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Review

A Systematic Literature Review of Methods for Improved Utilisation of the Non-Energy Benefits of Industrial Energy Efficiency

Therese Nehler

Division of Energy Systems, Linköping University, S-581 83 Linköping, Sweden; therese.nehler@liu.se; Tel.: +46-13-28-20-84

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Abstract: Improvements in industrial energy efficiency demonstrated various additional effects beyond pure energy savings and energy cost savings. Observed on many levels, these additional effects, often denoted as non-energy benefits, constitute a diverse collection, for instance, effects related to firms' production or improvements in the work environment and the external environment. Previous studies showed the potential of including quantified and monetised non-energy benefits in energy efficiency investments. However, there seems to be a lack of methodological overview, including all the steps from observation to monetisation and inclusion in investments. This study systematically reviews the academic literature on non-energy benefits relating to methods for observation, measuring, quantification, and monetisation of the benefits. The most commonly applied research design was a case study approach, in which data on non-energy benefits were collected by conducting interviews. Furthermore, the primary methods used to enable quantification and monetisation of observed non-energy benefits were based on classifications, indexes in relation to the energy savings, or frameworks. Calculation methods, databased tools, classification frameworks, and ranking were applied to evaluate the benefits' potential in relation to energy efficiency investments. Based on a synthesis of the review findings, this article contributes a novel scheme for improved utilisation of the non-energy benefits of industrial energy efficiency.

Keywords: energy efficiency; energy efficiency measures; non-energy benefits; industry; systematic literature review; investment decisions

1. Introduction

The industrial energy end-use represents a large share (approximately one-third) of the total energy use world-wide [1]. Improvements in industrial energy efficiency are essential in order to reduce the long-term environmental impacts of this energy use and to reach energy and environmental targets. The International Energy Agency (IEA) previously stated an industrial energy efficiency potential of 50% [2], and progress continues to be made in improving industrial energy efficiency [3]; however, there is still potential for further improvements. Estimations demonstrate that the overall manufacturing energy intensity could be improved by 44% in the next two decades [3]. Even if cost-effective, all of the suggested energy efficiency improvement measures in industry are not realised (e.g., References [4,5]). This gap between the theoretical possibilities and the energy efficiency improvement measures that are actually implemented is commonly explained by different types of barriers to energy efficiency that hinder the adoption of the improvement measures [4,6–8]. Previous studies on empirical barriers showed that different types of hindering factors are experienced by industrial firms, for instance, economic, organisational, and behavioural barriers [7]. Furthermore, studies also showed that the type of barriers seems to differ between various geographical regions, industrial sectors, and firms of various sizes [5,7,9–12]. To improve energy efficiency, different kinds of measures can be undertaken, for instance, the implementation of new technology or organisational and behavioural changes. Studies indicated that this diversity among energy efficiency improvement measures also affects their adoption; i.e., measures are facing different barriers due to their type and characteristics [13,14].

Studies on the driving forces for energy efficiency improvement measures gave a deeper understanding of what fosters adoption. Drivers for industrial energy efficiency are subject to empirical research in several regions and sectors, and the main drivers found include commitment from top management, cost reduction from reduced energy use, long-term energy strategy, people with real ambition, and the threat of rising energy prices [10,15–19]. In addition, similarly to barriers, the characteristics of the energy efficiency measures also seem to possess driving effects [13,14].

When implemented, energy efficiency improvement measures were shown to give rise to various additional effects beyond the energy effects, such as energy savings and energy cost savings [20–22]. These additional effects, often known as non-energy benefits, were observed on many levels and constitute a diverse collection [20,23,24]. For instance, these effects were seen in firms' processes and related equipment, but could also improve the work environment, as well as the external environment [21,25,26].

Previous studies showed the potential of including non-energy benefits in energy efficiency investments; if quantified and monetised, these effects might enhance the financial potential for energy efficiency investments, but the non-energy benefits that are difficult to monetise can also make energy efficiency investments more attractive in a qualitative way [21,22,27]. Pye and McKane [27] even argue that the non-inclusion of non-energy benefits creates underestimations of the value of such investments; however, as emphasised by Worrell et al. [22], negative side-effects should also be taken into account. Hence, non-energy benefits can be a means to overcome barriers to energy efficiency, both economic barriers and barriers of other types. On the other hand, these benefits can also act as drivers to energy efficiency by increasing the interest in energy efficiency investments. However, even if there is a clear potential in including non-energy benefits when investing in energy efficiency improvements, these benefits are not always considered in decisions on energy efficiency improvements [28]. One explanation could be that the observation and measurement of these additional effects are not always straightforward [28]. Some benefits are more difficult than others to observe and track to a specific measure, and a certain measure can give rise to several effects in an industrial firm [21]. Furthermore, the quantifiability and monetisation also vary among the benefits [24]. How non-energy benefits are investigated, from observation to monetisation and inclusion in investments, varies among previous studies. Moreover, there seems to be a lack of any methodological overview, including all the steps, in how non-energy benefits are studied, which was stressed in earlier studies by the IEA [29]; for example, studies on the quantification of non-energy benefits are still at an inception stage. To optimally utilise the benefits, a deeper understanding of how non-energy benefits should be observed, measured, quantified, and monetised is required. Knowledge of that kind would serve as a basis for developing methods and calculation tools that include and acknowledge non-energy benefits easily, for instance, in investment evaluations. This calls for a methodological literature review of previous non-energy benefit publications to be conducted.

The aim of this study was to review the literature on non-energy benefits (and related concepts) in order to determine which methods are applied in investigating them. The following four research questions specify what was studied in detail:

- How were non-energy benefits investigated in previous studies, i.e., what types of studies and methods were applied in previous research to investigate the existence and observation of non-energy benefits?
- On what levels were non-energy benefits studied and reported?
- Which methods were applied to measure, quantify, and monetise non-energy benefits?
- Which methods, including calculation tools, were applied to study and evaluate the potential of non-energy benefits?

The remainder of the paper firstly gives an introduction to non-energy benefits (Section 2). Section 3 describes the method and the framework for analysis that was applied. Section 4 provides the descriptive results of reviewing the literature on non-energy benefits, and the main results are described and analysed. Finally, the paper ends by discussing and synthesising the results in Section 5, and by giving the conclusions and implications for future studies in Section 6.

2. Non-Energy Benefits—A Brief Background

Previous literature showed that energy efficiency improvements can give not only the expected energy effects, such as energy savings and energy cost savings, but also additional effects, so-called non-energy benefits [20–22]. Non-energy benefits are not limited to being the effects of improvements in industrial energy efficiency; such effects are also seen in other areas, for instance, in the residential and environmental sectors. In these areas, the effects are commonly known as co-benefits or ancillary benefits [30–32]. In industrial contexts, these benefits are also denoted by other terms, such as ancillary savings and productivity or production benefits [22,33]. The IEA [20] applies a broader view on the concept by describing these additional effects as multiple benefits, which includes benefits at all societal levels: the individual level, the sectoral level, the national level, and the international level. The first two of these levels constitute the firm level and the industrial sector. According to the results of Rasmussen [24], the term "non-energy benefits" is the most commonly used term in industrial contexts. In industrial firms, these benefits constitute a broad set of effects which are observed in relation to areas such as production, operation and maintenance, work environment, and waste and emissions [22,25]. Improved productivity, the extended lifetime of equipment, improved air quality, and reduced product waste are examples of commonly observed benefits in industrial contexts [21,22,25]. In Figure 1, below, further examples of industrial non-energy benefits are displayed and categorised according to where in an industrial firm these benefits might appear.

Figure 1 illustrates the diversity among non-energy benefits and their effects on various areas within an industrial firm. The benefits are observed in relation to various industrial processes and can have impact on different organisational levels and on various individuals within the firm [20–22,25,27, 33–36].

The use of energy in industrial firms varies due to factors such as the size of the firms and type of production; however, whatever the type or size, improvements in energy efficiency within a firm are typically initiated by conducting an energy audit. The results of the audit create knowledge about the main energy-using processes and if there are processes in which energy is wasted or not used optimally [37]. The mapping of energy use is preferably done by dividing it into smaller energy-using parts, i.e., unit processes [38]. These unit processes can be various kinds of production processes or processes that support the production, for instance, ventilation [38]. The allocation of energy use also enables an analysis aimed at a description of which processes energy efficiency measures can be directed at, and also which energy efficiency improvements are relevant to implement in the firm [37]. Hence, energy efficiency improvement measures are typically directed towards specific processes within a given industrial firm. However, energy efficiency can also be treated and reported on a general level, for instance, as the overall energy efficiency of a firm or an industrial sector.

