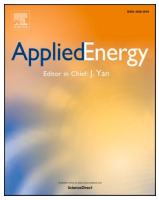
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How do companies manage energy? A systematic literature review on energy cost accounting, energy efficiency, and energy management

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HIGHLIGHTS

- There is a lack of empirical research on corporate energy practices.
- Descriptions of energy cost allocation and measurement practices are rare.
- Energy efficiency measures lack standardization and comparability.
- Simple financial criteria dominate in assessing energy investments.
- Practices on energy management are fragmented and inconsistent.

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ABSTRACT

It is imperative to recognize the indispensable role energy plays in sustaining business operations. Nevertheless, energy and topics associated with energy are often neglected, despite the crucial nature of information on energy consumption for the needs of managers in decision-making and the act of managing a company. As energy and its application are interdisciplinary topics, information is scattered throughout the literature. Consequently, the absence of a comprehensive study systematically collecting, describing and analyzing the current state of knowledge is striking. To address this deficiency, this systematic literature review synthesizes information from 39 papers published in 19 journals. The extracted contents of the papers were categorized, summarized, and analyzed according to their contribution toward first and second stage allocation of energy costs, energy measurement, energy efficiency, energy strategy, and energy-related investment decisions. The results of the study indicate a significant research gap in empirical investigations. The interdisciplinarity of the investigated topics leads to scattered information and frameworks for a structured analysis of corporate energy cost practices are lacking. To address this gap, this paper develops a framework for the collection of information on corporate energy practices based on the findings. This article puts forth the proposition that empirical investigations of corporate energy practices warrant scholarly attention. Such empirical studies need to find out what practice is doing, as the depth of the current state of literature is inadequate.

1. Introduction

"People do not want energy itself, but rather the services that energy provides and the products that rely on these services" [1]. In their innovative study on future net-zero emissions energy systems, Davis et al. [1] outline the importance of the often implicit relevance of accounting for and managing energy to achieve more sustainable corporate practices. This special relationship between sustainable corporate practices, carbon emissions, energy costs, and energy management emphasizes that interdisciplinary approaches are necessary to tackle these topics. Research on these topics is dispersed across various streams in the literature, however. The key to this literature review is to bring together complementary insights from various disciplines. Energy management requires data that builds on energy cost accounting, which captures the financial dimension of energy efficiency.

One pillar of this systematic literature review is *energy cost accounting*. For environmental management purposes, information on energy and its association with costs and products are of particular relevance in both the short- and long-term perspective [2]. To address these purposes, energy cost accounting information can be considered relevant to

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three different needs of managers [3–5]: attention directing, problem-solving, and scorekeeping. Information on energy consumption and energy costs draws management attention to opportunities and problems, provides information about potential solutions, and informs about whether the company is moving in the right direction or not [3]. To tackle this information need, the literature covers straightforward (conventional) energy cost accounting approaches on the one hand [6]. On the other hand, methods like Material Flow Cost Accounting (MFCA) [6,7] enlighten additional perspectives. Most often, significant energy costs are part of the overhead cost and hence, recorded as indirect costs [8], leaving energy as a large unmanaged potential [9]. A central topic for energy cost accounting is the allocation of energy costs to cost centers (1^{st} stage allocation) and cost objects (2^{nd} stage allocation). This allocation can be observed on several allocation bases, mainly addressing organizational considerations [10] or physical circumstances [10,11]. While several contributions to the literature describe 1^{st} stage energy cost allocation [12–15], 2^{nd} stage allocation is underdeveloped [16]. However, allocating consumed energy is never as accurate as a correct measurement. Such energy measurements are often done in a rather simple manner by utility companies and other suppliers for invoicing purposes [16]. Nevertheless, more or less sophisticated approaches to sub-metering are described [17–20].

As the second pillar, this review investigates *energy efficiency*. The usage of energy in a comparable and measurable way is needed, so improvements in energy efficiency practice are quantifiable. Energy efficiency has been investigated in different settings and industries [21–24]. This was often explored in the form of case studies, which either focus on one specific industry [21,22,25] or cover several industries [23,24,26]. Moreover, drivers and barriers to energy efficiency have been investigated and described [21,27–31]. Furthermore, the literature provides significant advances for measuring energy efficiency through metrics [32–39]. For a systematic and sustainable implementation of energy efficiency metrics, a long-term energy strategy is a necessity [40,41]. The incorporation of energy strategies is the subject of investigation in the literature [10,20,42,43]. Nevertheless, in prior studies [11,44] even companies in energy-intense industries did not always have an energy strategy.

The third pillar of this review is *energy management*, which generally aims to improve the handling of energy in companies toward a more efficient and ecological usage of energy without neglecting productivity. Around this topic, a body of literature [e.g., 45–49] has developed. The application of energy management to manufacturing systems promotes energy savings [50]. Subsequently, energy-related investment decisions are crucial for ensuring such sustainable growth. Hence, the question of how to assess and compare different investment opportunities arises. The literature knows about straightforward methods like payback time [23,43,51], but also more sophisticated approaches like the internal rate of return [11,52] or net present value [17,53].

Given the diversity of approaches identified across these three pillars, this review draws on contingency theory [54–61] from the management accounting literature to conceptually frame this variation. Contingency theory states that the design and effectiveness of management accounting systems depend on contextual factors like industry, organizational structure, regulatory environment, and technological infrastructure. This appears to be a valid assumption for our context of corporate energy practices and may explain differences between organizations and sectors. While this review does not apply contingency theory empirically, acknowledging its relevance helps to interpret the scattered empirical findings, it maps this review into the literature, and supports more targeted recommendations for future research.

Although prior research significantly increased the knowledge of companies' energy management practices and energy cost accounting information availability, several aspects are still not addressed sufficiently. For instance, the question arises, which impact technological innovations (such as the internet of things or artificial intelligence) in the past few years, have on energy cost accounting, energy metering, or energy management more broadly. In addition, while studies often investigate the underlying phenomena in (sector-)specific settings, a comprehensive investigation without restrictions to certain areas, which enables the identification of clear patterns, is still missing. Moreover, only little is known about energy-related investment decisions and how information on energy costs is utilized for that purpose. Subsequently, a comprehensive overview of energy cost accounting, energy efficiency, and energy management in practice is lacking, calling for a systematic literature review.

This review fills this gap by systematically reviewing studies from a wide range of literature, synthesizing information on how companies allocate, measure, assess, or more broadly quantify energy costs and energy efficiency. The objectives of this systematic literature review are threefold: First, to systematically synthesize empirical findings on corporate energy practices regarding energy cost accounting, energy efficiency, and energy management. Second, to critically evaluate existing methodologies, metrics and frameworks. Third, to identify and clarify gaps in the literature that future research should address. This systematic literature review fulfills these objectives, as it consolidates and critically evaluates the current state of knowledge and identifies key trends, methodologies, and research gaps. Further, systematic literature reviews analyze and synthesize existing contributions, delivering clear and conclusive insights for future research and managerial practice [62]. Moreover, literature reviews synthesize knowledge that can foster advancements in practice and policymaking to address societal challenges [63]. Hence, the insights of this review contribute to a deeper understanding of organizations' approaches toward the management of energy and its associated costs. Additionally, this study investigates how investments in energy and energy efficiency are assessed and how energy strategies are incorporated. For this purpose, the review is guided by the following research questions:

RQ 1: "What is known in the literature on empirical investigations on energy management and energy cost accounting?"

RQ 2: "What is known in the literature on methodologies and concepts of energy cost accounting in industry and manufacturing environments?"

This paper presents a systematic literature review of empirical studies on energy cost accounting, energy efficiency, and energy management in manufacturing companies. Two reviews conducted previously are most closely related to this review. The review by Mickovic and Wouters [16] highlights limited empirical research, insufficient detail on energy costs measurement and allocation, and a lack of cost information. Further, the review by Schulze et al. [64] emphasizes key elements of energy management, suggest future research for this evolving research field, and criticize a shortage of company-level studies. Both Mickovic and Wouters [16] and Schulze et al. [64] summarize research in the fields of energy management, energy cost accounting, or more broadly, companies' energy practices. However, the review at hand is more than an update as it extends the discussion in several directions. Besides the difference in the investigated timeframe, the focus of the previous reviews differ from this as they have a single focus on either energy cost information [16] or energy management [64], while this review combines both fields alongside additional facets to gather a comprehensive overview of corporate energy practices. Moreover, this review is the first to systematically combine the topics of energy measurement, energy cost allocation, energy efficiency, energy strategies, and energy-related investment decisions. Hence, presenting this comprehensive overview provides in-depth information for practitioners, policymakers and scholars.

This review contributes to the literature in several ways: Firstly, it provides an overview of the latest developments in the literature. The results lay the foundation for future research or change in organizational settings by providing information on what companies are doing in practice and hence, best practices are identified. Secondly, this review is the first to tackle the topics of energy efficiency and energy efficiency metrics in detail without focusing on narrow industries [65–67] or sectors [68–70]. This provides an understanding of how metrics are

defined, measured, and applied. Furthermore, it ensures consistency and comparability toward energy efficiency metrics for practitioners and may lay the foundation for developing more robust energy efficiency metrics in the future, which will improve energy efficiency assessment. Thirdly, the results of this review point out avenues for future research. For instance, no paper in the sample provided information on energy cost centers, even though they have been described and applied in prior literature [6,19,71]. Moreover, while not excluding them by design, there were no papers in the final sample that specifically investigated corporate energy practices in the North American or Australian continent, although these are areas of interest for energy topics in the corporate context. This geographic bias in the sample of papers may affect the generalizability of this review's findings. However, this absence does not automatically indicate a lack of researchers' interest as it also could be linked to a certain maturity as there are papers investigating these areas prior to the timely scope of this review [e.g., [9,12,42,72,73]. Nevertheless, future research should address these geographical areas specifically. Additionally, there are still not enough studies describing energy cost allocation practices, energy measurement, or energy strategies in detail, providing opportunities for future research. Fourthly, this review highlights the absence of a comprehensive framework for systematically and clearly detailing and describing a company's energy practices. This lack of clarity hinders reliable comparisons between companies and complicates effective benchmarking, which subsequently impedes a sustainable improvement of a company's energy efficiency.

The systematic literature review is structured as follows: Section 2 outlines the methodological approach for constructing the sample of papers, including search strategy, selection criteria and the framework for the analysis. Section 3 synthesizes empirical findings from the sample of papers, focusing on energy cost center, energy cost allocation, energy cost measurement, energy efficiency, energy strategy, and energy-related investment decisions. Section 4 discusses these findings and maps them to the literature. Finally, section 5 concludes and provides specific recommendations for future research.

2. Research method

This paper performs a systematic literature review following the guidelines of Tranfield et al. [74], which involves a structured and replicable process to identify, evaluate, and synthesize relevant publications on energy cost accounting, energy efficiency, and energy management. The research is building on prior reviews by Mickovic and Wouters [16] and Schulze et al. [64], but is more than a simple update. First, this section describes the method for identifying and selecting sample of papers, while subsequently introducing the content analysis.

2.1. Constructing the sample of papers

The search is conducted using an adequate search string that includes combinations of terms related to energy cost accounting, energy efficiency, and energy management, which is summarized in Fig. 1. The databases *Scopus* and *Web of Science* are used for this literature search. The final search terms include "*energy measur**", "*energy management*", "*energy metering*", "*cost accounting*" in the title and "*industry*", "*manufacturing*", "*empirical*", and "*energy cost accounting*" in the title, abstract, or keywords. The asterisk (*) is used to include different variants of the word stem "*measur*", such as measuring, measurement(s), or measure. The search was limited to articles and reviews, as this systematic literature review focuses on the current state of empirical information on corporate energy practices in peer-reviewed academic literature. Consequently, gray literature such as books or reports, though potentially informative, is outside the scope. To capture the dynamic landscape of new developments, the review includes publications since 2018, covering the period after the most recent review by Mickovic and Wouters [16]. This allows us to assess how previously identified research gaps and limitations have been addressed and whether they remain relevant. There is no limit for the search process to specific journals as results from a vast amount of research areas are relevant. Concluding, the specific search string is defined as follows: *((TITLE (energy measur*) OR TITLE (energy management) OR TITLE (energy metering) OR TITLE (cost accounting)) AND (TITLE-ABS-KEY (industry) OR TITLE-ABS-KEY (manufacturing) OR TITLE-ABS-KEY (empirical*) OR TITLE-ABS-KEY (energy cost accounting)) AND (DOCTYPE (ar OR re)) AND (PUBYEAR > 2017) AND (LIMIT-TO (LANGUAGE, "English")))*. This search string is run on both databases with minor (technical) adjustments due to the different search engines and yielded 1,430 publications in *Scopus* and 1,064 publications in *Web of Science*. As indicated in Fig. 2, this leads to 2,494 publications in total.

This literature review follows the steps proposed by Tranfield et al. [74] and is illustrated in Fig. 2. After removing duplicates using an Excel query and the DOI as primary key, 1,495 papers remain. All subsequent

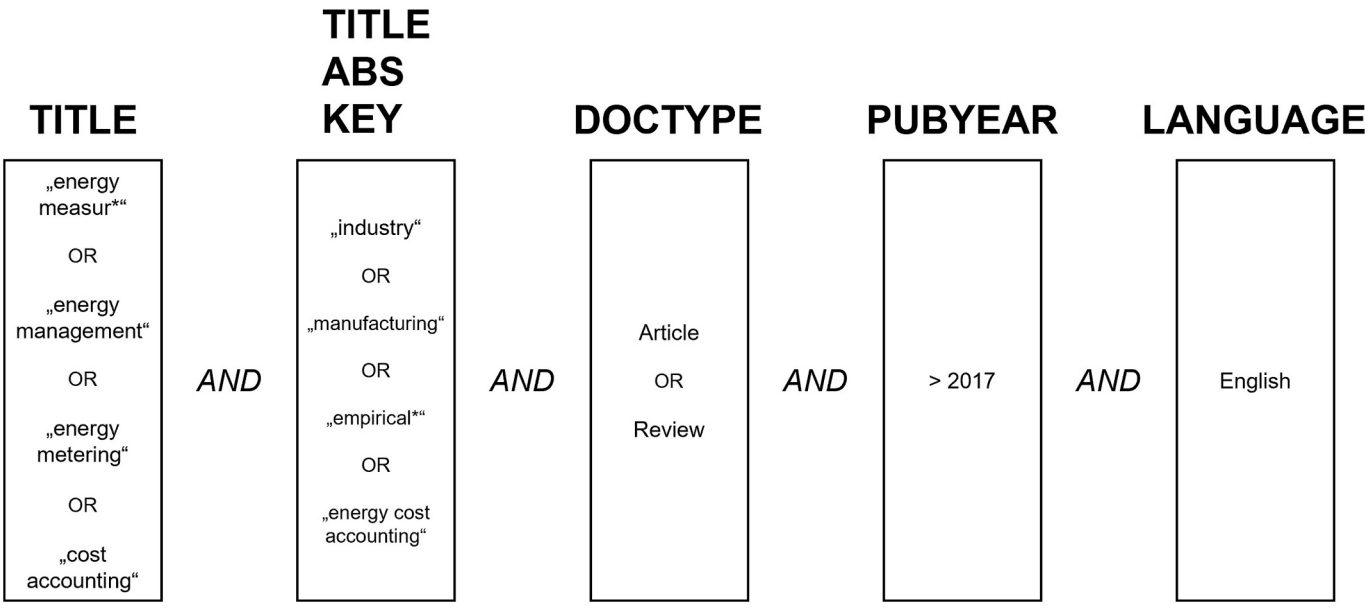


Fig. 1. Construction of the search string for the systematic literature review

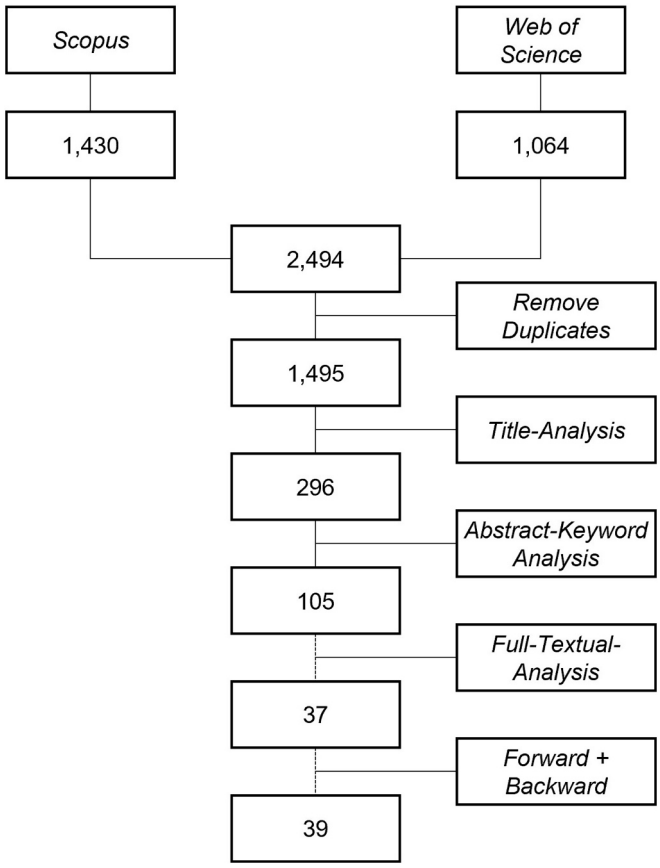


Fig. 2. Literature search process for the systematic literature review using Elsevier's Scopus database and Web of Science

