (see for example Tonn and Peretz (2007) for the case of state-level benefits). When NEBs appear on a national or international level, it could be possible to treat co-benefits and ancillary benefits as subcategories to NEBs. Therefore, the differences between these concepts can be visualised as in Figure 1.

Benefits occurring on an individual, sectoral and occasionally national level are in the literature recognised as NEBs.

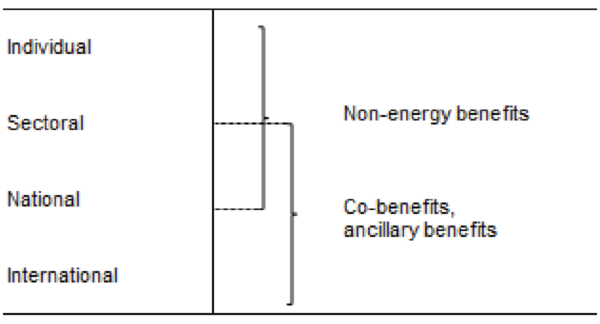

Figure 1. Benefit concepts by societal level.

Benefits occurring on an international, national and sometimes sectoral level are in turn recognised as ancillary or co-benefits. These benefits are often of an environmental character, for example reduced air emissions. As can be seen in the figure above, there is an overlapping between the concepts. For the case of industrial energy efficiency, which mainly concerns the individual (firm) and sectoral level, NEBs is the most adequate concept to use. Therefore, NEBs will be explored further below.

A DEEPER LOOK AT NEBS

Even though NEBs is the most common concept used for describing "extra" benefits stemming from energy-efficiency investments, the term "NEBs" and the benefits composing this concept are not categorised or defined in a clear way. The benefits stated as industrial NEBs in the literature are displayed in Table 1.

Note that both Sauter and Volkery and the IEA state several more benefits than the ones presented above. However, those not directly related to industrial energy efficiency are excluded here, for example job creation and other macroeconomic effects. The benefits stated above are related to industrial energy efficiency and appear on an individual and sectoral level.

Besides the lack of frameworks for categorisation of industrial NEBs, there is also a variation as to how productivity improvements are mentioned in the literature. Productivity benefits and NEBs have been used alternately (Finman and Laitner 2001, Worrell et al. 2003), implying that the two concepts could be used as synonyms to each other. On the other hand, productivity benefits are also referred to as a type of non-energy benefit (Worrell et al. 2003, Pye and McKane 2000, Mills et al. 2008, Boyd and Pang 2000), which contradicts the use of them as synonyms. Productivity is a measure of the ratio of output to input and in the context of energy efficiency investments, it is possible to observe benefits which are easily quantified and translated into monetary values, such as reduced material costs or increased production (e.g. Pye and McKane 2000). For these benefits, the connection to productivity is more or less straightforward. However, there are benefits which may affect productivity but are more difficult to observe and even more difficult to translate into monetary values. Examples of these benefits are improved work environment, employee satisfaction (Worrell et al. 2003) and improved public image. Due to the difficulties in quantifying these benefits, the relationship between them and productivity cannot be established to the same extent. Therefore, it is suggested to treat productivity benefits as a type of NEBs instead of using them interchangeably.

As Table 1 reveals, there have been few attempts to categorise industrial NEBs. The categories are either related to the type of benefits, for example "waste" or "production" (e.g. Worrell et al. 2003), or they are of a more theoretical character such as the dimensions of competitive advantage (Cooremans 2011). Moreover, studies have stressed the importance of quantifying NEBs and thereby show the financial potential of energy-efficiency investments (e.g. Pye and McKane 2000, Worrell et al. 2003). Therefore, one approach could be to categorise industrial NEBs into being quantifiable or not quantifiable since the ability to be quantified differs between benefits; some may be of a qualitative nature (Cooremans 2011). That could however lead to the rejecting of important benefits. Improved working environment have for instance been mentioned as a benefit

Table 1. NEBs related to industrial energy efficiency.