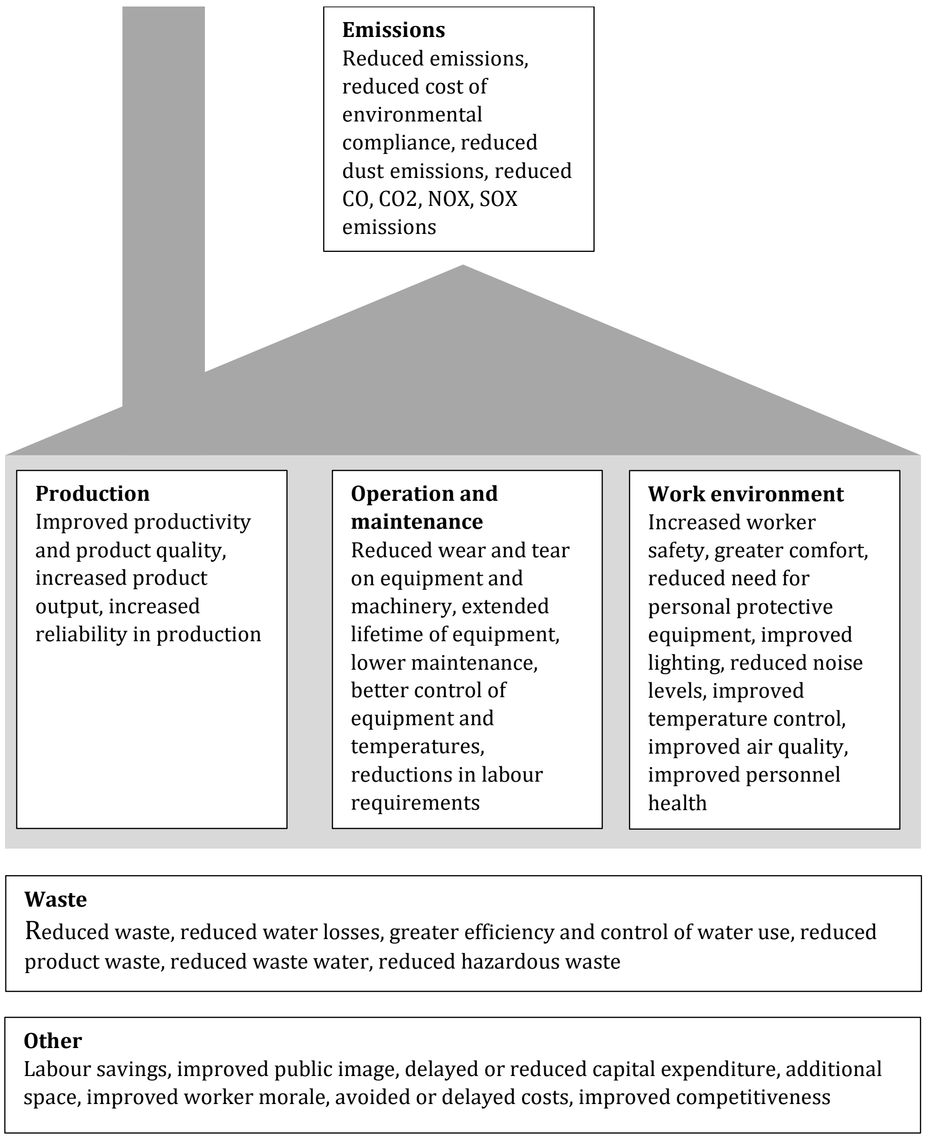

Figure 1. Examples of industrial non-energy benefits [20–22,25,27,33–36] categorised similarly to Finman and Laitner [25] and Worrell et al. [22].

In addition, the level of energy efficiency measures sets the premises for where and in which processes non-energy benefits can be observed. Moreover, it also depicts the level of non-energy benefits observed and reported. The most detailed level would be to study the non-energy benefits of a specific energy efficiency measure, for instance, reducing the system pressure in a compressed air system [39]. The next step would be to observe the benefits of a certain industrial process or technology, for instance, compressed air [39]. Non-energy benefits could also be studied more generally on an aggregated level, for example, the possible benefits of working with energy efficiency issues in general in an industrial firm [39].

Energy efficiency improvements often require investment by the industrial firm. As for any investment, the process for energy efficiency investment typically starts with an idea which, if a positive decision is achieved, ends with implementation [40]. During this process, economic evaluation plays a key role in the assessment of the investment, and a commonly used capital budgeting method among firms is the payback period [41]; however, methods such as net present value, internal rate of return, and lifecycle cost are also applied in the evaluation of energy efficiency investments and other types of investments [21].

It was previously emphasised that quantified and monetised non-energy benefits could improve the financial aspects of energy efficiency investments [27]. At the same time, previous research also demonstrated that non-energy benefits are seldom included in investment calculations [21], due to, for instance, lack of information on how to measure, quantify, and monetise non-energy benefits [28]. However, even the benefits that are difficult to monetise, such as improved work environment, can play an important role in investment proposals as comments and extra arguments or as part of the aim of the investment [21].

3. Method

The study presented in this paper started with a systematic review of the literature on non-energy benefits and related terms for industrial energy efficiency improvements. The aim of the literature review was to identify previously published studies that were relevant to the objective stated in Section 1. In particular, the review was designed to compile the relevant contributions of the studies found and to analyse their results in relation to the research questions formulated for this study. The literature review was conducted in a formalised way inspired by the systematic review methodology outlined by Tranfield et al. [42]. The use of such a sound methodology offers several advantages. For instance, to structure the review around a set of stated research questions facilitates the drawing of conclusions and minimises researcher bias [43]. Furthermore, it enables the transparency and replicability to be maintained during the review process [42].

The literature search was performed during the summer of 2018 using the scholarly database Scopus, and involved identifying relevant publications, that is, articles published in peer-reviewed journals and peer-reviewed conference proceedings. Other types of publications (e.g., reports) were, thus, omitted. Further selection criteria for inclusion were articles, conference papers, or reviews as document type, available as full-text, related to energy, engineering, environmental science, business, management, and accounting, or social sciences as research domains, related to the industrial sector and relevant to the studied topic. Since non-energy benefits constitute a diverse collection, these effects might appear in various areas related to industrial firms. Therefore, the number of research domains was extended to include areas other than energy in order to avoid the exclusion of related articles published in other areas. To be relevant for inclusion in the review, articles needed to cover methods applied for the observation, quantification, and/or monetisation of non-energy benefits (or related terms). The search settings were restricted to finding search strings in article titles, abstracts, and keywords.

According to the results of Rasmussen [24], the term non-energy benefits is the most commonly used in industrial contexts. However, to avoid excluding any studies, this search also included other terms describing similar effects: co-benefits, ancillary savings, and multiple benefits (see Section 2). These terms are also used in describing the additional effects of energy efficiency improvements in buildings, for instance, in the residential sector. However, energy efficiency in the residential stock and in buildings lies outside the scope of this review study, and articles describing various benefits in that context were, hence, excluded.

Four search strings were applied: "energy efficien*" was combined with (1) "non-energy benefits", (2) "co-benefits", (3) "multiple benefits", or (4) "ancillary". The exact search strings applied can be found in Appendix A.

The search process and the selection process are visualised in the flow chart below (Figure 2).

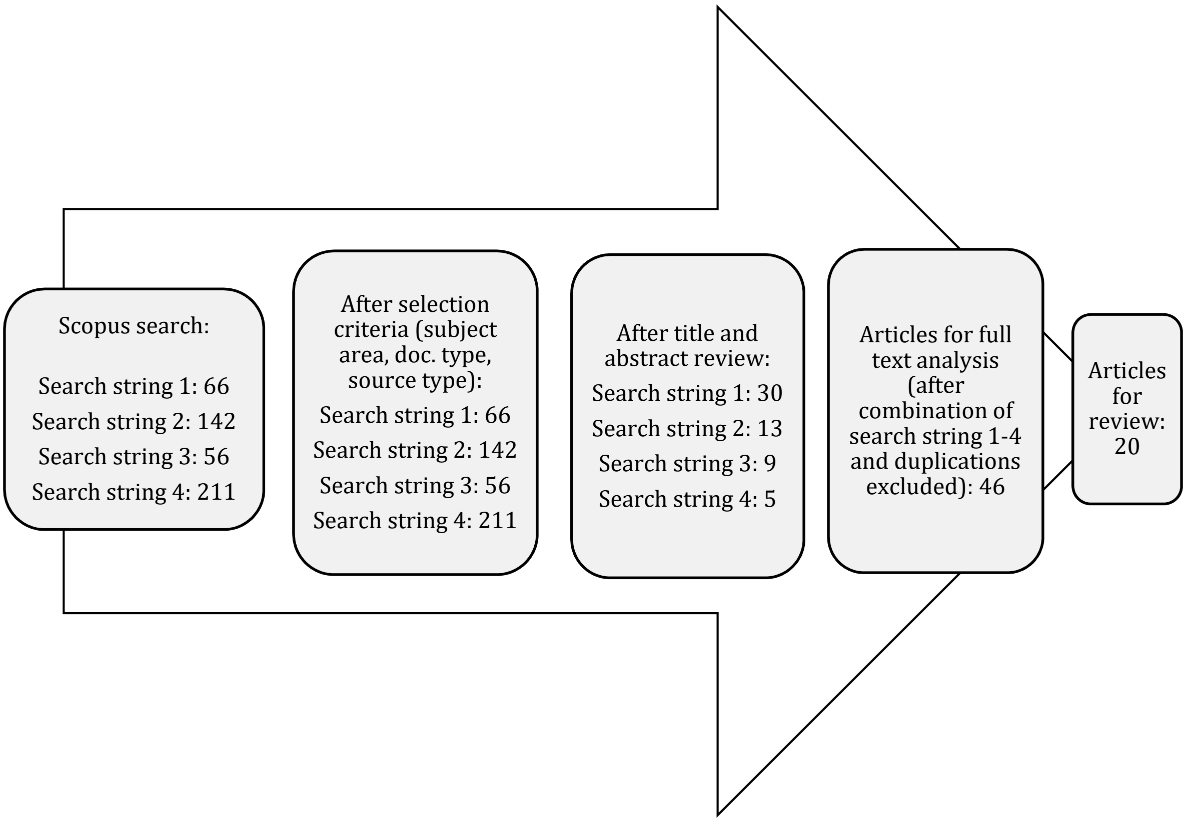

Figure 2. An overview of the literature search.

Identified and reviewed articles were coded in terms of their bibliographic characteristics, type of study, the geographical origin of the study, and the geographical scope of the study (i.e., which geographical area the study covered). Since the first research question concerned the methods applied in the studies for the observation of non-energy benefits, in addition to type of study, the articles were also analysed in terms of which methods were used to collect data on observed non-energy benefits. However, it should be noted that the research design typically determines which data instruments can be applied.