steps were performed manually. In the next step, the title analysis, 1,199 papers are removed, which results in 296 papers. A huge share of papers are excluded as they for example, deal with very technical topics like batteries in electric vehicles [e.g., [75]], topics concerning energy grids [e.g., [76]], or topics associated with natural science like biology [e.g., [77]]. 105 papers remain after the abstract-keyword analysis, which marks the next step of the systematic literature review. This reduction happens after eliminating papers focusing on a country-level instead of a company-level point of view [e.g., [78]], theoretical considerations or frameworks that are not applied in industry or a manufacturing environment [e.g., [79]], or topics being more about technical aspects of energy (for example, its generation) [e.g., [80]]. After the penultimate step, the full-textual analysis, 37 papers remain. Papers are excluded as they do not provide relevant information on a company level, although they initially seemed promising [e.g., [81,82]], focus on the description of methods without an empirical component sufficient enough for the scope [e.g., [83]], or simply do not match the focus of this review as they, for example, deal with things like energy efficiency metrics in the public sector [e.g., [84]]. Additionally, by evaluating the references (backward) and using Google Scholar to identify more recent publications citing a specific paper (forward), 2 additional papers are included, which leads to the final set of 39 papers, displayed in Fig. 2.

2.2. Content analysis

In the next step, the content of the final set of 39 papers is analyzed. Table 1 shows the attributes defined for the investigation, while Table 2 provides a detailed description of these attributes. The attributes concern characteristics of the company investigated in the paper, as well as the corresponding energy cost accounting, energy efficiency, and energy management practices.

The extensive literature review table consists of 22 different attributes covering three domains and bibliographical data. This table provides all available information on each paper of the sample and can be found in the appendix. It aims to suit various readers with different information needs by presenting information in the three different domains. These three domains deal with descriptive information, categorized information, and detailed information. For instance, readers striving for a fast overview of their particular field of interest could use the categorized information, which is also summarized in the condensed Table 5 at the end of section 3. On the other hand, readers interested in specific details in their particular field of interest can dive deep into the detailed information in the appendix.

Information on the bibliographic data (authors and year) can be found unnumbered in the upper left corner of the literature review table. This is followed by descriptive information in attributes **[A]** to **[F]**. These attributes are filled without restriction and enable the reader to find information describing the paper's case and empirical information. Attributes **[G]** to **[N]** are categorized to provide a fast overview to readers. Hence, only predetermined entries are possible. These categorized entries are ***YES***, ***y***, ***n***, and ***NO***, with each indicating a different meaning, where ***YES*** depicts the strongest category, indicating a very detailed description of an attribute's representation. A less detailed description is represented by ***y***, indicating an explanation in some detail. A sole mention of an attribute's representation without any detailed description is indicated by ***n***. Total absence of an attribute and its representation is indicated by ***NO***. Consequently, ***YES*** and ***y*** represent a recommendation to read up the paper if the readers are interested in the attribute, while ***n*** and ***NO*** represent that the paper is not recommended if readers want to be informed about this attribute. Attributes **[O]** to **[V]** are filled without restriction and provide detailed descriptions of the attributes, with each referring to one (or two in case of **[P]**) of the categorized attributes. The last two attributes are exceptions, as they focus on the application of Specific Energy Consumption (SEC) **[U]** and summarize the quantitative information on energy costs **[V]**.

Following this approach enables the representation of an organized presentation of the literature and hence, answering the research questions. By providing information at different levels of detail, various information needs are addressed, and a transparent overview of the literature is provided. Hence, a literature review's aims of mapping and assessing the literature set by Tranfield et al. [74] are satisfied. Moreover, the categorized attributes enable readers to rapidly identify papers worthwhile to read, while the detailed information enables them to filter on a deeper level on whether this paper is addressing their specific information needs.

3. Results

This section presents the findings and results of the systematic literature review. After presenting descriptive results, the subsequent section covers the results of the content analysis.

3.1. Descriptive analysis

The 39 papers of the final sample are distributed across 19 journals as listed in Table 3. One journal published the largest number of papers: The *Journal of Cleaner Production,* with 9 publications accounting for almost a quarter of all studies in the sample.

Fig. 3 and Table 4 both illustrate the geographical distribution of the companies investigated, while a paper can investigate more than one country. Except for North America and Australia, these companies are spanning all over the world, showing a global interest in these topics. Nevertheless, a regional emphasis can be seen in Europe and Asia, with a very dominant focus on Sweden (seven) and Italy (five). Most studies were conducted in Europe (22). It is worth mentioning that the United States as the world's largest economy and North America per se are not represented.

Table 1
Literature review table

Authors	Year	[A] Research Method	[B] # of Companies	[C] Industry	[D] Company Size	[E] Energy Intensity	[F] Energy Mix	[G] Energy Cost Center	[H] 1st Stage Allocation	[I] 2nd Stage Allocation	[J] Measurement of Energy	[K] Energy Audit	[L] Energy Efficiency	[M] Energy Strategy	[N] Investment Decisions
		[O] Description of energy cost center													
		[P] Description of allocation of energy costs													
		[Q] Description of energy measurement													
		[R] Description of energy efficiency													
		[S] Description of energy strategy													
		[T] Description of investment and criteria													
		[U] Description of application of Specific Energy Consumption (SEC)													
		[V] Summary of quantitative information on energy costs													

Table 2
Description of attributes used in the literature review table and analysis

Attribute	Description
Research Method	The research methodology applied in the paper.
# of Companies	The number of companies investigated in the empirical analysis of the paper.
Industry	The industry in which the focal company/companies is/are operating.
Company Size	The size of the focal company/companies investigated.
Energy Intensity	An economic indicator of whether energy consumption and its corresponding costs are critical for a company or not.
Energy Mix	The composition of the mix of energy sources and energy carriers used by the focal company/companies.
Energy Cost Center	A cost center that is specifically established to manage tasks like energy generation and/or supply for other cost centers.
1st Stage Allocation	The allocation of energy costs from a central point of measurement (i.e. invoice) to cost centers using a specified allocation base.
2nd Stage Allocation	The allocation of energy costs from cost centers to final cost objects (i.e. products or services) using a specified allocation base.
Measurement of Energy	The practice of quantifying and tracking energy consumption and its corresponding energy costs based on direct measurements.
Energy Audit	The systematic assessment of energy use within a company, aimed at identifying inefficiencies and opportunities for improvement.
Energy Efficiency	The systematic reduction of energy consumption relative to the output, represented through metrics.
Energy Strategy	The development and articulation of specific targets and actionable plans for improving energy efficiency and energy management.
Investment Decisions	Investment decisions related to capital expenditures aimed at reducing energy consumption (i.e., improving energy efficiency through the purchase of a new machine) and criteria and evaluation methods used for assessing these investment decisions.

Table 3
Sample of 39 papers published in 19 journals

Journal	Number of papers
Applied Energy	2
British Food Journal	1
Chemical Engineering & Technology	1
Cleaner Energy Systems	1
Cleaner Environmental Systems	1
EAI Endorsed Transaction on Energy Web	1
Energies	3
Energy	5
Energy Efficiency	2
Energy Policy	2
Energy Reports	1
Energy Strategy Reviews	2
Environmental Science and Pollution Research	1
International Journal of Computer Integrated Manufacturing	1
International Journal of Energy Economics and Policy	2
Journal of Cleaner Production	9
Journal of Industrial Ecology	1
Proceedings of the Estonian Academy of Sciences	1
Sustainability (Switzerland)	2
Total	**39**

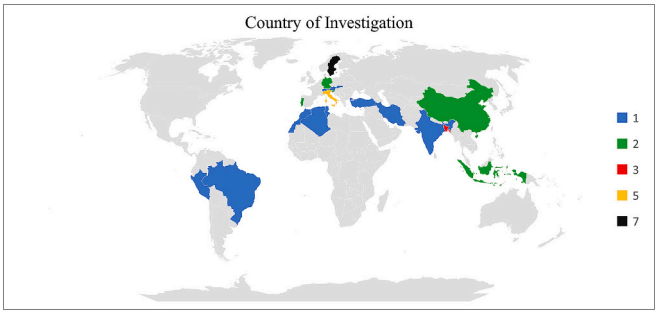


Fig. 3. Number of studies investigating each country

Fig. 4 displays the distribution of the papers in the sample over time, from 2018 onwards. Although 2019 led by providing eight published papers, a clear trend is not recognizable. However, it should be noted that the search was conducted in August 2024 and hence, publications for 2024 are incomplete.

Table 4
Number of studies investigating each country. Note that studies can take place in more than one country

Country	Number of papers
Algeria	1
Austria	1
Bangladesh	3
Brazil	1
China	2
European Union	1
Germany	2
India	1
Indonesia	2
Iran	1
Italy	5
Morocco	1
Peru	1
Portugal	2
Slovakia	1
Slovenia	2
Sweden	7
Switzerland	1
Tunisia	1
Turkey	1
Unknown	4
Worldwide	1

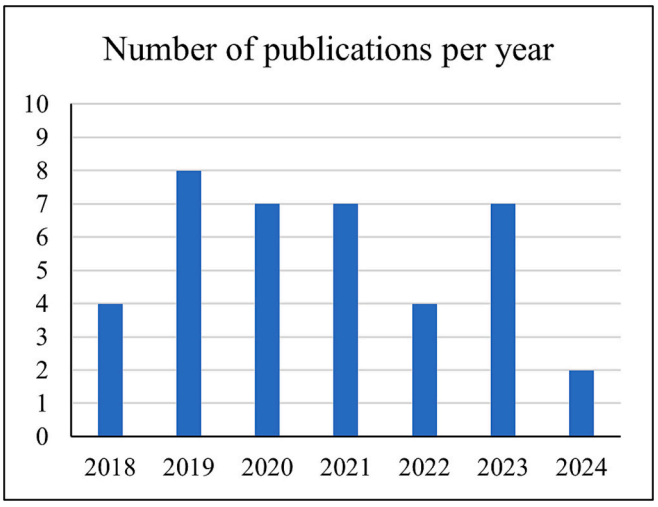


Fig. 4. Distribution of the sample papers by year

The research method is addressed referring to attribute [A], while each paper can be labelled with more than one research method. Hereby represents *archival data*, data gathered from sources as for instance publicly available data provided by the European Union or the United Nations. The term *case study* is defined as an in-depth investigation of company practices and procedures within one company, while *interviews* are referring to the collection of qualitative data, basically through the usage of open questions and potentially guided by interview guides. A *multiple case study* follows the definition of a case study but is executed in several companies. Lastly, the label *questionnaire* was assigned if empirical data was collected through the usage of questionnaires and surveys, whereby most questions had closed answer possibilities, such as multiple choice or Likert-scale questions. As displayed in Fig. 5, most papers are based on single case studies (12) or questionnaires (12).

Strongly related to the research method is the question of how many companies a single paper is studying, which refers to attribute [B] and ranges from 1 to 12,087. As shown in Fig. 6, most papers study either one company (10) or fewer than ten (8), while one outlier [85] is even analyzing 12,087.

Addressing attribute [C], Fig. 7 is offering information on the number of studies conducted in each industry, while each paper can be labelled with more than one industry. It is striking that more than half of

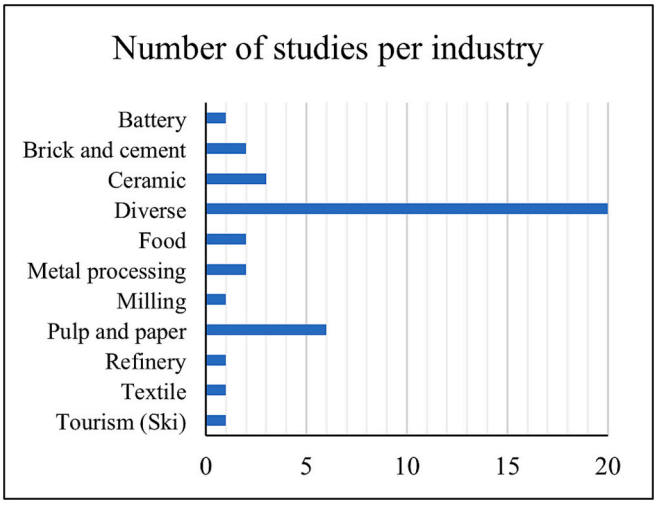


Fig. 5. Distribution of the sample papers by industry

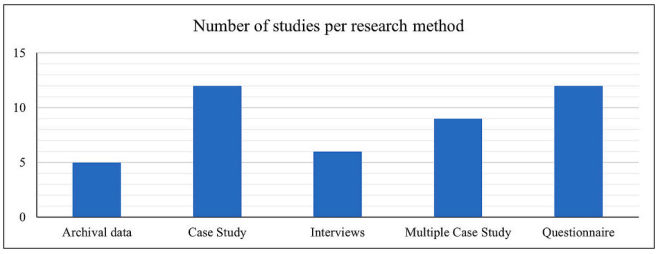


Fig. 6. Distribution of the sample papers by research method

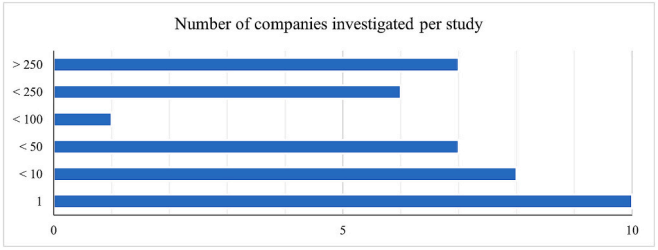


Fig. 7. Distribution of the sample papers by number of companies investigated in the study

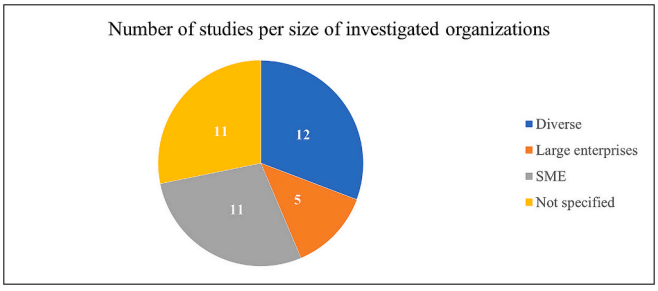


Fig. 8. Distribution of the sample papers by size of the investigated organizations

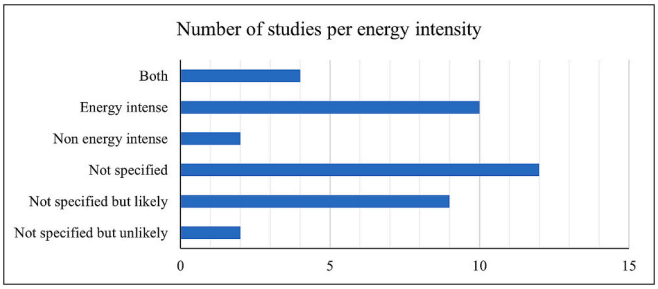


Fig. 9. Distribution of the sample papers by the energy intensity of the investigated companies

the papers (20) are addressing several industries, are not stating which industry they are investigating, or simply have a sample size that does not pay attention to a homogenous industry composition. Those papers dealing with a certain industry or addressing one are most often investigating the pulp and paper industry (6).

