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Including non-energy benefits in investment calculations in industry – empirical findings from Sweden

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Abstract

The threat of increased global warming accentuates the need for reducing anthropogenic emissions of GHG (Green House Gases). Improved energy efficiency in industry represents one of the most important means of reducing this threat. Furthermore, improved energy efficiency and cutting energy costs may be key factors for individual enterprises' long term survival and success because of increased environmental legislation and rise of energy prices. Despite the fact that extensive potentials for improved energy efficiency exists in industry, a large part remains unexploited explained by the existence of various barriers to energy efficiency. The research on barriers is well-developed and regards the non-investment of cost-effective technical measures that improve energy efficiency. In these studies, the actual investment decision is the analysing variable. However, if one extends the system boundary, there are indications that not only the actual reduction of energy cost but also other potential benefits should be taken into account in energy-efficiency investments. Including such factors, named non-energy benefits (NEBs), in the investment calculation mean the investment may have a considerably shorter pay-back period. The aim of this paper is to study if NEBs are considered and measured in energy-efficiency related investments in Swedish industry, and to study factors inhibiting the inclusion of NEBs in investment calculations. Results of this study indicate that NEBs seems to exist in the Swedish industrial companies participating in this study, but only few of the mentioned NEBs were included in investment calculations, explained by among other factors, the hidden cost of monetizing the NEB.

Introduction

The threat of increased global warming accentuates the need for reducing anthropogenic emissions of GHG (Green House Gases). Improved energy efficiency in industry represents one of the most important means of reducing this threat. Furthermore, improved energy efficiency and cutting energy costs may be key factors for individual enterprises' long term survival and success because of increased environmental legislation and rise of energy prices. Energy efficiency is on a national level measured as energy intensity, i.e. energy use in relation to GDP. According to the European energy efficiency action plan (EC, 2006), this means that improved energy efficiency is not merely an effect of increased energy costs or new legislative policy but also due to structural effects.

As regards technology for the individual company, improved energy efficiency is related to both production processes and support processes. In order to reduce industrial energy costs, there are two primary approaches. One is to focus on reducing the cost of the supply of energy, either through negotiation with the energy supplier, or by investing in new energy supply, or delivery of excess heat. The other is by reducing the cost of energy end-use which might be taken in four principally different ways, new technology, conversion of energy carriers, more efficient operation of current technology, and load management.

There is a large potential for improved energy efficiency in industry. Despite the fact that extensive potentials for improved energy efficiency exists in industry, a large part remains unexploited explained by the existence of various barriers to energy

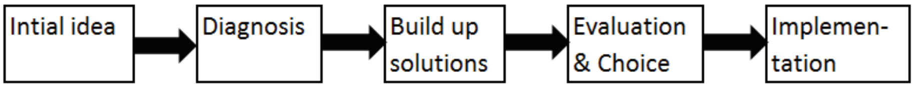

Figure 1. The investment decision-making model by Cooremans (2012).

efficiency. There are several research studies which have empirically examined barriers to improved energy efficiency, e.g. Gruber and Brand (1991), Sorrell et al. (2004), Schleich and Gruber (2008) and Trianni et al. (2012), stating that barriers differ between sectors and regions, and also depend on size of the company etc. Major barriers found in Swedish studies include imperfect information, lack of access to capital, and hidden costs (Rohdin and Thollander, 2006, Rohdin et al., 2007, Thollander and Ottosson, 2008). Research on barriers may be seen as well-developed and regards the non-investment of cost-effective technical measures that improve energy efficiency. However, if one extends the system boundary, research has shown, e.g. Pye and McKane (2000), that there are other benefits, apart from actual energy cost reductions that could be regarded in energy-efficiency investments. Examples of benefits are improved product quality, reduced maintenance, increased worker safety and reduced waste (e.g. Hall and Roth 2003, Lung et al. 2003). Including such factors, named non-energy benefits (NEBs) in the investment calculation mean the investment may have a considerably shorter pay-back period as well as be treated with an increased strategic perspective by the firm. Few studies however exist of the role of NEBs in industrial companies and more research is needed. The importance of studying these factors and the inclusion of these in industrial decision-making regarding energy-efficiency improvement measures cannot be understated as the inclusion of these factors may also lead to the reduction of barriers to energy efficiency.

The aim of this paper is to study if NEBs are considered in energy efficiency related investments in Swedish industry, and if not so, study barriers inhibiting the inclusion of NEBs. The aim has been split into three research questions, presented below:

- Do NEBs exist in Swedish industry?
- And if so,
- How are NEBs included in companies' investments in energy-efficiency improvement measures?
- What are the barriers inhibiting the inclusion of NEBs in investment calculations in energy-efficient technologies?

