

Review

Designing Policies and Programmes for Improved Energy Efficiency in Industrial SMEs

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Abstract: Climate change, due to anthropogenic emissions of greenhouse gases, is driving policymakers to make decisions to promote more efficient energy use. Improved industrial energy efficiency is said to play a key role in the transition to more carbon-neutral energy systems. In most countries, industrial small and medium-sized enterprises (SMEs) represent 95% or more of the total number of companies. Thus, SMEs, apart from using energy, are a major driver in the economy with regard to innovation, GDP growth, employment, investments, exports, etc. Despite this, research and policy activities related to SMEs have been scarce, calling for contributions in the field. Therefore, the aim of this paper is to critically assess how adequate energy efficiency policy programmes for industrial SMEs could be designed. Results show that scientific publications in the field differ in scope and origin, but a major emphasis of the scientific papers has been on barriers to and drivers for energy efficiency. Scientific contributions from studies of energy policy programmes primarily cover energy audit programmes and show that the major energy efficiency measures from industrial SMEs are found in support processes. The review further reveals an imbalance in geographic scope of the papers within the field, where a vast majority of the papers emanate from Europe, calling for scientific publications from other parts of the world. The study synthesizes the findings into a general method on how to design efficiency programs for the sector.

Keywords: industrial SMEs; energy efficiency; energy policy; barriers; drivers

1. Introduction

Climate change, due to anthropogenic emissions of greenhouse gases (GHGs), is driving policymakers to make decisions to promote more efficient energy use in the world's various economies. In 2015, the International Energy Agency estimated that SMEs globally account for 99% of companies and account for at least one-third of the total industrial energy demand [1]. Improved industrial energy efficiency is stated to play a key role in the transition to more carbon-neutral energy systems. Cost-efficient energy efficiency measures are not always implemented in companies and the potential level of energy efficiency is therefore not always realized, resulting in an energy efficiency gap, which is explained by various barriers hindering the implementation of such efficiency measures [2–5].

In contrast to the widely studied barriers, only a few empirical studies of specific driving forces have been conducted (e.g., [6–9]), Thollander and Ottosson [10] categorized drivers into four different types: market-related, policy instruments, potential energy policies and organisation-related. Energy efficiency decision-making revolves around a number of basic steps. As stated by

Cooremans [11], making decisions about energy efficiency measures is a process with the following steps: initial idea, diagnosis, build-up of solutions, evaluation and choice, and implementation. Relating Cooremans' model to research on energy efficiency in industry, research on improved energy efficiency in industry can be categorized into the following primary areas: studies of the energy efficiency potential, company-specific measures and methods to improve energy efficiency, policy-specific measures and methods to improve energy efficiency, and barriers to and drivers for adoption of measures for greater energy efficiency.

While numerous publications concern barriers and driving forces related to energy efficiency as well as categorize models for research on energy efficiency, a lesser number of publications concern policies and measures for energy efficiency in industries. For example, Tanaka [12] categorizes policies and measures into prescriptive policies (regulations, negotiated agreements), economic policies (taxes and tax reductions, subsidies, loans) and supportive policies (capacity building, public disclosure, cooperative measures). One major energy policy for industry is Voluntary Agreement Programmes (VAPs). VAPs are effective means to motivate and encourage industries to reduce their energy demand and GHG emissions [13]. The policies and measures are often not used separately but combined or used as alternatives. A key measure to raise the awareness of the energy efficiency potential and reveal opportunities for improvements in industries is to conduct an energy audit. Energy audit policy programmes have been established worldwide in order to encourage energy auditing in companies. Price and Lu [14] compared stand-alone energy auditing programmes and energy audit integrated programmes around the world and found among other things that subsidies for audits, certification of auditors, standardized guidelines and follow-up activities are of great importance when designing an efficient energy audit program.

Much attention, in terms of research and policy, has been directed at energy-intensive industries, while non-energy-intensive and small and medium-sized enterprises (SMEs) have received less attention [15]. This is despite the fact that a larger relative energy efficiency potential is identified in non-energy-intensive and SME industries, in relation to the energy-intensive sector [16]. In most countries, industrial SMEs represent 95% or more of the total number of companies [17]. There is no standardized definition of 'SMEs'. The EU Commission defines SMEs as enterprises employing fewer than 250 employees, with an annual turnover below 50 million EUR and/or an annual balance sheet not exceeding 43 million EU [18]. In Japan, the Basic Law for SMEs defines SMEs as enterprises employing fewer than 300 employees or with 300 million JPY (Japanese yen) of capital funds, and small-scale enterprises as having fewer than 20 employees [19]. Furthermore, a commonly used definition is the one by Shipley and Elliot [20], where small firms are those that have fewer than 250 employees while medium-sized firms comprise 250–500 employees.

Within the European Union, the first European directive, strongly promoting improved energy efficiency among SMEs, came in 2006 [21]. Based on that, a number of member states launched energy audit programmes for SMEs. In Sweden, for example, the directive gave rise to the first national energy audit program in the country [22]. The second European directive from 2012 further emphasized energy efficiency among SMEs with the additional note that large companies need to undertake energy audits every four years. Energy efficiency in general as well as SMEs have thus received much greater attention in the past decade [23].