The size investigated company size is addressed in attribute [D]. Fig. 8 highlights that in contrast to the results of Mickovic and Wouters [16], the focus has shifted away from solely investigating large enterprises. However, many papers (11) do not even address the size of the investigated company. Most papers (12) are investigating a diverse peer group of small, medium-sized and large enterprises.

Attribute [E] addresses the energy intensity of the investigated companies. Fig. 9 highlights that in a majority of cases (23), there was no specification on whether the companies dealt with are energy intense or not. However, due to the circumstances (e.g., the industry) outlined in the paper, nine of them appear to likely study energy intense companies, while two of them appear to likely study non energy intense companies. Nevertheless, it is intriguing that only two papers actively investigate non energy intense companies.

Attributes [G] to [N] in Table 6 are addressing the Energy Cost Center, 1st and 2nd Stage Allocation, Energy Measurement, Energy Efficiency, Energy Audit, Energy Strategy, and Energy-related Investment Decisions. These findings are classified (see Fig. 10), with the dominant classification being *NO* and *n*, which represents no finding and denotes scattered information in the literature. Hence, many papers focus on detailed aspects and only very few papers focus on broader concepts. However, taking a closer look at the different categories reveals that especially the field of allocation is quite underdeveloped, while on the other hand, every paper at least mentions the concept of energy efficiency. Nevertheless, most papers (5) go into further detail on energy measurement and energy efficiency. Table 5 is summarizing the occurrence of categorized attributes in the sample of papers to provide an overview.

3.2. Content analysis

3.2.1. Energy Cost Center

Energy costs are not treated in a special cost center. Although initially described by Bierer and Götze [6] and later on applied by Dobes [19] and Sucic et al. [71], no paper in the sample is describing or even referring to an energy cost center.

3.2.2. Energy Cost Allocation

Detailed descriptions of energy cost allocation practices are still lacking in the literature. Although not specifically providing information on energy cost allocation, several papers mention the importance of allocation [86–90]. Dekamin et al. [91] for instance, do not provide further information but allocate their energy costs according to their application of MFCA.

The application of both 1st and 2nd stage energy cost allocation is seldom described in detail. Trianni et al. [92] provide a framework for benchmarking energy management practices and list energy cost allocation as one. They classify four levels of energy cost allocation, ranging from ‘no energy-specific cost allocation’ to ‘process specific energy cost allocation’. However, they do not go in detail on how they assess the energy cost allocation practice of their case companies. Viesi et al. [93] describe 2nd stage allocation of energy consumption in their case study of an Italian skiing resort by allocating the measured energy from each cost center (ski lift) to the final KPIs on the basis of skier-days (1 person skiing 1 day). Moreover, Dekamin et al. [91] describe energy cost allocation to final products according to MFCA. Besides these occurrences – and they are not 2nd stage cost allocation in the traditional way – no description of 2nd stage allocation could be observed, leaving very high demand for future empirical studies.

3.2.3. Energy Cost Measurement

The methods and granularity of energy measurement are central in advancing both the practice of energy cost accounting and the effectiveness of energy management initiatives. Examining recent empirical studies reveals significant variation in measurement approaches, underscoring the ongoing need for standardized protocols.

Insights into energy measurement practices reveal three key dimensions of energy measurement granularity: the energy carrier, the frequency, and the unit of measurement. The literature reports detailed measurements for various energy carriers, including gas [94–97], electricity [65,86,94,96–98], heat [86], compressed air [98], coal [94], diesel [96] as well as total energy consumption [66,92]. Simultaneously,

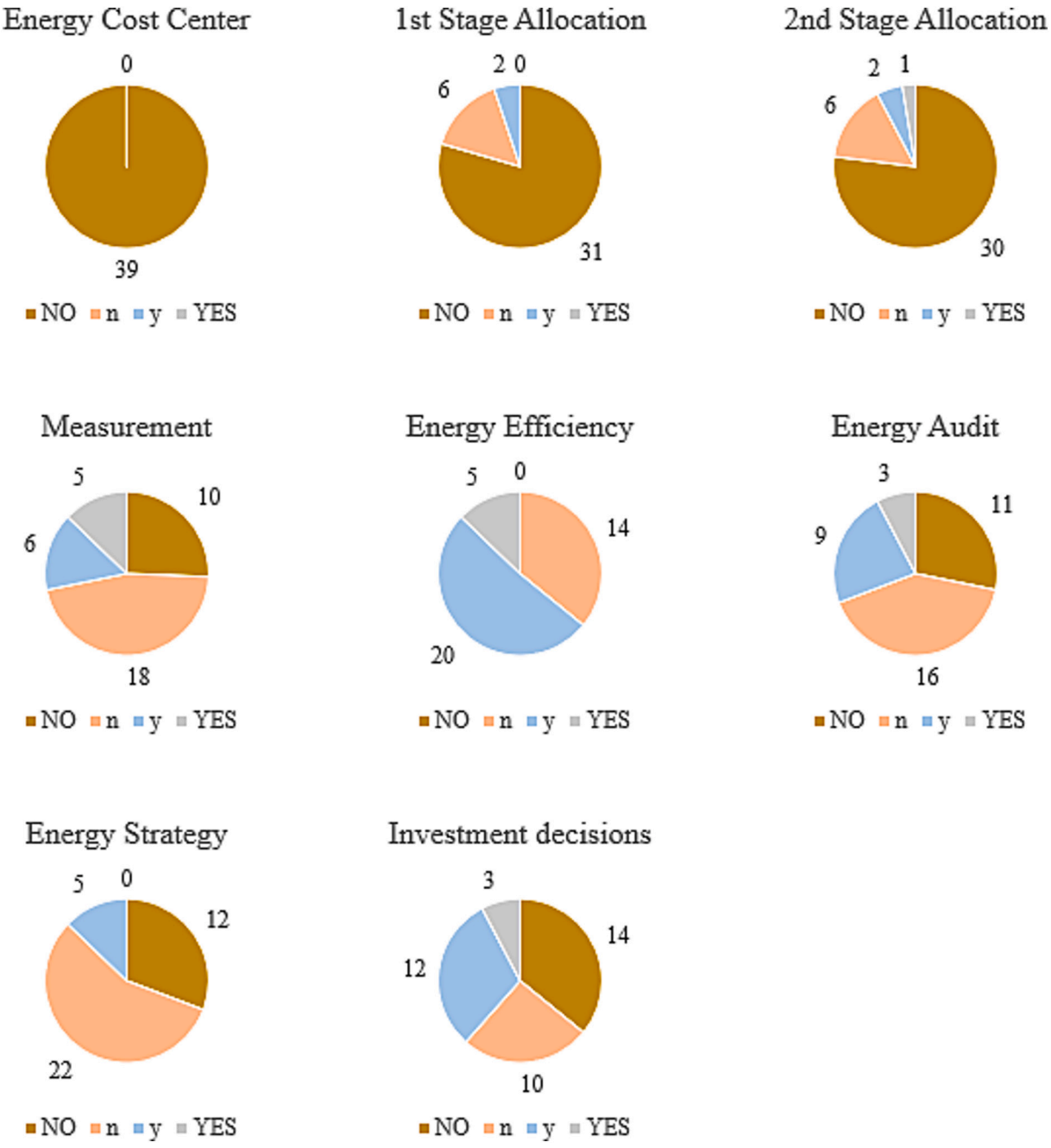


Fig. 10. Occurrence of categorized attributes in the sample of papers by attributes. In this figure 'YES' indicates a very detailed explanation, 'y' a less detailed explanation in some detail, 'n' a sole mention without any detailed explanation, and NO the total absence of an attribute

Table 5
Summary of the occurrence of categorized attributes in the sample of papers by paper. In this table 'YES' indicates a very detailed explanation, 'y' a less detailed explanation in some detail, 'n' a sole mention without any detailed explanation, and NO the total absence of an attribute.

Authors	Year	[G] Energy Cost Center	[H] 1st Stage Allocation	[I] 2nd Stage Allocation	[J] Measurement of Energy	[K] Energy Audit	[L] Energy Efficiency	[M] Energy Strategy	[N] Investment Decisions
Andersson and Thollander	2019	NO	n	n	YES	n	y	NO	NO
Andersson et al.	2021	NO	NO	NO	n	n	n	n	NO
Bernabé-Custodio et al.	2023	NO	NO	NO	y	n	y	n	NO
Cabello Eras et al.	2020	NO	NO	NO	YES	n	YES	n	NO
Cagno et al.	2019	NO	NO	NO	n	NO	y	NO	n
Cagno et al.	2022	NO	NO	NO	NO	y	YES	n	NO
Caporale et al.	2023	NO	NO	NO	NO	y	y	n	n
Cooremans and Schönenberger	2019	NO	NO	NO	n	y	y	n	YES
Cunha et al.	2020	NO	NO	NO	NO	y	n	NO	n
Dahlqvist and Söderholm	2019	NO	NO	NO	n	y	y	n	y
Dekamin et al.	2022	NO	y	y	n	NO	y	n	NO
Hasan and Trianni	2023	NO	NO	NO	NO	y	YES	NO	NO
Hasan et al.	2018	NO	n	n	n	n	y	y	NO
Hasan et al.	2019	NO	NO	NO	NO	y	y	n	y
Herce et al.	2021	NO	NO	NO	n	YES	y	n	y
Hossain et al.	2020	NO	n	n	n	y	YES	n	y
Hrovatin et al.	2021	NO	NO	NO	NO	n	y	NO	n
Janošovský et al.	2020	NO	NO	NO	n	NO	n	NO	y
Knayer and Kryvinska	2023	NO	NO	NO	n	n	y	NO	n
Kumalawati et al.	2023	NO	n	n	NO	NO	n	n	n
Lawrence et al.	2018	NO	NO	NO	n	n	n	n	n
Lawrence et al.	2019	NO	n	n	YES	n	n	y	y
Luken and Saieed	2023	NO	NO	NO	NO	n	n	NO	YES
Ma et al.	2019	NO	NO	NO	y	NO	n	NO	NO
Ma et al.	2021	NO	NO	NO	YES	NO	y	n	NO
Onjewu et al.	2022	NO	NO	NO	y	n	y	y	n
Patel et al.	2022	NO	NO	NO	NO	YES	y	n	y
Ruivo et al.	2021	NO	NO	NO	y	NO	n	n	n
Sa et al.	2018	NO	NO	NO	NO	NO	n	n	YES
Sarvestani et al.	2024	NO	NO	NO	y	NO	n	NO	NO
Schulze et al.	2018	NO	NO	NO	n	n	y	y	NO
Schützenhofer	2021	NO	NO	NO	n	YES	y	NO	y
Sola and Mota	2020	NO	NO	NO	y	NO	y	n	y
Solnørdal and Nilsen	2020	NO	n	n	n	n	n	y	y
Trianni et al.	2019	NO	y	y	n	y	y	n	y
Trianni et al.	2020	NO	NO	NO	n	n	YES	n	y
Trianni et al.	2021	NO	NO	NO	n	n	y	n	n
Viesi et al.	2023	NO	NO	YES	n	NO	n	n	NO
Yandri et al.	2024	NO	NO	NO	YES	n	n	NO	NO

frequency of measurement varies considerably, ranging from minutely intervals [95], to daily [98,99], weekly [98], monthly [65,96,97], and yearly intervals. [66,92,100–102] Some studies even provide measurement information for the duration of specific processes [94] or custom intervals [86]. Finally, the units of measurement include kWh [65,96,98], Nm^3 [95], GJ [99], m^3 [98], and toe (tonnes of oil equivalent) [97,103] alongside functional units tailored to the specific contexts [96].

The level of aggregation in measurement is another key aspect, which varies across the studies. While some studies focus on low-tier level energy consumption like machines [e.g., 93,95], production lines [e.g., 65], or multiple entities along the production process [e.g., 94], many studies aggregate energy consumption data at higher levels like the entire company [e.g., 69,104]. Ma et al. [95] state that the implementation of modern measurement and metering technologies allows for both machine-level but also aggregated monitoring, enhancing the potential for process-specific optimization. Additionally, such usage of smart metering allows for the provision of energy consumption information for every desired level [93,94] but is described rather as a potential for energy efficiency than the status quo in companies' practice [100]. Moreover, the study by Herce et al. [103], reports industry-wide energy consumption rather than providing information at company level, which supports broad sectoral analyses but limits process-specific insights. Papers like the case study by Solnørdal and Nilsen [90], emphasize general trends in energy consumption monitoring and measuring rather than describing operational metering in granularity.

Although measurement is acknowledged as a necessity for energy cost accounting, the description often lacks detail, relying instead on generalized statements about energy consumption. Various studies [87,88,91,105] simply state the importance of energy measurement without going into further detail on how the measurement was actually conducted. Additionally, studies like Trianni et al. [92] and Lawrence et al. [66], report on overall energy use without elaborating on measurement specifics. Concluding, while empirical studies on energy management have made strides in measurement practices, a considerable gap in methodological consistency and detail remains. A

standardized framework to discuss energy measurement would not only improve the comparability of studies but also strengthen the field's contribution to advancing energy efficiency practices across industries.

3.2.4. Energy Efficiency

A consistent theme is the emphasis on energy efficiency as an essential component of energy management, though vague definitions, limited metrics and the presence of drivers and barriers. Several studies [64,66,86,90,92,93,97,100,106] emphasize the importance of energy efficiency, yet often do so without detailing energy efficiency metrics. Consequently, Lawrence et al. [107] underline the significance of energy efficiency metrics but note that implementation remains very limited. Echoing this common theme of recognizing the need for efficiency without specifying concrete metrics, Sarvestani et al. [99] describe the undeniable necessity of improving energy efficiency but do not provide concrete metrics. Similarly, Yandri et al. [96] call for enhanced energy efficiency as long term goal and Kumalaweti et al. [89] talk about ways of achieving energy efficiency, both without elaborating on their concept of energy efficiency or providing measurable metrics. In contrast, Cagno et al. [108] provide a framework for assessing the impact from the adoption of energy efficiency metrics. Moreover, studies like Schützenhofer [69] note, that while many organizations aim to improve energy efficiency, challenges in implementing practical energy efficiency metrics persist. More generally, studies [70,87,88,101,109–111] explore such barriers hindering but also drivers facilitating the implementation of energy efficiency metrics in different settings.

