

Article

Determinants of Energy Efficient Innovation: A Systematic Literature Review

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Abstract: Engaging firms to generate and adopt energy efficient innovation is crucial for balancing energy needs for sustainable development. In addition, a reduction in energy consumption can address environmental problems and lower production costs by reducing materials and/or energy costs and costs related to compliance with regulations. Considering the lack of systematic reviews focused on the determinants of energy efficient innovation, we address this gap and set forth to enhance the body of knowledge in the field of energy efficient innovation. To achieve the research aim, a systematic literature review and qualitative content analysis were conducted. This study offers two contributions. First, the study distinguishes the determinants of energy efficient innovation in three levels: micro-level, meso-level, and macro-level. According to the findings, the following determinants of energy efficient innovation are highlighted at the micro-level: (1) cost savings; (2) previous experience; (3) technological capabilities; (4) green capabilities; (5) innovation capabilities; (6) knowledge development; (7) organizational innovations; (8) financial resources; (9) investment in tangible assets. Meanwhile, the determinants are distinguished at the meso-level: (1) competitive pressure; (2) customer and provider pressure; (3) external knowledge cooperation; (4) social pressure; (5) voluntary agreements. Finally, the determinants are disclosed at the macro-level: (1) government subsidies; (2) current or future regulation. Second, the study provides insights on the determinants of energy efficient innovation and sets an agenda for future research. The study demonstrates the need for further investigations on the drivers of energy efficient innovation as compared to general eco-innovation.



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1. Introduction

The improvement of energy efficiency and companies' involvement in the development of energy efficient innovations are essential for balancing energy needs and sustainable development [1]. According to the International Energy Agency (IEA) [2], it is necessary to transform the world's energy system, and thus the energy community must be convinced to redirect energy investments and switch to low-carbon development that delivers expectations of economic growth and social development. Moreover, the reduction of energy consumption can address environmental problems [3] and lower production costs by reducing materials and/or energy costs and costs related to compliance with regulations. These actions exert a positive and significant effect on the profitability and competitive advantage of firms [4,5]. Resource savings is an important indicator of the relationship between eco-innovation and cost performance [6,7], and therefore numerous studies confirmed the importance of eco-innovation on firms' financial and environmental performance [6,8–10]. Consequently, energy efficient innovations are essential for a green economy [1] and for energy intense industries, which account for a significant part of

the world's resource and energy consumption [5]. Therefore, energy efficient innovations create a positive environmental effect through resource savings [11].

Although the phenomenon of eco-innovation triggered several literature reviews, most studies focused on the determinants of eco-innovation without distinguishing energy and environmental efficiency dimensions. Thus, limited efforts have been devoted to distinguishing energy efficient eco-innovation and environmental efficient eco-innovation [1,9]. Pacheco et al. [12] conducted a systematic review and investigated the scientific literature on the determinants of eco-innovation in manufacturing SMEs. The study revealed 23 determinants in seven different categories (external context, internal context, strategies, learning, structure, operations, and results). Meanwhile, Zubeltzu-Jaka et al. [13] identified the main clusters of determinants related to eco-innovation by conducting a meta-analytic study. The study revealed that the “market pull” and “technology push” clusters were the main triggers of eco-innovation at the firm level. Pham et al. [14] applied a systematic review of environmental innovation intending to reveal the determinants of eco-innovation at the firm level from a knowledge-based resource perspective. The scholars developed a conceptual model of environmental innovativeness by distinguishing external and internal determinants. Furthermore, Munodawafa and Johl [9] conducted a systematic review of eco-innovation and performance from resource-based and stakeholder perspectives. The study revealed that human capital, market demand, regulation, and supply chain requirements were the major contributors to eco-innovation and performance relationships. Salim et al. [15] investigated the internal factors related to the internal capabilities of manufacturing firms, which enhance eco-innovation performance. The study classified the internal capabilities of the firms into strategy, structure, and culture. Furthermore, the study revealed the positive effect of internal factors on eco-innovation performance compared to the effect of external factors. Bossle et al. [16] conducted a systematic literature review on the drivers of the adoption of eco-innovation. The study classified the drivers into internal and external factors. Furthermore, the scholars concluded that eco-innovation in some cases might boost the performance of the firms. The literature concludes that the generation and adoption of eco-innovation are impacted by regulation, normative pressures, and the need for efficiency. In sum, a range of factors was investigated in a broad area of eco-innovation. However, a systematic review of factors impacting energy efficient eco-innovation is missing.

Therefore, we address this research gap and set forth to enhance the body of knowledge in the field of energy efficient innovation. The research question is formulated as follows: what are the antecedents and motivations behind the generation and adoption of energy efficient innovation? More specifically, we focus on the determinants of energy efficient innovation, which is defined as “innovation that reduces the use of energy and/or materials” (Rennings and Rammer [17]; Ghisetti and Rennings [4]). Thus, energy efficient innovation refers to eco-innovation associated with energy efficiency as the goal of the firm and innovations that save energy and/or materials. For the purpose of this study, we use the terms “energy efficient innovation”, “energy innovation”, and “energy eco-innovation” interchangeably. A literature review on energy efficient innovation and a detailed explanation of the terminology applied in this study are presented in Section 2. The study aims to systematically classify and analyze scientific studies conducted on the determinants of energy efficient innovation. Thus, this study offers two contributions. First, the study distinguishes the determinants of energy efficient innovation. Secondly, the study provides insights on the determinants of energy efficient innovation and sets an agenda for future research.

The paper is structured as follows. In the next section, theoretical background and terminology on energy efficient innovation are presented. Section 3 provides a detailed explanation of the research protocol. Section 4 provides descriptive findings and a discussion of the reviewed literature on the determinants of energy efficient innovation. Future research agendas are highlighted in Section 5 and conclusions are provided in Section 6.

2. Theoretical Background

The literature investigates energy efficient innovation as a specific subset of eco-innovation [1,17–19], which contributes to improving both the environmental quality of products and the resource efficiency of products and processes [17]. A multidisciplinary approach to eco-innovation has led to various definitions adopted in the scientific literature. According to Schiederig et al. [20], four different terms “eco/ecological”, “environmental”, “green”, and “sustainable”, which describe the same phenomenon, are used interchangeably in the scientific community. Furthermore, all four notions investigate to some extent the same topic [20]. Accordingly, six important aspects, summarizing different notions, were distinguished: (1) innovation object: product, process, service, method; (2) market orientation: satisfy needs/be competitive on the market; (3) environmental aspect: reduce negative impact; (4) phase: full life cycle must be considered (for energy or material reduction); (5) impulse: intention for reduction may be economical or ecological; (6) level: setting a new innovation/green standard to the firm. Franceschini et al. [21] investigated scientific studies on the application of these four notions and observed some similarities. On the other hand, the study suggests considering the context in which the terms are applied. According to the Eco-Innovation Observatory [22], eco-innovation is defined as “the introduction of any new or significantly improved product (goods or service), process, organizational change or marketing solution that reduces the use of natural resources (including materials, energy, water, and land) and decreases the release of harmful substances across the whole life-cycle”.