	Mentioned NEBs	Categorisation (if any)
Pye and McKane (2000)	Increased productivity, reduced costs of environmental compliance, reduced production costs (labour, operations and maintenance, raw materials), reduced waste disposal costs, improved product quality (reduced scrap/rework costs, improved customer satisfaction), improved capacity utilisation, improved reliability, improved worker safety, improved efficiency, reduced emissions, extended life of equipment, reduced operating time, reduced ancillary operations, reduced cleaning and maintenance requirements, increased capacity, decreased noise.	
Finman and Laitner (2001) Worrell et al. (2003)	Use of waste fuels, reduced product waste, reduced waste water, reduced hazardous waste, materials reduction, reduced dust emissions, reduced CO, CO_2, NO_x, SO_x emissions, reduced need for engineering controls, lowered cooling requirements, increased facility reliability, reduced wear and tear on equipment/machinery, reductions in labour requirements, increased product output/yields, improved equipment performance, shorter process cycle times, improved product quality/purity, increased reliability in production, reduced need for personal protective equipment, improved lighting, reduced noise levels, improved temperature control, improved air quality, decreased liability, improved public image, delaying or reducing capital expenditures, additional space, improved worker morale.	Six categories: (1) Waste (2) Emissions (3) Operations and maintenance (4) Production (5) Working environment (6) Other
Cooremans (2011)	Follows Worrell et al. (2003) but adds reduced legal risks, carbon and energy price risks, disruption of energy supply and commercial risk.	Relates to competitive advantage: (1) Cost (2) Value (3) Risk
IEA (2012)	Health, increased asset values, industrial productivity, safer working conditions, improved quality, reduced capital and operating costs, reduced scrap and energy use, improved competitiveness.	By economic level: (1) Individual (2) Sectoral (3) National (4) International
Lilly and Pearson (1999)	Extended life of equipment, reduced air emissions and related fines, reduced wear and tear, reduced operations and maintenance expenses.	
Mills et al. (2008)	Improved productivity, improved process control, enhanced reliability, reduced operation and maintenance costs.	
Sauter and Volkery (2013)	Reduced operation and maintenance costs, increased motivation, safer working conditions, improved competitiveness, productivity gains, reduced resource use and pollution.	

which is not easily quantified but still positive for a firm's productivity (Worrell et al. 2003). Thus, only classifying NEBs into being quantifiable or unquantifiable may not be the optimal procedure.

By glancing at another field of research, namely IT investments, this conclusion regarding quantifiable versus unquantifiable benefits is confirmed. During the nineties and beginning of the twenty-first century, IT investments were in a similar position as energy-efficiency investments are today. The benefits from IT investments were difficult to identify and measure and were often not realised after the implementation (e.g. Dempsey et al. 1998, Love and Irani 2004, Peppard and Ward 2005). In a cost/benefit framework, the three categories hard, soft and unquantifiable are applied to divide costs and benefits where hard and soft represent easily quantified (hard) and quantifiable, although not as easily, (soft) costs and benefits (Dempsey et al. 1998). Depending on which category the benefit belongs to, its measurability will of course vary. Another classification is the one of tangible (quantifiable) and intangible (difficult to quantify) benefits (Farbey et al. 1995). Despite the difficulties in measuring certain benefits, the importance of acknowledging the so-called soft, unquantifiable or intangible benefits have been stressed, at least as "extra arguments" (Farbey et al. 1995, Dempsey et al. 1998). An additional difference between benefits of IT investments is when in time they occur. Benefits like for example improved efficiency occur within the nearest future after the investment implementation, while improved public image is a benefit realised further on in time (Peppard and Ward 2005). IEA also apply a time reference for when a benefit will take place, but the described benefits are of an environmental, economic or social character (IEA 2012). One of the economic benefits is applicable to industrial energy efficiency, namely industrial productivity, which is said to occur at short term.