The exploration of sector-specific practices, particularly within energy-intensive industries, is another recurring aspect. This is evident in the studies by Hossain et al. [88], identifying eleven distinct energy efficiency metrics tailored to the cement industry and Cabello Eras et al. [98], describing 27 for providing compressed air. Similarly, Andersson et al. [112] provide insights into energy efficiency in the pulp and paper industry. Sector-specific energy efficiency metrics are also investigated among small and medium sized enterprises (SMEs) [104] and in Italian energy audits [103]. In very specific settings, Bernabé-Custodio et al. [65] elaborate on energy efficiency management based on ISO 50001 and Dekamin et al. [91] use MFCA and more specifically the comparison of input energy and energy content of the output as an energy efficiency metric. Such customized solutions highlight the growing recognition of the industry-specific nature of energy efficiency needs. Notably, Hasan and Trianni [113] categorize energy efficiency metrics across industries, offering a more structured approach.

Studies investigate the factors that influence energy efficiency and energy efficiency's reciprocal impact on organizational outcomes and other usages of energy efficiency. On the one hand, the influence of energy management systems [105,114] and additional technologies [105] on energy efficiency is subject of investigations. On the other hand, the effect of energy efficiency on economic performance [101], environmental performance [114], and sales performance [115] is investigated. Moreover, there are descriptions of other usages for energy efficiency, like Ma et al. [95] depicting the comparison of machines based on energy efficiency. Another application scenario is improving process efficiency, leading to energy savings more or less by the way [102]. Dahlqvist and Söderholm [116] even investigate energy efficiency as criteria for investment decisions.

3.2.5. Energy Strategy

Explicit discussions on energy strategies remain limited, with few studies articulating structured formalized energy strategies. While many studies focus on energy management, energy cost savings, or energy efficiency improvements as a goal, they stop short of detailing strategies or simply state the importance of strategies [70,85,91,95,98,101,103,104,108,111,112,114–117]. Ruivo et al. [97] for example discuss sector-specific strategies to achieve energy savings, without talking about energy strategies in detail. Accordingly, Viesi et al. [93] observe that energy efforts are often implemented without a cohesive, overarching strategy and summoned as part of a broader environmental strategy. Kumalawati et al. [89] attest a positive influence of strategic aspects on economic growth, still without talking about explicit energy strategies. This lack of formal energy strategy contrasts with the emphasis placed on energy efficiency, suggesting a gap between organizational intentions and structured energy planning.

Energy management strategies are sometimes embedded within broader frameworks. Supporting this perspective, Bernabé-Custodio et al. [65] indicate that implementing ISO 50001 implicitly incorporates strategic elements, as the standard requires systematic energy efficiency improvements. Similarly, Schulze et al. [67] state that organizations adopting ISO 50001 indirectly adopt a strategic approach to energy. Such frameworks provide a structure that can substitute a formal strategy by aligning organizational practices with energy management objectives. However, this reliance on standard-based structures may limit the development of customized strategies that address specific organizational needs or (sector-)specific challenges.

Few studies explicitly focus on comprehensive energy strategies, pointing to a broader research gap in this area. Hasan et al. [87] provide one of the limited examples, examining how long-term energy strategy is one of the most important drivers for energy efficiency. Long- and short-term energy reduction targets are seen as strategic targets in a case study by Solnørdal and Nilsen [90], while Caporale et al. [85] specify the implementation of internal monitoring systems as an energy strategy. Lawrence et al. [107] represent one of the few exceptions, exploring energy strategies in more detail by analyzing long-term energy strategies. However, such studies remain, as most research focuses on operational practices or efficiency improvements, often without addressing alignment with long-term strategic objectives.

3.2.6. Energy-related investment decisions

The literature mainly relies on simple financial metrics for evaluating energy-related investment decisions. In a more general manner, Patel et al. [114] state that financial assessment is necessary for energy-related investment decisions. Across several studies [69,88,90,102–104,106,109,111,117], the payback period emerges as the most commonly used criterion, reflecting a focus on short-term financial returns. Adding to that, studies like Sola and Mota [111], Solnørdal and Nilsen [90], and Lawrence et al. [107] highlight that organizations prioritize investments that provide quick financial returns, with preferred payback periods ranging between half a year and up to three years. Similarly, Trianni et al. [92] and Lawrence et al. [107] find that although companies consider alternative financial metrics like return on investment (ROI), net present value (NPV) or the internal rate of return (IRR), simple payback remains the dominant choice due to its straightforward calculation and immediate applicability.

Although simple approaches dominate, some studies explore the application of more advanced decision-making criteria. In this context,

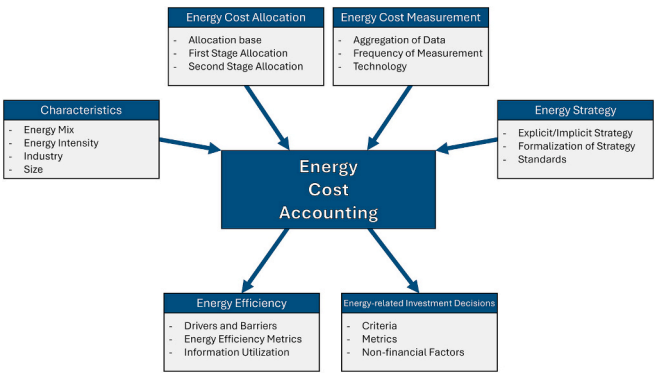


Fig. 11. Framework for a company's energy practice

Sa et al. [117] investigate a range of criteria including: payback time, IRR, cost-benefit analysis, and combinations of those, while Patel et al. [114] propose the usage of ROI for energy-related investment decisions. Cooremans and Schönenberger [101] report a relatively low number of usages for NPV, IRR, compared to a high number for payback periods, with most organizations relying on one method, although some organizations use a combination of two or even all three criteria. This suggests a gap in the adoption of comprehensive financial models that account for long-term benefits and risks associated with energy projects. Trianni et al. [104] further underline this by observing that while IRR is sometimes used, this is typically secondary to payback periods. Their study highlights a need for increased awareness within organizations to adopt more sophisticated methods that provide a better understanding of the investment's impact.

Although financial metrics remain central, studies recognize the growing relevance of non-financial factors, drivers, barriers and broader strategic considerations in energy-related investment decisions. Illustrating this point, both Dahlqvist and Söderholm [116] and Cagno et al. [100] report energy efficiency as criterion for investment decisions, while Onjewu et al. [115] point out that more emphasis should be placed on energy efficiency for investment decisions. Similarly, Kumalawati et al. [89] emphasize that companies increasingly acknowledge the importance of aligning energy investments with broader sustainability goals, even if these factors are not formally integrated into decision-making processes. Moreover, studies discuss barriers that hinder investments in energy efficiency, like high investment costs and investment priorities [68] or specific firm characteristics [66]. In contrast, Sola and Mota [111] discuss potential drivers that facilitate investments in energy efficiency.

4. Discussion

The analysis of the results of the systematic literature review leads to the conclusion that managing energy costs consists of several related sub-disciplines that influence the energy cost accounting and that several aspects are influenced by the application of energy cost accounting. These facets are discussed in this section and summarized in Fig. 11.

4.1. Energy cost allocation

The results underline a significant gap in the literature regarding the detailed description and application of energy cost allocation practices. As pointed out in the framework in Fig. 11, investigating a company, it is essential to understand how energy costs are allocated for both the 1st and 2nd stage cost allocations and on which basis this allocation took place.

The lack of theoretical frameworks for energy cost allocation reveals significant gaps in practical implementation, highlighting the need for approaches to connect conceptual models with industry-specific applications. Although studies acknowledge the importance of energy cost allocation [86–90], explicit descriptions of energy cost allocation in practice remain scarce, which confirms prior findings of Mickovic and Wouters [16]. The limited attention in the literature toward 1st stage energy cost allocation suggests a tendency to overlook this foundational aspect or overlook the importance of addressing energy costs on the level of cost centers. A valuable starting point towards energy cost allocation is provided through different levels of energy cost allocation [92], addressing both 1st and 2nd stage allocation. While some studies [91,93] offer case-specific insights into 2nd stage allocation, these instances deviate from traditional definitions of 2nd stage allocation. The absence of robust examples of both 1st and 2nd stage allocation points to a critical research gap, emphasizing the need for empirical studies that explore practical applications and industry-specific challenges.

Methodologies or frameworks for an efficient allocation of energy costs are absent. This absence highlights the need for more comprehensive research to establish standardized practices. Moreover, the findings underscore an urgent demand for not only empirical studies that describe energy cost allocation practice but also provide insights into their implementation. Additionally, cross-industry studies could uncover best practices and lead to standardization of energy cost allocation. By addressing these gaps, companies are better supported in achieving accurate cost allocation, improved energy information, and hence, better decision-making.

Emerging technological innovations in energy metering demonstrate the confluence of engineering advancements and economic efficiency in reducing energy consumption and energy costs. The usage of smart metering devices [94,95,100] raises an important question: to what extent is energy cost allocation still relevant in modern accounting systems, if all energy costs could be traced? Addressing this question could refine the role of energy cost allocation in energy management practices and clarify its application in different organizational contexts.

4.2. Energy cost measurement

The findings reveal a lack of detailed understanding of how energy cost measurement is done in practice. As indicated in Fig. 11, inspecting a company, understanding how frequently energy costs are measured, on which level energy cost information is aggregated and which technological solutions are used for these measurements is crucial.

Energy is measured in an incoherent way. The studies in the sample exhibit a range of intervals used for energy measurement. Energy measurements with high frequency [86,94,95,99], provide detailed insights into energy consumption patterns, enabling adjustments and optimizations, while low frequency measurements or aggregated data [66,92,100–102], offer broader overviews but lack specificity required for detailed analysis. The diversity of measurement intervals reflects the tension between the need for precision and the challenges of data collection, analysis, and reporting in practical settings.

Variations in energy measurement practices highlight the integration of modern metering technologies to combine granular data with scalable insights. This variation ranges in the level of aggregation from process-specific data [e.g., 65,95], to plant- or company-level data [e.g., 69,104]. Aggregated data can facilitate sector-wide analysis [103], but sacrifices details as a trade-off. More flexible data aggregation, tailored to the specific information need, is supported by the adoption of modern metering technologies such as smart meters and sensors, but their application in practice [94,95,100] remains limited. Hence, the literature only hints at the potential of technical innovations, which underscores the need for balanced approaches that combine granularity with scalability to support both operational and strategic goals.

The findings emphasize a critical need for frameworks on companies' energy practices to address energy measurements. It is essential that standardized frameworks for energy practices integrate granular insights with broader sustainability efforts to enable advancements in energy measurement and its applicability. Such frameworks should be able to accommodate both granular, process-level insights and aggregated, sector-level analyses, bridging the gap between operational precision and strategic applicability. Future research should focus on developing and testing such frameworks, drawing on advanced metering technologies and transparent reporting practices. By addressing these gaps, the field can foster more consistent comparisons across studies and companies, enhance the utility of energy data, and support more effective energy efficiency practices.

4.3. Energy efficiency

The literature highlights energy efficiency as a central topic, yet it frequently lacks specificity in defining metrics and methodologies. The framework in Fig. 11 indicates that studying a company, it is essential to examine how energy efficiency metrics are defined, how they are applied in practice, which drivers and barriers they face, and which

influence they unfold.

The general importance of energy efficiency is acknowledged but concrete energy efficiency metrics are still underdeveloped. However, prior literature made notable efforts to measure energy efficiency [32–39]. Still, while the necessity of improving energy efficiency is emphasized [96,99], measurable metrics for achieving it are rare. Similarly, the importance of energy efficiency is often highlighted [64,66,86,90,92,93,97,100,106] without offering practical metrics to measure it. At the same time, sector-specific approaches to energy efficiency [88,98,103,104,112] acknowledge sector-specific needs but the lack of standardized metrics challenges universal methodologies. Studies using standardized frameworks like MFCA to quantify energy efficiency [91] or providing frameworks for the assessment of energy efficiency [108], represent steps toward more structured methodologies but remain the exception rather than the rule. This aligns with prior findings emphasizing the need for clear and meaningful metrics and methodologies to compare energy efficiency [32,35,36,39]. Moreover, the adoption of energy efficiency metrics often encounters significant drivers and barriers, which are frequently mentioned [69,70,87,88,101,107,109–111]. The general lack of specificity limits the applicability, as practitioners and researchers require actionable energy efficiency metrics to effectively implement energy efficiency improvements.

Energy efficiency's dual-direction relationships with other organizational aspects highlight its multifaceted impacts and underline the complexity and the need for empirical research. The demonstration of energy efficiency improvement's positive impact on environmental and sales performance [101,114,115] aligns with prior findings demonstrating energy efficiencies' positive influence on productivity [38]. In contrast, energy management systems' influence on energy efficiency [105] adds to prior findings that the employment of standards influences energy efficiency assessment [37]. This highlights the interdisciplinarity of energy efficiency, suggesting that its impact extends beyond mere energy cost savings to broader organizational benefits. Moreover, the diverse applications of energy efficiency as a concept, ranging from machine comparisons [95] to investment decisions [116], shows its flexibility but reveal fragmented interpretation, urging structured foundations for comparisons. Structured categorizations of energy efficiency metrics [108,113] provide such foundations for comparisons but future research needs to provide more detailed empirical investigations.

The findings of this review reveal the need for adaptable yet comparable energy efficiency metrics, emphasizing their role in enabling insights and fostering sustainable practices. This echoes earlier findings [33,35,39], that underline the importance of sector-specific but harmonized metrics to ensure applicability and meaningful comparisons. Future research should focus on energy efficiency metrics that are adaptable to different sectors and organizational contexts but still enable comparisons. Additionally, exploring the interconnected benefits of energy efficiency could further solidify its role as a strategic goal.

4.4. Energy strategy

The notable lack of explicit, formalized energy strategies reflects a significant gap in both academic research and practical application. This is outlined in the framework in Fig. 11, as investigating a company, understanding how explicit but also to what extent an energy strategy is formalized and how standards are addressed is vital.

The absence of detailed energy strategies suggests a disconnect between high-level intentions and actionable plans. While the importance of energy strategies is often mentioned [88,95,101,112,116], linked to economic growth [89], or energy-related efforts and targets are seen as components of broader environmental strategies [93], structured approaches or cohesive plans are lacking. In a similar manner, sector-specific strategies for energy savings [97] or energy management systems aligned to ISO 50001 acting as a de facto strategy [65,67] are acknowledged but stop short of offering detailed strategic frameworks. Only few studies [107,109] offer valuable insights by directly addressing the formulation and impact of energy strategies. Despite these contributions, the broader literature leaves the strategic dimension of energy untouched, although the potential of energy strategies is apparent. This highlights the reliance on implicit strategic approaches, leaving organizations without clear and actionable roadmaps to fully address unique needs or challenges but providing avenues for future research.

The lack of explicit energy strategies underlines the need for frameworks that integrate energy objectives with corporate goals, promoting sustainability, competitiveness, and continuous improvement. Moreover, the absence of explicit energy strategies calls for efforts to bridge this gap. Developing and documenting formal energy strategies can provide organizations with practical roadmaps or milestones to integrate energy objectives into broader strategic goals, fostering long-term competitiveness and sustainability. The literature points to a need for more comprehensive, long-term energy strategies that align with corporate goals and provide structure for continuous improvement. Future research should aim to establish frameworks for creating, implementing, and evaluating energy strategies. Furthermore, exploring the interplay between standards and energy strategies could offer additional insights. By addressing these gaps, researchers and practitioners can enhance the strategic foundations of corporate energy practices, driving both economic and environmental benefits.

4.5. Energy-related investment decisions

Investment decisions regarding energy are made in a simplistic manner, without fully utilizing non-financial information. As stated in the framework in Fig. 11, studying a company, identifying which criteria are used for energy-related investment decisions and which metrics are used to assess them is as essential as understanding the role of non-financial factors and non-energy benefits.