The articles were also analysed to determine which perspective on energy efficiency was applied: specific energy efficiency measures, energy efficiency improvements for a certain technology or energy-using process (e.g., compressed air), or energy efficiency improvements in general within an industrial firm. The level of energy efficiency perspective applied in the studies has an influence on how and at which level non-energy benefits are studied, which was the rationale for including this parameter in the descriptive analysis. For instance, taking a general perspective on energy efficiency in the investigation of observed non-energy benefits does not necessarily relate possible benefits to the specific measures implemented by an industrial firm, as opposed to studying specific energy efficiency measures (e.g., reduced system pressure in a compressed air system). Instead, a general perspective on energy efficiency will probably lead to information about the possible observed non-energy benefits in general as a consequence of implemented energy efficiency improvements in general. In analysing the content of the articles, it appeared important to also distinguish between the level of observed non-energy benefits and the level at which the benefits were reported. By including this parameter in the analysis, the situation in which the evaluation was made became decisive; that is, whether the reviewed publications only evaluated measures after implementation (an ex-post perspective), or whether they also made estimations, calculations, or similar to forecast the potential of the non-energy benefits (an ex-ante perspective). The distinction between these perspectives is important because it also relates to the second and third research questions in this study. Measurements and quantification and methods for evaluation of the non-energy benefits' potential will naturally depend on whether they concern investment evaluations made after implementation or investment estimations made before implementation. When analysing the articles in relation to methods for evaluation of non-energy benefits' potential, both perspectives were included; thus, the suggested methods for evaluation after and before were considered. Moreover, to avoid excluding any ideas in relation to the evaluation of non-energy benefits, other suggestions and considerations which could not be considered as methods were also included. An example of this would be non-energy benefits' importance due to their characteristics when making decisions on energy efficiency investments, for example, their ability to act as drivers and foster positive decisions and implementation.

4. Results and Analysis

4.1. Descriptive Analysis of the Publications Included in the Review

A total of seven journal articles and 13 conference articles were identified as relevant to include in the literature review on non-energy benefits of energy efficiency measures, based on the selection criteria outlined in Section 3. Information on the publications is displayed in Table 1. A complete summary of the relevant publications included in the review, together with a bibliography and some of the results of the analysis, is provided in Appendices B and C.

Table 1. Descriptive analysis of the relevant publications for the review in the area of non-energy benefits in industry. USA—United States of America; OECD—Organisation for Economic Co-operation and Development.

Author	Year	Type of Publication	Type of Study—Research Design	Geographical Origin/Scope	Level of Energy Efficiency Improvement
Nehler [39]	2018	Journal	Literature review	Sweden/Global	Specific, technology/process
Nehler et al. [26]	2018	Journal	Multiple case study	Sweden/Global, USA, Sweden	Specific, technology/process
Krutwig and Starosta [44]	2017	Conference	Literature review, multiple case study	Romania/n/a	Technology/process
Rasmussen * [24]	2017	Journal	Literature review	Sweden/Global	General
Cagno et al. [45]	2016	Conference	Multiple case study	Italy/Italy	Specific
Christiansen et al. ** [46]	2016	Conference	Multiple case study	Denmark/Denmark	Specific
Nehler and Rasmussen [21]	2016	Journal	Multiple case study	Sweden/Sweden	Technology/process, general
Gudbjerg et al. ** [47]	2014	Conference	Multiple case study	Denmark/Denmark	Specific
Rasmussen * [23]	2014	Conference	Literature review	Sweden/Global	General
Nehler et al. [28]	2014	Conference	Multiple case study	Sweden/Sweden	Technology/process, general
Lung et al. [33]	2005	Conference	Multiple case study	USA/USA	Specific, technology/process, general
Hall and Roth [34]	2003	Conference	Multiple case study	USA/USA	Technology/process
Worrell et al. *** [22]	2003	Journal	Multiple case study	USA/6 OECD countries incl. USA	Specific, technology/process
Worrell et al. [48]	2002	Journal	Literature review, multiple case study	USA/Global	Specific, technology/process
Finman and Laitner *** [25]	2001	Conference	Multiple case study	USA/6 OECD countries including USA	Technology/Process

Table 1. *Cont.*

Author	Year	Type of Publication	Type of Study—Research Design	Geographical Origin/Scope	Level of Energy Efficiency Improvement
Laitner et al. [49]	2001	Conference	Multiple case study	USA/USA	Specific, technology/process
Pye and McKane [27]	2000	Journal	Multiple case study	USA/USA	Specific
Skumatz et al. [36]	2000	Conference	Multiple case study	USA/USA	Technology/process
Gordon et al. [50]	1999	Conference	Multiple case study	USA/USA	Technology/process
Lilly and Pearson [35]	1999	Conference	Multiple case study	USA/USA	Specific

* Rasmussen [23] was a previous version of Rasmussen [24]. ** Gudbjerg et al. [47] presented early results of Christiansen et al. [46]. *** Worrell et al. [22] and Finman and Laitner [25] were based on the same dataset.

The reviewed articles were published between 1999 and 2018, and, as can be seen from Figure 3, half of them were published between 1999 and 2005, and the other half were published between 2014 and 2018. A few articles published before 1999 were found in the systematic literature search, but none of these matched the review criteria and were, hence, omitted. Furthermore, some of the articles were also related to others of the included articles in various ways; Rasmussen [23] was a previous version of Rasmussen [24], Gudbjerg et al. [47] presented early results of Christiansen et al. [46], and Worrell et al. [22] used the same dataset as Finman and Laitner [25] in their study. In spite of this, it seemed relevant to include all of these articles in the review, since there were differences between the publications.

In Figure 3, the number of publications per year is displayed, together with the origin of the publications. All of the publications from 1999 to 2005 originated in the USA, whereas the later publications were mainly from various European regions. Several publications originating from other countries, for instance China and Japan, were found in the literature search, but these publications did not match the posed review criteria and were, hence, not included in the review.

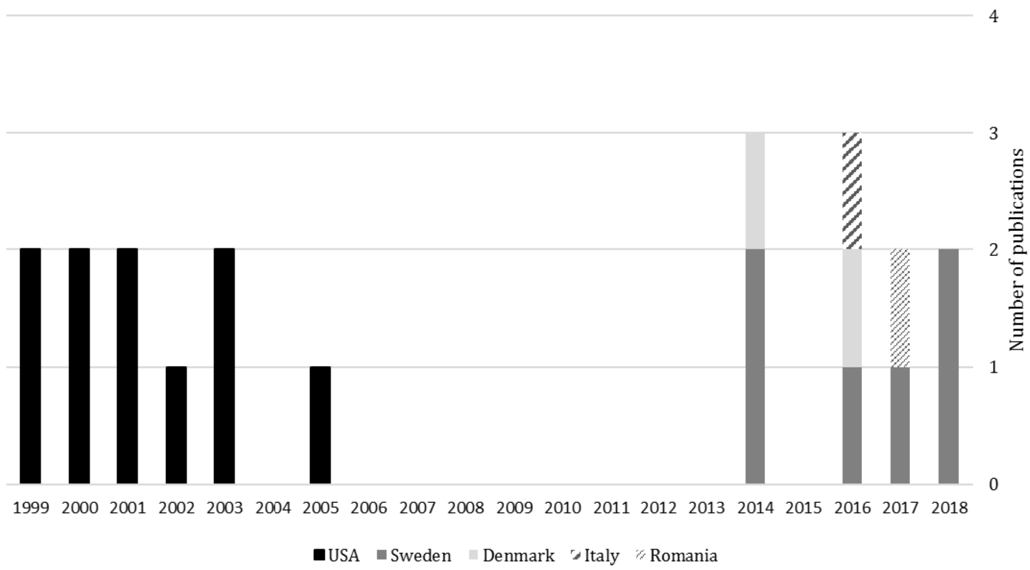

Figure 3. The number of published articles per year and by geographical origin in the area of non-energy benefits in industry.

This might be an indication that the interest in studying non-energy benefits started in the USA around the year 2000 and then decreased in that area. A new interest in the studied topic then appeared approximately ten years later and was also transferred to European regions.

There is no significant difference between conference articles and journal articles regarding the relative distribution among them. However, as can be seen in Figure 4, there seems to be a shift towards more publications of the journal type over the past three years. This shift reflects the general movement within academia as a whole, with a much stronger focus today on journal publications, in particular journals being indexed in the most prominent databases.

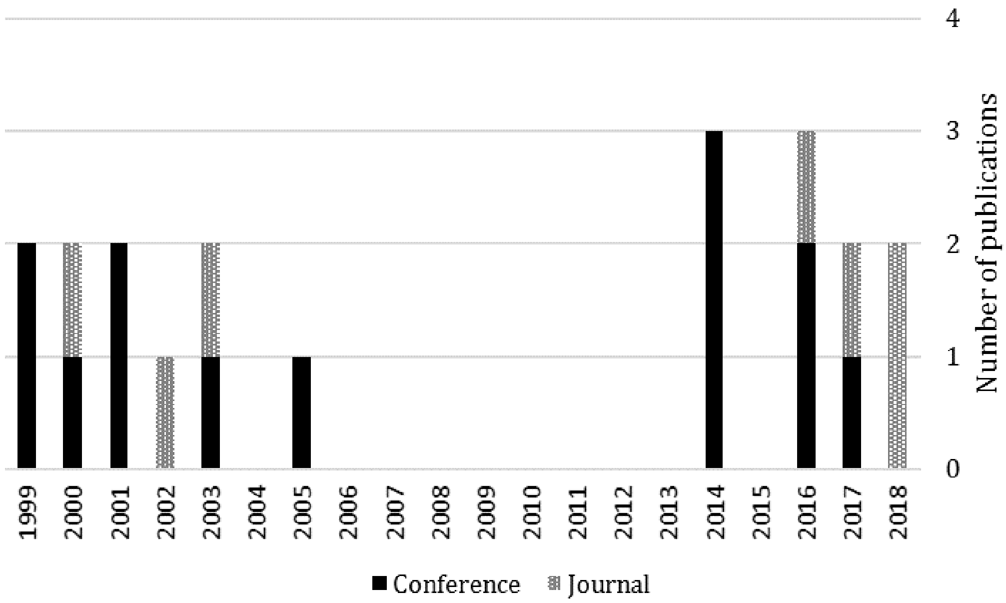

Figure 4. The number of published articles per year and by type of publication in the area of non-energy benefits in industry.

Even though the number of articles located is small, the increasing number of journal articles might also be an indication that the field of non-energy benefits turned into a more mature and well-theorised research area. On the other hand, 15–20 years ago, fewer scientific journals existed and there might have been an increased interest in publishing research as conference articles instead of in scientific journals.