The three categories hard, soft and unquantifiable can be applied on NEBs together with the time aspect. Since a number of the more "softer" NEBs, such as improved public image or improved worker morale, are more likely to be realised further on in time, this categorisation will provide a framework which acknowledges the ability for a benefit to be quantified, without rejecting those of a more qualitative nature. Using a scale for the benefits' ability to be quantified is also preferred relative to dividing them into being only quantifiable or unquantifiable since there are benefits, for example increased productivity, that are caught somewhere in between (Dempsey et al. 1998).

This new framework for categorising NEBs can be illustrated in a matrix where the time frame is shown horizontally and the level of quantifiability is shown vertically. As mentioned above, three levels of quantifiability are applied; *high, medium* and *low quantifiability*, where *high* refers to those benefits that are easily quantified and *medium* represent the benefits which are possible to quantify although not as easily. Finally, *low* refers to those benefits that are difficult or not possible to quantify. The time scale is divided into *short term* and *long term*, respectively.

From the matrix in Figure 2, each NEB can be categorised according to its level of quantifiability and time frame. Hence, the concept NEBs can be defined as the benefits related to industrial energy-efficiency investments, beside energy savings, that are quantifiable at a certain level (which can be zero) and arise at some point in time. Moreover, these benefits appear on an individual (firm) and sectoral level.

Included in the matrix are the NEBs mentioned in the literature (Finman and Laitner 2001, Worrell et al. 2003, Pye and McKane 2000, Mills et al. 2008, Cooremans 2011, IEA 2012, Lilly and Pearson 1999, Sauter and Volkery 2013) and they are equal to those given in Table 1. The ability to quantify a benefit and to ascertain when in time it will arise can of course vary between firms or industries and thus affect where in the matrix the benefit should be located.

Investment behaviour and decision-making

When the NEBs are identified and quantified to the extent possible, the next step would be to incorporate them into the investment analysis. However, in order to establish how this could be done, a number of questions need answering; what characterises energy-efficiency investments, what steps are included in the decision-making process, when should NEBs be incorporated, on what basis investment decisions are made, and so on. Therefore, the investment behaviour for energy-efficiency investments is covered below.

The traditional approach is to consider firms as profit-maximising and that they therefore should, according to theory, be investing in those investments with a positive net present value. The discount rate used for these projects should in turn be based on each investment's risk level. (DeCanio 1998) This implies that the risk of an investment is investment-specific rather than firm-specific (DeCanio and Watkins 1998). However, for investments in energy efficiency, this has been proven not to be the case. Energy-efficient investments are rejected and not adopted even though they should be considered as profitable (e.g. DeCanio 1993, DeCanio 1998, Cooremans 2012).

One implication of this investment behaviour regarding energy-efficiency investments is the so-called efficiency paradox, or the energy-efficiency gap, meaning that there is a difference between the actual energy-efficiency level and the potential, optimal one. There are several findings in the literature emphasising an existing energy-efficiency gap (e.g. Jaffe and Stavins 1994, DeCanio 1998, Backlund and Thollander 2011). Various explanations for this gap have been suggested in the literature. Among these are both market failures and non-market failures (Jaffe and Stavins 1994). Jaffe and Stavins focus on the diffusion phase of new technology, i.e. the gradual adoption process, and seek to answer what factors that are determining the adoption rate along with the potential effects of possible economic incentives and regulations. Mentioned market failures which are said to have a negative effect on the adoption rate are lack of information, principal-agent problems and artificially low energy prices. An