The expanding studies on eco-innovation have involved various scholars with a wide spectrum of backgrounds [9]. As a result, several theories such as the resource-based view [23], stakeholder perspective [24], absorptive capacity perspective [25], institutional-based view [26] have been adopted by the scholars within areas such as Finance & Economics [27], Agriculture [28], Strategic Management [29], Engineering [30], and Environmental Science [31]. The resource-based view perceives the role of resources as the most relevant for the competitive advantage and innovation processes of a firm [23]. Therefore, studies on eco-innovation emphasize the importance of a firm’s competencies achieved through the use of resources [9]. Consequently, the adoption of the resource-based view predominates in eco-innovation studies [32]. Meanwhile, the absorptive capacity perspective assumes that the innovative performance of the firm is influenced by prior knowledge and the ability to develop new knowledge. Therefore, studies investigate how absorptive capacity, knowledge accumulation capabilities, and cooperation strategies affect the environmental innovation of firms [25]. The stakeholder perspective emphasizes the importance of stakeholders impacting organizational activities. Therefore, corporate environmental strategies, the adoption of eco-innovation and environmental performance are impacted by both internal and external stakeholders [24]. Furthermore, the institutional-based view emphasizes the importance of regulatory and social pressures rather than just market institutions to understand the economic behaviour of the firm. Thus, the adoption of an institutional-based view attempts to explain how the institutional context creates incentives and puts pressure on firms, leading to more environmentally sustainable economic activities [26] and how institutional frameworks shape the dynamics of eco-innovation.

From the conceptual perspective, scientific investigations have focused on the involvement of firms in eco-innovation in general [32]. In fact, it would be incorrect to consider all eco-innovations to be homogeneous because eco-innovation can have a diverse effect through reduction of pollution or reduction of energy and/or material use [3,4,27,33]. Recent studies distinguished the energy efficiency dimension and classified eco-innovations into broader types. According to Ghisetti and Rennings [4], eco-innovation is classified as follows: (1) energy efficient innovation, that is, an innovation that reduces energy and/or material use; (2) environmental innovation, that is, an innovation that reduces negative environmental impacts, such as air, water pollution, and harmful materials. However, both types of eco-innovation (i.e., those that reduce pollution or those that reduce energy) face the “double externality problem” typical for eco-innovation [34,35], and reduce

the negative environmental impact. Meanwhile, Arranz et al. [36] suggested measuring eco-innovation activity of the firm by considering the following criteria: (1) less energy per production; (2) lower environmental impact; (3) improvement in health and safety; (4) compliance with regulatory requirements. Fernando and Wah [37] proposed to measure the environmental performance of the firm by considering the following criteria: energy usage, achievement of regulatory compliance, the perspective of organizational processes, and capital expenditures. The studies by Capozza et al. [38] and Segarra-Blasco and Jové-Llopis [39] took a step even further and distinguished energy innovation into the following types: (1) innovation aimed at reducing energy consumption (i.e., energy efficient innovation) and (2) innovation focused on increasing the use of renewable energy sources (i.e., renewable energy innovations). The distinctive feature of energy efficient innovation in comparison to environmental innovation (e.g., technologies aiming to reduce the noise) lies in the notion that this type of innovation is to some extent a private good and reduces the costs which are incurred by the firms due to the use of energy and materials [17]. Moreover, empirical evidence confirmed that energy efficient innovation and environmental innovation are inherently different, either in drivers and productivity or in the role of barriers to innovation [4,17]. Therefore, in this study, we focus on energy efficient innovation, which is different from environmental innovation and subsequently, factors impacting the generation and the adoption of energy innovation by firm are inherently different.

Although energy efficiency policies typically focus on the meso- or macro-scale, the implementation of eco-innovation practices is observed at the micro-level of the firm [40]. Thus, eco-innovations are driven either by external pressure, i.e., government regulation and stakeholder pressure, or by firms' recognition that eco-innovations contribute to competitive advantage and increased performance through cost reduction and/or improved reputation in the market [41]. It appears that the generation and adoption of eco-innovation depend on different determinants, and firms are more likely to prioritize strategic investments for eco-innovation once they are aware that eco-innovation will improve the performance [3,42]. However, firms' strategies differ in approaching the implementation of eco-innovation, from passive compliance with government regulations to proactive implementation of eco-innovation in exploring new markets [40]. Furthermore, eco-innovation is not necessarily driven by the firm's strategy to develop environmentally sustainable economic activity but can be the result of developed innovation. Therefore, the development of eco-innovation could be related to other objectives than the target to reduce environmental impact [1,17,18]. This is especially relevant for energy efficient innovation, which focuses on operational cost and energy savings.

The scholars revealed that energy efficient innovation could significantly affect the profitability of the firm compared to environmental innovation [4]. Although environmental innovation demonstrates profitability in the long run due to environmental regulation, the outcomes are not so obvious in the short term. Therefore, energy efficient innovation positively affects profitability and leads to a "win-win" situation in which the environmental impact is reduced while improving the economic performance of firms [4,17]. Therefore, it is important to gain an understanding of the determinants of energy efficient innovation and to gain insight into the motivations of organizations to generate and adopt energy eco-innovation [37]. In this study, we set forth to enhance the body of knowledge in the field of determinants of energy efficient innovation and investigate the antecedents and motivations behind the generation and adoption of energy efficient innovation.

3. Materials and Methods

The systematic literature review (SLR) on the determinants of energy efficient innovation in this study follows the guidelines presented in scientific studies [43]. In particular, SLR is a precise method to summarize the academic literature to answer the research question(s), which is based on a consistent process [44]. The method is grounded on the systematic approach to the collection of secondary data, the critical evaluation of research studies, and the qualitative or quantitative synthesis of the findings [45]. Thus, the method

relies on pre-planned methods, which minimize bias and random errors, and has the potential to achieve rigorous scientific investigations. Therefore, SLR is recognized as a more transparent method for the development of theories [46]. We adapted the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [47] to focus specifically on the determinants of energy efficient innovation. The research design and process included in this research protocol are presented in Figure 1.

