New robes for NEB research – open and expanding data

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Keywords

non-energy benefits (NEBs), end-use efficiency, database, web tools, accessibility, econometrics, energy efficiency investments, consumer preferences

Abstract

Conventionally, the relevance of energy efficiency improvements (EEIs) is assessed on the basis of the potential energy cost savings compared to the investments made. However, the value of the secondary effects of these EEIs is often just as high or even higher. These side effects are frequently referred to as Non Energy Benefits (NEBs) in spite the fact that some side effects are negative and not positive.

The past decade has seen a substantial increase in research and attention towards NEBs. Some energy consultants use NEBs to leverage client interest in energy efficiency, however, the value of NEBs is not systematically assessed nor the information compiled on a larger scale. This paper presents an online NEB tool with a database containing data of face-to-face interviews from more than 100 implemented EEIs, yielding nearly 300 identified NEBs and an analysis of these data. Visualisation and quantification of NEBs make it possible to include the side effects in assessments of the attractiveness of an EEI – for the mutual benefit of energy advisors and their clients – and society at large.

A unique feature of the database is that it permits interested users to search e.g. by industry, EEI type (30+), investment size, NEB type (4 categories with each up to 10 subcategories), and the entity/person that has entered the data. It is also possible to distinguish the method chosen for quantifying the NEBs and the perceived reliability of the values. This flexibility makes it possible to accommodate differences in data collection resources of those providing data for the database. The tool is dynamic as the database is designed to continuously expand through input from its users.

The tool includes case examples with more detailed narrative description of specific EEI projects and the associated NEBs. The results of the preliminary analysis find the value of EEIs to be 1.4 times higher with NEBs than when looking at the energy cost savings alone. The finding implies that investments in EEIs create greater value than what is included in the decision to invest. Such knowledge may be able to have a significant influence on the incentive to invest in EEIs. All data is openly accessible for use in future investment decisions or further NEB research.

Introduction

Rising global and national focus on climate change, energy security, and resource challenges have increased the attention to national energy policy measures. Energy efficiency (EE) has been acknowledged as one of the more cost effective approaches to alleviate these concerns and has received much political attention and incorporation in local, national and international policies (Kanellakis et al. 2013).

An apparent incentive to invest in energy efficiency improving technologies lie in the economic benefit of saving energy, a benefit that is measured by projecting the energy cost savings on the energy bill. However, a growing body of research highlights the existence of additional side effects (cost and benefits). These side effects (termed non energy benefits – NEBs[1]) occur

1. The side effects are interchangeably termed "non-energy benefits", "multiple benefits", "ancillary benefits", "non-energy impacts" and "co-benefits" (IEA 2014, ACEEE 2015). The term non-energy benefits (NEBs) is used for the remainder of this paper.

after implementation of EEIs, like energy cost savings, but are usually not included in the investment decision as their occurrence and value is indistinct and challenging to determine.

NEBs can be seen as an example of goods that are not traded in a market (non-marketed goods), as they are not priced in relation to the transaction causing them – the investment in EEIs. NEBs cover a range of economic (e.g. material consumption, production capacity, maintenance etc.) social/health (e.g. stress, safety, noise etc.) and environmental effects (e.g. CO_2 and other GHG emissions) that are allocated within markets in an indirect manner. The prioritization of investments is typically strategically linked to expected benefits (Cooremans 2012). When decision makers are unaware of all potential benefits, their motivation to invest can be skewed and otherwise effective investments may be unexploited. Economic valuation methods can be used to estimate the value of non-marketed goods when the good to be valued is well defined and/or adequate data is obtainable – rare characteristics when it comes to NEBs.

Various attempts have been made to identify and monetize NEBs. In a survey of 74 EEIs, Hall and Roth (2003) found the value of NEBs to be 2.5 times the projected energy cost savings. Worrell et al (2001 and 2003) surveyed 77 EEIs and found that monetization of NEBs more than halved the payback period of EEI investments. In spite of these indications of the significant value of NEBs, no universally recognized quantification method exists to date (ACEEE 2015).

This paper presents a new type of NEB analyses through an online NEB identification, quantification, and visualization tool along with preliminary results of the tools freely accessible database, currently consisting of data from more than 100 implemented EEIs.

Searching for a common path

Research on NEBs started in the late 1990s (ACEEE 2015) and can roughly be divided into two strands: i) identifying and describing the types and importance of NEBs and ii) valuing NEBs. The first is fairly well covered and has revealed a large quantity of possible NEBs, whereas there is no universally recognized method and limited sources available on methods for valuing/quantifying NEBs (IEA/OECD 2014). The methodological void can to a large extent be explained by the difficult task of framing and specifying the factors that influence the occurrence and value of NEBs.

To portray the complexity of NEB quantification, a division can be made between the scale and scope of current methodologies. The scale describes the level at which the value of NEBs is assessed, i.e. whether focus is on a state and the macroeconomic impact of a sum of EEIs on e.g. GDP and job creation (wide scale) or whether the focus is on an EEI made by an individual company and the impact on e.g. indoor climate in that company (narrow scale). Table 1 summarizes the apparent scales of common methodologies for NEB valuation.

The scope on the other hand, describes the anchoring point for the NEB valuation and identification, i.e. whether the method targets specific actors, industries, technologies, NEBs (narrow scope) or several of these simultaneously (wider scope).

The most recent NEB publication by the American Council for an Energy-Efficient Economy (ACEEE) state that "evaluators have yet to develop standard protocols for defining, measuring, recording, and evaluating energy's multiple benefits" (ACEEE 2015: iv). The same report finds that "information documenting the project-level coincidence of energy and non-

Table 1. Scale of NEB valuation methodologies.