This paper initially presents the method applied in the study, continuing with a literature review of NEBs followed by the result section. Finally, major conclusions are discussed.

Method

The methodological approach for empirically studying NEBs is similar to research about barriers to improved energy efficiency, as with a wider system boundary, the non-inclusion of NEBs constitutes a barrier for improved energy efficiency, but the inclusion of NEBs may help overcome some barriers. Reviewing the research field of studies on barriers to energy efficiency reveals that there are various means of categorizing barriers but that the means of empirically studying barriers are similar, independent of the taxonomy of barriers[1]. According to Weber (1997) barrier models have three features: the objective obstacle, the subject hindered, and the action hindered (Weber, 1997). The methodological approach in barrier studies is expressed as: What is an obstacle to whom reaching what in energy conservation? (Weber 1997). Similarly, studies on NEBs may be expressed as: what is a NEB to whom reaching what? The three factors may, inspired by Weber (1997), be expressed as:

- What is a NEB: improved working conditions, increased productivity, reduced maintenance, reduced labour, reduced emissions, reduced legislative burden, etc.
- … is a NEB to whom: the company, the employees, the production department, the controller, the consumer, the maintenance department, the board of directors, etc.
- … inclusion of NEBs reaching what: improved cost-effectiveness of energy-efficiency investments and in a longer time frame increased strategic view of energy-related investments.

As stated by Cooremans (2012), investments may be seen as a process beginning with an initial idea, diagnosis, the build up of solutions, evaluation and choice, and ending up with an implementation (or not). Figure 1 presents the investment decision-making model by Cooremans (2012).

If relating the model of Cooremans (2012) to barriers, the two latter steps of the investment decision-making model (evaluation & choice and implementation) are the primary part for studies on barriers and this is also the case for studies of NEBs.

In studies of NEBs, the research design should consist of a purpose of the study, a number of research questions, a method for collecting the data, and finally an analysis of the collected data. For such research design two major approaches may be taken, that of case study research (e.g. Yin, 2003) and that of a survey (e.g. Bryman, 2012). The major difference of these two approaches are the analysis of data, and in most cases the collection of data, where surveys often use a questionnaire, case studies are often conducted using interviews (Yin, 2003). For such a complex subject as NEBs, it is argued that a case study using in-depth interviews and a questionnaire might both be useful approaches. The difference between the two primary approaches are that while case study research is often extremely time-consuming, and thus cannot in most cases cover a large number of cases (companies), a questionnaire can cover a larger number of companies. In this first explorative study of NEBs in the Swedish industry, inspired by Yin (2003), a case study was chosen as the primary approach using in-depth interviews.

1. For various taxonomies of barriers, please see e.g. Sorrell et al. (2004), Trianni et al. (2012), and Thollander and Palm (2013).

An interview guide was developed, based on the available scientific literature on the subject, and included open-ended questions. Inspired by Yin (2003) the interview guide was reviewed by senior colleagues as well as staff from the Swedish Energy Agency, before being used.

Due to the semi-structured character of the interviews, there were also opportunities for follow-up questions. The eight companies studied (anonymized in this paper) were selected based on Swedish industry's energy use and aimed to include companies from some of the major energy-using sectors, as these sectors contribute for more than 70 % of Swedish industry's annual energy use. Hence, the companies selected are major energy users and are thus more eager to implement energy-efficiency investments or measures. This study was carried out at enterprise level and did not aim to explicitly compare different industrial sectors. The annual use of energy for the companies ranged from about 40 GWh/year to 2.8 TWh/year where the majority may be categorized as very energy-intensive according to the European definition[2] (EC, 2003). The interviewed respondents were people responsible for energy issues at the company, such as the energy manager or similar roles. The reason for this is that the energy manager is likely to have extensive experience in energy efficiency investments or measures implemented at the company, both regarding the production processes and the support processes. From one company there were two persons interviewed. The interviews were carried out based on the interview guide described above and each interview lasted for about one hour. Moreover, the interviews were conducted via telephone and all interviews were recorded and partly transcribed. All of the interviews were conducted in Swedish, hence, all quotations have been translated into English. In this paper the term non-energy benefits (NEBs) is used to describe benefits related to energy-efficiency improvements in industrial companies.

Initially, questions were asked about the respondents' perception of the existence of NEBs followed by questions on the inclusion (or not) of NEBs in their investments. Also, questions were asked about factors inhibiting the inclusion of NEBs. In the analysis of the latter, the six barriers outlined by, e.g. Sorrell et al (2004), are used to analyse the responses. It should be noted that the barriers are ambiguous. Thus, one empirical finding may be classified into several different theoretical barriers.