This indication of a shift might also be reflected in Figure 5, which displays the main methods applied among the reviewed articles to investigate and observe non-energy benefits. It can be seen that various kinds of case study approaches were the most common method used among the publications. Some of the later publications used literature reviews as methods to study non-energy benefits, in particular among the later publications. Two publications, one among the early publications and one among the later, used a combination of a literature review and a case study approach, which started with a literature review and then empirical data was applied in the case study approach. The application of literature reviews among the later publications might also be seen as an indication that non-energy benefits as a research field are now explored in a more scholarly way and, thus, the topic developed into a better-theorised one.

A few of the articles described a specific industrial focus, but most of the publications were either not focused on a specific type of industry, or the type of industry covered was not explicitly mentioned in the article.

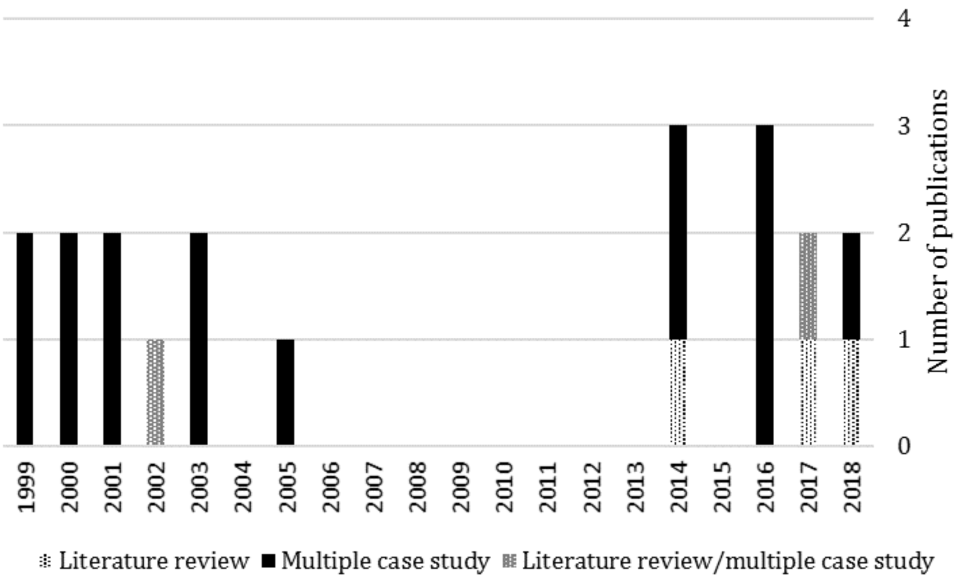

Figure 5. The number of published articles per year and by type of study in the area of non-energy benefits in industry.

How non-energy benefits were studied in relation to the perspective on energy efficiency differs among the reviewed articles. From Figure 6, it is apparent that there is a variation between the reviewed publications on which level energy efficiency measures were studied. In the majority of the articles, the specific level, the technology/process level, or a mixture of these two levels were considered. The remainder of the articles took either a more general perspective on energy efficiency measures or a mixed approach.

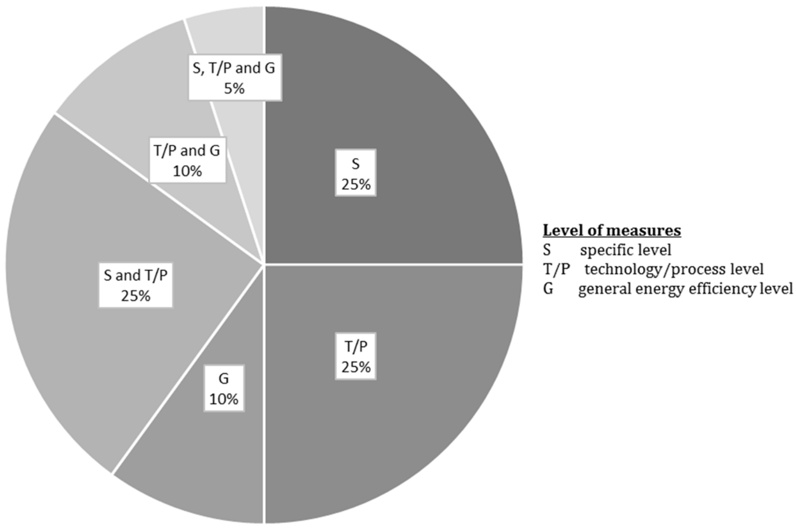

Figure 6. The relative distribution among the articles by level of energy efficiency measures studied.

The perspective applied in each of the reviewed articles is naturally a consequence of the stated objectives in that publication. For instance, the review articles by Rasmussen [24] and Rasmussen [23], and exploratory articles like Nehler and Rasmussen [21] and Nehler et al. [28] take a wider perspective and apply a more general perspective on energy efficiency, while other studies focus on specific energy efficiency measures, such as the evaluation of energy efficiency projects [22,27,33,35,45,46]. Moreover, the aims of some of the reviewed articles were in between, i.e., they had a certain focus on energy efficiency technologies or on energy-using processes. For instance, Nehler [39], Nehler et al. [26], and Gordon et al. [50] all studied energy efficiency measures and non-energy benefits in relation to the energy-using process of compressed air. Krutwig and Starosta [44], Hall and Roth [34], and Skumatz et al. [36] are other examples of publications that aimed to study energy efficiency at a technology and process level.

In analysing the articles included in the review, the time perspective came to be crucial, i.e., whether evaluation was made before or after the implementation of the measure. All of the studies included in the review took an ex-post perspective; i.e., the additional effects of energy efficiency measures were evaluated after implementation. In addition, almost half of the total number of articles also included an ex-ante perspective; i.e., these studies also described suggested methods, models, or calculations to forecast impacts such as energy and non-energy savings for future measures or investments. Table 2 compiles the time perspectives, i.e., before and after implementation, applied in the reviewed articles.

Table 2. The time perspective applied in studying non-energy benefits in the reviewed publications in the area of non-energy benefits in industry.

Author and Year	Ex-Post Perspective	Ex-Ante Perspective
Nehler, 2018 [39]	Yes	No
Nehler et al., 2018 [26]	Yes	No
Krutwig and Starosta, 2017 [44]	Yes	Yes (database)
Rasmussen, 2017 [24]	Yes	No
Cagno et al., 2016 [45]	Yes	Yes (classification scheme)
Christiansen et al., 2016 [46]	Yes	Yes (database)
Nehler and Rasmussen, 2016 [21]	Yes	No
Gudbjerg et al., 2014 [47]	Yes	Yes (database)
Rasmussen, 2014 [23]	Yes	No
Nehler et al., 2014 [28]	Yes	No
Lung et al., 2005 [33]	Yes	Yes (conservation supply curves, payback)
Hall and Roth, 2003 [34]	Yes	No
Worrell et al., 2003 [22]	Yes	Yes (conservation supply curves, payback)
Worrell et al., 2002 [48]	Yes	No
Finman and Laitner, 2001 [25]	Yes	No
Laitner et al., 2001 [49]	Yes	Yes (conservation supply curves, payback)
Pye and McKane, 2000 [27]	Yes	No
Skumatz et al., 2000 [36]	Yes	No
Gordon et al., 1999 [50]	Yes	No
Lilly and Pearson, 1999 [35]	Yes	Yes (net present value, payback, cost/benefit ratios, levelised costs)

As seen in Table 2, various methods were applied to forecast the impact of non-energy benefits on future measures and investments. Krutwig and Starosta [44], Christiansen et al. [46], and Gudbjerg et al. [47] built databases in which information and values regarding non-energy benefits were gathered. The databases serve as tools to enable the inclusion of non-energy benefits in the planning of new energy efficiency measures. Cagno et al. [45] also developed a classification scheme which can be applied in evaluating future measures. The remainder of the articles that took an ex-ante perspective used various kinds of calculations: payback period, net present value, payback, cost/benefit ratios, levelised costs, and conservation supply curves [22,33,35,49]. The methods that were applied in the reviewed articles for future evaluations of energy efficiency measures are described in more detail in Section 4.4.

4.2. Methods for Observing Non-Energy Benefits

A case study approach (see Table 4 below) was the most common research design applied in the reviewed articles for observing non-energy benefits. However, the type and number of cases varied among the reviewed publications. Among the early publications, a number of cases, i.e., energy efficiency projects or measures, were typically evaluated in terms of energy savings and non-energy benefits [22,27,33,35]. The number of cases varied from three up to 81, and the emphasis was on economic evaluation of the cases. Some of the later publications also based their studies on the evaluation of several energy efficiency projects or measures, e.g., Krutwig and Starosta [44], Cagno et al. [45], and Christiansen et al. [46]. However, in these articles, the objective was not only to evaluate the projects or measures economically. For instance, the studies of both Krutwig and Starosta [44] and Cagno et al. [45] aimed to classify and characterise the benefits to enable further assessments. The remainder of the reviewed publications conducted literature reviews or a mixture of a literature review and a case study to compile and map the observed non-energy benefits.

As displayed in Table 3, the research instrument applied to collect data in relation to the observation of non-energy benefits was typically to conduct interviews with the relevant personnel within the firm. For instance, Nehler and Rasmussen [21] interviewed energy managers or personnel with similar roles regarding their experiences of non-energy benefits. Nehler [39] also added the suppliers' perspective on non-energy benefits in relation to energy efficiency measures in compressed air systems by conducting interviews with staff involved in the sale of compressed air solutions. Two of the reviewed publications, Nehler et al. [26] and Nehler and Rasmussen [21], also applied questionnaires to study the perceived non-energy benefits as outcomes of energy efficiency improvements. Questionnaires are typically a data collection method that gathers a lot of data at one time. However, the study by Nehler and Rasmussen [21] revealed that, if the concept of non-energy benefits is not clearly understood by the respondents, it might lead to ambiguous answers.

Table 3. Methodological approach applied in the observation of non-energy benefits in the reviewed publications in the area of non-energy benefits in industry. n/a—not available.