	← NARROW SCALE – WIDE SCALE →			
	Project level	**Sector level**	**National level**	**International level**
Short description	The value of NEBs to the individual energy consumer (the energy end user).	The value of NEBs to economic sectors.	The value of NEBs to society.	The value of NEBs at an international level.
Focus	End users are: individuals/households, companies or public institutions.	Sectors include: industrial, transport, residential, commercial etc.	The national state as a whole.	Multiple states, regions or globally.
Examples of NEBs	E.g. maintenance, product quality, indoor climate, stress, sustainability, etc.	E.g. industrial productivity, competitiveness, asset values, etc.	E.g. job creation, reduced energy-related public expenditures, energy security, GDP, national competitiveness, health impacts, etc.	E.g. reduced GHG emissions, climate change, moderating energy prices, reduced pressure on natural resources.
Examples of valuation methods	Preference-based valuation, hedonic regression, computational approaches using primary, secondary and regression estimates.	Sectoral or partial models, partial equilibrium models, Input-output analysis, bottom-up engineering models, agent models.	Macro-econometric models, computed general equilibrium models (CGE).	

energy value creation is derived mostly from case studies that are prepared independently of each other and without reference to a standard methodology" (ACEEE 2015: 22).

Studies on NEB valuation at the project level have generally had a narrow scope, focusing in-depth on e.g. the causes and value of a particular NEB, NEBs experienced by a certain consumer group, certain industry or technology specific NEBs. Examples are given below.

- Valuation by actors with a certain function, e.g. energy managers from the major energy-using sectors in Sweden (Nehler et al. 2014).
- Tenant or homeowner specific NEBs (Weinszierhr et al. 2015, Kunkel and Kontonasiou 2015).
- Industry/sector specific NEBs, e.g. from manufacturing or construction industry (Nösperger et al. 2015, McClain et al. 2007).
- Technology specific NEBs, e.g. from pumps, lighting, insulation (Lung et al. 2005, Willoughby et al. 2011).
- One specific NEB, e.g. productivity (Worrell et al. 2001).

This short overview gives an indication of the complexity of NEB identification and valuation. There seems to exist a data collection dilemma between obtaining precise quantifications for NEBs and producing results that are more generally applicable. The aim is to incorporate NEBs as part of the cost and benefits evaluated when deciding whether or not to invest in EEIs. Precise and specific quantifications may be too costly and time consuming to achieve, but perhaps indicators are just as effective, e.g. whether there is an expected small or large benefit to gain from certain EEIs or whether specific NEBs are expected to arise.

A tool for project level NEBs

The Danish Technological Institute (DTI), the electricity retail and energy company AURA, and the consultancy Ea Energy Analyses have developed an online NEB tool[2] aimed at identifying, quantifying, visualizing, and documenting project level NEBs. The project objective is to increase the attractiveness of investing in EEIs by emphasizing the existence and value of NEBs. The tool is a free online platform providing information about NEBs, a suggested methodology for their identification and valuation (including an interview guide and tool instructions), a database of cases where the method has been applied, and the possibility of tailored data extraction. The tool is primarily developed for energy consultants and other advisers dealing with energy efficiency projects in industry, trade and services and has been funded by Elforsk, the R&D programme of the Danish Energy Association. The Elforsk funded project was completed in April 2016[3]. The site is currently hosted by DTI in collaboration with AURA and Ea Energy Analyses.

A WIDE SCOPE ON A NARROW SCALE

The NEB tool consists of a database with documented NEB identification and valuation from over 100 EEIs. NEB identification is made through structured face-to-face interviews after implementation of an EEI, with identical survey questions to allow for collection of quantifiable and comparable data. The survey mode is expected to establish a valuable contact between the energy consultants (agents) and their clients (respondents), which can be viewed as relationship management, giving the consultant the opportunity to maintain or establish contact with a client, while giving the client the opportunity to voice reflections, concerns and give feedback about their project.

Knowledge about the good being valued (NEBs) is generally of great importance, when choosing the relevant valuation technique (Bateman et al. 2002). The fact that the type of NEBs may differ greatly (e.g. maintenance, indoor climate, safety, CO_2 emissions) from project to project makes it challenging to customize the survey technique, design, and especially the valuation scenario. Energy consultants and/or advisors using the tool are able to differentiate their choice of valuation method (calculated, measured, or preference-based) to accommodate variations in NEB types as well as restrictions on time, resources and data availability from project to project. The tool is strictly focused on project level NEBs and gathers information on various characteristics of the individual EEI (e.g. investment size, annual energy cost saving, technology invested in, industry, and the respondent's function in the organization[4]) and includes both positive and negative NEBs.

A unique feature of the database is that it permits interested users to search e.g. by industry, EEI type (30+), investment size, NEB type (4 categories with each up to 10 subcategories, see Figure 1), and the functional role of the person in the particular organization, who has identified the NEB(s). Using the chosen search criteria, the user can extract data on the areas of interest by viewing online bar charts of NEBs' influence on the simple payback period or by downloading entire datasets to excel for further analysis. The tool is dynamic as the database is designed to continuously expand through input from its users.

The four main NEB categories shown in Figure 1 are recognizable and relatable areas of interest to most organizations[5]. The tool allows for unlimited types of NEBs in the sense that each main NEB category contains an 'others' option where unlisted NEBs can be defined. The option enables the inclusion of all NEBs experienced from an EEI, but also facilitates identification of new NEBs. Qualities that make the NEB tool stand out in the research field are summarized in Figure 2.

TIME AND COSTS ARE OF ESSENCE

It is important that the method is transparent, easily understood and applicable. If the use is too complex, expensive and time consuming, the result may be that the tool will be left unused.

The intended use by several agents (mostly energy consultants), helps decrease the cost burden on the individual. Moreover, a stated preference valuation method is included in

2. The tool can be found at neb.teknologisk.dk.

3. An analyses of the NEB tool's preference-based valuation method and database results was made in the last phase of the NEB project as the topic of a master's thesis (Christiansen 2016).