Non-energy benefits and other related concepts

In addition to direct energy savings and energy cost savings, energy-efficient investments or measures may deliver an array of different benefits often described as NEBs. Reviewing the literature, it is apparent that the concept of these benefits is not clearly defined. Other synonymous concepts described in the literature are multiple benefits (IEA, 2012), productivity benefits (e.g. Worrell, et al. 2003), ancillary benefits (e.g. Mundaca, 2008, Lung et al. 2005) and co-benefits (e.g. Jakob, 2006, Ürge-Vorsatz et al. 2009). According to IEA (2012), the term multiple benefits includes co-benefits, NEBs and ancillary benefits. Hence, multiple benefits are the most inclusive concept to use when investigating the outcomes (aside from energy savings) of energy-efficiency measures. In the report from IEA (2012), the benefits are categorized into four levels depending on at which level the benefit may arise; the individual level, the sectoral level, the national level and the international level. The individual levels include benefits (e.g. health and well-being impacts, increased disposable income and energy affordability and access) that appear to individuals, households and enterprises and the sectoral level comprises benefits (e.g. industrial productivity and competitiveness and increased asset values) to economic sectors; the industrial, transport, residential and commercial sectors. At the national level, the following categories of benefits were mentioned; job creation, reduced energy-related public expenditures, energy security and macroeconomic effects. Reduced GHG emissions are one of the benefits that may arise at the international level.

In spite of the fact that the term multiple benefits cover the other concepts, the term NEBs appears to be the most commonly used in literature regarding industry. However, NEBs are also used synonymously together with productivity benefits (Laitner et al. 2001, Worrell et al. 2003). NEBs stemming from energy-efficiency improvements are described in several areas, e.g. the industrial sector (Lilly and Pearson, 1999, Pye and McKane, 2000, Finman and Laitner, 2001, Laitner et al. 2001, Worrell et al. 2003, Hall and Roth, 2003) and the residential and building sectors (Mills and Rosenfeld, 1996, Skumatz and Dickerson, 1997 and Schweitzer and Tonn, 2003). Many of the NEBs related to the industry could be grouped into benefits related to production, operation and maintenance, working environment, waste or emissions (e.g. Finman and Laitner, 2001, Laitner et al. 2001, Worrell et al. 2003). Mills and Rosenfeld (1996) describe the benefits in the residential and building sectors from a user perspective and seven categories are mentioned; improved indoor environment, comfort and safety, reduced noise, labour and time savings, improved process control, increased amenity or convenience, water savings and waste minimization and direct and indirect economic benefits from down-sizing equipment. Skumatz and Dickerson (1997) and Schweitzer and Tonn (2003) classify the benefits more broadly, adding two additional levels, the utility/ratepayer level (e.g. payment-related benefits) and the societal level (e.g. environmental, economic and social benefits), In the building and residential area, benefits are also named co-benefits or ancillary benefits (Jakob, 2006, Mundaca 2008, Ürge-Vorsatz, 2009) and these two concepts are often used equivalent (Jakob, 2006, Mundaca 2008). The term ancillary benefits is also mentioned in the industrial sector where the benefits are described as "ancillary savings and production benefits" (Lung et al. 2005). Thus, as mentioned above, there is no clear definition in which context the terms are used and moreover, the concepts can be defined in more than one way.

INDUSTRIAL NON-ENERGY BENEFITS

Reviewing the literature on industrial NEBs reveals a number of benefits (Lilly and Pearson, 1999, Pye and McKane, 2000, Finman and Laitner, 2001, Laitner et al. 2001, Hall and Roth, 2003, Worrell et al. 2003, Lung et al 2005). The most common-

2. According to the European definition (EC, 2003), an 'energy intensive business' shall mean a business entity where either the purchases of energy products and electricity amount to at least 3,0 % of the production value or the national energy tax payable amounts to at least 0,5 % of the added value.

ly mentioned benefits are listed in table 1 (categorized similar to Finman and Laitner, 2001, Laitner et al. 2001 and Worrell et al. 2003). The benefits in the table above were selected by means of a consensus process based on the benefits reported (Lilly and Pearson, 1999, Pye and McKane, 2000, Finman and Laitner, 2001, Laitner et al. 2001, Hall and Roth, 2003, Worrell et al. 2003, Lung et al 2005). Some of the benefits were renamed in order to report them in the same manner (e.g. reduced maintenance and increased production). Furthermore, if benefits were described as cost savings or as a reduced cost, the "cost-element" was removed because the question could be monetized is a separate issue that will be discussed in next section**.**