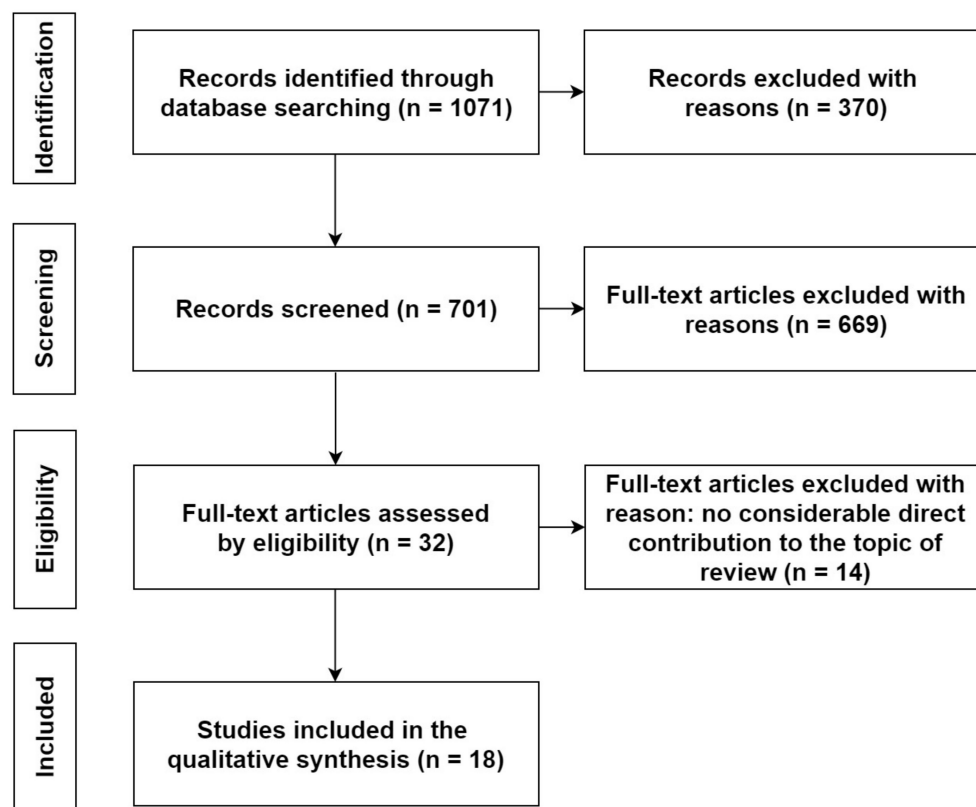


Figure 1. Research design (developed by authors according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [47]).

Notably, SLR is conducted in stages. Stage 1: Planning the review, which consists of (1) identification for the need for a review; and (2) development of a review protocol. Stage 2: Conducting the review, which consists of: (1) identification of research and study selection (detailed explanation is presented in Section 3.1); (2) broad literature screening (detailed explanation is presented in Section 3.2); (3) literature assessment for eligibility (detailed explanation is presented in Section 3.3); (4) qualitative synthesis (detailed explanation is presented in Section 3.4). Stage 3: Presentation of results (Section 4) and recommendations for future research (Section 5).

3.1. Records Identified through Database Searching

The identification process of the initial records was performed in September 2021. For this study, a search was performed, and data were collected from one of the most relevant scientific citation databases [39], the ISI Web of Science Core Collection (WoSCC). The decision to conduct the search in this database was made considering several arguments. First, the database is multidisciplinary, indexing the most cited journals in the respective fields [46,48]. Although some studies have attempted to compare databases, such as WoS, Scopus, and Google Scholar, the scientometric community has not yet reached a common opinion of “which one is better” [49]. Second, Gao et al. [50] recommended the WoS database for social sciences due to the high proportion of exclusive journals. Moreover, the database gained a high reputation and recognition in the scientific community, and thus, it

became a primary source of citation data [51]. Therefore, WoS appears to be more suitable for searching and analyzing the scientific literature at the publication level [49]. Third, the database was used by other scholars for the reviews of the literature [50,52]. In addition, WoS Social Science Citation Index (SSCI)/Journal Citation Report was selected due to the impact factor in the Journal Citation Report (JCR) ranks of its journals [53]. The literature refers to WoS SSCI as the most well-known bibliographic database [54,55], which contains more than 3500 of the most influential social science journals in their respective fields.

The search terms used in the literature review on the determinants of energy efficient innovation are presented in Table 1. To address the research question and the purpose of this study, two streams of search keywords were used: (1) energy efficient innovation and (2) determinants. Based on the analysis of the terminology presented in Section 2, we adopted a broader search. This approach let us extract the studies, which investigate and clearly separate the determinants of energy efficient innovation. For the first stream, the search terms included four terms that define innovation, which aims to reduce the harm of economic activities in the environment (see [20] for a detailed explanation of the terms). In addition, the term “energy efficient innovation” was included. For the second stream, the determinants included “drivers” and “driving forces”. In particular, quotation marks and an asterisk were used in the keyword search for a purposeful combination of two keywords: energy with innovation (e.g., energy innovation). This approach lets us diminish the risk to trace keywords separately used in the title or abstract. The asterisk helps to extract the different word endings (e.g., innovat*), such as innovation, innovations, innovative, etc. The topic search includes title, abstract, author keywords, and keywords plus. The timespan was defined as all years.

Table 1. Search terms used in the literature review of determinants of energy efficient innovations.

Topic	Search Terms
Energy efficient innovation	(“energy efficient innovation*” OR energy-innovation OR “energy innovation” OR “eco-innovat*” OR “ecolog* innovat*” OR “environment* innovat*” OR “green innovat*” OR “sustainab* innovat*”)
Determinants	(determinant* OR driver* OR “driving force*”)

The initial search resulted in 1071 publications. Later, additional filters were added to achieve the most relevant results. Thus, the type of document was limited to articles only, in order to avoid incomplete research, such as conference papers. The language was limited to the English language. Following previous studies [56–59], we limited the search strategy to articles indexed in WoS SSCI as a scientific field, which includes management-related areas and enables us to retrieve high-quality publications [59]. In total, 701 articles were exported with full record and cited references in the “.txt” format and used in the screening stage.

3.2. Records Screening

The screening of records ($n = 701$) included a careful reading of abstracts and full-text papers (only when necessary). Notably, this stage is essential for SLR and let us assess the validity of individual studies and thus, diminish the risk of bias assessment [60]. In order to reduce the risk of bias screening, two researchers performed this process separately according to the agreed inclusion and exclusion criteria (Table 2).

Table 2. Article inclusion and exclusion criteria.

Article Inclusion Criteria	Article Exclusion Criteria
(1) Studies that investigate and clearly separate the determinants of energy efficient innovation as part of the study or as a whole study;	(1) Studies that do not distinguish the energy efficiency variable and consider both energy efficient and environmental efficient innovation as equal;
(2) Include a clear description of the field-work and the results deriving thereof.	(2) Studies that investigate the results (outcome) of energy efficient innovation (i.e., competitive advantage, firm performance and etc.);
	(3) Studies that investigate environmental innovation;
	(4) Studies that investigate barriers of energy efficient innovation;
	(5) Studies that investigate special natural ecological systems, such as forests, water, etc.
	(6) Other systematic literature reviews, bibliometric analysis, etc.