The SME sector, apart from using energy, is also a major driver in the economy with regard to innovation, GDP growth, employment, investments, and exports. Despite this, research and policy activities related to improved energy efficiency in SMEs have been scarce. Energy policies towards industrial SME and non-energy-intensive industry have also been fewer compared with policies and programmes targeting large, energy-intensive industry [15]. Typically, energy audit programs are the most common means used in industrial SME and non-energy-intensive industry, while for large and energy-intensive industry, Long-Term Agreements (LTAs) or Voluntary Agreements (VAs) have been more common [24]. In addition, energy networks, investment subsidies, benchmarking and sector guidelines have been suggested as relevant policies to consider for industrial SMEs [19]. The majority

of research towards improved energy efficiency and industrial SMEs consists of evaluations of national energy audit programs, e.g., Fleiter et al. [25], Andersson and Newell [26], and Thollander et al. [27], while international comparisons are scarce, some exceptions being Price and Lu [14], Tanaka [12] and Thollander et al. [28]. Price and Lu [14] found key factors for cost-effective policy measures to be, among others, subsidies for energy audits, certification of the auditor and follow-up activities, and that policy makers should consider integrating energy audits into other policy programmes. Tanaka found, by surveying over 300 policies, that policies and energy efficiency measures are not of a general character and fit specifically one country and industry sector [12]. Tanaka further found that there are too few evaluations of policy measures to understand how they could be transferred to another situation [12].

Thollander et al. [28] found that the primary policy means targeting medium-sized companies and energy-intensive industrial SMEs are VAs as well as law enforcement followed by energy audit programmes and energy efficiency networks [28]. For small companies and non-energy intensive SMEs, energy audit programmes (preferably locally or regionally anchored), followed by energy efficiency networks (also preferably locally or regionally anchored) are the preferred policy choices [28].

The aim of this paper is to critically assess how adequate energy efficiency policy programmes for industrial SMEs could be designed. A number of review studies have already been conducted in the area of energy efficiency, e.g., a study on driving forces for SMEs [29], barriers to energy efficiency [30], and on energy management in industry [31]. To the authors' knowledge, no previous literature review has been made regarding the design of energy efficiency policy programmes aimed at industrial SMEs. The paper is unique as in the authors' awareness it remains the first scientific review of industrial SMEs and energy policy programme design, and makes an important contribution in addition to the numerous policy reports. The paper is structured as follows: after this introduction, the paper continues with a method presentation, followed by a review of the literature. The paper ends with a concluding discussion.

2. Method and Delimitations

The major method of this study was a literature study. Scientific journal publications were searched in the Web of Science database, using the following search strings: 'Energy policy' and 'energy efficiency' and 'small and medium-sized' and 'industry*'. Papers from 1970 until 2018 were selected. In total 33 scientific publications were found. Where applicable, conference papers and policy reports from international bodies were also included in the analysis, however not in the actual presentation of the review, the reason being that conference papers and policy reports, unlike journal papers, have not undergone a rigorous peer-review process *per se*, and that such inclusion was made for the participating countries in the study published in 2014 [28]. The analytical model used when undertaking the literature review was Cooremans' decision-making model [11]. The analysis of the content of the journal papers included in this review was inspired by the analysis in the review by D'Agostino et al. [32], and papers were categorized based on country of origin, scientific method applied, sectors analysed and affiliations of authors.

Prior to the literature review, a study on energy policy design for SMEs was undertaken within the IEA IETS Framework during 2011–2014 in the form of four workshops [28]. In that study, the major method was workshops by individual national energy experts within the field. The literature review undertaken in the present current paper is a means to further deepen the understanding of energy efficiency policy programme design for industrial SMEs.

Inspired by Tanaka [11] and also supported by Lindén and Carlsson-Kanyama [33], this study categorizes publications in three broad categories: Administrative, Informative, and Economic policies. The study emphasizes energy end-use efficiency policy design. A challenge in policy-related research is that the policy landscape sometimes changes rapidly leading to research on policy, when published, no longer being up to date. It is therefore stressed that the current paper is delimited to study the current policy situation.

3. Results

In the following section, the results from the scientific literature review are presented, where the 33 selected papers are categorized into 'barriers and drivers' (following the Sorrell et al. [34] definition of a barrier being "a postulated mechanism that inhibits a decision or behaviour that appears to be both energy efficient and economically efficient" [34] and drivers defined as factors promoting investment in energy efficiency [35]), 'energy programmes' (energy efficiency programmes targeting industries, driven by the government) and a 'general category'.

3.1. Barriers and Drivers

A study of barriers to energy efficiency in 65 European foundries was made by Trianni et al. [36], showing that barriers are generally perceived as higher than average in Swedish foundries and lower than average in German foundries. The barriers varied with firm size where small enterprises tend to experience greater barriers than larger enterprises mainly due to organisational issues, and foundries with simpler production tend to have a higher perception of barriers.

Bradford and Fraser [37] investigated the barriers to energy efficiency in 112 SMEs in the UK. It was evident that the energy use behaviour, internal constraints and attitudes towards possible policy options vary with categories of firms. Manufacturing firms in the UK expressed in a survey that they had adopted efficiencies because they are large users of electricity and they were most likely to monitor their energy use and actively work to reduce the use. Of the SMEs in the UK that had not taken steps to reduce their energy use, 50% perceived that the government's obligations to reduce emissions would not affect them or their operations, nor did they perceive that the nature of their business leads to significant GHG emissions or offers the potential to reduce the emissions.