QUANTIFIABLE/MONETIZABLE INDUSTRIAL NON-ENERGY BENEFITS

To be able to see the full potential of energy-efficiency investments, NEBs related to the investment have to be considered and assigned monetary values (if possible) (Finman and Laitner, 2001). The authors have studied 77 case studies with documented NEBs. In 52 of the cases the benefits could be quantified and monetized resulting in halving the payback time for the project (from 4.2 year based only on energy savings to 1.9 including NEBs). Moreover, in more than half of the 52 cases the NEBs were equal to or greater than the energy savings. In another paper (Laitner et al. 2001) several examples of NEBs are categorized together with comments about the opportunity to quantify them. According to the authors, benefits related to production improvements, operating and maintenance, waste reduction and emissions reduction should be quantifiable. This is acknowledged by Lilly and Pearson (1999) showing that NEBs related to operating and maintenance and reduced emissions could be quantifiable and monetized through metering before and after implementing the measure. For other benefits recognized it was not possible to assign them a monetary value, consequently they were omitted from calculations. For example, Laitner et al. (2001) states that NEBs connected to the working environment could be difficult to quantify and monetize. Regarding monetized NEBs, Laitner et al. (2001) propose a method for assessing NEBs related to energy-efficiency investments or measures. Observed benefits are quantified and monetized and thereafter incorporated into calculations of the cost of conserved energy (CCE) to construct conservation supply curves (CSC). From the CSCs, the potential for energy-efficiency improvement is given. The method was tested using data from measures performed in the U.S. iron and steel industry and the authors showed that the inclusion of NEBs in cost calculation doubled the savings. However, there are important issues to consider when using the method according to Laitner et al. (2001). First, all NEBs cannot be monetized and consequently they will not be considered in the method. Moreover, experienced benefits depend on the type of energy efficiency measure and also on site-specific factors at the company. Finally, there are also negative impacts related to energy-efficiency investments or measures and these should be considered as well as the NEBs.

The same study including the method described above has also been presented by Worrell et al. (2003). Moreover, the same methodology has been used by Lung et al. (2005) when studying results from 81 energy-efficiency projects implemented in U.S. industry. They found that in 54 of 81 projects, the NEBs could be quantified. Most of the quantified benefits were related to operations and maintenance and production. Improved working conditions (improved worker safety, reduced noise, improved air quality) and lower emissions were

Table 1. Categories of benefits related to energy-efficient investments or measures in industry (based on Lilly and Pearson, 1999, Pye and McKane, 2000, Finman and Laitner, 2001, Laitner et al. 2001, Hall and Roth, 2003, Worrell et al. 2003 and Lung et al. 2005).

Category	Examples
Production	Increased production Improved product quality Increased production reliability Increased equipment life Shorter process cycle time Reduced raw materials use
Operation and maintenance	Reduced maintenance Lower cooling requirements Reduced labor requirements Reduced need for engineering controls
Working environment	Increased worker safety Reduced noise Improved air quality Improved temperature control Improved lighting
Waste	Reduced waste water Reduced hazardous waste Use of waste fuel, heat, gas Materials reduction
Emissions	Reduced emissions (CO,CO_2, NO_X, SO_X) Reduced dust emissions
Other	Improved public/corporate image Improved worker morale Increased sales levels

not quantified. Hence, these benefits were not included in the method. When quantified benefits were included in the method, the authors found, for most of the projects, that it was more cost-effective to implement the energy efficiency measure than to buy more energy. Considering total costs for all projects, including savings from NEBs, reduced payback time from 1.43 year to 0.99 year, which is comparable to the results of Finman and Laitner (2001).

Hall and Roth (2003) have studied results from 74 case studies and showed that some of the respondents participating were able to quantify a large portion of the ten NEBs proposed. The following benefits were considered; sales levels, productivity, non-energy operating costs, equipment life, maintenance costs, waste generation, personnel needs, injuries or illnesses, defect or error rates and employee morale or satisfaction and measures perceived by the participants included e.g. lighting systems, HVAC, compressed air systems, washers, motors, pumps, variable speed drives, boilers, refrigeration, building envelope insulation and sealing and water heating systems. The participants estimated that 3.27 NEBs (of the ten given) could on average be quantified and monetized for every technology measure installed especially for maintenance and waste benefits. Four of the participants experienced change in number of injuries and/or illnesses, but none of them could report a monetized value for the benefit. For the other seven categories of benefits, several participants experienced a change due to energy-efficiency measures but only between two and nine of the participants experienced that there was a change that could be monetized. Another interesting result is that the annual monetized NEBs were about 2.5 times the energy savings (Hall and Roth, 2003).