Notably, the data were downloaded in the “.txt” format and used in MS Excel, with the aim of screening all titles, keywords, and abstracts of the articles. The screening process included the following stages: (1) records were screened and evaluated from 1–3 by two researchers separately; (2) the results of each researcher were compared; (3) articles with different ratings were discussed, and a final decision was made. Based on the authors’ names from A–Z, all articles were sorted. Aiming to avoid bias by sorting, for example: (1) by date (it is possible that the newest articles are more likely to be selected); (2) by total citations (it is possible that articles that have a higher citation rate are more likely to be selected; (3) by journals (it is possible that certain journals are more likely to be selected and favoured by researchers). Later, other information related to the article was hidden by applying the hide function in MS Excel, except for (i) title of the article, (ii) author keywords, and (iii) abstract. Two researchers rated each article from 1 to 3, where 1—not acceptable for further analysis, 2—not entirely clear from the abstract and full-text review is needed, and 3—acceptable for further analysis. Only a few articles required a full-text review at this stage. In addition, “dummy” articles ($n = 30$) were added that were completely outside the scope of this study and from different topics in order to randomize and slow down researchers for automatic article evaluation. Later, the results of both researchers were compared and discussed. The most attention was paid to the articles that were evaluated “2”, and those articles in which some information was not entirely clear from the abstract during the discussion stage. Notably, the records evaluated by “1” and “3” were almost consistent between researchers, and only slight and insignificant errors occurred. Subsequently, based on the inclusion and exclusion criteria, two researchers agreed to proceed with 32 articles for full-text review.

3.3. Eligibility

In total, 32 full-text articles were assessed for eligibility. After full-text analysis, 14 articles were rejected for the following reasons: (1) although the abstract stated that energy innovation was investigated, the full-text analysis revealed a lack of clear separation between the determinants of energy and environmental innovation ($n = 9$); (2) the article did not include a clear description of the field-work and the results deriving thereof ($n = 2$); (3) the article did not emphasize a considerable direct contribution to the topic of review ($n = 3$), that is, no distinct conclusions were made on the determinants that trigger energy efficient innovation. Notably, it was not possible to reject these 14 articles in the record screening stage without a full-text review. Thus, only a few articles required full-text review in the records screening stage, and mainly due to the information presented in the abstract. Considering the focus of this study on the determinants of energy efficient innovation, a

clear difference between the determinants of energy efficient innovation and environmental innovation is necessary. Thus, 18 articles were selected for qualitative synthesis.

3.4. Qualitative Synthesis

To address the research question and the purpose of this study, a qualitative content analysis was conducted following the guidelines [61]. Notably, “Mendeley Desktop” software was used at this stage. According to Bengtsson [61], content analysis is a method that is suitable when “a researcher cannot use statistical analysis to give meaning to the data”. Content analysis offers researchers a flexible and pragmatic method to develop and extend knowledge [62]. The advantage of this method is that large volumes of textual data and different textual sources can be dealt with and used to corroborate evidence [63]. After the planning and data collection stage, the data analysis occurred in the following sequence. Stage 1: decontextualisation. An in-depth analysis of the articles was conducted with the aim of identifying the determinants of energy efficient innovation. Stage 2: recontextualisation. The identified determinants were checked to see whether all aspects of the content have been covered in relation to the purpose of the study. Stage 3: categorization. The determinants are described by contents of the categories [63] (three levels of determinants), and the content of the categories is described through sub-categories, i.e., detailed and aggregated determinants. This study classifies the determinants using a multilevel framework, which allows us to understand the different determinants of energy efficient innovation and review the results of previous studies. Thus, the classification included three levels: (1) micro-level, (2) meso-level and, (3) macro-level. Micro-level refers to the organization’s level: strategy, business logic, resources and capabilities, etc. Meso-level refers to the sectorial and industrial level: the role of market dynamics, networks, pressure groups, etc. Macro-level refers to the institutional level: policy instruments, government subsidies, current or future regulations, etc. (see [41] for a detailed explanation of levels). Stage 4: compilation. A summary of categories and sub-categories is presented as a table to allow the reader to get a quick overview of the results [61]. Additional data are provided for each study to better reflect the results, such as (1) references; (2) sample size, data collection, and analysis method(s); (3) examined phenomenon; (4) determinants of energy efficient innovation. After a qualitative content analysis, the final results of the examined phenomenon are presented in the following sections.

4. Results and Discussion

In total, 18 articles were identified as relevant for the literature review on determinants of energy efficient innovation, based on the inclusion and exclusion criteria outlined in Section 3. Given that energy efficient innovation is investigated as a specific subset of eco-innovation [1,17–19], the search was not limited to a certain publication year (timespan: all years). The reviewed articles were published between 2009 and 2021 (Figure 2). In particular, only 3 articles were published in 2009–2014. Meanwhile, in 2010–2011, a number of publications focused on the determinants of eco-innovation. However, these publications did not distinguish and investigate the energy efficiency variable. Later, in 2015–2018, the stream of investigations has gained momentum, and 6 articles investigating the determinants of energy efficient innovation were published as part of the study or as a whole study. The obtained results are not surprising and are in line with other studies, which emphasize a lack of investigations focused on different drivers of the specific field of eco-innovation [33] and specific factors that influence the introduction of energy innovation by firms [38,39]. Of the 18 articles, half ($n = 9$) were published in 2019–2021. Thus, the obtained data demonstrate the increasing attention of scholars to this particular field in recent years.

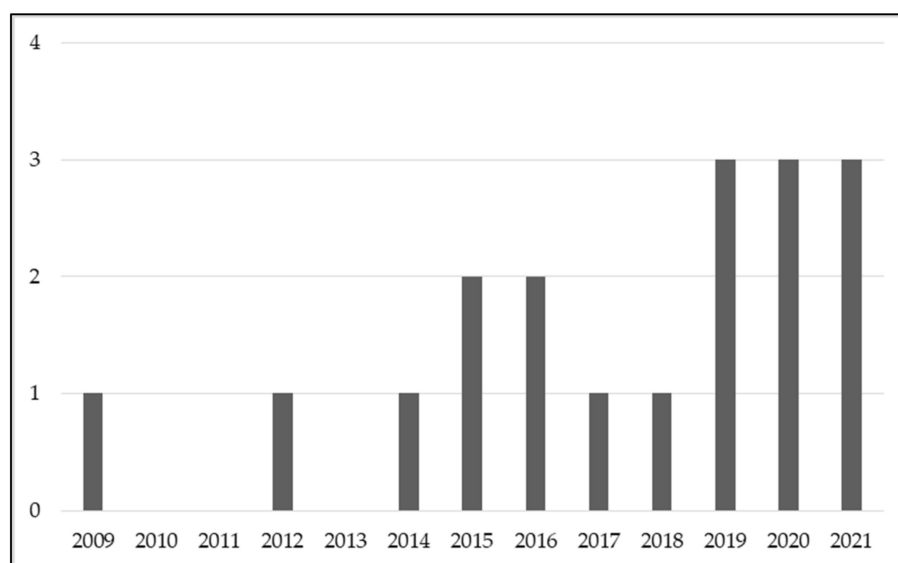


Figure 2. Number of articles investigating the determinants of energy efficient innovation, published per year.