Trianni et al. [8] studied 222 manufacturing SMEs in northern Italy with an interview survey where it was seen that barriers were perceived as greater in the early stages of the decision-making process, especially informational and behavioural barriers. Installers, tech suppliers and manufacturers had an important role in promoting drivers such as energy audits, and previous experience with implementation of energy efficiency measures would reduce barriers and promote drivers. Cagno et al. [38] interviewed people responsible for energy issues in 15 metalworking SMEs in The Netherlands in order to analyse the interactions between barriers/drivers and policy instruments, especially the LTA3 or VAPs. The analysis shows that VAPs are not recognised as an important driver by SMEs and there is a misalignment between SMEs and governmental organisations on the relative importance of barriers, drivers and the role of VAPs. The most important steps in the decision-making process according to governmental organisations do not necessarily match the results from the interviews with the SMEs, which could pose an issue with effectiveness of suggested policies.

Forty-eight manufacturing firms in Northern Italy were included in a study by Trianni et al. [39] aiming to obtain the values of perceived and real barriers, since both of these influence the adoption of energy efficiency measures at the firms. The major perceived barriers were economic and informational while behavioural barriers were ranked lowest by the respondents. However, the analysis of the real barriers showed that the major barriers were lack of interest and other priorities, which points out a misalignment between perceived and real barriers in SMEs. The results also show differences among SMEs due to firm size, energy expenditures, complexity of production, etc., and the authors suggest that SMEs should not be bundled together to promote industrial energy efficiency.

Cagno and Trianni [6] conducted semi-structured interviews with 71 companies in the Lombardy region in Italy to analyse energy efficiency drivers. The companies had been part of a regional energy program performing energy audits at SMEs as a means to increase the adoption of energy-efficient technology. The result of the analysis of the total sample emphasized the importance of allowances or public financing since that was ranked as the major driver. External pressures such as increased energy prices or implementation of fees and taxes were also highly ranked drivers while the increase of internal competencies was ranked as the lowest driver. However, the perception of drivers varied due to firm size, sector and supply chain complexity. In order to quantify barriers to energy efficiency,

Cagno and Trianni [40] performed face-to-face semi-structured interviews with 15 metalworking SMEs in the Lombardy region of Italy. Large differences were found when considering barriers to specific energy-efficient technologies. Compressed air and HVAC system (i.e. heating, ventilation, and air conditioning) measures presented higher barriers regarding investment costs, reliable information sources and hidden costs. The analysis also showed that barriers are perceived as higher by small enterprises, and by companies with lower production complexity and lower innovativeness.

Barriers to adoption of energy-efficient technologies in China were examined by Kostka et al. [41]. The analysis from an interview-based survey of 480 privately owned SMEs suggested that informational barriers are the core bottleneck inhibiting improvements while financial and organisational barriers were, contrary to the hypothesis, less significant. The role of ownership structure, governmental regulation and support, and skilled labour were also pointed out as important determinants.

Trianni et al. [42] investigated 20 primary metal manufacturing SMEs in the Lombardy region in order to understand how firm size and innovativeness affect the perception of barriers. Medium-sized companies showed a more pronounced perception of barriers compared to smaller ones. A higher level of market innovation reduced the barriers significantly and more innovative enterprises faced fewer barriers related to technology, external risks and lack of information.

A study among 60 micro and small companies in Sweden [43] revealed that the major barriers to energy efficiency were lack of time, other priorities, slim organisation and lack of technical skills. The companies in the study had previously been part of a local energy program and now stated that information was the main thing they obtained from the program and most of the implemented measures did not come from the energy audits.

The perception of barriers in Portuguese SMEs varies considerably with regard to sector, according to Henriques and Catarino [44]. Major behaviour-related barriers such as limited time and information were seen in the companies, suggesting both internal and external strategies to overcome these.

Hrovatin et al. [45] studied the factors impacting the decision to invest in energy-efficient and clean technologies in 848 Slovenian manufacturing firms. The energy costs, market share and export orientation significantly increased the investments. It was seen that economic crisis reduced the likelihood to invest in clean technologies but had no impact on investments in energy-efficient technologies. The study also implied that policy measures should target less energy-intensive SMEs since the energy efficiency gap appears to be greater among these.

In a review of the challenges for energy efficiency in industrial SMEs in Zimbabwe [46], the main barriers found were related to financial and technical capacity, awareness and cultural issues in the organisation. The need for demonstration projects and evidence-based case studies, independent consultants and structured energy management were stressed as a means to improve the development in SMEs.

In a study focused on the financial barriers to energy efficiency projects in SMEs in China, Dong and Huo [47] identified 11 financial key barriers, e.g., insufficient fiscal incentives, inadequate energy market trading mechanisms and low priority of energy savings. Furthermore, measures were suggested to overcome the key barriers found in the analysis such as a long-term development plan to assure returns and loan interest rate discounts, and establishment of financial institutes to promote energy efficiency in SMEs.