To summarize the findings above, NEBs related to production, operating and maintenance, waste and emissions seem to be the most commonly monetized (Lilly and Pearson, 1999, Finman and Laitner, 2001, Laitner et al., 2001, Hall and Roth, 2003, Lung et al., 2005). However, NEBs related to emissions were also found to not be monetized (Lung et al., 2005). According to Hall and Roth (2003), it was more difficult to report a value for NEBs related to sales levels, equipment, personnel needs, defects and error rates and employee morale and satisfaction, hence, these benefits were monetized to a lower extent. NEBs related to working environment and injuries and illnesses were not monetized (Laitner et al. 2001, Hall and Roth, 2003).

Given the review above, it seems clear that omitting NEBs from evaluations regarding investments or measures in new energy-efficient technology may result in an underestimation of the potential for the investment or measure. Moreover, this finding stresses the importance of monetizing the NEBs in order to be incorporated in the investment calculation. As stated by Pye and McKane (2000), including monetized NEBs into energy efficiency projects will enhance the financial aspect of investments in energy-efficient technology.

Results

DO NEBS EXIST IN SWEDISH INDUSTRY?

When the respondents were asked if they had noticed any benefits related to energy-efficiency investments or energy-efficiency measures, all of the companies mentioned a few to several NEBs. The most commonly cited NEBs were reduced maintenance, use of waste heat, fuel and gas, improved air quality, reduced emissions and improved public/corporate image. Other NEBs noted by the companies were increased equipment life, lower cooling requirements, improved worker safety, reduced noise, improved temperature control, improved lighting and reduced waste water. The NEBs mentioned by the respondents correspond to the industrial NEBs described in the existing literature (Lilly and Pearson, 1999, Pye and McKane, 2000, Finman and Laitner, 2001, Laitner et al. 2001, Hall and Roth, 2003, Worrell et al. 2003, Lung et al 2005). An interesting benefit mentioned by one company is reduced risk related to oil price fluctuations and risk related to currency fluctuations (which is not seen in the existing literature) when investing in a conversion to another new energy carrier (from buying oil externally to use of internal waste fuel). Moreover, the same company mentioned that previously realized energy-efficiency investments often triggered new energy-efficiency investments to be initiated. This finding is in line with Stern and Aronsson (1984) who stated that individuals may be slow to adopt new energy-efficient technologies, but once they do, they often continue in that path.

According to the respondents, reduced maintenance is often mentioned as a benefit from investments and measures in new energy-efficient technologies and moreover, reduced maintenance was also seen for implemented measures related to pumps (e.g. variable speed drives), lighting and ventilation. Furthermore, some of the respondents mentioned that if pumps operate in an energy-efficient mode, it will also affect the equipment positively in terms of increased equipment life-time. According to the respondents, energy-efficient measures which are related to lighting and ventilation measures, improved the work environment by means of improved air quality, improved temperature control, improved worker safety, reduced noise and improved lighting. The use of waste (bio) fuel in industrial heating processes, instead of using oil, also reduced the emissions e.g. CO_2-emissions at some of the interviewed companies. Some of the respondents have also noted NEBs related to production, e.g. improved product quality and increased production reliability, due to implementation of investments and measures in energy-efficient technologies. Several of the companies also mentioned that energy-efficient investments or measures in general, have improved their public and corporate image.

The number of companies studied is limited, yet it is important to note that most companies interviewed have experienced several NEBs and also, the answers covered NEBs from several categories of benefits (according to the categories presented in Table 1). Perhaps this may be explained by the fact that these companies are large energy-users, and moreover, the majority being energy-intensive. Large energy users have probably implemented several energy-efficiency investments and measures increasing the potential for NEBs to be generated. However, some of the respondents stress that investments in energy-efficient technologies are rarely implemented solely with the motive of improving energy efficiency. For instance, the motive of many investments is to improve productivity and this is also true for energy-efficient investments. Hence, in that case improved productivity may not be defined or treated as a benefit.

To summarize the results, the most common categories of NEBs mentioned by the respondents were improved working environment, operation and maintenance and waste. Moreover, according to the answers given by the respondents, NEBs seems to exist among the Swedish industrial companies participating in this case study. In the following section, results are presented on how these NEBs are incorporated into investment routines at the studied companies.

HOW ARE NEBS INCLUDED IN COMPANIES' INVESTMENTS IN ENERGY-EFFICIENCY IMPROVEMENT MEASURES?