Author and Year	Research Design	Methods for Data Collection
Nehler, 2018 [39]	Literature review	Literature review
Nehler et al., 2018 [26]	Multiple case study	Interviews, questionnaire
Krutwig and Starosta, 2017 [44]	Literature review, multiple case study	Literature review, interviews
Rasmussen, 2017 [24]	Literature review	Literature review
Cagno et al., 2016 [45]	Multiple case study	Interviews
Christiansen et al., 2016 [46]	Multiple case study	Interviews
Nehler and Rasmussen, 2016 [21]	Multiple case study	Interviews, questionnaire
Gudbjerg et al., 2014 [47]	Multiple case study	Interviews
Rasmussen, 2014 [23]	Literature review	Literature review
Nehler et al., 2014 [28]	Multiple case study	Interviews
Lung et al., 2005 [33]	Multiple case study	n/a
Hall and Roth, 2003 [34]	Multiple case study	Interviews
Worrell et al., 2003 [22]	Multiple case study	n/a
Worrell et al., 2002 [48]	Literature review, multiple case study	Literature review
Finman and Laitner, 2001 [25]	Multiple case study	n/a
Laitner et al., 2001 [49]	Multiple case study	n/a
Pye and McKane, 2000 [27]	Multiple case study	n/a
Skumatz et al., 2000 [36]	Multiple case study	Interviews
Gordon et al., 1999 [50]	Multiple case study	Interviews
Lilly and Pearson, 1999 [35]	Multiple case study	Meetings with relevant people in the firm

In five of the reviewed publications, the data collection process was not described in detail; thus, it was not clear how the information about observed non-energy benefits was collected. These publications state that a number of cases (i.e., energy efficiency projects or measures) were studied. However, the exact process for this or *how* the data was retrieved was not described in the articles.

4.3. Levels of Studied and Reported Non-Energy Benefits

In the reviewed publications, non-energy benefits were studied mainly at a specific measure level or a technology (process) level. However, as displayed in Table 4, there are variations between the studies in how the results were reported. Even though several of the publications observed non-energy benefits at a specific level, in some cases, the results were reported on an aggregated level, for instance, how the inclusion of monetised benefits impacts upon the payback period.

Table 4. Level of observed and reported non-energy benefits in the reviewed publications in the area of non-energy benefits in industry.

Publication	Level of Observed Non-Energy Benefits	Level of Reported Non-Energy Benefits
Nehler, 2018 [39]	Specific, technology/process	Specific, technology/process
Nehler et al., 2018 [26]	Specific, technology/process	Specific, technology/process
Krutwig and Starosta, 2017 [44]	Technology/process	Technology/process
Rasmussen, 2017 [24]	General	General
Cagno et al., 2016 [45]	Specific	Specific
Christiansen et al., 2016 [46]	Specific	Specific
Nehler and Rasmussen, 2016 [21]	General	General
Gudbjerg et al., 2014 [47]	Specific	Specific
Rasmussen, 2014 [23]	General	General
Nehler et al., 2014 [28]	Technology/process, general	Technology/process, general
Lung et al., 2005 [33]	Specific, technology/process, general	Technology/process, general
Hall and Roth, 2003 [34]	Technology/process	Technology/process, general
Worrell et al., 2003 [22]	Specific	Specific, technology/process, general
Worrell et al., 2002 [48]	Technology/process	Technology/process
Finman and Laitner, 2001 [25]	Specific	General
Laitner et al., 2001 [49]	Specific	Specific, technology/process, general
Pye and McKane, 2000 [27]	Specific	Specific
Skumatz et al., 2000 [36]	Technology/process	Technology/process, general
Gordon et al., 1999 [50]	Technology/process	Technology/process
Lilly and Pearson, 1999 [35]	Specific	Specific

4.4. Methods for Measuring, Quantifying, and Monetising the Non-Energy Benefits

Most of the reviewed articles evaluated energy efficiency measures after their implementation. As can be seen in Table 5 below, the methods for the measurement, quantification, and monetisation of non-energy benefits varied among the reviewed publications. Several publications [22,25,27,33–35, 44–49] reported that cases (energy efficiency projects) were evaluated in terms of energy savings and non-energy benefits; however, the exact process for this, i.e., how various benefits and parameters were measured in practice, was not described in any of these publications.

Table 5. Methods applied in the quantification and monetisation of non-energy benefits in the reviewed publications in the area of non-energy benefits in industry. n/a—not available.

Author and Year	Methods for Quantification and/or Monetisation
Nehler, 2018 [39]	- *
Nehler et al., 2018 [26]	- *
Krutwig and Starosta, 2017 [44]	n/a
Rasmussen, 2017 [24]	Framework based on time frame and quantifiability
Cagno et al., 2016 [45]	Classification framework based on type of non-energy benefits
Christiansen et al., 2016 [46]	Index based on calculations or estimations relating to the energy savings
Nehler and Rasmussen, 2016 [21]	Classification of non-energy benefits as costs and revenues
Gudbjerg et al., 2014 [47]	Index based on calculation or estimations relating to the energy savings
Rasmussen, 2014 [23]	Framework based on time frame and quantifiability
Nehler et al., 2014 [28]	Barriers to quantification and monetisation
Lung et al., 2005 [33]	Assessment based on non-energy benefits as reduced costs and increased revenues
Hall and Roth, 2003 [34]	Assessment based on the degree of change, i.e., how much non-energy benefits changed after implementation
Worrell et al., 2003 [22]	n/a
Worrell et al., 2002 [48]	Classification of the non-energy benefits based on their importance to the firm (from somewhat important to significant importance)
Finman and Laitner, 2001 [25]	n/a
Laitner et al., 2001 [49F]	n/a
Pye and McKane, 2000 [27]	n/a
Skumatz et al., 2000 [36]	Relative to the energy savings, multiplier
Gordon et al., 1999 [50]	n/a
Lilly and Pearson, 1999 [35]	n/a

* The aim of the publication did not include quantification or monetisation of non-energy benefits.

Quantifiability is an aspect that was central to many of the articles, and several of them stressed that certain non-energy benefits were more difficult than others to quantify and monetise. For instance, Nehler et al. [28], Nehler and Rasmussen [21], and Lilly and Pearson [35] described that benefits in relation to operation and maintenance were easier to quantify and monetise than benefits related to work environment such as safety, noise, and improved air quality. In relation to this, several of the publications addressed the issue that estimations had to made when benefits were unmeasurable or difficult to quantify. Christiansen et al. [46] and Gudbjerg et al. [47] applied an index related to the energy savings for the measure; the value of the non-energy benefits was assessed as a percentage of annual energy savings. If possible, the index was based on calculations and measurements giving objective values; however, if this was not possible, the authors based it on estimations, i.e., subjective ratings from personnel closely involved in the project. Skumatz et al. [36] also related the value of the benefits to energy savings to create multipliers for different types of measures. Similar to the approach described above, Hall and Roth [34] made their assessment based on how much various non-energy benefits changed after the implementation. According to these authors, productivity benefits led to larger monetary values than, for instance, employee morale and satisfaction. Benefits that could not be assigned monetary values were ranked in terms of the size of the change; moreover, negative values were also considered [34].

Several of the publications approached the quantification and monetisation of non-energy benefits using various types of classifications. Cagno et al. [45] classified the effects as benefits and losses which, in turn, were related to when, i.e., during which part of the investment process, the effect was observed: in relation to the implementation of the investment or during the service phase after the implementation. The time frame (time passed before non-energy effects are observed) in relation to quantifiability was also applied in Rasmussen [23] and Rasmussen [24] in constructing a framework to structure the benefits. This classification served as a means to quantify and incorporate the benefits into the investment process [23,24]. The impact of non-energy benefits on the cash flow, i.e., seeing benefits as costs and revenues, was another way to enable quantification that was proposed by both

Lung et al. [33] and Nehler and Rasmussen [21]. Nehler et al. [28] studied these aspects from the other side. These authors addressed various factors that hinder the quantification and monetisation of non-energy benefits. For instance, there seemed to be a lack of information about how to measure and quantify; moreover, experiences from the interviewed firms indicated that the process of metering and quantifying could be time-consuming and was not considered worth doing [28]. Another classification approach based on the importance of non-energy benefits to the firm was applied by Worrell et al. [48]. These authors reported that firms classified the benefits along a scale ranging from somewhat important to significantly important.

4.5. Methods for Studying the Potential of Non-Energy Benefits in Relation to Energy Efficiency Investment Decisions

After the evaluation of possible non-energy benefits from implemented measures and investments, the next step would be to consider how to make use of the benefits' potential. As displayed in Table 6, several of the reviewed articles described methods for calculating or estimating the potential of non-energy benefits, while others discussed and gave suggestions for how non-energy benefits could be included in decision-making on future energy efficiency investments and measures. Three publications did not consider the aspect of evaluating the potential at all [36,39,50].

Table 6. Methods applied to evaluate the potential of non-energy benefits in the reviewed publications in the area of non-energy benefits in industry. n/a—not available.