4. The term *organization* is used to refer to both public and private entities throughout this paper.

5. The selection of NEB categories is based on the projects initial literature review (Gudbjerg et al. 2014).

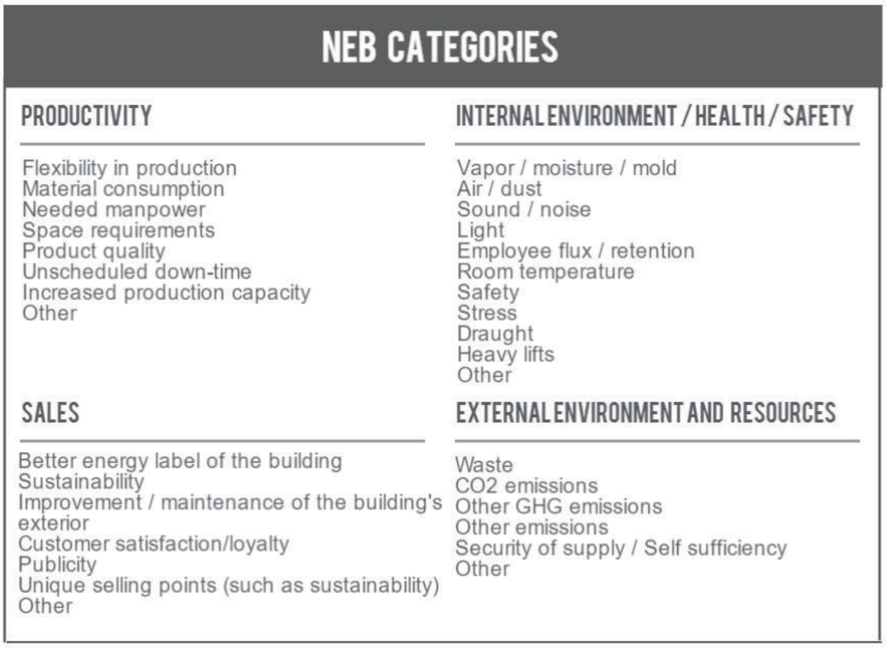

Figure 1. NEB Categories.

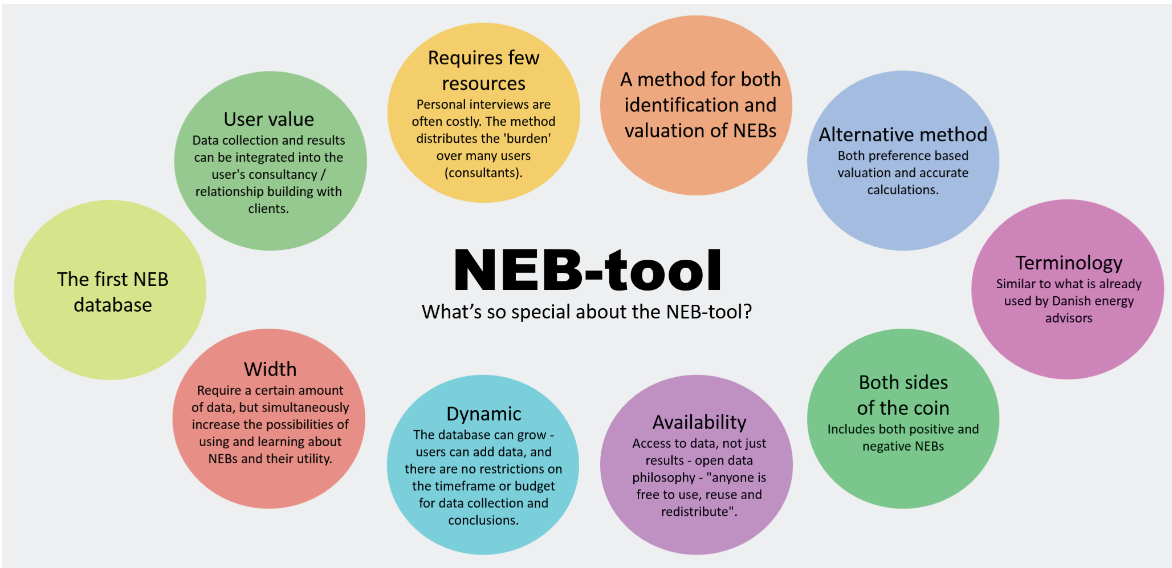

Figure 2. NEB tool quality summation.

the NEB tool to decrease the time and cost burden of data collection and allow for inclusion of NEBs that can be otherwise hard-to-measure (Skumatz 2006). These valuations are identified through individual's willingness to pay (WTP) or willingness to accept (WTA) a change in the utility they receive, i.e. NEBs. Simply put, the value of a good or service, e.g. a LED light bulb, is assessed by the maximum amount of other services/goods an individual is prepared to give up to have the light bulb (or obtain if the change is negative). Money is commonly used as a measure of value in a market economy, though the price on the market is not necessarily a measure of individual's maximum WTP, as the good or service is bought when the market price is greater than or equal to their WTP (Freeman 2003). The choice of using a relative valuation method (similar to contingent valuation) is made available in the NEB tool, to capture hard-to-measure NEBs while alleviating potential cost and time barriers of data collection.

The valuation method

The monetary value of the annual energy saving is presented to the respondents and hereafter indexed to 100+ percent. The 100+ percent is conveyed as the known benefit of the EEI and the NEBs are valued relative to this index. The valuation is done by first identifying the NEBs of the specific EEI, as experienced by the respondent on behalf of the organization. For each identified NEB, the respondent is asked to state the value of the NEB as a percentage of the annual energy savings, i.e. the relative value of the NEB. The NEBs can then be assigned a monetary value based on the relative value and the value of the annual energy saving, see Figure 3 for a simple example.