Cagno et al. [7] explored the relationship between drivers and barriers in the decision-making process in 61 manufacturing SMEs in Italy. The findings suggest that the most important drivers in the first step of the decision-making process are regulatory drivers (e.g., long-term energy strategy, voluntary agreements). External drivers (e.g., technical support, clarity and trustworthiness of information) play an important role in the middle part of the decision-making process while in the final steps internal drivers (e.g., staff with real ambitions, information about real costs, cost reduction from lower energy) seem to be of more relevance.

In a survey of 42 small food retailers the barriers to and drivers for energy efficiency measures were examined together with the acceptability of energy efficiency policies [48]. Of the five top-ranked barriers, four were related to economic barriers where too high initial cost of equipment and lack of internal finances were ranked equally high. The driver ranked highest among the participating food retailers was energy cost reduction from energy efficiency measures. Both the highest ranked barrier and driver to energy efficiency were economic, for which reason not unexpectedly subsidies were the most acceptable policy and taxes the least.

An analysis of the results from a questionnaire sent to 263 manufacturing firms in China [49] shows that SMEs find it harder to receive loans from banks and face higher technology risks than larger companies. Kong et al. [49] suggest that governments should support SMEs financially in addition to existing subsidies in order to engage them in energy-efficient development.

About 500 companies, the majority of which are SMEs, were analysed by the results from an online self-assessment questionnaire [50]. The companies were evaluated and benchmarked in five sections: general data about the company, energy status, energy management, self-evaluation of performance, and future outlook and vision. The authors conclude that lack of awareness and commitment from top management are major barriers in SMEs leading to a low priority of energy efficiency, which should be taken into account when designing policies. The collection of high-quality data and information from the companies is crucial to overcome barriers related to investment risks and the online questionnaire is suggested as a tool to lower the perception of barriers for both SMEs and banks [50].

3.2. Energy Programme

Lo et al. [51] conducted in-depth interviews with 11 companies enlisted in the Ten-Thousand Enterprises Program in Changchun, China, an industrial city where the majority of the enterprises are energy intensive. The study showed a high variety of adoption of energy efficiency measures within the range of firms. Large enterprises owned by central governments have made huge progress in energy efficiency action in recent years. Small local government-owned ones have done far less because of insufficient enforcement of regulation by local governments. Suk et al. [52] measured the current status of energy-saving activities in Korean companies, mainly in the petrochemical industry, using data from a self-evaluating survey where the respondents represent the heavy energy-consuming SMEs in Korea. Energy-saving activities requiring low costs and fewer resources were more likely to be adopted by the firms. The most effective policy measure for energy-saving activities according to the firms' self-evaluation was the possibility to receive subsidies.

In an evaluation of the first two years of a German energy policy programme providing grants for energy audits in SMEs, Fleiter et al. [25] found that firms adopted up to three more energy efficiency measures than they would have without attending the programme. If planned measures were included, the programme had an adoption rate of 72% compared to 50% in the US IAC programme and 40% in Swedish Project Highland. The programme reduced barriers related to information and capacity while financial barriers were persistent. The evaluation of Project Highland performed by Thollander et al. [27] showed that even though the programme reduced some of the information-related barriers, the companies still faced problems such as obtaining information, staff awareness and poor information quality, and in order to further increase the adoption rate companies need more detailed information. Generally, the energy efficiency measures adopted most were support processes (space heating, ventilation, lighting and compressed air) which were also the most commonly recommended measures in energy audits. Evaluation of the Swedish energy audit programme targeting industrial SMEs showed an average of six implemented measures per audit, and 340 MWh/year saved per audited company [27]. Data from the German energy audit programme revealed a lower number of adopted measures, 3.8 per audit with a total energy savings of 200 MWh/year and audited company [25]. Notably, the audit cost for the Swedish programme was four times larger than the German programme [25,53]. Also, the savings per measure from the two national energy audit

programmes reveal similar savings per implemented measure, 56 MWh/year (Swedish programme) and 52 MWh/year (German programme).

In a study by Cagno and Trianni [54], the most effective energy-saving opportunities for energy reduction in industries were investigated. Included in the study were 217 SMEs in Italy where data from energy audits were analysed and compared to data from the American IAC database. When comparing the two databases it was found that the same energy-saving opportunities were implemented most often, and regarding the implementation costs and energy savings considerable similarities were found, implying transferability in the databases.

Paramonova and Thollander [55] evaluated the Swedish energy audit programme by analysing quantified data from over 700 participating SMEs. The programme showed an implementation rate of 53% and an energy efficiency saving of 6% of the companies' energy end-use. The evaluation revealed the need for energy-related education and further development of energy management practices within SMEs.

In a comparison of the evaluations of five energy audit programmes, mainly targeting SMEs in Australia, Germany, Sweden and USA, Andersson et al. [56] concluded that comparison is hampered due to inconsistency in categorisations of both energy efficiency measures and energy end-use data. The lack of guidelines for what performance indicators and free-rider effects to include in an evaluation and how to calculate those also complicates the comparison of programs.

Paramonova and Thollander [57] conducted interviews and questionnaires to evaluate industrial energy efficiency networks (IEEN) in Sweden targeting SMEs. The lack of general characteristics and designs of Swedish IEEN together with the lack of a standardized approach to evaluate the networks complicates the evaluations.