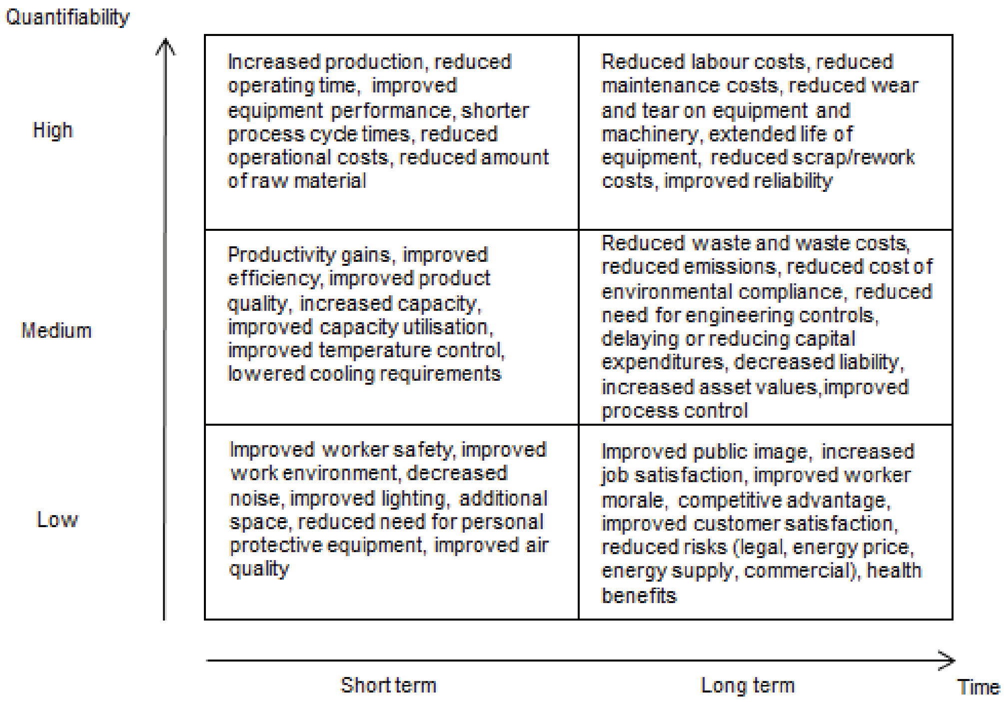

Figure 2. Matrix defining industrial NEBs.

example of a non-market failure is in turn high discount rates. Government programs and regulations such as subsidies and building codes might have a positive effect on the adoption rate. However, it is also noted that if governmental support increases at a too high rate, it can affect the diffusion of energy-efficiency technology in a negative direction since it may seem more beneficial to wait. (Jaffe and Stavins 1994) The value of waiting has been stressed later on as well with the explanation that there are problems of irreversibility and uncertainty regarding future technological progress. The ambiguous effects from governmental interventions for energy-efficiency improvements are also confirmed; it may be more beneficial to wait for an even better investment in the future (Van Soest and Bulte 2001).

The efficiency paradox has also been tested empirically (DeCanio 1998). By studying firms participating in the Green Lights program, a number of factors are identified as either economic or organisational and it is further analysed whether or not they have an impact on the profitability of the energy-saving investments. Examples of organisational and institutional factors are size indicators, financing methods and variables for providing equipment. Economic variables are for example growth rate of electricity price and a number of cost variables. Economic factors matter but both organisational and institutional factors also show significant impacts on the profitability of the investment projects and on the firms' investment behaviour. This implies that there exist internal barriers within firms for energy-efficient investments, indicating that investments in energy efficiency are facing firm-varying evaluation and not investment-specific as suggested by theory (DeCanio 1998).

From above it is implied that when the investment behaviour for energy-efficiency investments is studied, two perspectives should be applied: the firm perspective and the investment perspective, respectively. There are differences not only attributable to the firm but to the type of investment as well, i.e. investment characteristics such as uncertainty and the level of irreversibility related to the investment.

FIRM AND INVESTMENT CHARACTERISTICS

Energy-efficiency investments are said to be characterised by a high risk level (due to irreversibility) and a low real return (due to hidden and transaction costs) (e.g. Cooremans 2011). Uncertainty is also an often mentioned characteristic and barrier for energy-efficiency investments, which can include uncertainty for whether the new investment will meet future standards, or if cheaper technology will come along in the future (e.g. De Groot et al. 2001). This was also mentioned above as a possible explanation for the energy-efficiency gap (Van Soest and Bulte 2001). One implication of the high level of uncertainty is that it can affect the evaluation method, which is taken into account in a study on power generation using a real options modelling framework (Blyth et al. 2007). The real options approach is applied to quantify the investment risk, in this case uncertain climate change policy, which is considered as a regulatory risk. This risk implies that the investment is characterised with uncertain future cash flows, which in turn imply that it might pay to wait. Therefore it is stressed that it is not sufficient with a positive net present value (NPV) for the investment to be seen as beneficial, it also has an opportunity cost attached to it which can be seen as an opportunity cost of waiting (Blyth et al. 2007).