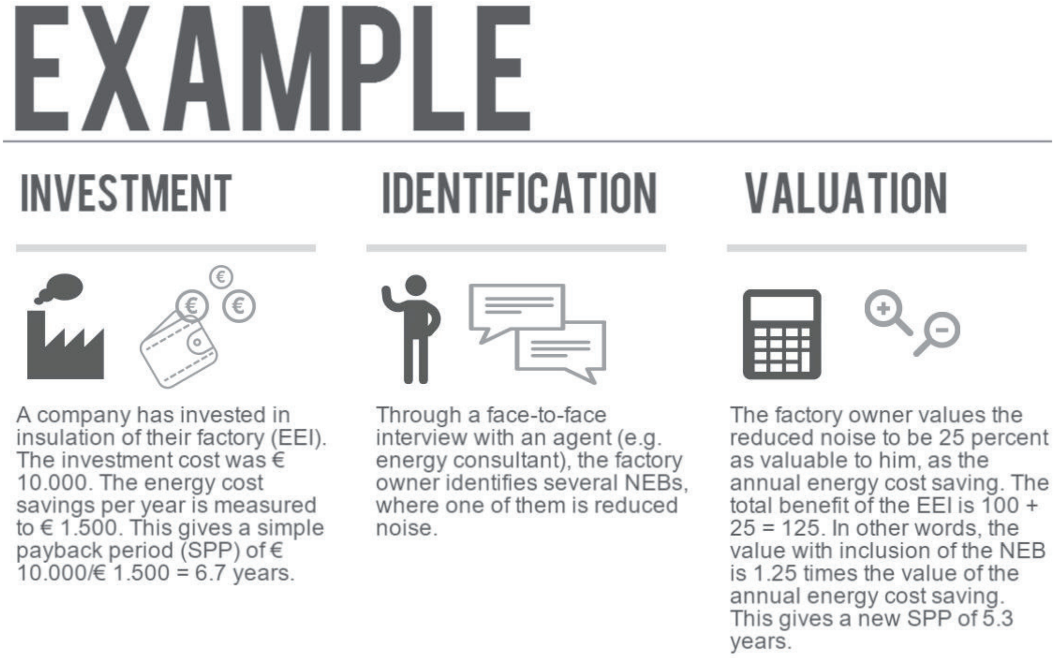

Figure 3. Example.

Let the expert make the judgement

Preference-based valuation is almost always based on individuals' own preferences for a good (Bateman et al. 2002). However, the method of surveying experts on the preferences of individuals, termed the "Delphi method", has been applied as an alternative method in preference based studies, mainly Contingent Valuation studies, when obtaining information that is otherwise hard to obtain (Navrud 2000, Strand et al. 2014).

The NEB tool method uses a method similar to the Delphi method, as respondents are individuals who are expected to have a thorough knowledge of the organization *and* the implemented EEI. The expert is used to both identify NEBs and provide estimates of the user population's WTP for the identified NEBs as opposed to surveying all individuals in the organization.

The sample population[6] consist of individuals who may be experiencing NEBs at the project level, i.e. workers and users of the public or private work place who have implemented one or more EEIs, within the given industries. Each workplace is expected to consist of many different individuals, differentiated by their socio-economic characteristics (e.g. gender, age, education, interest etc.) and features such as their relation to the EEI (e.g. their involvement in the decision to invest in the particular EEI, whether they work in close range to the area where the EEI was implemented etc.). All these individuals may experience different NEBs from the same EEI and they may also have different WTPs per NEB. Covering the preferences for NEBs of all types of individuals in each organization would be very time and cost consuming. The use of experts lowers the costs and complexity. The potential precision trade-off is not seen as a significant barrier due to the data transparency, which allows users to extract data collected with the valuation method they find most reliable (i.e. calculated, measured or preference-based).

It is not unlikely that also individuals outside the organization experience NEBs as a result of the EEI implementation. The type and value of these may differ from what is experienced inside the organization. Such potential spill over value of NEBs to the surrounding society is not included in the tool. The scale is kept narrow to capture the more directly attainable strategic benefits (or costs) of the organization.

WHO IS THE TOOL TARGETED FOR?

The NEB tool aims to directly engage different actors/stakeholders at different stages of an EEI. To simplify, the actors are divided into agents, respondents and investors.

Agents

The agent is any individual who collect and enter the data about NEBs from respondents by using the NEB tool. The tool uses a terminology similar to what is already used by Danish energy consultants, as these were expected to be the primary users, due to a likely knowledge about implemented EEIs via their advisory services and incentives to gather and use the data in their services. However, the open-source nature of the tool makes it available to other types of agents as well, e.g. electrical installers, architects, contractors, engineers, manufacturers, researchers etc.[7]

A recent study by the Danish Energy Agency (ENS 2015) on the barriers to energy efficiency in Danish businesses found, that the majority of the respondents turn to the utility compa-

6. A population is a statistical term used to describe all individuals, objects or events that a survey wishes to understand something about, i.e. individuals from *all* companies who have implemented EEIs or all individuals in society, as these may also experience NEBs. Because it is often costly and time consuming to survey all individuals in a population, the aim is to survey a representative sample of the population instead.

7. The agent must state their professional occupation when creating a new case in the NEB tool to increase transparency and avoid potential biases.

nies (i.e. energy consultants) for advice on energy efficiency, which is consistent with the expectation prior to the tools development.

Respondents

The respondent is an individual from an organization that has invested in one or more EEIs who identifies and valuates the NEBs of the specific project. It is the respondent feedback, which is entered into the NEB tool by the agent.

The respondent was initially defined as a decision maker employed at the organization with a thorough knowledge of the EEI. However, based on user tests the tool was modified to include seven functional groups to improve data credibility, as it was found that the affiliation with the EEI could greatly impact the types of NEBs identified as well as their perceived value. As the database increase it may become possible to analyze and identify trends in the variation of NEB types and value among the functional groups. Currently data availability is still too scarce.

Potential investors

The potential investors are energy end users who are considering an investment in an EEI. These stakeholders are the targets of the method's results, as it is in future cost-effectiveness tests and simple payback periods that relative NEB values are to be included.

WHEN IS THE TOOL USED?