The prioritization of simple financial metrics to evaluate energy-related investment decisions highlights both strengths and weaknesses. While simpler metrics like the payback period offer clarity and ease of calculation, they often fail to capture long-term benefits and broader sustainability goals. The recurring finding of the prioritization of short-term financial returns [69,88,90,102–104,106,109,111,117] underlines a conservative approach to investment decisions, emphasizing low-risk options with clear economic benefits. Moreover, this prioritization reflects tendencies to favor investments with immediate financial returns, aligning with constraints such as limited budgets and high competition for internal funding. Although alternative (more sophisticated) metrics like ROI, NPV, and IRR are mentioned [92,107], they are secondary choices and the prioritization of simpler over more complex metrics can limit the scope of investments to projects with fast returns. Potentially, this excludes long-term energy initiatives with high impact. Furthermore, this lack of more complex metrics may stem from lack of familiarity, lack of resources, or organizational cultures that favor immediate outcomes. Despite this prioritization of simpler metrics, more sophisticated approaches also combine criteria like IRR and cost-benefit analyses [117] or NPV, IRR, and payback periods [101]. However, the low usage of comprehensive models incorporating several metrics reveals a gap in awareness and capability to assess energy-related investment decisions in depth, highlighting the need for better education and tools to support more nuanced decision-making processes.

While financial factors dominate, the scarce consideration of non-financial criteria and non-energy benefits highlights the need for their systematic integration into decision-making processes. Although the literature mentions non-financial criteria for decision-making [89,100,116], they are rarely formalized. In a similar manner, non-energy benefits are scarce [89,100,115], though prior literature pointed out that a broader set of operative implications has to be considered for decision making [118]. Nevertheless, such findings indicate that both non-financial criteria and non-energy benefits are part

of the consideration but often rather informal and secondary, than systematically incorporated into decision-making processes. Consequently, this suggests an opportunity for future research to systematically integrate both aspects into the evaluation and decision-making process.

The adoption of more comprehensive investment evaluation methods is associated with organizational size. High investment costs upfront and competing investment priorities are significant obstacles [66,68], which is especially an issue for smaller companies. In addition, the complexity and data requirements of metrics like NPV or IRR may act as deterrents for smaller companies or those in resource-constrained settings. This could explain why simple financial metrics are more common among small companies [104,109,114,117]. For large companies at the same time, regulatory incentives, government agencies and stakeholder pressure [111,117] could foster the adoption of more sophisticated metrics for energy-related investment decision-making. Additionally, the process of decision-making differentiates between SMEs and large companies due to aspects such as process maturity, number of process participants, and access to funding.

The reliance on simple financial metrics for energy investment decisions highlights the need for strategies to integrate long-term objectives and non-financial factors. This prioritization of simple financial metrics points to ongoing issues in balancing short-term financial priorities with long-term strategic objectives. Future research should therefore explore strategies to enhance the adoption of comprehensive evaluation frameworks and metrics, emphasizing the integration of non-financial factors. Tools and methodologies simplifying the application of more sophisticated metrics could further support organizations in making informed but at the same time balanced decisions, regardless of their size. Addressing these gaps aligns energy-related decision-making with broader goals of economic and environmental sustainability.

5. Conclusion

The overarching objective of this systematic literature review is synthesizing the knowledge on corporate energy practices in empirical studies. This review provides a comprehensive overview of the topic as well as of the subtopics of energy cost centers, energy cost allocation, energy measurement, energy efficiency, energy strategy, and energy-related investment decisions. In summary, this review yields 39 papers in 19 peer-reviewed journals, highlighting the broad relevance of energy-related topics. Nevertheless, two of the main important findings are a lack of detail and emphasis across all energy-related topics. Additionally, the scattered information and obvious absence of guiding frameworks are apparent.

This paper contributes in multiple ways. First, this review offers a structured overview of the literature on corporate energy cost practices by systematically integrating previously disconnected areas, laying foundations for future research. Second, this review provides the most comprehensive investigation of the literature on energy efficiency metrics. By avoiding limitations related to specific industries or other biases, the analysis ensures consistency and comparability across findings. This enables practitioners to critically check their own energy efficiency metrics, offers scholars a base for comparisons, and equips policymakers with empirical findings to develop guidelines for the implementation and reporting of energy efficiency metrics. Third, this review points to several avenues for future research, including energy cost centers, energy cost allocation, and energy strategy as most studies lack depth and fail to explore interconnections between these topics. Consequently, this review provides researchers with a clear call to further pursue empirical research on these overlooked aspects. Fourth, this review reveals the lack of a clear framework for describing corporate energy cost practices. Without such a framework, organizations cannot systematically analyze their energy practices or compare themselves to benchmarks or competitors, which impedes the improvement of corporate energy practices and ultimately, corporate energy efficiency.

Subsequently, these contributions support the relevance of contingency theory [54–61] in guiding future research. The observed diversity in corporate energy practices echoes the core idea of contingency theory that there is no universal best system but rather, systems must fit their context. Future studies should therefore adopt contingency-based perspectives to investigate how contextual variables such as industry characteristics (e.g., competitive dynamics, energy intensity), organizational structure (e.g., energy strategy, energy cost allocation), regulatory environment (e.g., reporting standards, mandatory audits), and technological infrastructure (e.g., energy measurement, energy monitoring) influence the design and effectiveness of corporate energy practices. Addressing these dimensions in future research offers avenues for explaining heterogeneity in corporate energy practices.

Nevertheless, there are limitations to this review. First, the sample of papers itself is a limitation. Although based on a careful and considerate process for identifying and selecting papers published in peer-reviewed academic journals, other sources including gray literature (books, reports, etc.) may provide more detailed empirical information on corporate energy practices. Second, the sample's regional focus – primarily on Europe, especially Sweden and Italy – hinders generalizability. The absence of North America, particularly the United States, represents a notable gap. Additionally, studies from less developed countries are also missing, despite their reliance on carbon intense energy sources and hence, potential to benefit from improved energy practices. Therefore, future studies should focus on these underrepresented regions to utilize the underlying potential. This includes conducting case studies, cross-country comparative analyses, leveraging international datasets or collaborating with local institutions to close these gaps. Third, the selection of subtopics in this review represents a limitation. Despite careful consideration, additional subtopics could have been selected. For instance, the impact on carbon emissions, tax implications arising from energy cost practices, or externality costs could have been included and subsequently lead to opportunities for future research.

CRediT authorship contribution statement

Philip Dickemann: Writing – review & editing, Writing – original draft, Visualization, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Full literature review table

Table 6
Summarized data for the literature review on energy cost accounting in manufacturing environments

Authors	Year	[A] Research Method	[B] # of Companies	[C] Industry	[D] Company Size	[E] Energy Intensity	[F] Energy Mix	[G] Energy Cost Center	[H] 1st Stage Allocation	[I] 2nd Stage Allocation	[J] Measurement of Energy	[K] Energy Audit	[L] Energy Efficiency	[M] Energy Strategy	[N] Investment Decisions
		[O] Description of energy cost center **[P] Description of allocation of energy costs** **[Q] Description of energy measurement** **[R] Description of energy efficiency** **[S] Description of energy strategy** **[T] Description of investment and criteria** **[U] Description of application of Specific Energy Consumption (SEC)** **[V] Summary of quantitative information on energy costs**													
Andersson and Thollander	2019	**[A]**	**[B]**	**[C]**	**[D]**	**[E]**	**[F]**	**[G]**	**[H]**	**[I]**	**[J]**	**[K]**	**[L]**	**[M]**	**[N]**
		Questionnaire, Interviews	28	Pulp and Paper	Not specified	Not specified but likely	Electricity Heat	NO	n	n	YES	n	y	NO	NO
		[O] - **[P]** No specific information on the allocation of energy costs neither on the first nor on the second stage. However, energy cost allocation was ranked low as a driver for developing energy KPIs. One interviewee explicitly stated that simplifying energy cost allocations could be a useful indicator to motivate energy-saving, although it sacrifices accuracy. **[Q]** Measurement is conducted for electricity, heat, and total energy cost on a plant, department, or process level. Plant level: 75% electricity, 64% heat, 46% energy costs. Department level: 71% electricity, 64% heat, 25% energy costs. Process level: 32% electricity, 18% heat, 7% energy costs. In addition, energy KPIs are available yearly, monthly, daily, or continuous. **[R]** There are no specific energy efficiency metrics. To compare the efficient usage of energy, SEC and electricity or heat per ton output are used. In addition, the paper denotes the importance of KPIs for energy efficiency. **[S]** - **[T]** - **[U]** Finding of the interviews is that SEC is often measured in energy use per ton of produced output (pulp and/or paper) aggregated at the plant level. However, there is no empirical data on this. In addition, electricity, heat, or energy cost per ton output was given as a measured KPI. **[V]** No information on actual energy costs. Only qualitative information on energy costs is available.													
Andersson et al.	2021	**[A]**	**[B]**	**[C]**	**[D]**	**[E]**	**[F]**	**[G]**	**[H]**	**[I]**	**[J]**	**[K]**	**[L]**	**[M]**	**[N]**
		Multiple Case Study	3	Pulp and Paper	Not specified	Energy Intense	Electricity Heat	NO	NO	NO	n	n	n	n	NO
		[O] - **[P]** - **[Q]** No further elaboration on how measurement is conducted.													

(*continued on next page*)

Table 6 (*continued*)

Andersson and Thollander	2019	**[A]**	**[B]**	**[C]**	**[D]**	**[E]**	**[F]**	**[G]**	**[H]**	**[I]**	**[J]**	**[K]**	**[L]**	**[M]**	**[N]**
		Questionnaire, Interviews	28	Pulp and Paper	Not specified	Not specified but likely	Electricity Heat	NO	n	n	YES	n	y	NO	NO

[R] Detailed and specific possibilities to improve energy efficiency in the specific pulp and paper setting are discussed but no information on energy efficiency metrics used.
[S] Specific energy strategies are not discussed. However, the importance of strategic energy management is mentioned.
[T] -
[U] SEC is given for electricity and heat separately for different purposes on different hierarchies. 26 different SECs (14 electricity, 12 heat) are distinguished.
[V] No information on actual energy costs.

Authors	**Year**	**[A] Research Method**	**[B] # of Companies**	**[C] Industry**	**[D] Company Size**	**[E] Energy Intensity**	**[F] Energy Mix**	**[G] Energy Cost Center**	**[H] 1st Stage Allocation**	**[I] 2nd Stage Allocation**	**[J] Measurement of Energy**	**[K] Energy Audit**	**[L] Energy Efficiency**	**[M] Energy Strategy**	**[N] Investment Decisions**

[O] Description of energy cost center
[P] Description of allocation of energy costs
[Q] Description of energy measurement
[R] Description of energy efficiency
[S] Description of energy strategy
[T] Description of investment and criteria
[U] Description of application of Specific Energy Consumption (SEC)
[V] Summary of quantitative information on energy costs

Bernabé-Custodio et al.	2023	**[A]**	**[B]**	**[C]**	**[D]**	**[E]**	**[F]**	**[G]**	**[H]**	**[I]**	**[J]**	**[K]**	**[L]**	**[M]**	**[N]**
		Case Study	1	Brick and cement	Not specified	Not specified but likely	Electricity	NO	NO	NO	y	n	y	n	NO

[O] -
[P] -
[Q] Measurement of the consumed energy in kWh per month for two distinct processes. In addition to that, hourly measurement (over the course of a day) for two production lines to establish benchmarks.
[R] Energy efficiency management based on ISO 50001. Energy efficiency was viewed as the relationship between energy required and energy used. Due to the implementation of energy efficiency management, process improvement and energy reduction was achieved.
[S] No specific energy strategy, but the implementation of ISO 50001 is named as a strategy for optimizing energy performance.
[T] -
[U] -
[V] Through the implementation of energy efficiency management according to ISO 5001, it was possible to decrease monthly energy consumption by 8% - in absolute values: 43,504 kWh. In monetary units, this was 18,067.23 S/ (Peruvian sol), which translates to roughly 5,000 $.

Cabello Eras et al.	2020	**[A]**	**[B]**	**[C]**	**[D]**	**[E]**	**[F]**	**[G]**	**[H]**	**[I]**	**[J]**	**[K]**	**[L]**	**[M]**	**[N]**
		Case Study	1	Battery	Not specified	Energy intense	Compressed Air	NO	NO	NO	YES	n	YES	n	NO

[O] -
[P] -
[Q] Usage of compressed air is measured in m^3 per day for four different sections (departments). In addition, electricity consumption for the compressors (aggregated) providing the compressed air was measured on a weekly basis in kWh.
[R] 27 different energy efficiency metrics based on findings in the literature are presented specifically for compressed air. Actions towards them were implemented in the case study.
[S] Specific energy strategies are not discussed. The implementation of strategies as a tool to identify energy-saving opportunities is mentioned.
[T] -
[U] The specific energy use of a compressor unit in MWh per ton was used as an energy KPI to assess the performance.
[V] No information on actual energy costs.

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Table 6 (*continued*)

Authors	Year	[A] Research Method	[B] # of Companies	[C] Industry	[D] Company Size	[E] Energy Intensity	[F] Energy Mix	[G] Energy Cost Center	[H] 1st Stage Allocation	[I] 2nd Stage Allocation	[J] Measurement of Energy	[K] Energy Audit	[L] Energy Efficiency	[M] Energy Strategy	[N] Investment Decisions
Bernabé-Custodio et al.	2023	Case Study	1	Brick and cement	Not specified		Not specified but likely	Electricity	NO	NO	NO	y	n	y	n	NO

[O] Description of energy cost center
[P] Description of allocation of energy costs
[Q] Description of energy measurement
[R] Description of energy efficiency
[S] Description of energy strategy
[T] Description of investment and criteria
[U] Description of application of Specific Energy Consumption (SEC)
[V] Summary of quantitative information on energy costs

Cagno et al.	2019	[A] Interviews	[B] 7	[C] Diverse	[D] Large (2), SME (5)	[E] Not intense (4), Energy intense (3)	[F] Not specified	[G] NO	[H] NO	[I] NO	[J] n	[K] NO	[L] y	[M] NO	[N] n

[O] -
[P] -
[Q] No detailed information on how measurement is conducted. Smart metering as an energy efficiency potential is explicitly mentioned. Yearly consumption data is available.
[R] There are no specific energy efficiency metrics. However, energy efficiency metrics are widely discussed and several energy efficiency potentials from prior literature were assessed in practice.
[S] -
[T] There is no information on specific investment criteria for energy-related investment decisions. Two case companies reported decisions based on energy efficiency considerations.
[U] -
[V] No information on actual energy costs.

Cagno et al.	2022	[A] Multiple Case Study	[B] 9	[C] Diverse	[D] Large (3), SME (6)	[E] Not intense (4), Energy intense (5)	[F] Not specified	[G] NO	[H] NO	[I] NO	[J] NO	[K] y	[L] YES	[M] n	[N] NO

[O] -
[P] -
[Q] -
[R] 20 different energy efficiency metrics (4 of them sector-specific) are presented. In addition, a framework is provided building on characteristics to support decision-makers in assessing the impact of the adoption of energy efficiency metrics. The characteristics are grouped into (i) objective and type, (ii) implementation-related characteristics, (iii) personnel-related characteristics involved in the adoption, and (iv) additional requirements. Further, this framework is applied to nine companies and their energy efficiency metrics.
[S] Specific energy strategies are not discussed. Saving energy through the implementation of energy efficiency actions is labeled as a saving strategy.
[T] -
[U] -
[V] No information on actual energy costs.