3.3. General Category

Liu et al. [58] conducted a survey among 125 Chinese SMEs to investigate the extent to which 15 different energy-saving actions were implemented. Among the participating companies, the most commonly adopted energy-saving action was the daily maintenance of production equipment in order to reduce energy use, while the action adopted least often was the promotion of eco-design. The energy management level of competitors and internal training on energy savings had significant positive impact on the companies' practice of energy-saving actions.

Zhang and Wang [59] investigated 90 enterprises in the iron and steel sector in China in order to examine the improvement of energy efficiency in the period 1990 to 2000. The study showed that the enterprises have improved their efficiency due to adoption of new technology regarding pulverized coal injection technology, continuous casting technology, and increase of updating and transformation of technique.

Palm [60] developed a categorization of companies using interviews from ten companies in Sweden: the ignorant company, the implementer of easy measures, the economically interested company, and the innovative environmentalist. The categorization was made as an aid for policymakers when developing policies and presenting them to companies.

Twenty enterprises in the metallic goods sector in Turkey were considered in a survey by Önüt and Soner [61]. The results from the study were used to compare the relative efficiency of companies where input factors were annual consumption of different energy sources and output factors were annual total sales and profit. The study showed that liquefied petroleum gas (LPG) was the least efficient source of energy but still primarily used due to high installation costs of natural gas.

Thollander et al. [62] derived data emanating from on-site energy audits in Belgium, Japan, Sweden and Italy in order to compile data on energy end-use and energy efficiency measures in industrial SMEs. The lack of a common taxonomy makes comparison difficult and hinders the possibility of drawing any general conclusions, calling for a common categorization for data on industrial energy end-use and energy efficiency measures. Even so, the analysis of the data revealed

that roughly half of the energy end-use is found in the production processes while the major energy efficiency potential is in the support processes.

A new framework for improving the diffusion of energy-efficient technologies in small and medium-sized enterprises in the apparel industry in Sri Lanka is proposed by Pathirana and Yarime [63]. The proposed framework would facilitate collaboration between SMEs, knowledge providers, funders and industry associations. The current lack of awareness of the benefits of membership in industry associations is suggested to be overcome by a mandatory registration for SMEs to improve the success of the framework. Furthermore, the authors emphasize the need for measures to improve the financial capabilities for SMEs in the apparel industry.

Andersson et al. [64] developed a method to calculate the energy efficiency index to enable benchmarking of the energy performance of companies. The method was applied to data from 11 small and medium-sized sawmills in Sweden. When comparing the calculated index to the stated potential in the energy audits there was a discrepancy. The authors mention the quality of data as a major barrier to benchmarking and call for a harmonized categorization of both energy end-use data and the production processes. Furthermore, they suggest a database with data from energy audits to allow accurate benchmarking.

4. Analysis

In the analysis, results are presented in relation to country of origin, scientific methods applied, sectors addressed, affiliations of authors and year of publication. A summary of the scientific publications may be found in Table A1 in Appendix A.

The majority of the studies have a single-country focus, mainly covering European countries. Four studies investigated more than one country [36,50,56,62]. The countries covered in the most studies are Italy [6–8,39,40,42,54], where enterprises in the Lombardy region have mainly been studied, followed by China [41,47,49,51,58,59] and Sweden [27,43,55,57,60,64].

The most commonly used method in the studies is quantitative, based on either questionnaires or semi-structured interviews. Using mixed methods was the second most preferred methodology with 13 studies using a mix of quantitative, qualitative and conceptual methods and literature reviews. One study used a qualitative analysis method exclusively, performing in-depth interviews with companies [51].

The vast majority of the studies include multiple sectors in the investigation, which consists of a wide variety of industrial sectors. Among the studies with a single-sector focus the metal sector is most represented with four studies [38,40,42,61].

The affiliations of the authors in the studied papers are predominantly three groups: Politecnico di Milano from Italy [5–8,36,39,40,42,54,62], Linköping University from Sweden [27,36,43,55–57,60,62,64] and Utrecht University from The Netherlands [5,15,38,39].

Notably, the three foremost affiliations in relation to publications on energy efficiency in SMEs are from Europe: Italy (Politecnico di Milano), Sweden (Linköping University) and The Netherlands (Utrecht University), while the papers from China, with the exception of Kansai Research Center with two publications, emanated from different affiliations.

The literature for the review was selected from 1970 to 2018 but as seen in Figure 1 there were no scientific peer-review publications available before 2007 and the majority of the publications are from 2012 and onwards.