The findings from the interviews showed that only few NEBs were included in companies' investment calculations regarding energy-efficiency improvement measures. This is illustrated by the following citation from one of the interviewees:

> In economic investment calculations, energy, heat and production are considered. The other is described beside the economic calculations.

The most common NEBs to include in investment calculations among these companies were NEBs relating to operation and maintenance. One probable explanation could be that there exists information about how to measure and quantify operation and maintenance costs. Hence, one factor affecting the inclusion of NEBs in investments calculations seems to depend on the ability to quantify and monetize the benefits. The following was stated by one of the respondents:

> When NEBs are included in investment calculations, they have to be monetized. The investment, the energy use and maintenance are hence included (in the investment calculation).

According to some of the respondents, other NEBs were sometimes included in the investment calculation but to a much lower extent, for example improved productivity, improved production reliability, use of waste heat, fuel or gas and reduced waste. As for reduced operation and maintenance, when included in investment calculations, these NEBs were quantified and monetized. Even if not included in investment calculations, the non-monetized NEBs were nonetheless often mentioned in the total investment evaluation/assessment as an (important) remark, especially NEBs related to work environment, e.g. improved worker safety, reduced noise and improved air quality. This is acknowledged by one of the respondents saying:

> Yes, all factors that speak favorably for an investment are good. Some of them are of course easier than others to value in money. Anyway, all benefits are mentioned when you want to make an investment.

The results described above are in line with findings of Lilly and Pearson (1999), Finman and Laitner, (2001), Laitner et al. (2001), Hall and Roth (2003), Worrell et al. (2003) and Lung et al. (2005), stating that NEBs have to be quantified and monetized to be included in investment calculations. In summary, previous research, as well as findings from this study, point to the fact that NEBS should be further emphasized in future industrial energy-efficiency decision-making.

WHAT ARE THE BARRIERS INHIBITING THE INCLUSION OF NEBS IN INVESTMENT CALCULATIONS IN ENERGY-EFFICIENT TECHNOLOGIES?

Risk

Risks of including NEBs could for example be the risk of low reliability of data on the monetary benefit of a NEB. Even for reduced maintenance costs, which are relatively "easy" to monetize, it may after all prove to be more difficult to monetize them due to difficulties of valuing the reduced time for maintenance personnel. This may create risk of an investment which includes this NEB and consequently, it turns out to show a higher cost-effectiveness than the investment in reality has (or the investment will not be considered for implementation at all). This implies risk of a too high present value or too short pay-back time in investment calculations. There is also a risk that the calculation is perceived as not credible if it is based on assumptions, which is stated by one of the companies:

> The calculation you do should be understandable to management, stick to the economic language. The calculation has to be credible, for example, how do you present a credible figure for reduction of noise? How do you quantify increased comfort, reduced ventilation flows?

All other answers given by the interviewed companies indicated that risk is not seen as a main barrier for inclusion of NEBs in investment calculations.

Split incentives

Split incentives occur when one person has relevant information about costs and possible NEBs, but finds it difficult to convince other persons to consider both the costs and the benefits. NEBs may then be disregarded unless they have been assigned monetary values, which are described by the following answer from one of the respondents:

> Cannot be valued in money. We have tried to include these as arguments in the investment evaluation, but our management did not agree.

All other answers given by the interviewed companies indicated that split incentives are not seen as a main barrier for inclusion of NEBs in investment calculations.

Access to capital

Lack of access to capital was not outlined by any of the respondents as a major barrier to the inclusion of NEBs.

Imperfect information

The barrier of imperfect information could include, for example, lack of access to data on the monetary values of NEBs and the lack of metering to quantify the NEB. Results indicated that imperfect information is one of the main barriers inhibiting the inclusion of NEBs in investment calculations. The respondents acknowledged this barrier and stated that for example lack of data is a problem:

> Difficult to monetize a reduction of the noise level.

This outlines the importance of the creation of indicators, a guide, or a standard on how to calculate the benefits and include a monetary value of the benefit. Related to calculation another respondent replied the following:

> For example, decreased variability, improved quality, we have not yet managed to include in the calculation formula. These are not included because you do not have knowledge of cost reduction or how much the added value really is.

The overall view of the companies were that NEBs related to work environment were difficult to monetize due to lack of information of how to measure these issues and also the lack of information of how to assign these issues a monetary value, which is concluded in following citations:

> Soft issues, e.g. work environment, improved lighting are difficult to include in the investment calculation. These can be used as arguments, but it is difficult to assign them monetary values.