Both investment characteristics (Cooremans 2012) and firm characteristics (DeCanio and Watkins 1998) have been explored in an attempt to explain the decision-making regarding investments in energy efficiency. Regarding investment characteristics, the term "strategicity" is suggested to describe an investment's strategic character (Cooremans 2012), which also should indicate its impact on the competitiveness of the firm, as stated in a previous article (Cooremans 2011). Empirically, energy-efficiency investments are considered as non-strategic or only moderately strategic. In the meantime, it is noted that profitability has an important role in the decision-making process, although not a decisive one, and that it is the most strategic investment who wins the internal competition (Cooremans 2012).

Regarding the differences between firms in adopting energy-efficient investments, firm characteristics such as number of employees, industrial sector, earnings per share and the growth rate of historical earnings have been found to have a significant impact on the probability of adopting energy-efficient investments (DeCanio and Watkins 1998). The number of employees, i.e. size, has a positive effect on the probability rate, as well as the performance indicators. It is also stated that the ownership structure has an impact on the investment behaviour since the variable insider control shows a negative, significant effect. There also seem to be differences depending on both regional and sectoral characteristics (DeCanio and Watkins 1998). A later Dutch study supports these findings as well, where differences in investment behaviour can be explained by both firm- and sector-specific factors such as firm size, energy intensity and competitive position. It is also noted that knowledge of existing and new technologies is higher in larger firms facing stronger competition (De Groot et al. 2001). A recent study on Swiss firms finds that capital intensity and R&D activities have a positive effect on the adoption of energy-efficiency investments (Arvanitis and Ley 2013). Concerning to what extent an energy-efficiency technology is used, here referred to as "intra-firm diffusion", these two factors do not have an influence. It is instead firm size which seems to be important (Arvanitis and Ley 2013).

Another common approach on energy-efficiency investments is to study their characteristics from a perspective of barriers and driving forces (e.g. De Groot et al. 2001, Thollander and Ottosson 2008, Sardianou 2008). Some of the barriers, such as uncertainty, are characteristics related to the investment itself whereas others can be related to the firm and its organisation. In a survey-based study on 135 Dutch firms, the barriers for investing in profitable energy-efficient technologies are categorised into three categories: general barriers related to the overall decision-making process, financing constraints and barriers related to uncertainty (De Groot et al. 2001). A low priority level for energy efficiency is mentioned among the general barriers which also is confirmed in a study of Greek industries (Sardianou 2008). Other examples of general barriers are more important investment opportunities, energy costs not being an important factor, internal organisational difficulties and currently satisfying technology. The driving forces are in turn divided into being market or policy related where potential cost savings is a market related driving force, along with a green image of the firm, while investment subsidies is a policy related driving force (De Groot et al. 2001).

Another categorisation is to divide the barriers into being either market related or behavioural and organisational related, and the driving forces into being market related, current and potential energy policies, or behavioural and organisational related, which is the case in a study on the Swedish pulp and paper industry (Thollander and Ottosson 2008). Technical risk is found to be the highest rated barrier whereas cost reductions, people with real ambition and having a long-term energy strategy are the highest rated driving forces. Among the other found barriers are cost of production disruption, possible poor performing equipment and other priorities for capital investments, while other driving forces are the risk of energy prices increasing in the future, international competition, environmental company profile and improved working conditions (Thollander and Ottosson 2008). Besides a low priority level for energy efficiency in investment decisions, other barriers evident for Greek industries are lack of access to capital, slow rate of return, high implementation costs, other, more important investment opportunities, uncertainty regarding future energy prices, limited information regarding the investments' profitability and energy efficiency not being a core activity, among others (Sardianou 2008).