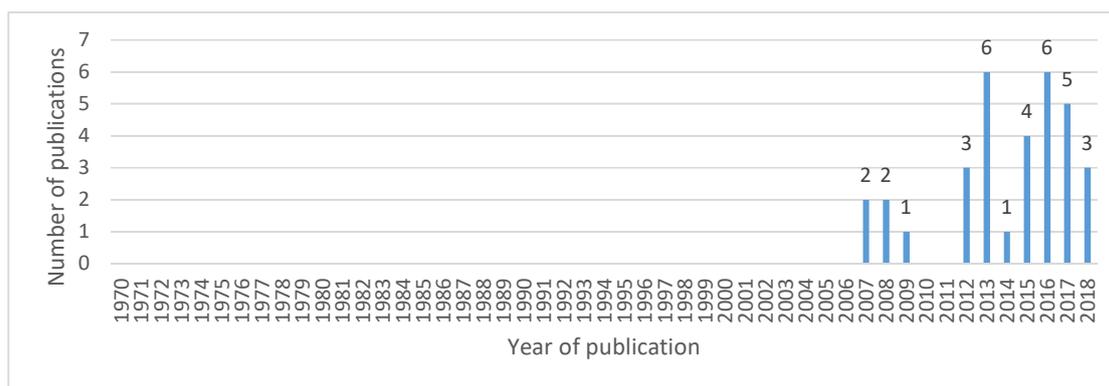


Figure 1. The year of publication of studies included in this review.

5. Concluding Discussion

This paper provided a literature review of scientific journal publications of energy policies for improved energy efficiency in industrial SMEs, with the aim of critically assessing how energy efficiency policy programmes could be designed. In total, the literature review covered 33 scientific journal publications.

Out of the 33 reviewed papers 27 were studies of barriers to and/or drivers for energy efficiency, of which five [8,25,27,54,55] were studies of energy programmes and the effect of barriers and/or drivers. Relating this to the Cooremans decision-making model shows that the major focus of the reviewed studies was found in the later part of the decision-making process, namely the choice step. Many of the findings in the studies of barriers to energy efficiency (e.g., [25,39,40,46,48]) are in line with the previous findings from Brunke et al. [4], saying that the most important perceived barriers are related to the economic category in the taxonomy from Cagno et al. [5].

Among the studies of energy programmes included in this review a majority were related to energy audit programmes ([25,27,54–56]) which confirms the findings from Tanaka [12] that identification of the energy efficiency potential by data collection or energy auditing is the most popular individual policy measure. In the papers discussing energy audit programmes it was found that the major energy efficiency potential is found in the support processes, not in the production processes [25,27,54,55,62].

A number of papers have focused on energy programmes and their evaluation. Based on the evaluations of the German energy audit programme [25] and the Swedish energy audit programme targeting industrial SMEs [27], it was found that, in terms of energy savings, between 50–56 MWh per year and measure could be achieved. Based on the array of papers being reviewed, it was found that the most promising energy efficiency measures were in the support processes (heating, ventilation, lighting, etc.), for which reason governmental R&D programmes should primarily target these areas in regard to improved energy efficiency in SMEs.

Notably, even though previous studies have considered VAPs to be effective means for energy efficient industries [12,13], they are not given much attention in studies of industrial SMEs. Only one reviewed paper studied the relation between VAPs and barriers and drivers where the results showed that SMEs, as opposed to governmental organisations, do not consider VAPs effective means [38].

Most of the studies were based on quantitative methods and only one study has undertaken an analysis based on a qualitative research approach. Notably, a number of the selected papers deal with barriers to and drivers for improved energy efficiency in industrial SMEs, even though this was not the main focus in the literature review. The vast majority of the topics covered in the studies include barriers to and drivers for energy efficiency in industrial SMEs, of which the majority focus on barriers. The reviewed papers' results seem to converge into the conclusion that barriers to energy efficiency in industrial SMEs vary with factors such as size, sector, production complexity, and geographic location, and that those factors should be considered when designing policies targeting SMEs. Few papers included in the review focused solely on drivers to industrial energy efficiency and the factors affecting

these. Cagno and Trianni [6] showed that drivers vary with factors such as demand variability and strength of competitors, which are factors that vary over time. Hence, drivers to implementation of energy efficiency measures should be considered dynamic rather than static in a company. The types of energy policy programmes researched were primarily energy audit policy programmes, which were shown to reduce some information-related barriers [25], while barriers such as obtaining information and the quality of the information still remain after the programme [27].

Results also indicate that there seems to be an imbalance in geographic focus of the research on energy efficiency in SMEs. Italy represents the most single-country studies, followed by China and Sweden. European countries highly dominate the studies. Viewing the affiliation of the author's studied publications provides us with the fact that three major groups are found: Politecnico di Milano from Italy, Linköping University from Sweden and Utrecht University from The Netherlands. This shows that the field is still quite small and also in a quite novel state in terms of maturity in the research area. Also, there is a scarcity of research in the field in countries outside of Europe, and also for a majority of the member states within Europe, with the exception of Italy and Sweden. This must be seen in light of the fact that SMEs are stated to be the core of GDP growth and employment within the European Union. Moreover, a large amount of research funds by the European Commission has been allocated towards energy efficiency improvements in SMEs in particular. Moreover, ever since the Energy Service Directive launched in 2006, EU member states have had to launch national energy policy activities, primarily energy audit programmes [65]. Given the last decade of major focus from the European Union and single member states on the topic of improved energy efficiency in SMEs and energy efficiency policy programmes, it appears that the research grants that fund such initiatives are not shown to a large extent in scientific journal publications. This could be an area of improvement to consider from various forms of funding bodies, both from Europe and elsewhere, to also set requirements for one or more scientific publications, emanating from a research grant to a research group.