The tool is used to value a change from status quo (before the EEI) to minimum one year after the EEI has been implemented (ex-post valuation). The NEB tool engages actors at two different stages – the involvement stage and the decision stage (see Figure 4).

The involvement stage is where the survey and valuation method is used to identify and valuate the size of NEBs. It engages both agents and respondents and takes place at least one year after the EEI is implemented. The time restriction is necessary as it enables the measurement of the annual energy savings (MWh) and gives the respondent some time to recognize NEBs, if these should arise.

Investors are engaged at the decision stage, by using the results from the NEB tool in their decision-making about whether or not to invest in EEIs. The aim is to increase the amount of investments in EEIs by decreasing the expected simple payback period, through inclusion of benefits in addition to the annual energy savings.

Sampling design and data collection insights

The target population[8] is limited to any public or private energy end user (organization) within ten sectors, who have invested in one or more energy efficiency improving technologies and who consist of individuals (workers or users of the workplace) affected by the (potentially) following NEBs. Here, an individual can be characterized as affected, if he/she is willing to accept or pay an amount larger or smaller than zero for the NEBs[9].

The sampling design is non-probabilistic as surveying and data gathering is intended to be continuous over time, performed by various agents (primarily energy consultants) surveying clients (respondents) who have invested in EEIs. This poses challenges on drawing more general conclusions about the type and value of NEBs as knowledge of data representativeness is weakened. However, the design allows for continuous expansion of the database spreading the costs of data collection across various actors. Provided that data availability on implemented EEIs greatly improve it will become possible to define and assign analytical weights to observations of lower or higher probability in order to improve the representativeness of the database results.

EXTRACT OF INSIGHTS

During the data collection process, some respondents were observed to have little knowledge about their energy savings and energy prices. Others were unaware of how to understand their energy bills in order to monitor their savings and voiced that the composition of the energy bill was not transparent[10]. Thus, the minimum requirement for data retrieval prior to the interview (e.g. investment size, annual savings and energy prices) turned out to be highly important, as many interviews would have been incomplete otherwise.

It was found to be a prerequisite for the respondent to be employed at the organization both before and after the EEI implementation to be able to identify and valuate the change/occurrence of NEBs. This means that the ability to identify and valuate NEBs may decrease with time if the amount of possible respondents is narrowed through e.g. job switching.

For some respondents it seemed difficult to distinguish between the causes of the identified NEBs. An example was a school in the Danish municipality Taarnby, where an EEI of the building envelope caused a decrease in daylight penetration. The decreased light was elicited a negative value, but after further elaboration from the respondent, it was found to be caused by a new exterior design of the building, which was constructed subsequent to the EEI. Such errors are assessed hard to account for with the current method.

Further, it was found that if EEIs are not implemented in areas used by people, e.g. insulation of an attic as part of a larger renovation project, replacement of a gas boiler situated in a secluded area etc., it becomes difficult to identify and valuate NEBs. This is an apparent weakness of the method, since EEIs in unpopulated areas are not necessarily without value.

Another weakness lies in the knowledge required of the respondent (expert) to both identify and valuate NEBs. In some cases, the necessary involvement in the EEI was split between individuals, where one part was not affected by the EEI but had

8. The target population refers to the individuals or in the NEB tool case, the type of organizations, that the data collection focuses on (Bateman et al. 2002).

9. In some observations the affected individual identified NEBs, but were unable to assign them a value. NEBs may be present without significant value or hard to value. The valuation method was perceived as a cognitive burden for some, who found it difficult to assign value to a 'good' they were not used to valuating.

10. E.g. the Danish electricity bills are composed or several items such as i) transport expenses, ii) cost recovered by the utility company, iii) the PSO tariff, iv) different state taxes, v) costs for the consumed electricity, and vi) costs of the subscription of the electricity agreement with the utility firm (SE 2015).