DECISION-MAKING

The decision-making process concerning industrial energy-efficiency investments has been studied previously. It can be described as a process where firms choose whether or not to adopt an investment, for example an energy-efficiency investment. One approach has been to use a model with a time perspective to study the behaviour regarding decision-making (Tonn and Martin 2000). The idea behind this life cycle decision-making model is that firms over time will move from a state where no energy-efficiency decisions are made towards a steady state where the firms are said to routinely seek for new energy-efficiency investments to invest in. The model has seven stages: (1) No energy saving decision-making, (2) Initial efforts, (3) Energy-efficiency program implementation, (4) Energy-efficiency program direct effect, (5) Routinisation of energy-efficiency program, (6) Enculturation of energy-efficiency program, (7) Steady state (Tonn and Martin 2000). When at the first stage, no knowledge exists regarding energy-efficiency investments even though there are opportunities, although unknown for the firms. At the second stage, the firm has received knowledge and started to evaluate energy-efficiency investments. Over time, this process evolves and at the sixth stage, energy-efficiency has become well-integrated in the firm's culture before it reaches the seventh stage, steady state. The key element in this life cycle decision-making model is knowledge, or more explicitly the diffusion of knowledge, concerning energy-efficiency investments. The level of knowledge varies between firms who thus are at different stages and will with time move forward in the model (Tonn and Martin 2000).

Whereas the above model describes the firm's position regarding their knowledge level and their thereof investment behaviour, there are other decision-making models which describe the different steps each investment needs to get through in order to be adopted. This has also been referred to as the implementation process (Neal Elliott and Pye 1998). Neal Elliot and Pye also present a seven-step model where the steps are as follows: (1) Opportunity identification, (2) Technology identification and project design, (3) Financial analysis, (4) Purchasing and procurement, (5) Financing, (6) Installation, (7) Start-up and training (Neil Elliott and Pye 1998). Another investment decision-making model presents the investment process in fewer steps, namely: Initial idea, Diagnosis, Build up solutions, Evaluation & choice and last, Implementation (Cooremans 2012). Cooremans (2012) summarises the five steps into a process of three phases: Identification, Development and Selection. The model is tested empirically and the first phase, identification, is found to be essential for an investment's proceeding. Both of the above described decision-making models share the view that the decision-making is a process. For the latter it is also stressed that external factors (the organisations' environment), organisational factors (structure, strategy and culture), individual factors (actors) and investment characteristics (type, scope and strategic character) are all affecting the decision-making process (Cooremans 2012).

Evaluation methods are often mentioned in the context of decision-making as a later step in the process. A survey of Australian firms from ten industries concluded that the most commonly used evaluation method is the payback method (80 per cent) with an average payback period of 42 months (Harris et al. 2000). The net present value (NPV) method is the second most common evaluation method (30 per cent) with a discount rate at on average 13 per cent. Approximately half of the firms also used a required rate of return on capital, on average 26 per cent. Almost 60 per cent of the included firms also considered themselves as having a conservative or very conservative risk attitude towards energy-efficiency investments (Harris et al. 2000). A study on the Swedish foundry and paper and pulp industry showed that the most common pay-off criterion used for energy-efficiency investments was on average three years or less (Thollander and Ottosson 2010), which is approximately 6 months less than for the Australian firms. In a previous literature review, it is concluded that the evaluation methods NPV, payback period and IRR (internal rate of return) are commonly used methods for both British and American firms (Cooremans 2011). However, which method that is used the most of NPV and the payback method seems to differ to some extent. Also, the quality of the calculations is not as high as it should be and other factors beside the financial characteristics affect the evaluation and the decision-making process, such as culture, intuition and investment characteristics, especially the strategic character of the investment (Cooremans 2011). This questions the financial importance for the adoption probability of an investment. Even though financial methods such as NPV, the payback method and IRR are frequently used for evaluating investments, energy-efficiency investments are not considered as strategically important, often due to the absence of a connection with the firm's core business, and they therefore end up being rejected or as a no-decision even though the financial outcome is positive (Cooremans 2011).