Based on the analytical model used in the study, two major areas of research were detected in the study: policy and its effects as well as barriers to and driving forces for energy efficiency, see Figure 2.

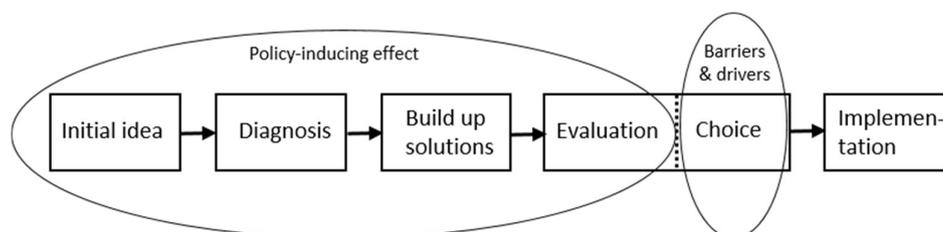


Figure 2. Analytical model based on the investment decision-making model by Cooremans [11].

As shown in Figure 2, the first sphere, policy-inducing effects, may promote industrial decision-makers in making adequate choices regarding cost-effective energy efficiency measures. Related to the first sphere, energy efficiency measures could be related to a vast array of different technologies and processes. Furthermore, the term SME is in most regards too vague to provide any real guidance into what specific technologies and processes should be targeted in a public policy programme. Prior to designing a public policy programme for industrial SMEs, two important parts are thus to select one distinct part of industrial SMEs, e.g., one specific sector, and second, for that sector map out the major energy end-using technologies and processes. Furthermore, for these selected technologies and processes, it is important to assess which already existing public policy programmes already provide support for deployment. Also, the energy efficiency potential should be estimated for the selected sector and its related technologies and processes.

The second sphere exemplifies the literature on barriers and drivers and what the majority of these studies emphasize, i.e., the actual decision-making and what is inhibiting or promoting this choice. Notably, what the studies on barriers reveal is that there is no consensus regarding what the

major barriers are that inhibit energy efficiency measures from being undertaken. Rather, these barriers seem to be contextual. This underlies the importance of regional and sector-specific studies on barriers and drivers prior to a public policy programme design.

When a design of policy has been made, the final part is to assess the degree of implementation for the policy, i.e., how many energy efficiency measures that can be assumed to be implemented thanks to the policy or in other words, how much of the stated energy efficiency potential that thanks to the policy can be deployed. In this step, the additionality of the new policy must be made, i.e., what additional effect does this policy have compared to other policies in place as well as the current energy efficiency technology and process development and business-as-usual activities such as replacement of old equipment.

Two possible primary methods could be used for this study on design of public energy efficiency policy programmes for industrial SMEs. The first would be to assess national governmental reports and findings while the second would be to analyse the available scientific literature in the field. The major method adopted in this study was the second method, i.e., a literature review of existing scientific journal publications. A previous international study on energy efficiency public policy design of industrial SMEs was published in 2014 where the major method was expert workshops, implicitly thus including national governmental reports and policy findings [28]. These two studies combined, i.e., the scientific literature study undertaken in this paper and the former expert workshop study, enables a generalization beyond the single studies alone, suggesting a general approach on how to design a public energy efficiency policy program towards industrial SMEs. The method is presented in Table 1.

The results from the studies of barriers to energy efficiency seem to converge into the conclusion that barriers to energy efficiency in industrial SMEs vary with factors such as size, sector, production complexity and geographic location, emphasizing the importance of the first step of the policy design method, targeting a homogenous company group. However, based on the array of papers being reviewed, it can be concluded that the most promising energy efficiency measures in industrial SMEs were in the support processes (heating, ventilation, lighting, etc.) and therefore, energy policy programmes towards industrial SMEs should primarily target support processes in regard to improved energy efficiency in SMEs.

Informative policies form the backbone in the energy policy mixes towards industrial SMEs and energy audit policy programmes towards industrial SMEs are often very cost-effective [28]. Regarding administrative policy instruments, administrative policy instruments for medium-sized enterprises may be a sound policy but according to Thollander et al. [28] may be less effective for small-sized enterprises. In regard to administrative policies, the governmental officials conducting the enforcement of laws, do not always seem to be sufficiently well-equipped and experienced in energy issues, leading to problems of actually enforcing/stressing adoption of BAT (Best Available Technology) [28].

As regards economic policy instruments, in both energy audit programmes and VAPs, informative policies are merged with economic policies, i.e., subsidies are provided if an SME is joining the programme meaning that the level of subsidy has large implications on the policy's cost effectiveness [28]. Further research is suggested on how much subsidy should be provided for various industrial SME policy programmes, e.g., an industrial energy audit programme.

Table 1. Major steps when designing policies for small and medium-sized industries.