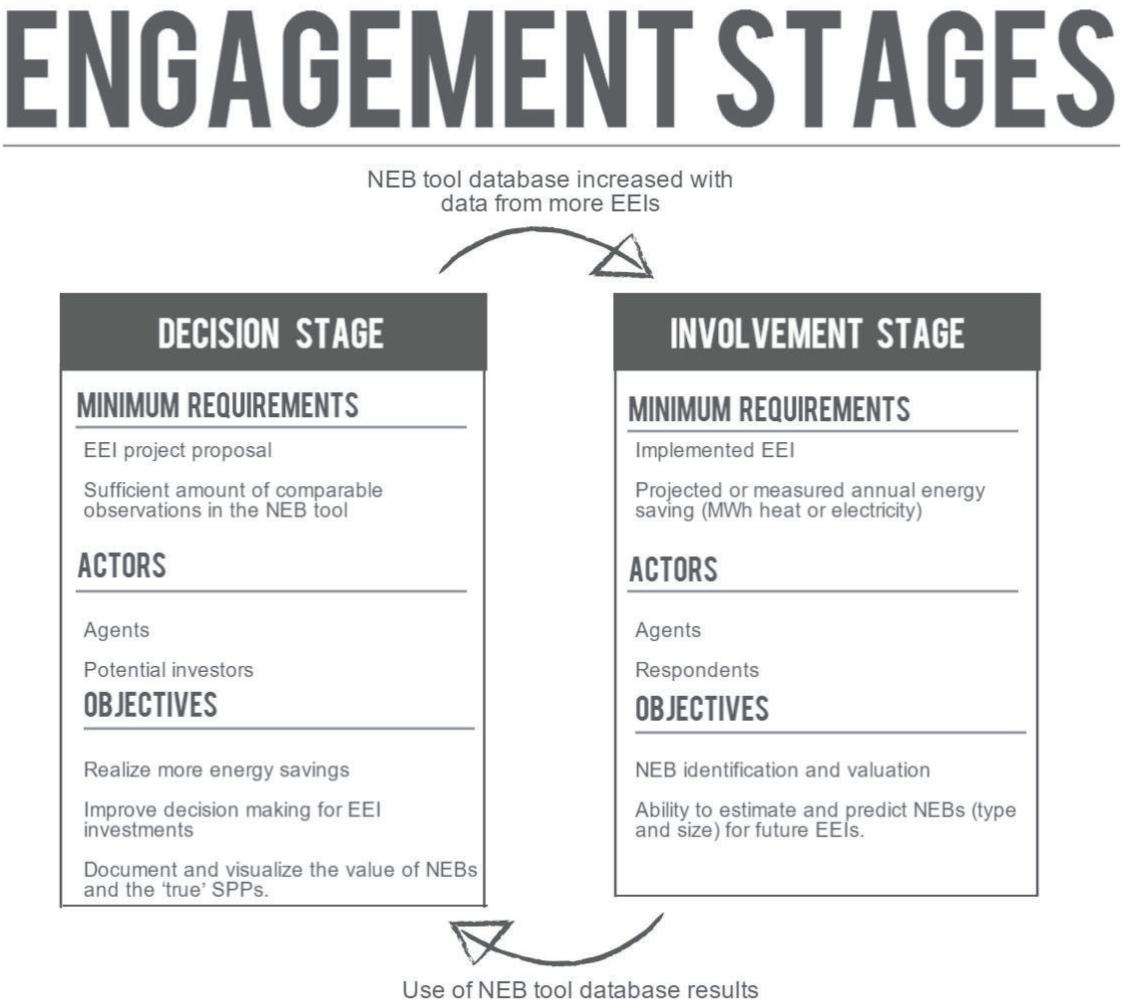

Figure 4. Stages of NEB tool engagement.

the necessary knowledge of the investment and ability to comprehend the valuation exercise whereas another did not, but was among the affected individuals. Interviews were discarded in such cases.

Although the interview is designed as structured, semi structured elements was necessary to include, when respondents found difficulty in identifying NEBs or assigning value to NEBs. This is one of the advantages of face-to-face interviews, as the interviewer is able to assist the respondent if questions are hard to understand (Bateman et al. 2002). It can however also be seen as a weakness in the survey design, as the internal validity may decrease due to potential large difference in the way surveys are conducted, this weakness may be further enhanced by the potentially large number of agents using the survey.

Awareness and use of the tool has steadily been increasing since the project was initiated and the NEB tool results are already being used in practice. Worth mentioning is EU Horizon 2020 project "STEAM-UP" about energy efficiency for steam plants, where knowledge about the NEB tool and methods are communicated. Further, the NEB tool and methodology has been included in the training material of a program for energy management training handled by UNIDO. See Figure 5 for more on the tools practical implementation.

Preliminary results

The NEB tool database currently consists of data from 112 EEIs[11]. From these, a total of 291 NEBs have been identified. The quantity of NEBs contained per EEI varies between one and five. The majority of respondents identified one (29 %) to two (28 %) NEBs and the least experienced five NEBs (7 %). Both three and four NEBs were experienced in 18 % of the cases.

The NEB tool quantifies NEBs relative to the annual energy cost savings, which allows for their value to be expressed in both monetary and relative terms. A non-parametric analysis of the monetary values revealed large differences in investment sizes (ranging from €565 to €7.8 million) and energy savings (ranging from €258 to €1.6 million) among the EEIs, which made the results misleading. The discovery found the relative WTP values to be most appropriate for further analyses as the distorting effect of the investment and savings size was removed. A large amount of tests was performed to identify potentially significant parameters. Separate tests were made for specific industries, energy end-users, technologies and NEB-

11. As the database is steadily growing the following analysis is to be viewed as a snapshot of the data available per April 2016.

CASE EXAMPLE: THE MISSING LINK–MOVING FROM RESEARCH TO PRACTICAL USE

A publically available database on NEBs, as observed by the organisations implementing EEIs, is one step towards greater awareness of the many advantages of energy efficiency. The data and the findings can be used in many different ways. For example, in relation to the implementation of an energy management system (e.g. ISO 50001) in a given organization.

In March 2016, a workshop was organised by Erik Gudbjerg on behalf of UNIDO for the energy team responsible for the energy management implementation in an industrial company. The theme of the workshop was NEBs. As introduction to NEBs, the team was asked to consider an EEI project in a clothes shop and identify the NEBs that might occur in relation to the EEI project. Next the team was asked to list the NEBs for their own EEI options identified as part of their energy mapping in the relation to the energy management system. What are the likely NEBs resulting from improvement of the boiler efficiency? What are the likely NEBs resulting from introducing automatic light controls? Etc. Once the NEBs had been listed, the energy team proceeded to assign a value to each of the NEBs. For some NEBs it is relatively easy to assign a value. Other NEBs are difficult to valuate and perhaps it is only possible to establish whether the value is positive or negative. The energy team was able to valuate surprisingly many of the listed NEBs. Finally, stock was taken of the total value of the EEI projects including their NEBs. The discussion of NEBs and the valuation process proved to be a revelation with regard to the total benefits of implementing an energy management system and for which part of the staff and management the different benefits occur.

Such NEB workshops can also be applied in larger fora. For example, UNIDO held a similar workshop for an audience of 300 participants at the international Energy Efficiency Forum and Fair, January 2016, organised by the Government of Turkey to make the energy efficiency movement widespread nationally and internationally.

Figure 5. Examples of practical implementation of the NEB tool.

groups, but only few determinants of the relative WTP were found. It is however not surprising considering the small sample size. A selection of tested hypotheses is presented below.