Author and Year	Methods Applied to Evaluate the Potential
Nehler, 2018 [39]	n/a
Nehler et al., 2018 [26]	Ranking based on non-energy benefits' importance as drivers
Krutwig and Starosta, 2017 [44]	Characterisation scheme applied in a database
Rasmussen, 2017 [24]	Framework based on time frame and quantifiability to enable the inclusion of non-energy benefits in the investment process
Cagno et al., 2016 [45]	Classification of non-energy benefits and losses to reveal their impact on the investment process
Christiansen et al., 2016 [46]	Online tool/database for energy efficiency measures in which non-energy benefits are included
Nehler and Rasmussen, 2016 [21]	Framework based on time frame and quantifiability to enable the inclusion of non-energy benefits in the investment process
Gudbjerg et al., 2014 [47]	Online tool/database for energy efficiency measures in which non-energy benefits are included
Rasmussen, 2014 [23]	Framework based on time frame and quantifiability to enable the inclusion of non-energy benefits in the investment process
Nehler et al., 2014 [28]	Suggestions on how to include non-energy benefits in the investment process
Lung et al., 2005 [33]	Conservation supply curves, payback
Hall and Roth, 2003 [34]	Ranking based on important non-energy benefits
Worrell et al., 2003 [22]	Conservation supply curves, payback
Worrell et al., 2002 [48]	Identification of the non-energy benefits which can act as drivers
Finman and Laitner, 2001 [25]	Payback
Laitner et al., 2001 [49]	Conservation supply curves, payback
Pye and McKane, 2000 [27]	Net present value, payback, internal rate of return
Skumatz et al., 2000 [36]	n/a
Gordon et al., 1999 [50]	n/a
Lilly and Pearson, 1999 [35]	Net present value, payback, cost/benefits ratios, levelised costs

As seen in Table 6, the publications approached the potential of non-energy benefits differently. Krutwig and Starosta [44], Christiansen et al. [46], and Gudbjerg et al. [47] collected data and information on energy efficiency measures and the related non-energy benefits, which served as a foundation for building databases. The objective of these databases was to be used as tools to enable the inclusion of non-energy benefits in the planning of new energy efficiency measures. In their database tool, Krutwig and Starosta [44] allowed the user to choose between 15 fixed categories of energy efficiency measures, and the output of non-energy benefits was categorised in a similar way to, for instance, Worrell et al. [22]. A measure under consideration could provide the user with possible non-energy benefits and also a calculation scheme that could be applied by the user. The authors also explained that, if detailed characteristics of the benefits were added into the tool, it would enable more precise calculations. Gudbjerg et al. [47] presented early results from the same study as Christiansen et al. [46] and the authors took a similar approach to Krutwig and Starosta [44]: a databased tool including more than 30 energy efficiency measures and four categories divided into 10 subcategories of non-energy benefits. This tool provides the user with information about how the values of the benefits were calculated, together with an estimated reliability of these values. At the time of the publication of Christiansen et al. [46], and based on data from 112 energy efficiency investments collected and included in the tool, the authors report that the value of all these investments is 1.4 times higher with non-energy benefits included than only based on energy savings.

Rasmussen [23,24], Cagno et al. [45], and Nehler and Rasmussen [21] applied another approach to take advantage of the non-energy benefits based on a classification. In the publications by Rasmussen [23,24] and Nehler and Rasmussen [21], a framework based on time frame and quantifiability was suggested. This framework aimed to enable the inclusion of non-energy benefits in the investment process by classifying them in terms of the point in time when it is possible to observe them after implementation. Furthermore, the benefits were also classified in another dimension, based on how quantifiable they were. The framework served to identify benefits with a large monetary impact on the investment process, i.e., benefits that were easily quantified and were observed soon after implementation. However, the non-energy benefits that were more difficult to monetise or appeared in longer time frames could anyway have an impact on future investments if included as extra comments in investment proposals. Cagno et al. [45] classified the additional effects of energy efficiency measures and investments as non-energy benefits and losses to reveal their impact on the investment process. These benefits and losses were further characterised by time, i.e., if the effects were observed by the time of implementation, they were designated implementation benefits/losses, or after, in which case they were designated service benefits/losses [45]. The authors argue that their model influences decisions on energy efficiency measures by considering the implementation phase and both benefits and losses.

Nehler et al. [26] and Hall and Roth [34] ranked non-energy benefits based on their general importance or on their importance as drivers. Furthermore, Nehler et al. [28] made suggestions about how to include non-energy benefits in the investment process, and in which parts of the process the benefits might have an impact that, in the long run, might contribute to making energy efficiency investments more interesting strategically for industrial firms. Worrell et al. [48] acknowledged the impact of non-energy benefits by describing them as drivers for the adoption of energy efficiency measures.

The remainder of the articles used various kinds of calculations. Payback was the simplest calculation method and was applied to include annual savings from non-energy benefits [22,33]; however, more complex methods were also used to evaluate non-energy impacts, such as net present value, and methods like cost/benefit ratios and levelised costs [35]. Conservation supply curves enable firms to forecast scenarios with non-energy benefits whereby it is more cost-effective to invest in energy efficiency measures than to buy more energy [22,33,49]. These calculation methods were applied at all levels, from impact evaluations at the specific measure level [33] to evaluations at higher levels, such as the technology/process level or the level of the industrial sector [22,48].

5. Discussion and Synthesis of the Review Findings

The analysis of the reviewed articles reveals that non-energy benefits were studied in various ways. Even though there was a lack of methodological description regarding the data collection in some of the publications, most of them applied a similar research design, consisting of some kind of case study approach; furthermore, similar methods for data collection were used, involving interviews with relevant people in relation to the observation of non-energy benefits. A few of the articles conducted literature reviews as methodological approaches instead. Non-energy benefits embrace a broad selection of phenomena and investigating them might be complex. Therefore, to grasp all types of effects, a case study methodology involving interviews conducted with people at various levels in the organisation seems to be a relevant approach in studying them. As addressed by Nehler and Rasmussen [21], there might be a risk of ambiguous answers if a questionnaire is applied; however, in less complex situations, questionnaires might be a convenient way of retrieving large amounts of data and information about non-energy benefits. Even in complex contexts, questionnaires can serve as a complementary method for triangulation in case study approaches.

In most of the reviewed articles, the level of observed non-energy benefits followed the perspective of energy efficiency applied by the articles, while the levels of reported non-energy benefits were sometimes different. Even where non-energy benefits were studied at a detailed level, in some cases, their effects were reported at a more aggregated level. It would be desirable, from the perspective of method development, to always focus on the non-energy benefits of specific measures, since knowledge of that kind can be built directly into a model for mapping the benefits, i.e., the benefits are directly attributed to the accountable measure. However, if the aim is to forecast the impact of non-energy benefits, then it might be relevant to report benefits at an aggregated level. It should be noted that information and values relating to non-energy benefits of specific energy efficiency measures and investments might be difficult to generalise to other cases, even if the same type of measure is under consideration, because every industrial firm is unique, and so are their production and processes. Hence, two similar measures might give rise to different effects depending on the firm and the related contexts. Christiansen et al. [46] also suggest that there could even be difficulties within a firm. For instance, production processes are continuously changing, and it is, thus, difficult to derive an increase or decrease in a benefit to a certain measure. Even if exact figures are collected by measurements made before and after an implementation, these figures might not be useful in future investments because these will differ from the previously evaluated ones (e.g., due to fluctuations in production). Therefore, it might be difficult to say that one specific type of measure always gives certain types of benefits or benefits of certain values. Nehler and Rasmussen [21] address another difficulty; one benefit can be observed due to various types of measures, and benefits might also have an impact on other benefits. For instance, new energy-efficient equipment can lead to improved productivity; however, improved lighting and ventilation (direct benefits) due to energy efficiency measures can also lead to improved productivity (indirect benefit); i.e., a non-energy benefit might be caused by several measures, and either directly or indirectly by other non-energy benefits, which challenges such evaluations.

Therefore, even if observed, measured, and quantified at a specific level, any attempt to generalise the values of non-energy benefits might encounter challenges. The use of indexes based on estimations as described by Christiansen et al. [46] and Gudbjerg et al. [47] or multipliers as described by Skumatz et al. [36] might be a way of circumventing this problem. As described by Christiansen et al. [46] and Gudbjerg et al. [47], any method applied in such cases should include information about how estimations and calculations were made, together with their accuracy. In some cases, it might be enough to apply rough figures if these are modest. However, as stressed by Nehler et al. [28], calculations and figures must be credible when business proposals are presented to top management.

From the conducted review, several methods for studying the potential of non-energy benefits were revealed. The procedures applied varied among them. For instance, the observation and utilisation of all kinds of possible non-energy benefits, i.e., methods that include both quantifiable and non-quantifiable benefits, might facilitate the overcoming of barriers to energy efficiency. Demonstrations of the impact of non-energy benefits through calculation methods, as presented and applied by, for instance, Lung et al. [33], Worrell et al. [22], Pye and McKane [27], and Lilly and Pearson [35], as well as other methods suggested by Cagno et al. [45], Rasmussen [23,24], and Nehler and Rasmussen [21], might be a means of overcoming economic barriers. An example of this would be the framework presented by Nehler and Rasmussen [21], which identifies benefits with a large monetary impact on the investment process, i.e., benefits that are easily quantified and observed soon after implementation. This distinction between the benefits is important because shorter payback periods are required by management according to the firms interviewed in the study [21]. However, in cases where quantification and monetisation of the benefits are difficult to do, the non-energy benefits might instead be utilised as drivers; i.e., identified and ranked benefits can act as drivers. This approach was suggested by, among others, Nehler et al. [26], Hall and Roth [34], and Worrell et al. [48].

Hence, the spread among the suggested methods for evaluating the potential of non-energy benefits could contribute to improvements in industrial energy efficiency in various ways. Therefore, the use of comprehensive methods for the utilisation of non-energy benefits might contribute to making use of the energy efficiency potential, resulting in improved industrial energy efficiency. Based on the findings from reviewing these publications on non-energy benefits within the industrial sector, a scheme (displayed in Table 7) that can guide us towards the improved utilisation of non-energy benefits was synthesised. This scheme contributes a comprehensive method for mapping the benefits to make better use of them by including all the steps: observation, measurement, quantification, monetisation, and evaluation.

First of all, the objective of the mapping must be stated. It is the mapping of possible non-energy benefits in the planning of an energy efficiency improvement that is under consideration, or the observed non-energy benefits of an implemented energy efficiency improvement, because this will decide which route to follow in the scheme. Hence, the first step would be to choose between an ex-ante perspective or an ex-post perspective. Furthermore, irrespectively of which perspective is taken, it is important to have a documented baseline; i.e., we need to know the current conditions within the firm regarding aspects such as industrial processes, production equipment, operation and maintenance, work environment, and emissions, in order to forecast and estimate, or observe, the possible non-energy effects due to a planned or implemented energy efficiency improvement.

Table 7. A guiding scheme for the improved utilisation of industrial non-energy benefits.

Ex-Post: After Implementation	**Ex-Ante: Before Implementation**
Observation	
What effects were observed since the implementation? Interview personnel and other people who might have perceived or been affected by possible effects. The interviews can also be complemented by handing out a questionnaire to concerned persons. Consider the time perspective in relation to the observation of possible non-energy benefits; benefits might arise later on, i.e., some effect(s) of implemented measures might not be observed immediately after the implementation.	What possible non-energy benefits are expected to be observed after an implementation? Interview personnel and other people who might have knowledge or experience about how an implementation of the measure will affect processes, equipment, work environment, external environment, etc. Compare with the effects observed for similar implemented measures. Consider the time perspective in relation to the observation of possible non-energy benefits, because the effect(s) of implemented measures might not be observed immediately; some of the benefits might arise later on.
Measuring	
Which of the observed non-energy benefits can be measured? Measure relevant parameters in relation to observed benefits. Compare measurements with the baseline values.	Is it possible to measure the future outcomes? Measure or calculate relevant parameters in relation to expected benefits. Compare measurements with the baseline values.