Authors	Year	[A] Research Method	[B] # of Companies	[C] Industry	[D] Company Size	[E] Energy Intensity	[F] Energy Mix	[G] Energy Cost Center	[H] 1st Stage Allocation	[I] 2nd Stage Allocation	[J] Measurement of Energy	[K] Energy Audit	[L] Energy Efficiency	[M] Energy Strategy	[N] Investment Decisions

[O] Description of energy cost center
[P] Description of allocation of energy costs
[Q] Description of energy measurement
[R] Description of energy efficiency

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Table 6 (*continued*)

Cagno et al.	2019	**[A]**	**[B]**	**[C]**	**[D]**	**[E]**	**[F]**	**[G]**	**[H]**	**[I]**	**[J]**	**[K]**	**[L]**	**[M]**	**[N]**
		Interviews	7	Diverse	Large (2), SME (5)	Not intense (4), Energy intense (3)	Not specified	NO	NO	NO	n	NO	y	NO	n

[S] Description of energy strategy
[T] Description of investment and criteria
[U] Description of application of Specific Energy Consumption (SEC)
[V] Summary of quantitative information on energy costs

Caporale et al.	2023	**[A]**	**[B]**	**[C]**	**[D]**	**[E]**	**[F]**	**[G]**	**[H]**	**[I]**	**[J]**	**[K]**	**[L]**	**[M]**	**[N]**
		Archival Data	12087	Diverse	SME	Not specified	Not specified	NO	NO	NO	NO	y	y	n	n

[O] -
[P] -
[Q] -
[R] There are no specific energy efficiency metrics. Energy savings are seen as improvements to energy efficiency.
[S] Implementation of internal monitoring systems and the adoption of energy-saving technologies are named potential strategies. Also, energy efficiency is seen as a strategic goal.
[T] There is no information on specific investment criteria for energy-related investment decisions. The investment (in% of annual turnover) in being more resource-efficient was analyzed as a variable.
[U] -
[V] No information on actual energy costs.

Cooremans and Schönen-berger	2019	**[A]**	**[B]**	**[C]**	**[D]**	**[E]**	**[F]**	**[G]**	**[H]**	**[I]**	**[J]**	**[K]**	**[L]**	**[M]**	**[N]**
		Questionnaire, Interviews, Case Studies	305 (Q), 27 (I) 5 (CS)	Diverse	Diverse	Not specified but likely	Electricity	NO	NO	NO	n	y	y	n	YES

[O] -
[P] -
[Q] No further elaboration on how measurement is conducted. electricity consumption is available on a yearly base.
[R] There are no specific energy efficiency metrics. Drivers and barriers to energy efficiency are investigated empirically. Further, the impact of energy efficiency investments on economic performance is investigated.
[S] Specific energy strategies are not discussed. The importance of including energy efficiency considerations in core business is mentioned and the implementation of an energy management system is considered part of the strategy.
[T] 232 companies used payback, 42 companies used NPV, and 52 companies used IRR. 179 use one criterion, 38 use two methods, and 29 use all three methods.
[U] -
[V] No information on actual energy costs. Energy costs were solely mentioned as reference values for energy intensity.

Authors	**Year**	**[A] Research Method**	**[B] # of Companies**	**[C] Industry**	**[D] Company Size**	**[E] Energy Intensity**	**[F] Energy Mix**	**[G] Energy Cost Center**	**[H] 1st Stage Allocation**	**[I] 2nd Stage Allocation**	**[J] Measurement of Energy**	**[K] Energy Audit**	**[L] Energy Efficiency**	**[M] Energy Strategy**	**[N] Investment Decisions**

[O] Description of energy cost center
[P] Description of allocation of energy costs
[Q] Description of energy measurement
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[U] Description of application of Specific Energy Consumption (SEC)
[V] Summary of quantitative information on energy costs

Cunha et al.	2020	**[A]**	**[B]**	**[C]**	**[D]**	**[E]**	**[F]**	**[G]**	**[H]**	**[I]**	**[J]**	**[K]**	**[L]**	**[M]**	**[N]**
		Questionnaire	694	Diverse	SME	Not specified but unlikely	Electricity Heat	NO	NO	NO	NO	y	n	NO	n

[O] -
[P] -
[Q] -
[R] There are no specific energy efficiency metrics. The adoption of energy efficiency actions both for electricity and heat was investigated.
[S] -
[T] There is no information on specific investment criteria for energy-related investment decisions. However, investment costs and investment priorities are investigated as potential barriers to the implementation of energy efficiency actions.
[U] -
[V] No information on actual energy costs. The price per kWh of electricity was used as a control variable in a regression analysis.

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Table 6 (*continued*)

Authors	Year	[A] Research Method	[B] # of Companies	[C] Industry	[D] Company Size	[E] Energy Intensity	[F] Energy Mix	[G] Energy Cost Center	[H] 1st Stage Allocation	[I] 2nd Stage Allocation	[J] Measurement of Energy	[K] Energy Audit	[L] Energy Efficiency	[M] Energy Strategy	[N] Investment Decisions
Cunha et al.	2020	Questionnaire	694	Diverse	SME	Not specified but unlikely	Electricity Heat	NO	NO	NO	NO	y	n	NO	n
Dahlqvist and Söderholm	2019	Questionnaire	101	Diverse	Large	Not specified	Not specified	NO	NO	NO	n	y	y	n	y

[O] -
[P] -
[Q] No specific information on how measurement is conducted. Costs for metering are discussed.
[R] The importance of energy efficiency as an investment criterion is empirically investigated. However, there is only aggregated information on a higher level. In addition, a variety of additional aspects related to energy efficiency is discussed but there are no specific energy efficiency metrics introduced.
[S] Specific energy strategies are not discussed. The existence of energy goals is mentioned as an important component of the overall business strategy.
[T] There is no information on specific investment criteria for energy-related investment decisions. However, energy efficiency is used as an investment criterion.
[U] -
[V] No information on actual energy costs. Rising energy costs are mentioned as motivation to be more energy efficient.

[O] Description of energy cost center
[P] Description of allocation of energy costs
[Q] Description of energy measurement
[R] Description of energy efficiency
[S] Description of energy strategy
[T] Description of investment and criteria
[U] Description of application of Specific Energy Consumption (SEC)
[V] Summary of quantitative information on energy costs

Authors	Year	[A]	[B]	[C]	[D]	[E]	[F]	[G]	[H]	[I]	[J]	[K]	[L]	[M]	[N]
Dekamin et al.	2022	Case Study	1	Agriculture	SME	Not specified but unlikely	Oil (Diesel)	NO	y	y	n	NO	y	n	NO

[O] -
[P] There is no separate allocation of energy costs, but the allocation of energy costs is part of the application of MFCA. Through the application of MFCA, energy is allocated to the products.
[Q] No further elaboration on how measurement is conducted. The authors simply state that measurement is conducted according to the MFCA method (following the flows).
[R] The MFCA approach compared the input energy of 30,687 MJ/ha to the (positive) output of 18,743 MJ/ha, which led to an energy efficiency ratio of 0.61. This indicates that 61% of the energy invested in coriander production was converted into useful energy output (coriander yield).
[S] No specific energy strategy, but strategies to improve energy efficiency are discussed.
[T] -
[U] Specific energy - labeled as SE - was given as the number of energy inputs necessary to produce the positive output.
[V] No information on actual energy costs. The MFCA approach accounted for costs and energy separately. Moreover, the focus of this study was on accounting for the non-cost aspects. Hence, no further focus was laid on specific energy costs.

Authors	Year	[A]	[B]	[C]	[D]	[E]	[F]	[G]	[H]	[I]	[J]	[K]	[L]	[M]	[N]
Hasan and Trianni	2023	Interviews Case Study	9 (I) 3 (CS)	Diverse	Diverse	Not specified (I) Energy Intense (CS)	Diverse	NO	NO	NO	NO	y	YES	NO	NO

[O] -
[P] -
[Q] -
[R] Various energy efficiency metrics are identified in the literature and assessed according to a framework. In addition to that, very specific energy efficiency metrics based on industry 4.0 technologies, are examined in three case studies.
[S] -
[T] -
[U] -
[V] Industry 4.0 technologies are examined for their potential to improve energy efficiency. The three case studies led to energy cost savings through the usage of Industry 4.0 applications like sensors, artificial intelligence, and the Internet of Things. The authors do not explicitly state energy cost savings in monetary values.

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Table 6 (*continued*)

Authors	Year	[A] Research Method	[B] # of Companies	[C] Industry	[D] Company Size	[E] Energy Intensity	[F] Energy Mix	[G] Energy Cost Center	[H] 1st Stage Allocation	[I] 2nd Stage Allocation	[J] Measurement of Energy	[K] Energy Audit	[L] Energy Efficiency	[M] Energy Strategy	[N] Investment Decisions
Dekamin et al.	2022	Case Study	1	Agriculture	SME	Not specified but unlikely	Oil (Diesel)	NO	y	y	n	NO	y	n	NO

[O] Description of energy cost center
[P] Description of allocation of energy costs
[Q] Description of energy measurement
[R] Description of energy efficiency
[S] Description of energy strategy
[T] Description of investment and criteria
[U] Description of application of Specific Energy Consumption (SEC)
[V] Summary of quantitative information on energy costs

Authors	Year	[A]	[B]	[C]	[D]	[E]	[F]	[G]	[H]	[I]	[J]	[K]	[L]	[M]	[N]
Hasan et al.	2018	Multiple Case Study	7	Milling	Large	Not specified but likely	Not specified	NO	n	n	n	n	y	y	NO

[O] -
[P] No specific information on the allocation of energy costs neither on the first nor on the second stage. Energy cost allocation and its importance is mentioned.
[Q] No further elaboration on how measurement is conducted. The necessity of monitoring energy costs is mentioned.
[R] There are no specific energy efficiency metrics. Drivers and barriers to energy efficiency are investigated empirically.
[S] One research question specifically dealt with (long-term) energy strategies. The existence of such a long-term energy strategy was found as one of the most important drivers for energy efficiency.
[T] -
[U] SEC is mentioned but there is no information on any usage of the concept.
[V] No information on actual energy costs. The necessity to work on energy cost information is mentioned.

Authors	Year	[A]	[B]	[C]	[D]	[E]	[F]	[G]	[H]	[I]	[J]	[K]	[L]	[M]	[N]
Hasan et al.	2019	Questionnaire	8	Diverse	SME	Non intense	Not specified	NO	NO	NO	NO	y	y	n	y

[O] -
[P] -
[Q] -
[R] There are no specific energy efficiency metrics. Drivers and barriers to energy efficiency are investigated empirically.
[S] Specific energy strategies are not discussed. Long-term energy management strategies are dedicated to a research question.
[T] Payback period is used to assess energy-related investments. They range between 1 to 4 years.
[U] -
[V] No information on actual energy costs.

Authors	Year	[A] Research Method	[B] # of Companies	[C] Industry	[D] Company Size	[E] Energy Intensity	[F] Energy Mix	[G] Energy Cost Center	[H] 1st Stage Allocation	[I] 2nd Stage Allocation	[J] Measurement of Energy	[K] Energy Audit	[L] Energy Efficiency	[M] Energy Strategy	[N] Investment Decisions

[O] Description of energy cost center
[P] Description of allocation of energy costs
[Q] Description of energy measurement
[R] Description of energy efficiency
[S] Description of energy strategy

(*continued on next page*)

Table 6 (*continued*)

Authors	Year	[A] Research Method	[B] # of Companies	[C] Industry	[D] Company Size	[E] Energy Intensity	[F] Energy Mix	[G] Energy Cost Center	[H] 1st Stage Allocation	[I] 2nd Stage Allocation	[J] Measurement of Energy	[K] Energy Audit	[L] Energy Efficiency	[M] Energy Strategy	[N] Investment Decisions
Herce et al.	2021	Archival Data	> 700	Diverse	Diverse	Not specified	Not specified	NO	NO	NO		n	YES	y	n y

[T] Description of investment and criteria
[U] Description of application of Specific Energy Consumption (SEC)
[V] Summary of quantitative information on energy costs

[O] -
[P] -
[Q] No specific information on energy measurement at the level of a single company. However, aggregated information on industry-specific energy consumption is given in toe. Moreover, the coverage of energy monitoring systems in different industries in Italy is analyzed.
[R] Investigation of energy efficiency metrics used as reported in the underlying Energy Audits. Moreover, so-called energy performance improvement actions and their occurrence across different sectors in Italy are investigated.
[S] Specific energy strategies are not discussed. However, energy efficiency strategies are mentioned.
[T] No assessment of investments based on energy metrics but the ratio between investment and saving as well as payback time is proposed as an indicator for investment decisions related to energy.
[U] -
[V] No information on actual energy costs. The cost-effectiveness of energy-related investments and the corresponding savings were investigated.

Authors	Year	[A] Research Method	[B] # of Companies	[C] Industry	[D] Company Size	[E] Energy Intensity	[F] Energy Mix	[G] Energy Cost Center	[H] 1st Stage Allocation	[I] 2nd Stage Allocation	[J] Measurement of Energy	[K] Energy Audit	[L] Energy Efficiency	[M] Energy Strategy	[N] Investment Decisions
Hossain et al.	2020	Multiple Case Study	7	Brick and cement	Not specified	Energy intense	Not specified	NO	n	n		n	y	YES	n y

[O] -
[P] No specific information on the allocation of energy costs neither on the first nor on the second stage. However, the allocation of energy costs is recognized as a vital factor for efficient energy management.
[Q] No discussion on the measurement of energy costs but energy cost monitoring was mentioned as important for energy management.
[R] 11 different metrics for the cement industry were analyzed and explained. In addition, barriers and drivers were investigated. The potential of energy efficiency was estimated at around 10% in the investigated industry.
[S] Specific energy strategies are not discussed. However, the importance of energy management and energy efficiency strategies is mentioned.
[T] Energy-related investments are assessed using the payback period as a criterion. Typical payback time in the sample ranges between three to four years.
[U] -
[V] No information on actual energy costs. However, the investigation of energy costs was mentioned as an important aspect of energy management. Moreover, companies in this study were selected based on high energy costs of at least 6% of their turnover.

[O] Description of energy cost center
[P] Description of allocation of energy costs
[Q] Description of energy measurement
[R] Description of energy efficiency
[S] Description of energy strategy
[T] Description of investment and criteria
[U] Description of application of Specific Energy Consumption (SEC)
[V] Summary of quantitative information on energy costs

Authors	Year	[A] Research Method	[B] # of Companies	[C] Industry	[D] Company Size	[E] Energy Intensity	[F] Energy Mix	[G] Energy Cost Center	[H] 1st Stage Allocation	[I] 2nd Stage Allocation	[J] Measurement of Energy	[K] Energy Audit	[L] Energy Efficiency	[M] Energy Strategy	[N] Investment Decisions
Hrovatin et al.	2021	Questionnaire	21	Diverse	SME	Not specified	Not specified	NO	NO	NO	NO	n	y	NO	n

[O] -
[P] -
[Q] -
[R] Investigation of the adoption and the extent of energy efficiency metrics in Slovenian SMEs. Drivers and barriers are assessed and analyzed.
[S] -
[T] No assessment of investment decisions based on energy metrics However, the impact of costs in general on energy efficiency investments is discussed.
[U] -
[V] No information on actual energy costs. However, energy costs are discussed as a driver for energy efficiency investments.

(*continued on next page*)

Table 6 (*continued*)

Authors	Year	[A] Research Method	[B] # of Companies	[C] Industry	[D] Company Size	[E] Energy Intensity	[F] Energy Mix	[G] Energy Cost Center	[H] 1st Stage Allocation	[I] 2nd Stage Allocation	[J] Measurement of Energy	[K] Energy Audit	[L] Energy Efficiency	[M] Energy Strategy	[N] Investment Decisions
Hrovatin et al.	2021	Questionnaire	21	Diverse	SME	Not specified	Not specified	NO	NO	NO	NO	n	y	NO	n
Janošovský et al.	2020	Case Study	1	Pulp and Paper	Not specified	Energy intense	Electricity Heat	NO	NO	NO	n	NO	n	NO	y

[O] -
[P] -
[Q] No further elaboration on how measurement is conducted. Heat and electricity consumption is available on a yearly base.
[R] No information on energy efficiency metrics was used. Process efficiency was the main target of this paper and energy savings occurred through this improved process efficiency.
[S] -
[T] A so-called simple rate of return was used to assess the energy-related investments. The investment sum was divided by the yearly cost savings.
[U] SEC was calculated separately on a yearly base for heat and electricity. The annual heat or electricity consumption was divided by the annual paper production.
[V] No information on actual energy costs. 4 industry specific energy saving potentials were analyzed. Their combined energy cost saving would be 158,000 € per year.