Discussion

From the review of NEBs and the investment behaviour related to industrial energy efficiency, several conclusions can be made. Regarding NEBs and other related concepts, such as co-benefits and ancillary benefits, both similarities and differences are observed. Due to the type of benefits that are usually included in each concept, together with the societal level that they occur, NEBs is the most appropriate term to use in the context of industrial energy efficiency. Few, previous attempts to categorise and define the different types of benefits composing NEBs have been made before, as shown in Table 1. One commonly cited is the one by Worrell et al. (2003) where the benefits are divided into six categories depending on their type, for example working environment or operation and maintenance. However, even if benefits are of the same type they still may have different characteristics. The categorisation presented here takes into account the level of quantifiability and the timing of the benefit which can simplify further analysis of an energy-efficiency investment. The need for quantifying NEBs has been stressed in the literature (Mills and Rosenfeld 1996, Pye and McKane 2001, Worrell et al. 2003), why it is justified to define the benefits by this characteristic. Using a scale of quantifiability rather than dividing the benefits into being either quantifiable or unquantifiable, is preferred since benefits that are not easily quantified but still important, will not be rejected. Previous findings from another field, namely IT investments, stress the importance of including the so-called soft and intangible benefits in order not to underestimate the investment's potential (Farbey et al. 1995, Dempsey et al. 1998). The time aspect which is included in the model can also enhance the precision of the calculations. By considering when in time a benefit will be measurable, the risk for under- or overestimating the investment's potential can be decreased. It can also simplify a future follow-up of the investment to see whether the expected benefits have been realised or not, something which also has been mentioned in the context of IT investments. This can be summarised by the following suggestion:

- *Suggestion 1*: The concept NEBs should be considered as the most adequate concept to use in an industrial context and can be defined as the benefits related to industrial energy-efficiency investments, beside energy savings, that are quantifiable at a certain level and arise at some point in time.

A barrier which has been mentioned in the literature is a low priority level for energy efficiency; a majority of the included firms consider energy efficiency as moderately important in their general investment decisions and moreover, energy costs are not considered as important enough for adopting energy-efficiency investments (De Groot et al. 2001). Including NEBs in addition to energy savings is thus essential. Depending on where in the decision-making process a firm is situated, different NEBs should be incorporated in the analysis. In the evaluation phase, which can also be referred to as financial analysis, the NEBs characterised by a high or medium level of quantifiability should be included, since these are the ones that can be translated into monetary values. Increased production, reduced waste costs, increased capacity, reduced amount of raw materials and reduced operating and maintenance costs are examples of quantifiable NEBs that can be included in the financial analysis. But as shown by Figure 2, there are also NEBs characterised by a lower quantifiability level. Depending on to what extent each benefit is quantifiable, benefits belonging to this category could also be included at the evaluation stage. Even those that are difficult to quantify, such as improved work environment and improved job satisfaction, should be considered in the evaluation phase, even though they are not possible to include in a financial evaluation. These benefits can serve as extra arguments, as stated in the field of IT investments (Farbey et al. 1995, Dempsey et al. 1998). Moreover, these benefits can also contribute to increasing the priority level for energy-efficiency investments, which is now considered as low according to previous findings. From this, a second suggestion is implied as below:

- *Suggestion 2*: Including quantifiable NEBs in the evaluation process can increase the priority level for energy-efficiency investments.