A summary of the relevant publications included in the review is presented in Table 3. The information on each study is as follows: (1) reference; (2) sample size, data collection, and analysis method(s); (3) examined phenomenon. The qualitative synthesis results revolve around the determinants of energy efficient innovation investigated in the selected articles ($n = 18$) and are coherent with the research objective. The analysis of 18 articles revealed that all selected studies focused on the determinants of energy efficient innovation as part of the study or as an entire study and, therefore, are in line with the scope of this systematic literature review. Although some studies were not entirely focused on the determinants of energy efficient innovation, we included results relevant to this study, that is, investigating the determinants of energy efficient innovation. In particular, almost all studies revealed that determinants have a direct or indirect effect on energy efficient innovation. Few articles included in this study analyzed and used one or more different terms, describing the same phenomenon, that is, an innovation that reduces the negative impact of economic activities on the environment, and thus confirms the notion that scientists use these terms interchangeably.

The findings of this study are provided in terms of our research question: what are the antecedents and motivations behind the adoption, development, or implementation of energy efficient innovation? Therefore, the determinants of energy efficient innovation were classified by using a multilevel framework, such as (1) micro-level, (2) meso-level, and (3) macro-level (Table 4). The determinants in each level are presented by considering the following groups: (1) detailed determinants investigated in the selected articles, and (2) aggregated determinants, based on a multilevel framework (detailed explanation is provided in Section 3.4).

The investigation lets us distinguish articles investigating the determinants of energy efficient innovation at each level. In particular, the distribution of the studies at all three levels is the same. Of the 18 articles selected for this study, 11 articles investigated micro-level. Meanwhile, 12 articles investigated the meso-level. Finally, 12 articles investigated macro-level. Moreover, five articles investigated all three levels in their research. Two out of three levels were investigated in seven articles. Finally, six articles investigated one level. To conclude, all three levels appear to be relevant in studying the determinants of energy efficient innovation and equally attracted the attention of academia. Moreover, the researchers used different terms describing the determinants (e.g., subsidies and government subsidies; customer demand and customer pressure) in some studies. An in-depth analysis of the articles allows us to combine some of the determinants in order to avoid repeatability.

Consequently, the determinants were combined if the data in the article included a clear description of the fieldwork and the results deriving thereof; that is, the determinants were combined if their meaning was the same, the determinants were attributed to the same level (micro, meso, and macro) and researchers clearly explained the meaning of the determinant. The findings of the articles reviewed on the determinants of energy efficient innovation are provided in the following subsections.

Table 3. Summary of reviewed articles on the determinants of energy efficient innovation.

References	Sample, Data Collection and Analysis Method(s)	Examined Phenomenon
[64]	9172 firms from Spain (PITEC), regression analysis and artificial neural network (ANNs)	The impact of eco-innovation drivers, aiming to achieve energy and environmental efficiency objectives
[65]	2056 European manufacturing SMEs, FLASH EUROBAROMETER 381, regression analysis	The relationship between external support and adoption of resource efficiency practices
[66]	6483 firms, manufacturing industry, Italian Community Innovation Survey, regression analysis	Different forces underlying the adoption of environmental innovations
[38]	8577 firms, Community Innovation Survey (CIS), multivariate probit analysis	Drivers motivating firms' decision to engage in energy efficient innovations
[3]	20 small and large firms in the Dutch brewing and paper industries, desk research and semi-structured interviews, case study	Internal and external factors, influencing the adoption of energy efficient eco-innovations
[67]	4458 Spanish manufacturing firms (PITEC), logit model	Determinants of energy efficient innovations
[68]	Spain manufacturing industry, various surveys carried out annually by the Spanish Institute of Statistics (INE), random-effect panel model	The role of different environmental policy measures on energy efficiency investment
[26]	22,936 firms from 9 European countries, Community Innovation Survey, univariate probit models	Institutional context's impact on firm's propensity to introduce energy efficient innovation
[4]	1063 German firms, Mannheim Innovation Panel (MIP), regression analysis	Energy efficient innovations and externality reducing innovations' impact on profitability of the firms
[5]	223 Slovenian companies, online questionnaire, regression analysis	Driving forces of eco-innovation process and its effect on company performance
[33]	1294 German firms, German Community Innovation Surveys (CIS), probit models	Determinants of eco-innovations by the type of environmental impact
[69]	92 firms from electronic appliances industry in Germany, online survey, logit regression models	The influence of customer benefit and regulation on environmental product innovation
[70]	26 OECD countries, OECD REGPAT database, Poisson regression model	The impact of energy prices and technological knowledge on green energy innovation
[34]	9206 European SMEs, Flash Euro barometer survey 426, generalized ordinal logistic model (GOLM)	Factors associated with intensity in resource efficiency practices of European SMEs
[39]	8213 European SMEs, Flash Euro barometer Survey 426, bivariate probit model	Factors driving the adoption of energy efficiency and renewable energy innovations
[25]	2933 Norwegian firms, Statistics Norway (SSB), logit regression analysis	The characteristics of firms' knowledge as the determinants of energy efficient innovation
[71]	Panel analysis of 19 OECD countries, regression analysis	The relationship between energy innovations, environmental policies and oil prices
[72]	3465 firms, Austria, Germany, and Switzerland, firm-level survey, regression analysis	Adoption of green energy technologies contributing to increased energy efficiency

Table 4. Determinants of energy efficient innovation.

Level	Aggregated Determinant	Detailed Determinant	References
Micro	Strategy and business logic	Cost savings	[3,33,38,39,66]
		Previous experience	[25,64]
		Technological capabilities	[34,70]
	Resources and capabilities	Green capabilities	[34,69]
		Innovation capabilities	[64]
		Knowledge development	[25]
		Organizational innovation	[33,67]
		Financial resources	[34]
		Investment in tangible assets	[67]
Meso	Market dynamics	Competitive pressure	[5]
		Customer and provider pressure	[34,38,39,69,72]
	Networks	External knowledge cooperation	[25,33,65,66]
		Social pressure	[26]
		Voluntary agreements	[4,72]
Macro	Policy instruments	Government subsidies	[3,4,33,34,39,64,66,68,72]
		Current or future regulation	[4,26,33,34,39,66,69,71,72]

4.1. Micro-Level

The integration of successful eco-innovation practices and alignment with the resources and capabilities of the companies and the overall strategy of the company appears to be inevitable. According to scholars, micro-level determinants are more important for the adoption of energy efficient innovation compared to meso- or macro-level determinants [3].