Authors	Year	[A] Research Method	[B] # of Companies	[C] Industry	[D] Company Size	[E] Energy Intensity	[F] Energy Mix	[G] Energy Cost Center	[H] 1st Stage Allocation	[I] 2nd Stage Allocation	[J] Measurement of Energy	[K] Energy Audit	[L] Energy Efficiency	[M] Energy Strategy	[N] Investment Decisions
Knayer and Kryvinska	2023	Multiple Case Study	386	Diverse	Diverse	Not specified	Diverse	NO	NO	NO	n	n	y	NO	n

[O] -
[P] -
[Q] No information on the measurement of energy costs but measurement methods are mentioned.
[R] The occurrence of energy management systems and eleven additional technologies that could have been adopted and their influence on energy efficiency were investigated empirically.
[S] -
[T] No assessment of investments based on energy metrics but multiple mentions of investment decisions that could be influenced by parameters related to energy efficiency or energy consumption.
[U] -
[V] No information on actual energy cost data in the investigated companies. However, questions on energy consumption and the associated energy costs were asked in the course of the case studies.

Authors	Year	[A] Research Method	[B] # of Companies	[C] Industry	[D] Company Size	[E] Energy Intensity	[F] Energy Mix	[G] Energy Cost Center	[H] 1st Stage Allocation	[I] 2nd Stage Allocation	[J] Measurement of Energy	[K] Energy Audit	[L] Energy Efficiency	[M] Energy Strategy	[N] Investment Decisions
Kumalawati et al.	2023	Questionnaire	169	Textile	Diverse	Not specified	Not specified	NO	n	n	NO	NO	n	n	n

[O] -

(*continued on next page*)

[O] Description of energy cost center
[P] Description of allocation of energy costs
[Q] Description of energy measurement
[R] Description of energy efficiency
[S] Description of energy strategy
[T] Description of investment and criteria
[U] Description of application of Specific Energy Consumption (SEC)
[V] Summary of quantitative information on energy costs

Table 6 (*continued*)

Knayer and Kryvinska	2023	**[A]**	**[B]**	**[C]**	**[D]**	**[E]**	**[F]**	**[G]**	**[H]**	**[I]**	**[J]**	**[K]**	**[L]**	**[M]**	**[N]**
		Multiple Case Study	386	Diverse	Diverse	Not specified	Diverse	NO	NO	NO	n	n	y	NO	n

[P] No specific allocation of energy costs neither on the first nor on the second stage. However, the necessity of the allocation of environmental costs (including energy costs) is recognized in a measurement indicator of the analysis.
[Q] -
[R] Broadly talk about achieving energy efficiency through energy savings but no further elaboration on energy efficiency.
[S] No specific energy strategy, but a positive influence of environmental strategies like energy conservation on economic growth is mentioned.
[T] No assessment of investment decisions based on energy metrics but mention of the influence of sustainability metrics (like energy-related metrics) on investment decisions.
[U] -
[V] No information on actual energy costs. Energy cost savings are mentioned as a desired result of environmental management accounting practices.

Authors	**Year**	**[A] Research Method**	**[B] # of Companies**	**[C] Industry**	**[D] Company Size**	**[E] Energy Intensity**	**[F] Energy Mix**	**[G] Energy Cost Center**	**[H] 1st Stage Allocation**	**[I] 2nd Stage Allocation**	**[J] Measurement of Energy**	**[K] Energy Audit**	**[L] Energy Efficiency**	**[M] Energy Strategy**	**[N] Investment Decisions**

[O] Description of energy cost center
[P] Description of allocation of energy costs
[Q] Description of energy measurement
[R] Description of energy efficiency
[S] Description of energy strategy
[T] Description of investment and criteria
[U] Description of application of Specific Energy Consumption (SEC)
[V] Summary of quantitative information on energy costs

Lawrence et al.	2018	**[A]**	**[B]**	**[C]**	**[D]**	**[E]**	**[F]**	**[G]**	**[H]**	**[I]**	**[J]**	**[K]**	**[L]**	**[M]**	**[N]**
		Archival data	48	Pulp and Paper	Not specified	Not specified but likely	Biomass, Oil Heat Electricity	NO	NO	NO	n	n	n	n	y

[O] -
[P] -
[Q] No further elaboration how measurement is conducted. Consumption information is available for all energy carriers on a yearly basis.
[R] There are no specific energy efficiency metrics. However, multiple facets of energy efficiency and its dependencies are discussed,
[S] Specific energy strategies are not discussed. On-site electricity production and investments in electricity infrastructure is mentioned as a strategic reorientation.
[T] There is no information on specific investment criteria for energy-related investment decisions. Barriers for investments in energy efficiency actions are discussed.
[U] SEC was separately measured for biofuel and fossil fuel but there were also aggregated values, indicating the total energy use. All SEC metrics were given in GWh/kton output. In addition, variables representing production, energy use, firm characteristics, time, and energy price were investigated regarding their effect on SEC.
[V] No information on actual energy costs. However, energy prices and especially electricity prices are investigated.

Lawrence et al.	2019	**[A]**	**[B]**	**[C]**	**[D]**	**[E]**	**[F]**	**[G]**	**[H]**	**[I]**	**[J]**	**[K]**	**[L]**	**[M]**	**[N]**
		Questionnaire	29	Pulp and Paper	Diverse	Energy intense	Not specified	NO	n	n	YES	n	n	y	y

[O] -
[P] The allocation of energy costs is analyzed as a driver of energy management, finding a significant relationship, while the difficulty of allocation is not a significant barrier.
[Q] The companies' measurement of energy costs is classified using the following scale: (0) No measurement, [A] Invoice checking, (2) Monthly monitoring by energy-carrier, (3) weekly measurement for each process, unit, or building, (4) comprehensive measurement against targets with effective reporting to management
[R] No information on energy efficiency metrics. However, extensive mention of energy efficiency, drivers, and barriers.
[S] Specific energy strategies are not discussed. A long-term energy strategy is analyzed as a driver of energy management, finding a significant relationship. In addition, 26% of the companies do have an energy strategy for 5 years, 52% have an energy strategy for 3 to 5 years, and 22% have an energy strategy for 1 to 3 years.

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Table 6 (*continued*)

Lawrence et al.	2018	**[A]**	**[B]**	**[C]**	**[D]**	**[E]**	**[F]**	**[G]**	**[H]**	**[I]**	**[J]**	**[K]**	**[L]**	**[M]**	**[N]**
		Archival data	48	Pulp and Paper	Not specified	Not specified but likely	Biomass, Oil Heat Electricity	NO	NO	NO	n	n	n	n	y

[T] The companies energy-related investments are classified using the following scale: (0) No investment, (1) only low or no-cost implemented, (2) low or medium-cost considered if the payback period is short, (3) some appraisal criteria used, as for other cost-reduction projects, (4) resources routinely committed to energy efficiency supporting business objectives. However, there is no information on which criteria (besides payback) are used or how they are assessed.
[U] -
[V] No information on actual energy costs.

Authors	**Year**	**[A] Research Method**	**[B] # of Companies**	**[C] Industry**	**[D] Company Size**	**[E] Energy Intensity**	**[F] Energy Mix**	**[G] Energy Cost Center**	**[H] 1st Stage Allocation**	**[I] 2nd Stage Allocation**	**[J] Measurement of Energy**	**[K] Energy Audit**	**[L] Energy Efficiency**	**[M] Energy Strategy**	**[N] Investment Decisions**

[O] Description of energy cost center
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[V] Summary of quantitative information on energy costs

Luken and Saieed	2023	**[A]**	**[B]**	**[C]**	**[D]**	**[E]**	**[F]**	**[G]**	**[H]**	**[I]**	**[J]**	**[K]**	**[L]**	**[M]**	**[N]**
		Archival data	58	Diverse	Diverse	Not specified	Not specified	NO	NO	NO	NO	n	n	NO	YES

[O] -
[P] -
[Q] -
[R] No further description of energy efficiency metrics but energy efficiency is part of the resource efficiency metrics investigated. Reduced energy consumption in kWh per year is named as the only specific measure.
[S] -
[T] Payback periods for companies are given. The payback periods are classified into four categories: Less than half a year, less than one and a half years, less than three years, or more than three years. Separate specification of the number of companies for each category for each of the three investigated countries is given.
[U] -
[V] No specific information on energy costs but average energy use reductions per sector and country (Algeria, Morocco, Tunisia) and average production cost savings per sector and country are provided. However, there is no clear connection between those values. Total investments and savings in energy are given in monetary values (€) per country but not on a company specific level

Ma et al.	2019	**[A]**	**[B]**	**[C]**	**[D]**	**[E]**	**[F]**	**[G]**	**[H]**	**[I]**	**[J]**	**[K]**	**[L]**	**[M]**	**[N]**
		Case Study	1	Ceramic	Not specified	Energy intense	Coal Electricity Gas	NO	NO	NO	y	No	n	NO	NOS

[O] -
[P] -
[Q] Data on energy consumption for gas, electricity, and coal is measured using smart meters during the whole production process. Information is therefore available, at every desired level.
[R] There are no specific energy efficiency metrics. However, to compare the efficient usage of energy overall energy consumption is used.
[S] -

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Table 6 (*continued*)

Luken and Saieed	2023	**[A]** Archival data	**[B]** 58	**[C]** Diverse	**[D]** Diverse	**[E]** Not specified	**[F]** Not specified	**[G]** NO	**[H]** NO	**[I]** NO	**[J]** NO	**[K]** n	**[L]** n	**[M]** NO	**[N]** YES

[T] -
[U] -
[V] No information on actual energy costs.

Authors	Year	[A] Research Method	[B] # of Companies	[C] Industry	[D] Company Size	[E] Energy Intensity	[F] Energy Mix	[G] Energy Cost Center	[H] 1st Stage Allocation	[I] 2nd Stage Allocation	[J] Measurement of Energy	[K] Energy Audit	[L] Energy Efficiency	[M] Energy Strategy	[N] Investment Decisions

[O] Description of energy cost center
[P] Description of allocation of energy costs
[Q] Description of energy measurement
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[V] Summary of quantitative information on energy costs

Ma et al.	2021	**[A]** Case Study	**[B]** 1	**[C]** Ceramic	**[D]** Not specified	**[E]** Energy intense	**[F]** Electricity Gas Oil (Diesel)	**[G]** NO	**[H]** NO	**[I]** NO	**[J]** YES	**[K]** NO	**[L]** y	**[M]** n	**[N]** NO

[O] -
[P] -
[Q] Smart meters, smart sensors, RFID meters, RFID tags, and additional technologies were used to collect energy consumption data. Gas consumption data is available minutely in Nm^3 but is often aggregated (e.g., monthly). Measurement for the level of specific machines but also aggregated (e.g., workshop).
[R] No information on the energy efficiency metrics used. However, the comparison of energy consumption between machines is based on their energy efficiency.
[S] Specific energy strategies are not discussed. However, the strategic importance of energy management is mentioned.
[T] -
[U] -
[V] No information on actual energy costs. However, by implementing the proposed method, the company reduced energy consumption by 3% and energy costs by 4%.

Onjewu et al.	2022	**[A]** Archival data	**[B]** 137	**[C]** Diverse	**[D]** SME	**[E]** Not specified	**[F]** Not specified	**[G]** NO	**[H]** NO	**[I]** NO	**[J]** y	**[K]** n	**[L]** y	**[M]** y	**[N]** n

[O] -
[P] -
[Q] Labeled as energy consumption monitoring, the influence of measurements on sales performance is investigated. However, no detailed information on the occurrence of energy measurements is given, as the focus of this study is on the influence these measurements (as well as other variables) have on sales performance.
[R] The influence of energy efficiency metrics on sales performance is investigated in this study. However, no detailed information on the occurrence of energy efficiency metrics is given, as the focus of this study is on the influence these measurements (as well as other variables) have on sales performance. Nevertheless, some examples of energy efficiency enhancements are given.
[S] Specific energy strategies are not discussed. However, the influence of energy consumption targets on energy measurements and energy efficiency is investigated. Several examples of such targets are given.
[T] No assessment of investment decisions based on energy metrics. However, it is mentioned that companies can benefit from investing in energy efficiency.

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Table 6 (*continued*)

Ma et al.	2021	**[A]** Case Study	**[B]** 1	**[C]** Ceramic	**[D]** Not specified	**[E]** Energy intense	**[F]** Electricity Gas Oil (Diesel)	**[G]** NO	**[H]** NO	**[I]** NO	**[J]** YES	**[K]** NO	**[L]** y	**[M]** n	**[N]** NO

[U] -
[V] No information on actual energy costs. However, energy costs are discussed in several contexts like energy cost reductions being a positive outcome of energy efficiency enhancements.

Authors	**Year**	**[A] Research Method**	**[B] # of Companies**	**[C] Industry**	**[D] Company Size**	**[E] Energy Intensity**	**[F] Energy Mix**	**[G] Energy Cost Center**	**[H] 1st Stage Allocation**	**[I] 2nd Stage Allocation**	**[J] Measurement of Energy**	**[K] Energy Audit**	**[L] Energy Efficiency**	**[M] Energy Strategy**	**[N] Investment Decisions**

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Patel et al.	2022	**[A]** Questionnaire	**[B]** 594	**[C]** Diverse	**[D]** SME	**[E]** Not specified	**[F]** Not specified	**[G]** NO	**[H]** NO	**[I]** NO	**[J]** NO	**[K]** YES	**[L]** y	**[M]** n	**[N]** y

[O] -
[P] -
[Q] -
[R] There are no specific energy efficiency metrics. The authors find a statistically significant positive effect of energy management practices on energy efficiency and a statistically significant positive effect of energy efficiency on environmental performance. In addition, they find a significant moderating effect of top management commitment.
[S] Specific energy strategies are not discussed. However, the necessity of integrating energy considerations into strategic planning is stated.
[T] In general, the paper states that a financial assessment is necessary for every energy-related investment. Return on investment is proposed for this purpose.
[U] -
[V] No information on actual energy costs. However, the general financial performance is assessed based on variables related to energy.

Ruivo et al.	2021	**[A]** Multiple Case Study	**[B]** 3	**[C]** Ceramic	**[D]** SME	**[E]** Not specified but likely	**[F]** Electricity Gas	**[G]** NO	**[H]** NO	**[I]** NO	**[J]** y	**[K]** NO	**[L]** n	**[M]** n	**[N]** n

[O] -
[P] -
[Q] Monthly energy consumption in toe is available in each company for gas, electricity and in total.
[R] There are no specific energy efficiency metrics. The term energy efficiency is used to talk about potential actions that lead to energy savings.
[S] Specific energy strategies are not discussed. However, there is a discussion about strategies to achieve energy savings. The term strategy is used to propose sector-specific solutions to save energy.
[T] There is no information on specific investment criteria for energy-related investment decisions. The investigation only considered low to no investment cost energy saving potentials.
[U] SEC was estimated in kJ per kg output.

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Table 6 (*continued*)

Patel et al.	2022	**[A]**	**[B]**	**[C]**	**[D]**	**[E]**	**[F]**	**[G]**	**[H]**	**[I]**	**[J]**	**[K]**	**[L]**	**[M]**	**[N]**
		Questionnaire	594	Diverse	SME	Not specified	Not specified	NO	NO	NO	NO	YES	y	n	y

[V] Information on actual energy costs is available for each company and also per ton of output but there is no information on disaggregation for different energy carriers.