- **Whether the relative WTP increases with investment size, the size of the energy savings and/or the simple payback period (SPP).** These are all quite related, but increases in their size (length for the SPP) were assumed to potentially entail larger side effects and/or side effects that affected more people. This was not confirmed from any of the separate tests.
- **Potential differences between EEIs that produced heat savings as opposed to electricity savings.** Data was collected on the type of energy saving that the EEI made (heat or electricity) to see whether there were significant differences in the relative WTP from NEBs arising from these. Heat savings were found to have a very small positive (coefficient: 0.008 %) and significant impact on the relative WTP for NEBs in the Productivity category, however only at a 10 % significance level.
- **Differences in the relative WTP of private or public energy end-user respectively.** Though the majority of energy end-users surveyed were public institutions (72 %), private firms were found to have a systematically higher WTP for NEBs than public institutions. This could be because private firms are more aware of effects on e.g. their productivity, i.e. the existence and value of different NEBs may be more obvious to private actors and that private actors are more used to thinking in monetary values than public actors. Another explanation could be that financing of EEIs in private firms are more often taken from the company's operating budget, as opposed to public EEIs that may be financed by the municipality or public investment pools (e.g. energy and renovations pools). The potential difference in the origin of financial resources could have an effect on the psychological awareness of 'getting your money's worth'. However, these considerations can only be seen as speculations.
- **Whether different technologies impact the type and relative size of NEBs.** It was of great interest to discover whether different technologies impact the type and relative size of NEBs. Such knowledge could be used in political decision making, when considering e.g. targeted renovation funds. Unfortunately, no significant results were reached, presumably due to the small and dispersed sample size.
- **If time influences the type and relative value of NEBs.** A preliminary regression of the data found the relative WTP for NEBs to be increasing with time from the EEI investment/implementation. This finding could indicate that NEBs either 1) increase in value with time, 2) that it takes time for NEBs to arise and/or 3) that it takes time for them to be realized by those affected. It might be relevant to survey the same energy end-users over time, to discover more about time's influence on NEBs.

Previous research by Hall and Roth (2003) found the value of EEIs to be greater by a factor of 2.5. The preliminary analyses of the NEB-tool data found the value of EEIs to be 1.4 times higher with NEBs than when looking at the energy cost savings alone. Though the factors cannot be directly compared due to differences in the methodological framing, the implication is the same – investments in EEIs create greater value than what is included in the decision to invest. Such knowledge may be able to have a significant influence on the incentive to invest in EEIs.

Validity and biases

The flexibility of the NEB tool to include all possible NEBs is an apparent strength in relation to previously applied NEB valuation methods that have focused on specific technologies, industries or NEBs. However, for the results to be incorporated in cost-effectiveness tests, it is highly important to assess the validity as well as the potential biases that may influence the WTP stated by respondents.

It was experienced that the elicitation question seemed abstract and hard to understand for some respondents, which is not uncommon for stated preference valuation studies (Pearce et al. 2006), as respondents are not used to directly valuate non-marketed goods. Supportive material such as a more extensive interview guide and visual aids has been made to support the agent in the interview process and to ease the cognitive burden experienced by some respondents.

The non-probabilistic design of the sampling strategy increases the concern for sampling bias, where some groups or individuals of the population have a higher possibility of being within the sample. The interviewer (agent) may be strategically biased to survey certain groups of the population, e.g. their main clients or to highlight NEBs in certain industries or stemming from certain technologies. It is expectedly very hard to prevent or reveal such biases, due to the heterogeneity of the agents expected to use the NEB-tool.

In relation to the good being valued, the preference-based NEB tool method contrasts most preference-based studies by potentially valuating an inexhaustible amount of undefined goods as opposed to one/few well-defined goods (NEBs). Even though NEBs are not stringently defined and presented to the respondents, a high level of content validity could be expected, due to the potential high level of familiarity of the good(s) as respondents define the good (NEBs) themselves. This however, may also significantly weaken the credibility of the scenario as it becomes hard or impossible to test whether the interviewer and the respondent both have an understanding of the good being valued, i.e. the good may become ambiguous to the interviewer (agent) (Mitchell & Carson 1989). The validity concern is hard to amend as NEBs seem very case-specific and scarcely defined in general. The NEB-tool may however contribute to more thorough classifications in the future.

CRITERION VALIDITY TEST

A criterion validity test[12] using comparable market prices was made on one of the observations. The company Saint Gobain Weber A/S (private energy end-user) had invested in an EEI of one of their production ovens/furnaces (EEI), to better utilize the heat. The investment was made in 2010.

The production manager interviewed (the expert) identified ‘increased production capacity/productivity’ as an experienced NEB and stated a relative WTP of 100 %, in relation to the annual energy saving of €140,220. The investment costs had amounted to €268,582 which gave a SPP of 1.9 years before the NEB was included and of 1 year (0.96 years) after the NEB was included.

12. Criterion validity refers to a comparison of results to reality or some standard outside the study, e.g. comparison to market prices or a simulation of markets (Mitchell & Carson 1989).

An attempt to assign a market price to the productivity increase was made, based on productivity data from the company 6 months before and 6 months after the EEI was implemented. The company’s own definition of productivity was defined by how many tonnes of clay the furnace processed per hour, data that the company collects and stores on a monthly basis. The results showed that the productivity had increased by 3.4 ton of clay per hour, however large variations were seen from month to month and it was difficult to determine the effect of economic trends and market conditions on the actual value.

Thus, what could be concluded was that both methods showed increases in productivity, however that a monetary comparison was not reached with the available information. Further, the test shows that even for the NEBs that may have comparable market prices, a criterion validity test is challenging to make. The test also prevailed, that it is difficult to assess the NEBs, as many different aspects of the production process continuously change, so cause and effect of each measure is blurred, and it is unclear what results have emerged on the basis of which initiatives.

Conclusion

There is no doubt that NEB identification and valuation is a complex and challenging arena to tackle. The amount of possible NEBs can seem countless and dilemmas exist with regards to framing and specifying the factors that influence the occurrence and value of NEBs. This paper presents an online database called the NEB tool and preliminary results from above 100 implemented EEIs which find a value 1.4 times higher with NEBs than when looking at the energy cost savings alone.

The NEB tool brings a new type of NEB analyses where data can expand with less dependence on time and resource restrictions and where data is open and accessible for use, reuse and redistribution among all interested parties. Though the preference-based valuation method can be perceived to entail a precision trade-off, the option to choose between valuation methods may prove beneficial by easing the data collection burden and allowing for a more general applicability within a wider scope.