Cost savings. Cost savings were found to be a decisive determinant for the adoption of energy efficient innovation [3,33,38]. The firms are more likely to introduce eco-innovation, which contributes to financial advantage and reduction of high production costs. Apparently, cost savings are the main motivation for energy savings purposes [33]. This conclusion is in line with various studies on the determinants of energy innovation. According to Yurdakul and Kazan [6], eco-innovation has a significant effect on the reduction of energy consumption and material costs, both in total and per-unit, through the improvement of product, process, and business methods. Meanwhile, cost savings do not have a significant effect on environmental innovations [33]. The adoption of eco-innovation requires the firm to consider profitability. However, eco-innovation, which reduces the negative environmental impact, does not provide such obvious advantages compared to energy eco-innovation [3]. The need for cost savings is a key and significant factor that motivates companies to engage in energy efficient innovation, even when compared to renewable energy innovation and other types of eco-innovation [38]. This notion is in line with the study conducted by Segarra-Blasco and Jové-Llopis [39]. The scholars disclosed that cost savings and catching up with the main competitors were the most significant determinants for implementing energy eco-innovation. Meanwhile, cost savings have not been disclosed as the main drivers of renewable energy innovation [39]. Furthermore, Borghesi et al. [66] revealed that energy expenditure intensity was highly related to energy efficient innovation. Therefore, the higher energy expenditure per unit of value leads to a higher motivation for the introduction of energy eco-innovation. Chappin et al. [3] analyzed the Dutch brewing and paper industries and revealed that the financial advantage obtained due to energy efficient innovation was important for both industries, but especially for the paper industry. However, Moreno-Mondéjar and Cuerva [34] disclosed

that cost savings motivated firms to engage in energy eco-innovation only up to a certain point. Therefore, the study confirmed that motivation related to cost savings did not lead to medium or large investments by firms [34].

Previous experience and knowledge development. The accumulated firm experience in relevant fields appears to be a significant contributor to energy efficient innovation. For instance, studies demonstrated a positive relationship between firm knowledge development and energy efficient innovation [25]. Notably, the previous experience of the company is measured by the developed and implemented eco-innovation in the previous year [64]. Apparently, previous experience is strongly related to individual skills, education level, training, and experience of employees [25]. Meanwhile, knowledge development is commonly measured through R&D activities and refers to the absorptive capacity of the firm [25]. According to Arranz et al. [64], previous experience in eco-innovation facilitates and encourages further development. Scholars state that both energy and environmental innovation experience positively and significantly impacts eco-innovation activities [64]. To conclude, if a company developed and/ or implemented an innovation, which consumes less energy (energy experience) or innovation, which reduces the negative environmental impact (environmental experience), the effect on further eco-innovation development is positive. These findings were confirmed by other studies, indicating that the development of internal knowledge was positively related to energy efficient innovation [25]. Thus, prior knowledge (staff training and experience) is positively related to the implementation of energy efficient innovation.

Financial resources. The lack of financial resources was found to be significantly associated with a less proactive environmental strategy of SMEs [34]. While eco-innovations, increasing efficiency, reducing energy or material costs, and increasing revenues [5] demand significant investments, larger firms have more resources and capabilities to conduct these programs. Moreno-Mondéjar and Cuerva [34] disclosed that companies defined by a low level of financial resources were associated with a low level of investment in energy and resource efficiency practices. On the other hand, financial resources combined with green capabilities positively affected higher investments in energy and resource efficiency practices of the firms. Therefore, the study confirmed that the financial capabilities of the firms stimulated the development of energy efficient innovation [34].

Investment in tangible assets. Energy efficient innovation is related to investments in tangible assets [67]. For instance, investment in tangible assets (i.e., more efficient machinery), the introduction of sustainable materials, and the development of processes, which rely less on the intensive use of technology, have a direct relationship with energy efficiency. However, empirical evidence shows that the profile of the firm is an essential factor that contributes to the introduction of energy efficient innovation [67].

Organizational innovation. Organizational innovations, such as new business practices for how work is organized and new company procedures, have been revealed to be a decisive determinant for the adoption of eco-innovations [33,67]. In particular, environmental management systems (EMS) are a common example of organizational measures adopted by companies [17]. According to Horbach and Rammer [33], organizational eco-innovation, that is, EMS, appears to be particularly important in driving green cost-saving technologies. Meanwhile, Walton et al. [1] state that proactive energy management of the company includes the following activities: (1) energy audit and (2) development of a strategy or policy related to energy consumption. Therefore, referring to other studies [67], we can conclude that organizational innovations are very significant drivers of energy efficient innovation.

Innovation capabilities. Innovation capabilities, defined as organizational routines and processes, lead to the adoption of innovation in the firm. Thus, the greater innovation capability of the firm leads to a greater probability of innovation [64]. It appears that R&D is crucial for the development of innovations that contribute to economic and social growth [73]. The scholars confirmed the positive impact of innovation capabilities on eco-innovations [64]. Furthermore, the energy culture framework [74] (consisting of energy-related factors such as norms, material culture, and practices) demonstrates

the key resources involved in developing energy efficient innovation [1]. However, the studies focused on the R&D, and eco-innovation nexus are not consistent. For instance, Borghesi et al. [66] did not disclose significant evidence between R&D expenditures and eco-innovation.

Green capabilities. Green capabilities, defined as the firm's knowledge and perceptions about environmental issues and relevant business procedures, are implemented for the purpose to act and react to these issues [69]. Green organizational capabilities are associated with higher investments in resource efficiency and are measured as the ability of firms to develop new green products and processes in response to stakeholder pressures [34]. Kammerer [69] disclosed that green capabilities have a positive and significant impact on energy efficient innovation, as well as other types of eco-innovations. These findings are in line with the study by Moreno-Mondéjar and Cuerva [34]. In conclusion, green capabilities are especially important, with the aim of adopting energy efficiency practices and ensuring the highest investment level of the firm.

Technological capabilities. Technological capabilities refer to tangible technologies, intangible experience, and specialized knowledge of companies in order to adopt an environmental strategy [34]. These capabilities can be a proxy for technological knowledge, which is measured by innovation activities undertaken in the past [70]. According to Kruse and Wetzel [70], a key determinant of innovation that contributes to green energy technologies is the available technological capabilities. Referring to the technology-push hypothesis, scholars suggest that innovation is induced by advances in the technological capabilities of an economy [70]. Meanwhile, Sun et al. [75] revealed that green technology increases energy efficiency. Furthermore, Larissa [76] concludes that countries can improve energy production by using modern technology. Finally, Moreno-Mondéjar and Cuerva [34] revealed that an effective combination of technological and organizational capabilities allows companies to increase resource efficiency and cope with the pressure of stakeholders.