Another way might be to relate NEBs which are difficult to measure (e.g. work environment) to other parameters or benefits that could be easier to measure (e.g. productivity). However, answers given by the respondents indicated that it is still difficult to evaluate them monetarily. This is illustrated by one of the respondents talking about work environment as a NEB:

> There are studies that show how productivity changes at different indoor temperatures. A comfortable temperature makes the staff feel better, productivity increases and the error rates decrease and this could also result in increased quality. But it is not easy to assign monetary values.

The barrier imperfect information could also include for example lack of access to data on the NEBs due to lack of metering. This is illustrated by following answers:

> … difficult to just say that this investment provides 10 % less waste …

The company seems to experience a reduction in waste after implementing an energy-efficiency improvement, but it is not possible to evaluate the magnitude of the reduction due to lack of metering.

> Reduced number of production shutdowns should be monetized and included in the calculation, but it is difficult to prove …

Lack of metering makes it difficult to refer the decrease in production stops to implemented energy-efficiency improvements.

It should be noted that some of the factors inhibiting the inclusion of NEBs stated above, may not solely be related to imperfect information, but may very well fit under some other categories, especially the barriers hidden costs and bounded rationality. The lack of data on how to measure and monetize NEBs can be reduced by collecting and analyzing information, but often this is associated with hidden costs. Due to imperfect information and hidden costs, new ways of collecting and measuring data are not realized. Hence, all citations given in this section could also be categorised as hidden costs and bounded rationality (see sections below).

Hidden costs

As described above, lack of data and lack of information about how to measure and monetize NEBs is an often stated problem relating to the inclusion of NEBs in the investment calculation. To collect information about how to monetize the NEB could be associated with higher costs compared to NEB savings which is acknowledged by one of the companies participating in the study:

> Should be able to do that, (I) believe that it is not that important to us, (maybe) then parts of the processes, but then it's still not resulting in large amounts (of cost reductions).

Searching for information is often associated with high costs, e.g. costs related to collecting and analyzing information. Hence, all citations categorised as imperfect information could also be placed in this section making hidden costs one of the main barriers to include NEBs in the investment calculation.

Bounded rationality

Organizations and individuals do not act based on complete information, instead they act more by "rule of thumb" meaning for example that few solutions are considered and previous solutions to similar problems are often chosen. The results from the interviews indicated that bounded rationality is one barrier to include NEBs in investment calculations and this is illustrated below:

> We ourselves are the main obstacle, we are not good enough at presenting all the benefits of new technologies.

Furthermore, due to close connections to the barriers imperfect information and hidden costs, bounded rationality is found to be one of the main barriers for inclusion of NEBs in investment calculations. Hence, the results indicate that the main barriers for inclusion of NEBs in investment calculations are imperfect information, hidden costs and bounded rationality.

Concluding discussion

The results from the interviews revealed that NEBs do exist in the studied companies. However, results from this study also showed that the companies did not monetize NEBs in a structured way. In fact, respondents stated that only a few of the NEBs they mentioned are actually monetized.

According to the companies interviewed, the major barriers to include NEBs in investment calculations are imperfect information, hidden costs and bounded rationality. The major underlying factors are lack of information and metering. Searching for information is very time-consuming and time is strongly related to cost. Hence, the barrier imperfect information is strongly related to the hidden cost barrier. A large magnitude of hidden costs means one saves less than one gains. If so, one follows the same patterns as before and does not consider improved ways of conducting investment assessments. This may be categorized as bounded rationality.

In conclusion, NEBs exist, but could be difficult to monetize. One of the major barriers for the monetizing in the studied companies was imperfect information. Improved information on the positive effects of including NEBs may overcome information imperfections and may lead to cost-effective energy-efficiency measures being undertaken, that otherwise would not have been implemented. The same findings hold for hidden cost, and bounded rationality, while risk, split incentives and lack of access to capital was not found to be major barriers to the inclusion of NEBs in this study.

Findings from this paper strongly indicate a need for a structured model or standard, to be developed on how to monetize NEBs. The development of such a model would improve the use of NEBs in common investment decisions in industrial companies. Improved knowledge of NEBs and the magnitude of their monetized value could in the long-run even make energy an issue of increased strategic importance for a company.

In Figure 2, the importance of including NEBs, from an improved energy-efficiency point of view, are theoretically described including the difference between operational and strategic issues in a company. One major advantage of including NEBs, as shown in Figure 2, is that the potential for improved energy efficiency is increased as compared to only considering the reduction in energy cost. This may in turn lead to that the issue becomes of increased strategic importance in companies.