Design Step	Comment
Decide primary target sector group	Primary target sector group should be set and, preferably, should be as homogenous as possible, both in terms of sector(s) and company size.
Map the annual energy	The annual energy demand and end-use is important and mapping the energy use and major technologies and processes are key steps. The share of energy use in support and production processes varies between sectors.
Review the current energy policies	For the major energy end-using technologies and processes in the former step, it is important to assess which existing public policy programs are in place and thus already provide support for deployment.
Make an energy efficiency potential estimation	Using available policy documents and scientific papers, an estimation should be made of the energy efficiency potential for the policy program. If no documents and studies are available, one can undertake a pilot ex-ante study where companies are asked about this.
Review the barriers and drivers for energy efficiency	Review the scientific publications regarding barriers and drivers for the specific sector group targeted. If the information regarding barriers and/or drivers for the targeted sector group is scarce, this could be supplemented with interviews or questionnaires in a pre-phase study.
Suggest appropriate policy	Consider the most appropriate policy or policy mix in relation to the findings in the previous steps.
Evaluate the impact of the policy programme	Make an evaluation of the policy programme to evaluate the achieved energy efficiency and cost-effectiveness of the programme. Include the expected implementation rate in the potential estimation. Anderson and Newell [26] found that approximately half of the energy efficiency measures in the American IAC were implemented and evaluation of the Swedish Project Highland showed an implementation rate of above 40% [27]. A common estimation of the implementation rate can be 50%. Further, aim to include quantified non-energy-benefits (NEBs) in the assessment of energy efficiency measures which could cut the payback time of measures [66].

In a previous scientific study, expert workshops in combination with governmental reports and conference papers, were used in order to answer the question how industrial SME energy efficiency policy programmes could be designed. In other scientific conference papers such as Price and Lu [14] and Price [13] energy audit policy programs and VAPs were studied, however not with the emphasis on industrial SMEs. This preliminary study has added yet another piece to the puzzle in that scientific journal publications on industrial SMEs and energy efficiency policy programme design has been reviewed, see Figure 3. Further research is suggested in methodological approaches on how SMEs and policies could be developed further.

As there is no common definition of an industrial SME or standardized way of categorizing energy end-use among industrial SMEs, this complicates comparison of the efficiency of policy programmes and calls for further research to be undertaken in this area. We suggest formation of a harmonized global definition of SMEs as a topic for further research. Also, future research to identify and map the sizes and energy use of the industrial SME sectors in respective countries is suggested.

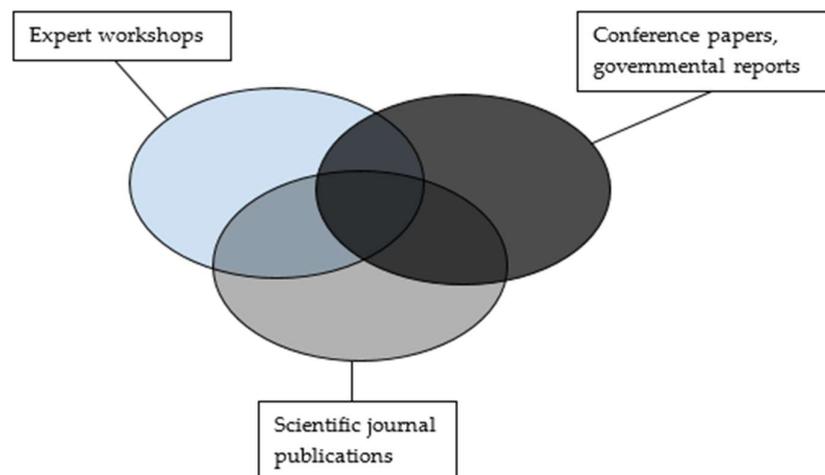


Figure 3. Methodological approaches on SMEs and energy policy programme design.

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Appendix A

Table A1. Scientific journal publications on energy policies for improved energy efficiency for industrial SMEs.

Geographical Focus	Industrial Sector		Study Method				Study Focus				Ref.	
	Country	Single Sector	Multiple Sectors	Literature Review	Conceptual	Quantitative	Qualitative	Barriers	Drivers	Energy Program		Other
Italy		x			x				x			[6]
Italy		x			x	x	x	x				[7]
Italy		x			x		x	x	x			[8]
Germany		x			x		x		x			[25]
Sweden		x			x		x	x	x			[27]
Europe	x				x		x					[36]
United Kingdom		x	x			x	x	x				[37]
The Netherlands	x				x		x	x				[38]
Italy		x			x		x					[39]
Italy	x		x		x		x					[40]
China		x			x	x	x					[41]
Italy		x			x		x					[42]
Sweden		x			x	x	x					[43]
Portugal		x			x		x	x				[44]
Slovenia		x			x		x	x				[45]
Zimbabwe		x	x				x					[46]
China		x			x		x					[47]
Ireland	x				x	x	x	x				[48]
China		x				x	x	x				[51]
Republic of Korea		x			x		x	x				[52]
Italy		x			x		x		x			[54]
Sweden		x			x		x		x			[55]
Australia, Germany, Sweden, USA		x			x	x			x			[56]
China		x			x			x				[58]
China	x		x		x			x		x		[59]
Sweden		x		x		x	x	x		x		[60]
Turkey	x				x		x				x	[61]
Sweden		x			x	x					x	[57]
China		x			x		x	x			x	[49]
Belgium, Japan, Italy, Sweden		x			x						x	[62]
Sri Lanka	x				x	x	x	x				[63]
Austria, Czech Republic, Hungary, Italy, Slovenia		x			x	x					x	[50]
Sweden	x				x	x					x	[64]

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