References

ACEEE (2015). Energy’s Multiple Benefits. American Council for an Energy-Efficient Economy. American Council for an Energy-Efficient Economy. Report IE1501.

Bateman, I. J., Carson, R. T., Day, B., Hanemann, M., Hanley, N., Hett, T., Jones-Lee, M., Loomes, G., Mourato, S., Özdemiroglu, E., Pearce, D., W., Sugden, R., and Swanson, J. (2002): Economic Valuation with Stated Preference Techniques – a Manual. Edward Elgar, Cheltenham, UK, Northampton, MA, USA.

Christiansen, I. S (2016): Test of a Method for Elicitation of Energy End-Users Preferences for Non-Energy Benefits. Master thesis. University of Copenhagen, Science.

Cooremans (2012): Investment in Energy Efficiency: Do the Characteristics of Investments Matter? Energy Efficiency. Vol. 5. No. 4. Springer, 497–518.

ENS (2015): Barrierer i energieffektiviseringen af erhvervslivet. Energistyrelsen, Denmark.

Finman, H. and Laitner, J. A. (2001): Industry, Energy Efficiency and Productivity Improvements. The European Council for an Energy Efficient Economy. Proceedings of the 2001 Summer Study on Energy Efficiency in Industry, 561–570.

Gudbjerg, E., Dyhr-Mikkelsen, K., and Andersen, C., M. (2014). Spreading the word – an online non-energy benefit tool. ECEEE Industrial Summer Study Proceeding, 171–178.

Hall, N. P. and Roth, J. A. (2003): Non-energy benefits from commercial and industrial energy efficiency programs: Energy efficiency may not be the best story. Proceeding of the 2003 International Energy Program Evaluation Conference: 689–702.

IEA/OECD (2014): Capturing the Multiple Benefits of Energy Efficiency. OECD/ International Energy Agency.

Kunkel, S. and Kontonasiou, E. (2015): Indoor air quality, thermal comfort and daylight policies on the way to nZEB – status of selected MS and future policy recommendations, eceee 2015 Summer Study, 1261–1270.

Kanellakis, M., Martinopoulos, G., & Zachariadis, T. (2013): European Energy Policy – A Review. Energy Policy, 62, 1020–1030.

Lung, R., A. McKane, R. Leach, and Marsh, D. (2005): Ancillary Savings and Production Benefits in the Evaluation of Industrial Energy Efficiency Measures. The American Council for an Energy Efficient Economy. ACEEE 2005 Summer Study Proceedings; 103–114.

Mitchell, R., C., and Carson, R., T. (1989): Using Surveys to Valuate Public Goods: the Contingent Valuation Method. Resources for the Future.

McClain, E., Skumatz, L. A., Jennings, J. (2007): Commissioning in Public Sector Building – Non-Energy Benefits (NEBs), not savings, are the selling point. eceee 2007 Summer Study, 1073–1080.

Navrud, S. (2000): Strengths, Weaknesses and Policy Utility of Valuation Techniques and Benefit Transfer Methods. In: Prepared for OECD-USDA workshop, The Value of Rural Amenities: Dealing with Public Goods, Non-market Goods and Externalities. Washington, DC.

Nehler, T., Thollander, P., Ottoson, M., and Dahlgren, M. (2014): Including Non-Energy Benefits in Investment Calculations in Industry – Empirical Findings from Sweden. Business Models to Improve Industrial Efficiency. The European Council for an Energy Efficient Economy. eceee 2014 Industrial Summer Study, 711–719.

Nösperger, S., Mazoyer, J. L., and Vitt, E. (2015): Making Non-Energy Benefits a Real Asset and Changing Professionals' Habits: Renew the Partnership Approach Through the DECADIESE Method. eceee 2015 Summer Study on energy efficiency, 3–14.

SE (2015): Sådan Læser du din El-Regning. SE Energi og Klima. Available at: https://www.se.dk/se-energi-og-klima/privat/kundeservice/kundeservice/forstaa-din-elregning. Accessed 6th of December 2015.

Skumatz, L., A., and Gardner, J. (2005): Methods and Results for Measuring Non-Energy Benefits in the Commercial and Industrial Sectors. The American Council for an Energy Efficient Economy. 2005 ACEEE Summer Study on Energy Efficiency in Industry, 163–176.

Skumatz, L. (2006): Measuring Hard to Measure Non-Energy Benefits (NEBs) from Energy Programs: Methods and Results. American Evaluation Association, Portland.

Strand, J., Carson, R. T., Navrud, S., Ortiz-Bobea, A., and Vincent, J. (2014): A "Delphi Exercise" as a Tool in Amazon Rainforest Valuation. World Bank.

Weinsziehr, T., Gröger, M., Verhoog, M. and Bruckner, T. (2015): Multiple Benefits as Incentive for Municipal Climate Mitigation Efforts? The Case of a German Shrinking and Aging Middle Size City. eceee 2015 Summer Study on energy efficiency; 487–497.

Willoughby, S., Dahlgren, M., Jia, H., Guo, S., Schaefer, T. (2011): Quantifying Non-Energy Benefits of a Carbon Reduction Initiative for a Glassware Company. eceee Summer Study, Energy Efficiency First, 685–690.

Worrell, E., Laitner, J., Ruth, M., and Finman, H. (2001): Productivity Benefits of Industrial Energy Efficiency Measures. Energy 28, 1081–1098.

Acknowledgements

The development of the NEB-tool and database is partially financed through Elforsk, the Danish Energy Association's research and development program.

The authors would like to thank and acknowledge the assistance and contribution made by the energy company AURA, who headed the project, and the project participant Danish Technological Institute. Individuals deserving a special mention are Nanna Munk Ravnsborg, Christina Monrad Andersen, Iben Østergaard, and Jean-Marc Huet.