4.2. Meso-Level

Market dynamics (competitive pressure, customer, and provider pressure). Environmentally conscious consumers and providers demand environmentally friendly products, including eco-friendly production processes. Therefore, companies face demands from suppliers, customers, and competitors to engage in environmental practices [34]. In addition, companies must innovate with the aim of exploiting market dynamics and responding to changes in consumer demand and lifestyle [16]. Notably, competitive pressure forces firms to implement eco-innovation and increase their competitive advantage (i.e., gain market share through the implementation of energy efficient innovation) [5]. Although novelty for the market does not trigger eco-innovation due to the additional costs experienced by private companies, the adoption of these innovations is motivated by other reasons, such as the reduction of social costs related to the reduction of pollution [64]. Capozza [38] states that market demand is positively associated with both types of eco-innovations (energy and environmental). Meanwhile, other studies revealed similar results. The studies conducted by Segarra-Blasco and Jové-Llopis [39] and Kammerer [69] revealed that the pressure of the customer and the provider was a significant driver, motivating companies to adopt energy efficient innovation. Furthermore, Moreno-Mondéjar and Cuerva [34] revealed that the pressure of customers, suppliers, and competitors motivated firms to invest in resource efficiency. However, these determinants per se are not very strong for higher-level investments. Thus, a combination of pressures from the perspective of customers, providers, and technical expertise is required.

Pressure groups (social pressure and voluntary agreements). Social pressure represents characteristics of the context defined by the public, media, non-governmental organizations, and other social actors, which determine the so-called social norms [26]. Voluntary agreements include voluntary public schemes, negotiated agreements, unilateral commitments recognized by the public administration, unilateral commitments, third party initiatives, and private agreements [72]. Policies that inform consumers about energy

efficiency and policy instruments raise awareness of energy efficiency among consumers and thus are an effective driver for the adoption of energy efficient innovation [72]. Similar findings were confirmed by Garrone et al. [26], who found that regulatory stakeholders were able to exert pressure on firms to introduce energy efficient innovation. Meanwhile, Woerter et al. [72] revealed that voluntary agreements and standards were significantly related to the adoption of eco-innovations. These findings are consistent with a study by Ghisetti and Rennings [4]. In conclusion, energy efficient innovation adopted as a response to voluntary codes or agreements exerts a significant and positive effect on the performance of firms.

Networks (external knowledge cooperation). External sources of knowledge, such as learning networks and strategic alliances, provide information on multiple factors related to eco-innovations [25,66]. In particular, cooperation compensates for limitations related to internal resources [25]. Therefore, relationships with other companies operating in the value chain are essential in the adoption of energy efficient innovation [33]. Borghesi et al. [66] investigated the Italian manufacturing industry and confirmed that belonging to the business network is essential for energy efficient innovation. The study confirmed that eco-innovation activity was strongly embedded in network relationships. Thus, networks and social capital of organizations, i.e., knowledge acquisition from several information sources, are relevant for increasing innovation capabilities and innovation adoption. The provision of information from other firms is important for energy efficiency [66]. Although external consultancy, advice and external funding may not lead to significant additional gains, external knowledge acquisition through consultancy and advice plays an indirect role in overcoming knowledge barriers and influences the effects of the adoption of energy efficient innovations [65]. Moreover, this source of knowledge enhances the ability to adopt eco-innovations and especially in SMEs. Solnørdal and Thyholdt [25] revealed that external knowledge cooperation was positively related to energy efficient innovation. For instance, cooperation with universities, private, and public research institutions increases the probability of energy efficient innovation. Thus, eco-innovations are knowledge-demanding and require external cooperation, aiming to compensate for the lack of internal resources and capabilities of the firms. Additionally, cooperation with competitors increases the probability of adopting energy efficient innovation. Finally, the interaction of higher-educated employees and external cooperation contribute to more extensive adoption of energy efficient innovation. In particular, universities are important providers of technological know-how and expertise in energy eco-innovation [25].

4.3. Macro-Level

Policy instruments. Policy instruments such as government subsidies and government regulation are the most studied determinants of eco-innovation in the extant scientific literature. Subsequently, energy efficient innovation is driven by these determinants.

García-Quevedo and Jové-Llopis [68] revealed that subsidies granted at a national level and clearly designed to promote firms' use of energy saving technologies affected energy efficient innovation. These findings are in line with studies that reveal that regional funding is a key determinant of energy efficient innovation and that companies that receive subsidies are more likely to adopt energy eco-innovation [66]. Ghisetti and Rennings [4] state that investment in eco-innovation without subsidies results in decreased profitability. Meanwhile, Moreno-Mondéjar and Cuerva [34] revealed that government subsidies impacted the highest-level investment in energy eco-innovation. Segarra-Blasco and Jové-Llopis [39] disclosed that government subsidies influenced the energy efficient innovation of firms from new member states of the EU. Arranz et al. [64] investigated external funding at three institutional levels: (i) from local/regional institutions; (ii) from national institutions; (iii) from the EU, and confirmed that external financing, that is, subsidies, had a positive effect on energy eco-innovation. Furthermore, Bodas-Freitas and Corrocher [65] found that financial support influenced the adoption of energy efficient innovation, contributing to lower production costs. The study by Horbach et al. [33]

confirmed that subsidies were an important determinant of energy efficient innovation, although subsidies were also relevant for environmental innovation. Woerter et al. [72] found that subsidies were significantly and positively related to investment in green energy technologies. The investigation carried out in the context of three countries revealed that subsidies were more effective in Austria compared to Switzerland and Germany. However, subsidies are more important for energy efficient innovation than government regulation [72]. Meanwhile, other scholars revealed that regulation and taxes were not motivating firms to pursue energy efficient innovation and renewable energy innovation [38]. These findings are similar to the study by García-Quevedo and E. Jové-Llopis [68], indicating a positive and significant effect of subsidies on energy efficient innovation. On the other hand, García-Quevedo and E. Jové-Llopis did not reveal that environmental policies and taxes were significant for energy eco-innovation [68]. The explanation resides in the fact that the size of these taxes is too small to motivate the firms to invest in energy efficient innovation.