Another finding in the study was that most investments were not primarily undertaken with the motive of improving energy efficiency, but rather an outcome of striving for improved productivity etc. These findings point out that improved energy efficiency may not be a major part of the overall practices at the operational level of the studied companies. Whether this is an outcome of lack of strategic emphasis on energy efficiency related issue among the company board of directors, or if it is an outcome of too few resources allocated to improving energy efficiency on an operational level, is an area for future research to study.

Cooremans (2012) outlined that lack of a strategic approach is one of the main factors inhibiting energy-efficiency investments in general. Notably, the strategic dimension in a company is the means for how companies should focus their activities in a time-span of several years, while investments in energy-efficiency measures, are often taken on an operative level. However, as shown in Figure 2, inclusion of NEBs, even though of importance, may not fully make energy efficiency a strategic issue in a company. That decision also involves a more long-term strategic approach at top management decision-level.

Relating Cooremans (2012) model to NEBs, as shown in Figure 3, the inclusion of benefits in the model emphasizes gains for the fourth and fifth part of the investment process. However, as the decision-model shows, building up knowledge on

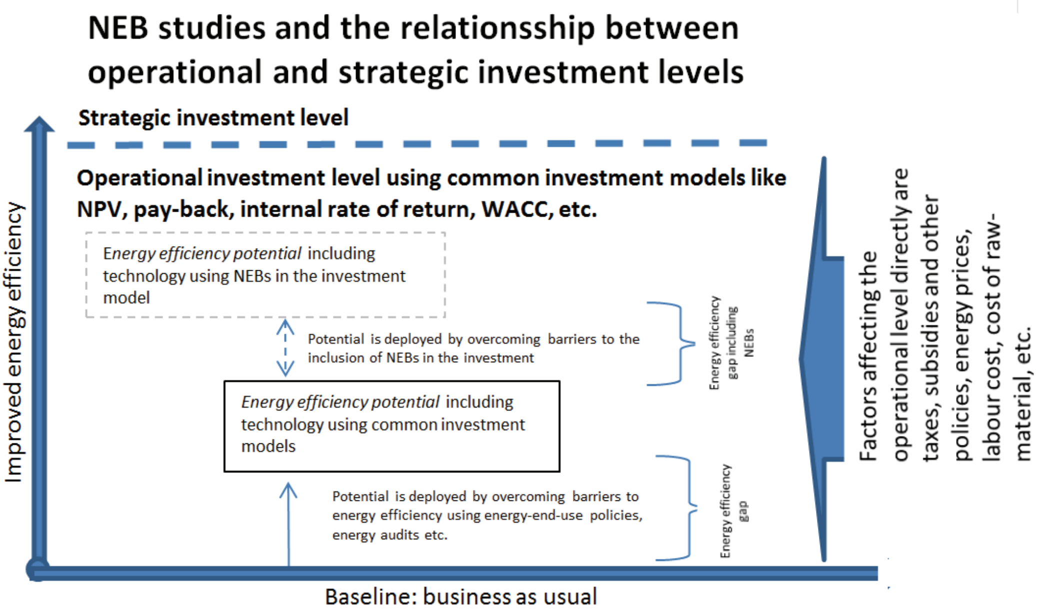

Figure 2. Inclusion of NEBs and its effect on the energy-efficiency potential, and its relationship to the operational and strategic dimensions of investments in an industrial company.

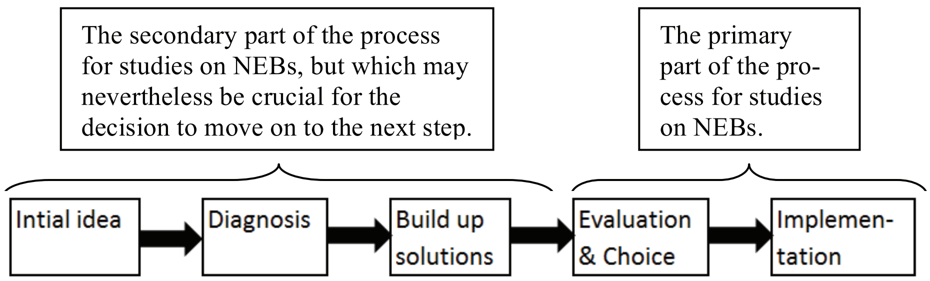

Figure 3. The inclusion of NEBs in relation to the investment decision-making model by Cooremans (2012).

NEBs may have large contributions in the future for measures that may not even "survive" the first step. There is thus a primary and a secondary gain of studies of NEBs.

We emphasize further research to be conducted on monetization of NEBs of various technologies and processes, and in various sectors, preferably in an international environment, i.e. not only national studies, in order to make a standardized model as general, and applicable, as possible.

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