There are also benefits that can be considered to be of a more strategic character, such as improved public image and improved competitiveness. These strategic benefits may be difficult to quantify and are likely to arise further on in time. The strategic character of an investment has been emphasized as an important determinant for a positive investment decision (Cooremans 2011, Cooremans 2012). According to Cooremans, an investment is considered as strategic if it is able to benefit competitive advantage (Cooremans 2011) and it is the most strategic investment which tends to win the internal competition between investments (Cooremans 2012). Therefore, NEBs of a strategic character can be used as a complement to other evaluation tools and perhaps at a later step in the decision-making process, especially when there is more than one investment opportunity. Hence:

- *Suggestion 3:* NEBs of a low quantifiability level, especially those of a strategic character, can serve as extra arguments at a later step in the decision-making process to select between similar investment opportunities.

Uncertainty, irreversibility, slow rate of return and technical risk are barriers mentioned in the literature (e.g. Cooremans 2011, De Groot et al. 2001, Sardianou 2008, Thollander and Ottosson 2008) that can be met by NEBs. These barriers often imply a high demanded rate of return. By identifying and including quantifiable benefits related to production, such as increased output, reduced operating time, improved product quality or reduced wear and tear on equipment, the reward from an energy-efficiency investment will be higher and may break even or outweigh the high risk and meet the demanded rate of return. Also, by acknowledging when in time each benefit arises, it can be estimated what level of return that can be expected at short term and long term, respectively. The fact that many investments are characterised by irreversibility will not be changed by the presence of NEBs. However, if there are such important NEBs associated with the investment, they can counteract this negative aspect and increase the probability of a positive decision. Also, by including as many NEBs as possible in the investment evaluation, the investment itself will be more competitive against future, possible investment opportunities since the value of investing today will be higher, that is, without the NEBs included in the analysis this value is probably underestimated. There will always be uncertainty regarding what might come along, as in new technology or requirements from future energy policies, but including NEBs in the evaluation and decision-making process can at least enhance the probability of investing in today's opportunities.

It is not only barriers that could be met by NEBs; the literature also mentions a number of driving forces which in turn correspond to various benefits. Improved public image is a NEB (Worrell et al. 2003) as well as a driving force in terms of a green firm image (De Groot et al. 2001, Thollander and Ottosson 2008). Improved working conditions is a driving force for energy efficiency (Thollander and Ottosson 2008) and can be achieved through several NEBs, such as improved lighting, improved worker safety, reduced noise and improved air quality. Cost reductions due to energy savings is a major driving force (De Groot et al. 2001, Thollander and Ottosson 2008). If the potential cost savings due to for example reduced operational costs, (i.e. a NEB), are added to the equation, it should further enhance the probability of adopting energy-efficiency investments.

- *Suggestion 4:* Including quantifiable NEBs may increase the reward from energy-efficiency investments and increase the value of investing today, overcoming known barriers such as uncertainty, irreversibility and technical risk, as well as reinforcing driving forces such as a green public image and improved working conditions.

The above stated four suggestions can be summarised as follows:

- *Suggestion 5:* By defining and categorising NEBs according to their level of quantifiability and time frame, they can be included in the decision-making process at several stages and altogether increase the probability for adopting energy-efficiency investments. Hence, the concepts of NEBs and investment behaviour can be integrated and thereby contribute to improved energy efficiency.

Conclusion

From this paper it is concluded that NEBs, or non-energy benefits, is the most appropriate benefit concept to use in an industrial energy-efficiency context. Moreover, a framework for defining and categorising NEBs according to their level of quantifiability and when in time they are expected to arise, is presented. Applying this framework can help firms to decide which NEBs to include in the decision-making process and at which stage. Including NEBs in the decision-making process may be one way to meet and hopefully overcome known barriers for energy-efficiency investments and thus enhance the probability rate of adoption for this investment category.

Further research is needed in order to determine whether the adoption rate of energy-efficiency investments actually is improved when NEBs are included in the decision-making and evaluation processes. Therefore, the framework presented here needs to be tested empirically. Also, concepts from behavioural economics should be acknowledged when studying the investment behaviour and the decision-making process in order to take the analysis further. An additional need for research is apparent from the research field of IT investments, namely if the expected NEBs are actually realised after implementation.

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