Table 7. *Cont.*

Ex-Post: After Implementation	Ex-Ante: Before Implementation
Quantification	
Which of the observed non-energy benefits can be quantified? Quantify the observed non-energy benefits based on the measurements conducted. If it is not possible to quantify the effects or if they are not measurable, quantification might be made by theoretical calculations or estimations. The use of tools such as indexes, multipliers, and classifications (see Section 4.4) could assist in the estimation process. Another approach could be to compare the effects with those observed for similar measures that were implemented before.	Is it possible to quantify the future outcomes based on the measurements? If this is not possible or if they are not measurable, quantification might be made by estimations. Another approach could be to compare the effects with those observed for similar measures that were implemented before.
Monetisation	
Which of the observed non-energy benefits can be monetised? Monetise the observed non-energy benefits based on the quantification conducted. If it is not possible to quantify the effects or if they are not measurable, monetisation might be made by theoretical calculations or estimations. The use of tools such as indexes, multipliers, and classifications (see Section 4.4) could assist in the estimation process. Another approach could be to compare the effects with those observed for similar measures that were implemented before.	Is it possible to monetise the future outcomes based on the measurements? If this is not possible or if they are not measurable, monetisation might be made by estimations. Another approach could be to compare the effects with those observed for similar measures that were implemented before.
Evaluation and impact assessment	
Which method is suitable for evaluating the potential of the non-energy benefits? If all the steps above are fulfilled, the value of the non-energy benefits can be included in investment calculations or other calculations to evaluate the benefits' impact. Consider the time perspective in the choice between various methods for economic calculations, since various methods or capital budgeting tools (e.g., payback, internal rate of return, net present value, lifecycle cost) handle the time perspective in different ways. Other suggested methods that can be applied to evaluate the potential of the non-energy benefits include conservation supply curves, database tools, or methods based on various forms of classification frameworks or rankings (see Section 4.4).	If all the steps above are fulfilled, the value of the non-energy benefits can be included in investment calculations or other calculations to evaluate the benefits' impact in planning the implementation of an energy efficiency improvement. Similarly to the ex-post evaluation, the time perspective must also be considered in the economic calculations, for instance, by offering the possibility to choose between various capital budgeting tools (e.g., payback, internal rate of return, net present value, lifecycle cost).

Hence, according to the scheme above, the mapping and evaluation of non-energy benefits will probably be based on a mixture of experience, observations, calculations, and/or estimations in various ways. Therefore, in the future design of models for the mapping and evaluation of non-energy benefits, transparency will be important. A user of such a model must have the opportunity to see how values were determined. Moreover, since non-energy benefits constitute a diverse set of phenomena, a model should enable all types of benefits at all levels within an industrial firm to be captured, for instance, by presenting examples of possible non-energy benefits related to an energy efficiency measure of a certain type or related to a specific technology or energy-using process, both quantifiable and monetisable benefits, and non-monetisable. This could also be complemented by suggestions of how these benefits might be measured, estimated, calculated, monetised, or quantified. Although the scheme for mapping and evaluation focuses on benefits, negative effects should also be considered in order to arrive at fair figures and evaluations.

A model should be able to handle both the mapping and evaluation of implemented investments and measures, and also evaluations of future investments and measures, and to forecast their impacts in various contexts, i.e., both ex-post and ex-ante evaluations. Also, the time perspective in relation to the observation of non-energy benefits must be accounted for. This is because the effects of implemented measures might not be observed immediately, which implies that a model must handle both non-energy benefits that are observed at once and those that arise later on. However, there has to be an interaction between these perspectives. Therefore, a model should be designed in a way that enables it to be developed, for instance, so that new data and information regarding non-energy benefits can be added. A deepened understanding and further knowledge about the non-energy benefits of implemented improvements will enable a better evaluation of future improvements, which hopefully will lead to better-informed investment calculations in the planning of future energy efficiency improvements.

6. Conclusions

This study contributes a review of existing publications on methods for the observation, measurement, quantification, and monetisation of non-energy benefits. Furthermore, assessments of the potential of these benefits made in the publications to predict or evaluate the potential of non-energy benefits were also compiled and structured based on the perspective applied: ex-ante or ex-post. The most commonly applied research design in the reviewed publications was some kind of case study approach, while the data collection on non-energy benefits was mainly achieved by conducting interviews with concerned persons, such as energy managers or people with similar roles. The non-energy benefits were mainly studied as the effects of specific measures and the effects of measures at the technology/process level. All the reviewed publications focused on the evaluation of implemented measures, an ex-post perspective, but some of them also made suggestions about methods for forecasting non-energy benefit impacts, i.e., an ex-ante perspective.

The review findings revealed that different types of methods were applied in order to quantify and monetise the non-energy benefits, for instance, methods based on indexes in relation to energy savings, the classification of the benefits in various ways, and frameworks to evaluate quantifiability. However, some of the articles lacked methodological descriptions of how the processes of quantification and monetisation were conducted. Most of the publications also evaluated the potential of the benefits, and various methods for doing so were presented, such as calculation methods, database tools, classification frameworks, and ranking.

Based on the findings above, a scheme for the improved utilisation of the non-energy benefits was synthesised. This scheme contributes a comprehensive take on mapping the benefits in order to make better use of them by taking all the steps into account: observation, measurement, quantification, monetisation, and evaluation (including impact assessment). Furthermore, the scheme provides a novel approach to the mapping and utilisation of non-energy benefits; it distinguishes between the two perspectives, ex-ante (planning for an implementation) and ex-post (after implementation).

Since only peer-reviewed conference articles and journal articles were included in the review, information of interest to the topic studied may have been missed due to the review criteria, which might have a limiting effect on this study. However, this review aimed to compile the academic contributions in the research field. Also, the review results are based on an analysis made by the author, and the risk of researcher bias must always be considered; however, the use of a transparent method such as a systematic literature review minimises this risk.

Even though data and knowledge in the reviewed studies were gathered from industry, this is a synthesised academic perspective on methods for the evaluation of non-energy benefits. A sound method or tool should be developed together with the users in the industry, i.e., concerned people in the organisation at different levels: economic, energy, work environment, external environment, production, etc., to assure its usefulness. This offers further possibilities to fit the method or tool to the prevailing context and conditions. For instance, the method should not only give suggestions on possible non-energy benefits in relation to a certain type of measure, but these suggestions can also be adjusted to a specific type of industrial process or a specific industrial sector. However, this requires knowledge of specific non-energy benefits in specific contexts, which could be an area for future studies to concentrate on. Further studies are also needed on specific non-energy benefits to gather information about whether and by how much the value of the benefits varies according to type of production, type of firm, conditions in the firm, firm size, etc.

Within a longer time frame and at a general level, methods for mapping non-energy benefits, as well as methods for utilising them, such as including them in investments decisions, could contribute to exploiting the potential for further energy efficiency improvements in industry.

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Appendix A

TITLE-ABS-KEY (*"non-energy benefit*"*) AND TITLE-ABS-KEY (*"energy efficien*"*)) AND (LIMIT-TO (DOCTYPE, *"ar"*) OR LIMIT-TO (DOCTYPE, *"cp"*) OR LIMIT-TO (DOCTYPE, *"re"*)) AND (LIMIT-TO (SUBJAREA, *"ENER"*) OR LIMIT-TO (SUBJAREA, *"ENGI"*) OR LIMIT-TO (SUBJAREA, *"ENVI"*) OR LIMIT-TO (SUBJAREA, *"BUSI"*) OR LIMIT-TO (SUBJAREA, "SOCI")) AND (LIMIT-TO (SRCTYPE, "j") OR LIMIT-TO (SRCTYPE, "p"))

(TITLE-ABS-KEY (*"co-benefits"*) AND TITLE-ABS-KEY (*"energy efficien*"*)) AND (LIMIT-TO (DOCTYPE, *"ar"*) OR LIMIT-TO (DOCTYPE, *"cp"*) OR LIMIT-TO (DOCTYPE, *"re"*)) AND (LIMIT-TO (SUBJAREA, *"ENVI"*) OR LIMIT-TO (SUBJAREA, *"ENER"*) OR LIMIT-TO (SUBJAREA, *"ENGI"*) OR LIMIT-TO (SUBJAREA, *"SOCI"*) OR LIMIT-TO (SUBJAREA, *"BUSI"*)) AND (LIMIT-TO (SRCTYPE, *"j"*) OR LIMIT-TO (SRCTYPE, *"p"*))

(TITLE-ABS-KEY (*"multiple benefits"*) AND TITLE-ABS-KEY (*"energy efficien*"*)) AND (LIMIT-TO (DOCTYPE, *"ar"*) OR LIMIT-TO (DOCTYPE, *"cp"*) OR LIMIT-TO (DOCTYPE, *"re"*)) AND (LIMIT-TO (SUBJAREA, *"ENER"*) OR LIMIT-TO (SUBJAREA, *"ENGI"*) OR LIMIT-TO (SUBJAREA, *"ENVI"*) OR LIMIT-TO (SUBJAREA, *"SOCI"*) OR LIMIT-TO (SUBJAREA, *"BUSI"*)) AND (LIMIT-TO (SRCTYPE, *"j"*) OR LIMIT-TO (SRCTYPE, *"p"*))

(TITLE-ABS-KEY (ancillary) AND TITLE-ABS-KEY ("energy efficien*")) AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "cp") OR LIMIT-TO (DOCTYPE, *"re"*)) AND (LIMIT-TO (SUBJAREA, "ENER") OR LIMIT-TO (SUBJAREA, "ENGI") OR LIMIT-TO (SUBJAREA, "ENVI") OR LIMIT-TO (SUBJAREA, "SOCI") OR LIMIT-TO (SUBJAREA, *"BUSI"*)) AND (LIMIT-TO (SRCTYPE, *"j"*) OR LIMIT-TO (SRCTYPE, *"p"*))

Appendix B

Table A1. A compilation of the descriptive analyses of the articles included in the systematic literature review on methods for studying the non-energy benefits of industrial energy efficiency measures. ECEEE—European Council for an Energy-Efficient Economy; ACEEE—American Council for an Energy-Efficient Economy; USA—United States of America; OECD—Organisation for Economic Co-operation and Development; IBIMA—International Business Information Management Association.