Notably, some scholars disagree that regulations do not promote energy efficient innovation. For instance, Horbach and Rammer [33] confirmed that the expected regulation triggered energy eco-innovations. Moreno-Mondéjar and Cuerva [34] found that regulation was positively associated with an investment in energy efficient innovation. These findings are similar to those of other studies. For instance, Kammerer [69] found that regulation had a positive impact on the different measures of eco-innovation. Stricter regulation influences the motivation of the firms to adopt eco-innovations. Segarra-Blasco and Jové-Llopis [39] disclosed that both government subsidies and government regulation were strongly related and played a key role in the promotion of energy efficient innovations among SMEs in the EU. Sterlacchini [71] found that the stringency of EU environmental policies has had a more positive impact on energy innovation patents in 19 OECD countries. Meanwhile, other scholars argued that energy efficient innovations adopted as a response to current or future regulation had a positive effect on the competitiveness of firms and were coherent with the five forces framework [4]. Garrone et al. [26] confirmed that government regulations were relevant for energy eco-innovation activities and that large firms were, on average, relatively more sensitive to regulatory pressures. Finally, Borghesi et al. [66] revealed that the current and expected presence of environmental regulation or taxes was highly correlated with energy eco-innovation, including the reduction of CO₂.

To conclude, macro-level determinants are the most intensively investigated in the field of energy efficient innovation. However, the findings were mixed, and different effects of both regulation and subsidies were examined on the motivation of firms to engage in energy efficient innovation.

5. Agenda for Future Research

This systematic literature review shows the importance to distinguish energy dimension and classifies the determinants of energy efficient innovation in three levels: (1) micro-level, (2) meso-level, and (3) macro-level. The review reveals that the three levels are almost equally distributed and studied by researchers. Thus, the importance of every level in investigating the determinants of energy efficient innovation is outlined. Regarding the research question: what are the antecedents and motivations behind the adoption, development, or implementation of energy efficient innovation? and the review findings, this study proposes an agenda for future research in the field of energy efficient innovation.

5.1. Micro-Level: Agenda for Future Research

The research findings confirm the importance of investigating the determinants of energy efficient innovation at the firm-level. It is important to distinguish energy efficient innovation from environmental innovation while investigating the determinants of eco-innovations from the perspective of firms. Although previous studies reveal that cost savings are the most studied determinant, other determinants related to strategy and business logic have been less investigated. Therefore, future research should consider other micro-level determinants related to strategy and business logic, such as differen-

tiation strategy [77], green identity [78], R&D expenditures [73,79], green creativity and green organizational identity [80], managerial environmental concern [81], proactive environmental strategy [82], and competitive advantage [83]. Notably, some studies, which investigated competitive advantage in relation to eco-innovation, did not distinguish the energy dimension. Furthermore, it is necessary to investigate competitive advantage in the context of international markets [84]. The explanation resides in the fact that a number of SMEs and especially from small and open economies, are forced to compete in the international arena. Therefore, energy efficient innovation is a significant determinant contributing to the competitiveness of the firms and international expansion. Regarding the resources and capabilities of the firms, the studies investigating the determinants of energy efficient innovation as the part or as a whole study are evenly distributed across the domain. However, the following determinants are less investigated: (1) innovation capabilities [64], (2) knowledge development [25], (3) financial resources [34], (4) investment in tangible assets [67], and thus more comprehensive research is needed. Although most of these determinants are studied in the broad field of eco-innovation, it is important to distinguish the energy dimension.

5.2. Meso-Level: Agenda for Future Research

The second level of research is related to the meso-level environment, i.e., market dynamics, networks, pressure groups, etc. Future research should consider investigating other meso-level determinants that are currently less investigated: shareholders [85], supply chain actors [86], and local authority [87]. These determinants are studied in the broad field of eco-innovation without distinguishing the energy efficiency dimension.

5.3. Macro Level: Agenda for Future Research

This study confirms the importance of investigating the determinants of energy efficient innovation at macro-level. Although most of the articles investigated policy instruments such as government subsidies and government regulation, the findings were mixed, and different effects of regulation and subsidies on energy efficient innovation were examined. Future research should consider investigating other macro-level determinants, such as geographic and regional factors [88,89]. Furthermore, future research should address the impact of government regulation on energy efficient innovation. Although studies agreed that, in fact, external financial support triggered energy eco-innovation, the impact of government regulation provided mixed results.

6. Conclusions and Limitations

This paper is dedicated to a comprehensive and systematic identification and classification of the determinants of energy efficient innovation. Despite the popularity of eco-innovation, little effort has been devoted to the specific eco-innovation fields. Considering a lack of systematic reviews focused on the determinants of energy efficient innovation, we address this gap and set forth to enhance the body of knowledge in the field of energy efficient innovation. More specifically, we focus on the determinants of energy efficient innovation. To achieve the research aim, a systematic literature review and qualitative content analysis were conducted. The study adopted a multilevel framework, and the determinants were classified by using three levels: (1) micro-level, (2) meso-level, and (3) macro-level.

In conclusion, this study offers two contributions. First, the study distinguishes the determinants of energy efficient innovation. The investigation of all determinants related to energy efficient innovation let us state that all three levels attracted the equal attention of scholars and are relevant for future investigations. Several determinants of energy efficient innovation were distinguished at the micro-level: (1) cost savings; (2) previous experience; (3) technological capabilities; (4) green capabilities; (5) innovation capabilities; (6) knowledge development; (7) organizational innovations; (8) financial resources; (9) investment in tangible assets. Meanwhile, the determinants at the meso-level

areas follow: (1) competitive pressure; (2) customer and provider pressure; (3) external knowledge cooperation; (4) social pressure; (5) voluntary agreements. Finally, the following determinants were identified at the macro-level: (1) government subsidies; (2) current or future regulation. Second, the study provides insights on the determinants of energy efficient innovation and sets an agenda for future research relevant for all three levels. Future research should consider investigating other micro-level strategy and business logic determinants, such as differentiation strategy; green identity; R&D expenditures; green creativity and green organizational identity; managerial environmental concern; proactive environmental strategy. Future research at the meso-level should consider investigating other determinants of energy efficient innovation, such as shareholders, supply chain and local authority. For the macro-level, future research should consider investigating other determinants, such as geographic and regional factors. Furthermore, future studies can further expand the sixteen determinants identified in this study. Additionally, some determinants have close interrelations between each other as moderating or mediating factors on firms' motivation to engage in energy efficient innovations. Although most of the determinants are studied in the broad field of eco-innovation, it is important to distinguish the energy dimension in future studies.

This systematic literature review follows the guidelines presented in scientific studies and relies on pre-planned methods, which minimize bias and random errors, albeit it has some limitations. For instance, only empirical studies included in the articles were analyzed in this study, while the remaining scientific literature could present relevant information on the topic. Furthermore, the analysis of the determinants did not differentiate between the different sizes of organizations and the different industries. Hence, it can be assumed that differences exist in the context of capabilities for different firm sizes and different industries. Another possible drawback of this study is that the scope of journals covered by the SSCI is limited to those with an official impact factor. It takes time for newer journals to be included in the SSCI, so it does not contain data from “just launched” publications [55]. Therefore, for future studies, it is important to (1) differentiate between the different sizes of organizations and sectors and (2) include other reputable databases (e.g., Scopus).

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