Authors	**Year**	**[A] Research Method**	**[B] # of Companies**	**[C] Industry**	**[D] Company Size**	**[E] Energy Intensity**	**[F] Energy Mix**	**[G] Energy Cost Center**	**[H] 1st Stage Allocation**	**[I] 2nd Stage Allocation**	**[J] Measurement of Energy**	**[K] Energy Audit**	**[L] Energy Efficiency**	**[M] Energy Strategy**	**[N] Investment Decisions**

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[Q] Description of energy measurement
[R] Description of energy efficiency
[S] Description of energy strategy
[T] Description of investment and criteria
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[V] Summary of quantitative information on energy costs

Sa et al.	2018	**[A]**	**[B]**	**[C]**	**[D]**	**[E]**	**[F]**	**[G]**	**[H]**	**[I]**	**[J]**	**[K]**	**[L]**	**[M]**	**[N]**
		Questionnaire, Interviews	10	Diverse	Large (5), SME (5)	Energy intense	Not specified	NO	NO	NO	NO	NO	n	n	YES

[O] -
[P] -
[Q] -
[R] There are no specific energy efficiency metrics. The extent of various cases for decision-making impacting energy efficiency is investigated.
[S] Specific energy strategies are not discussed. However, strategies and motives for the implementation of energy management systems are investigated. This is summoned in the environmental strategy.
[T] The application of a wide range of criteria for decision-making is investigated, including payback time, internal rate of return, cost-benefit analyses, and combinations of those.
[U] -
[V] No information on actual energy costs. Energy cost savings are found as a strong motivation for the implementation of energy management systems.

		[A]	**[B]**	**[C]**	**[D]**	**[E]**	**[F]**	**[G]**	**[H]**	**[I]**	**[J]**	**[K]**	**[L]**	**[M]**	**[N]**
Sarvestani et al.	2024	Case Study	1	Refinery	Not specified	Not specified	Gas	NO	NO	NO	y	NO	n	NO	NO

[O] -
[P] -
[Q] Measurement of the total consumed energy in GJ per day based on 30 points of measurement. Only the total consumed energy in GJ per day is available.
[R] Vaguely mentioned as an "undeniable necessity" to improve energy efficiency.
[S] -
[T] -
[U] Detailed description of SEC and its calculation. Implemented as energy [in GJ] necessary to provide a ton of refined gas. This was used as an index to assess the efficiency of the refinery on a daily basis.
[V] No specific information on energy costs but the implemented artificial intelligence approach uncovered improvement potential to reduce energy consumption and improve energy efficiency.

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Table 6 (*continued*)

Sa et al.	2018	**[A]**	**[B]**	**[C]**	**[D]**		**[E]**	**[F]**	**[G]**	**[H]**	**[I]**	**[J]**	**[K]**	**[L]**	**[M]**	**[N]**
		Questionnaire, Interviews	10	Diverse	Large (5), SME (5)		Energy intense	Not specified	NO	NO	NO	NO	NO	n	n	YES
Authors	**Year**	**[A] Research Method**	**[B] # of Companies**	**[C] Industry**	**[D] Company Size**	**[E] Energy Intensity**	**[F] Energy Mix**	**[G] Energy Cost Center**	**[H] 1st Stage Allocation**	**[I] 2nd Stage Allocation**	**[J] Measurement of Energy**	**[K] Energy Audit**	**[L] Energy Efficiency**	**[M] Energy Strategy**	**[N] Investment Decisions**	
		[O] Description of energy cost center														
		[P] Description of allocation of energy costs														
		[Q] Description of energy measurement														
		[R] Description of energy efficiency														
		[S] Description of energy strategy														
		[T] Description of investment and criteria														
		[U] Description of application of Specific Energy Consumption (SEC)														
		[V] Summary of quantitative information on energy costs														
Schulze et al.	2018	**[A]**	**[B]**	**[C]**	**[D]**		**[E]**	**[F]**	**[G]**	**[H]**	**[I]**	**[J]**	**[K]**	**[L]**	**[M]**	**[N]**
		Questionnaire	236	Diverse	at least 69 large		Not specified	Not specified	NO	NO	NO	n	n	y	y	NO
Schützen-hofer	2021	**[O]** - **[P]** - **[Q]** No further elaboration on how measurement is conducted. Consumption information is only available as an efficiency score. **[R]** There are no specific energy efficiency metrics. However, a measurement item called 'operational controls' is used to investigate aspects regarding energy efficiency. In addition, energy efficiency is derived from energy consumption efficiency and energy cost efficiency. **[S]** Specific energy strategies are not discussed. However, a measurement item called 'strategic/planning controls' is used to investigate aspects of an energy strategy. **[T]** - **[U]** - **[V]** No information on actual energy costs. Energy costs are only available as energy cost efficiency score.															
		[A]	**[B]**	**[C]**	**[D]**		**[E]**	**[F]**	**[G]**	**[H]**	**[I]**	**[J]**	**[K]**	**[L]**	**[M]**	**[N]**
		Multiple Case Study	45	Diverse	Large		Non intense	Not specified	NO	NO	NO	n	YES	y	NO	y
		[O] - **[P]** - **[Q]** No further elaboration on how measurement is conducted. Only aggregated measurement information is available on the energy consumption of buildings, processes and transportation in GWh. **[R]** No information on the energy efficiency metrics used. However, intense empirical investigation of energy efficiency potential in Austrian companies and energy savings observed through implemented energy efficiency metrics. **[S]** - **[T]** Energy-related investments are labeled as Energy efficiency actions. The payback period is used as a criterion to assess them. **[U]** - **[V]** No information on actual energy costs. However, energy cost savings for four different activities improving energy efficiency were provided in saved € per year.															

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Table 6 (*continued*)

Authors	Year	[A] Research Method	[B] # of Companies	[C] Industry	[D] Company Size	[E] Energy Intensity	[F] Energy Mix	[G] Energy Cost Center	[H] 1st Stage Allocation	[I] 2nd Stage Allocation	[J] Measurement of Energy	[K] Energy Audit	[L] Energy Efficiency	[M] Energy Strategy	[N] Investment Decisions
Schulze et al.	2018	Questionnaire	236	Diverse	at least 69 large		Not specified	Not specified	NO	NO	NO	n	n	y	y	NO
Sola and Mota	2020	Questionnaire	228	Diverse	Diverse		Energy intense	Not specified	NO	NO	NO	y	NO	y	n	y
Solnørdal and Nilsenn	2020	Case Study	1	Diverse	Large		Not specified	Not specified	NO	n	n	n	n	n	y	y

[O] Description of energy cost center
[P] Description of allocation of energy costs
[Q] Description of energy measurement
[R] Description of energy efficiency
[S] Description of energy strategy
[T] Description of investment and criteria
[U] Description of application of Specific Energy Consumption (SEC)
[V] Summary of quantitative information on energy costs

[O] -
[P] -
[Q] No specific information on the measurement of energy costs. However, in the aggregated result managers slightly agreed that their company is continuously monitoring energy use in processes and plants.
[R] 15 potential drivers for investments in energy efficiency and their perceived importance for the company were investigated. 11 of them were combined into 4 factors (production, economics, competitiveness, and environment) influencing organizational energy management.
[S] Specific energy strategies are not discussed. In the aggregated result managers were neutral on long-term strategic planning in the energy era and their participation in said planning. In addition to that, multiple factors contributing to the strategy were discussed.
[T] From the 15 potential drivers for investments in energy efficiency, 3 were criteria for energy-related investment decisions: significant energy cost reduction, a low payback time (<3 years), and a low initial investment.
[U] -
[V] No information on actual energy costs.

[O] -
[P] No specific information on the allocation of energy costs neither on the first nor on the second stage. However, the case company has two full-time employees responsible for the allocation of resources to energy issues,
[Q] No specific information on the measurement of energy costs. However, a systematic monitoring and measuring of energy consumption is mentioned.
[R] No information on the energy efficiency metrics used. A program deployed in the case company emphasizing energy efficiency is mentioned.
[S] The necessity for energy strategies is mentioned several times. Long- and short-term energy reduction targets are set as energy strategies.
[T] Investments in energy projects are assessed based on payback time, which should be around 2 to 3 years.
[U] -
[V] No information on actual energy costs. Energy costs were mentioned as an important input for investment decisions.

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Table 6 (*continued*)

Authors	Year	[A] Research Method	[B] # of Companies	[C] Industry	[D] Company Size	[E] Energy Intensity	[F] Energy Mix	[G] Energy Cost Center	[H] 1st Stage Allocation	[I] 2nd Stage Allocation	[J] Measurement of Energy	[K] Energy Audit	[L] Energy Efficiency	[M] Energy Strategy	[N] Investment Decisions
Sola and Mota	2020	Questionnaire	228	Diverse	Diverse		Energy intense	Not specified	NO	NO	NO	y	NO	y	n	y

[O] Description of energy cost center
[P] Description of allocation of energy costs
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Trianni et al.	2019	Multiple Case Study	3	Metal (1) Pulp and paper (2)	Large (2) SME (1)	Not specified but likely	Electricity Gas Oil	NO	y	y	n	y	y	n	y

[O] -
[P] The energy cost allocation of a company is classified in the following levels: (0) No energy-specific cost allocation, (1) allocation per unit of output, (2) (first stage) allocation to department/division level, (3) process specific energy cost allocation.
[Q] No specific information on how measurement is conducted. Annual energy consumption of electricity (in GWh), oil (in GWh), and gas (in GWh) is available.
[R] Although energy efficiency is one of the central aspects of this paper, there are no specific energy efficiency metrics. However, the relevance of defining KPIs for energy efficiency is underlined and many energy management practices related to energy efficiency are discussed.
[S] Specific energy strategies are not discussed. The energy strategy is considered part of the approach toward energy efficiency.
[T] The companies' energy-related investments are classified using the following levels: (0) No investment differentiation, (1) payback time threshold < 3 years, (2) payback time threshold < 3 years and different thresholds based on the investment, (3) net present value, internal rate of return, or specific evaluation process for energy-related investments. However, there is no information on which criteria are actually used by the case companies or how they are assessed.
[U] -
[V] No information on actual energy costs.

Trianni et al.	2020	Multiple Case Study	16	Diverse	SME	Non intense (3) Energy intense (11), Not specified (2)	Not specified	NO	NO	NO	n	n	YES	n	y

[O] -
[P] -
[Q] No further elaboration on how measurement is conducted. Information is available for one example company on the total energy consumption in kW.
[R] 17 different energy efficiency metrics or actions were assessed on 22 factors based on findings in the literature. In addition to that, these energy efficiency metrics were verified in 11 interviews.
[S] Specific energy strategies are not discussed. However, a long-term energy strategy is mentioned as a benefit.
[T] Investments in energy efficiency actions are assessed using the total investment cost, payback time, and the total energy savings.
[U] -
[V] No information on actual energy costs. Energy costs were solely mentioned as reference value for the decision whether a company is energy-intense or not.

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Table 6 (*continued*)

Trianni et al.	2019	**[A]** Multiple Case Study	**[B]** 3	**[C]** Metal (1) Pulp and paper (2)	**[D]** Large (2) SME (1)	**[E]** Not specified but likely	**[F]** Electricity Gas Oil	**[G]** NO	**[H]** y	**[I]** y	**[J]** n	**[K]** y	**[L]** y	**[M]** n	**[N]** y

Authors	**Year**	**[A] Research Method**	**[B] # of Companies**	**[C] Industry**	**[D] Company Size**	**[E] Energy Intensity**	**[F] Energy Mix**	**[G] Energy Cost Center**	**[H] 1st Stage Allocation**	**[I] 2nd Stage Allocation**	**[J] Measurement of Energy**	**[K] Energy Audit**	**[L] Energy Efficiency**	**[M] Energy Strategy**	**[N] Investment Decisions**

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[P] Description of allocation of energy costs
[Q] Description of energy measurement
[R] Description of energy efficiency
[S] Description of energy strategy
[T] Description of investment and criteria
[U] Description of application of Specific Energy Consumption (SEC)
[V] Summary of quantitative information on energy costs

Trianni et al.	2021	**[A]** Interviews	**[B]** 217	**[C]** Diverse	**[D]** SME	**[E]** Non intense (113), Energy intense (104)	**[F]** Not specified	**[G]** NO	**[H]** NO	**[I]** NO	**[J]** n	**[K]** n	**[L]** y	**[M]** n	**[N]** n

[O] -
[P] -
[Q] No further elaboration on how measurement is conducted.
[R] No information on the energy efficiency metrics used. Detailed information on the impact of the adoption of energy efficiency metrics and the willingness to adopt and implement them.
[S] Specific energy strategies are not discussed. However, the necessity of energy cost information for the development of strategies is mentioned.
[T] No assessment of investments based on energy metrics. However, the importance of energy information in investment decisions is mentioned.
[U] No elaboration on SEC. However, increased SEC is briefly mentioned as a result of negative energy savings in Slovenia.
[V] No information on actual energy costs. The urge to have energy cost information is mentioned.

Viesi et al.	2023	**[A]** Case Study	**[B]** 1	**[C]** Tourism (Ski)	**[D]** SME	**[E]** Not specified but likely	**[F]** Biomass Electricity Oil	**[G]** NO	**[H]** NO	**[I]** YES	**[J]** n	**[K]** NO	**[L]** n	**[M]** n	**[N]** NO

[O] -
[P] No first stage allocation of energy costs to cost centers as energy consumptions were directly measured for each ski lift (cost center). Second stage allocation based on skier days (1 person skiing 1 day) to KPIs.
[Q] Direct measurement of the consumption of electricity for ski lifts and buildings. No measurement for oil and biomass.
[R] No specific energy efficiency metrics, but they talk broadly about the necessity of energy efficiency improvements.
[S] No specific energy strategy, but the improvement of energy efficiency is part of the broader environmental strategy.
[T] -
[U] -
[V] Specific cost information is only available for heating purposes. Everything else is just mentioned in consumption numbers. Energy efficiency potentials that could be tackled would lead to a decrease in operating costs according to the authors, but no specific numbers are calculated or mentioned.

Authors	**Year**	**[A] Research Method**	**[B] # of Companies**	**[C] Industry**	**[D] Company Size**	**[E] Energy Intensity**	**[F] Energy Mix**	**[G] Energy Cost Center**	**[H] 1st Stage Allocation**	**[I] 2nd Stage Allocation**	**[J] Measurement of Energy**	**[K] Energy Audit**	**[L] Energy Efficiency**	**[M] Energy Strategy**	**[N] Investment Decisions**

[O] Description of energy cost center
[P] Description of allocation of energy costs
[Q] Description of energy measurement
[R] Description of energy efficiency
[S] Description of energy strategy

(*continued on next page*)

Table 6 (*continued*)

[T] Description of investment and criteria
[U] Description of application of Specific Energy Consumption (SEC)
[V] Summary of quantitative information on energy costs

		[A]	[B]	[C]	[D]	[E]	[F]	[G]	[H]	[I]	[J]	[K]	[L]	[M]	[N]
Yandri et al..	2024	Case Study	1	Metal	Not specified	Not specified but likely	Electricity Gas Oil (Diesel)	NO	NO	NO	YES	n	n	NO	NO

[O] -
[P] -
[Q] Measurement of the consumed energy on a monthly base in kWh. Values available both in total and individual values for electricity, gas, and diesel. The values for gas and diesel are both available in kWh and the functional unit (mmBTU and liter). In addition to that, the amount of on-site generated electricity (PV) is also available in kWh.
[R] Further improvement of energy efficiency in the future is mentioned as a long-term goal.
[S] -
[T] -
[U] -
[V] No information on actual energy cost data. However, the main idea of this paper is to set energy goals based on the best-demonstrated performance (BDP). They run a simulation for this BDP in the target company, which would achieve an energy cost saving of 7%.

Data availability

No data was used for the research described in the article.

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