Author and Year	Publication	Type of Publication Research Design Geographical Origin Geographical Scope	Level of Energy Efficiency Improvement Measures	Level of Observed Non-Energy Benefits	Level of Reported Non-Energy Benefits
Cagno et al. (2016) [45]	Proceedings of the ECEEE Industrial Summer Study, Berlin	Conference Multiple case study Italy Italy	Specific	Specific	Specific

Table A1. *Cont.*

Author and Year	Publication	Type of Publication Research Design Geographical Origin Geographical Scope	Level of Energy Efficiency Improvement Measures	Level of Observed Non-Energy Benefits	Level of Reported Non-Energy Benefits
Christiansen et al. (2016) ** [46]	Proceedings of the ECEEE Industrial Summer Study, Berlin	Conference Multiple case study Denmark Denmark	Specific	Specific	Specific
Finman and Laitner (2001) *** [25]	Proceedings of the ACEEE Summer Study on Energy Efficiency in Industry, USA	Conference Multiple case study USA Six OECD countries including USA	Technology/process	Specific	General
Gordon et al. (1999) [50]	Proceedings of the ACEEE Summer Study on Energy in Industry, USA	Conference Multiple case study USA USA	Technology/process	Technology/process	Technology/process
Gudbjerg et al. (2014) ** [47]	ECEEE, Proceedings of the ECEEE Industrial Summer Study, Arnhem	Conference Multiple case study Denmark Denmark	Specific	Specific	Specific
Hall and Roth (2003) [34]	Proceedings of the International Energy Program Evaluation Conference	Conference Multiple case study USA USA	Technology/process	Technology/process	Technology/process, general
Krutwig and Starosta (2017) [44]	Proceedings of the 30th International Business Information Management Association Conference, IBIMA 2017, Spain	Conference Literature review, multiple case study, Romania n/a	Technology/process	Technology/process	Technology/process
Laitner et al. (2001) [49]	Proceedings of the ACEEE Summer Study on Energy Efficiency in Industry, USA	Conference Multiple case study USA USA	Specific, technology/process	Specific	Specific, technology/process, general
Lilly and Pearson (1999) [35]	Proceedings of the ACEEE Summer Study on Energy Efficiency in Industry, USA	Conference Multiple case study USA USA	Specific	Specific	Specific
Lung et al. (2005) [33]	Proceedings of the ACEEE Summer Study on Energy Efficiency in Industry, USA	Conference Multiple case study USA USA	Specific, technology/process, general	Specific, technology/process, general	Technology/process, general
Nehler (2018) [39]	Renewable and Sustainable Energy Reviews	Journal Literature review Sweden Global	Specific, technology/process	Specific, technology/process	Specific, technology/process
Nehler et al. (2018) [26]	Energy Efficiency	Journal Multiple case study Sweden Global, US and Swedish	Specific, technology/process	Specific, technology/process	Specific, technology/process
Nehler and Rasmussen (2016) [21]	Journal of Cleaner Production	Journal Multiple case study Sweden Sweden	Technology/process, general	General	General

Table A1. *Cont.*

Author and Year	Publication	Type of Publication Research Design Geographical Origin Geographical Scope	Level of Energy Efficiency Improvement Measures	Level of Observed Non-Energy Benefits	Level of Reported Non-Energy Benefits
Nehler et al. (2014) [28]	ECEEE, Proceedings of the ECEEE Industrial Summer Study, Arnhem	Conference Multiple case study Sweden Sweden	Technology/ process, general	Technology/ process, general	Technology/ process, general
Pye and McKane (2003) [27]	Resources, Conservation and Recycling	Journal Multiple case study USA USA	Specific	Specific	Specific
Rasmussen (2014) * [23]	ECEEE, Proceedings of the ECEEE Industrial Summer Study, Arnhem	Journal Literature review Sweden Global	General	General	General
Rasmussen (2017) * [24]	Energy Efficiency	Journal Literature review Sweden Global	General	General	General
Skumatz et al. (2000) [36]	Proceedings ACEEE Summer Study on Energy Efficiency in Buildings	Conference Multiple case study USA USA	Technology/ process	Technology/ process	Technology/ process, general
Worrell et al. (2003) *** [22]	Energy	Journal Multiple case study USA Six OECD countries including USA	Specific, technology/ process	Specific	Specific, technology/ process, general
Worrell et al. (2002) [48]	Energy Engineering: Journal of the Association of Energy Engineering	Journal Literature review, multiple case study USA Global	Specific, technology/ process	Technology/ process	Technology/ process

* Rasmussen [23] is previous version of Rasmussen [24]. ** Gudbjerg et al. [47] present early results of Christiansen et al. [46]. *** Worrell et al. [22] and Finman and Laitner [25] are based on the same dataset.

Appendix C

Table A2. A compilation of the methods applied to the study of the non-energy benefits of industrial energy efficiency measures in the reviewed articles. ECEEE—European Council for an Energy-Efficient Economy; ACEEE—American Council for an Energy-Efficient Economy; USA—United States of America; IBIMA—International Business Information Management Association; n/a—not available.

Author and Year	Publication	Methods for Data Collection	Methods for Quantification and/or Monetisation	Methods Applied to Evaluate the Potential
Cagno et al. (2016) [45]	Proceedings of the ECEEE Industrial Summer Study, Berlin	Interviews	Classification framework based on type of non-energy benefits	Classification of non-energy benefits and losses to reveal their impact on the investment process
Christiansen et al. (2016) [46]	Proceedings of the ECEEE Industrial Summer Study, Berlin	Interviews	Index based on calculation or estimations which relates to the energy savings	Online tool/database for energy efficiency measures in which non-energy benefits are included

Table A2. *Cont.*

Author and Year	Publication	Methods for Data Collection	Methods for Quantification and/or Monetisation	Methods Applied to Evaluate the Potential
Finman and Laitner (2001) [25]	Proceedings of the ACEEE Summer Study on Energy Efficiency in Industry, USA	n/a	n/a	Payback
Gordon et al. (1999) [50]	Proceedings of the ACEEE Summer Study on Energy in Industry, USA	Interviews	n/a	n/a
Gudbjerg et al. (2014) [47]	ECEEE, Proceedings of the ECEEE Industrial Summer Study, Arnhem	Interviews	Index based on calculation or estimations which relates to the energy savings	Online tool/database for energy efficiency measures in which non-energy benefits are included
Hall and Roth (2003) [34]	Proceedings of the International Energy Program Evaluation Conference	Interviews	Assessment based on the degree of change, i.e., how much non-energy benefits changed after implementation	Ranking based on important non-energy benefits
Krutwig and Starosta (2017) [44]	Proceedings of the 30th International Business Information Management Association Conference, IBIMA 2017, Spain	Literature review, interviews	n/a	Characterisation scheme applied in a database
Laitner et al. (2001) [49]	Proceedings of the ACEEE Summer Study on Energy Efficiency in Industry, USA	n/a	n/a	Conservation supply curves, payback
Lilly and Pearson (1999) [35]	Proceedings of the ACEEE Summer Study on Energy Efficiency in Industry, USA	Meetings with concerned people in the firm	n/a	Net present value, payback, cost/benefits ratios, levelised costs
Lung et al. (2005) [33]	Proceedings of the ACEEE Summer Study on Energy Efficiency in Industry, USA	n/a	Assessment based on non-energy benefits as reduced costs and increased revenues	Conservation supply curves, payback
Nehler (2018) [39]	Renewable and Sustainable Energy Reviews	Interviews	- ****	n/a
Nehler et al. (2018) [26]	Energy Efficiency	Interviews, questionnaire	- ****	Ranking based on non-energy benefits' importance as drivers
Nehler and Rasmussen (2016) [21]	Journal of Cleaner Production	Interviews, questionnaire	Classification of non-energy benefits as costs and revenues	Framework based on time frame and quantifiability to enable inclusion of non-energy benefits in the investment process
Nehler et al. (2014) [28]	ECEEE, Proceedings of the ECEEE Industrial Summer Study, Arnhem	Interviews	Barriers to quantification and monetisation	n/a
Pye and McKane (2003) [27]	Resources, Conservation and Recycling	n/a	n/a	Net present value, payback, internal rate of return
Rasmussen (2014) [23]	ECEEE, Proceedings of the ECEEE Industrial Summer Study, Arnhem	Literature review	Framework based on time frame and quantifiability	Framework based on time frame and quantifiability to enable inclusion of non-energy benefits in the investment process

Table A2. *Cont.*

Author and Year	Publication	Methods for Data Collection	Methods for Quantification and/or Monetisation	Methods Applied to Evaluate the Potential
Rasmussen (2017) [24]	Energy Efficiency	Literature review	Framework based on time frame and quantifiability	Framework based on time frame and quantifiability to enable inclusion of non-energy benefits in the investment process
Skumatz et al. (2000) [36]	Proceedings ACEEE Summer Study on Energy Efficiency in Buildings	Interviews	Relative to the energy savings, multiplier.	n/a
Worrell et al. (2003) [22]	Energy	n/a	n/a	Conservation supply curves, payback
Worrell et al. (2002) [48]	Energy Engineering: Journal of the Association of Energy Engineering	Literature review	Classification of the non-energy benefits based on their importance to the firm (from somewhat important to significant importance)	Identification of the non-energy benefits which can act as drivers

* Rasmussen [23] is previous version of Rasmussen [24]. ** Gudbjerg et al. [47] present early results of Christiansen et al. [46]. *** Worrell et al. [22] and Finman and Laitner [25] are based on the same dataset. **** The aim of the publication did not include quantification or monetisation of non-energy benefits.

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