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Ex-post impact and process evaluation of the Swedish energy audit policy program for small and medium-sized enterprises

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Abstract

The industrial sector accounts for 35-40% of total energy use in Sweden, where 30% of industrial energy use comes from non-energy intensive small and medium-sized enterprises. This sector has not historically received much attention when it comes to improving energy efficiency due to limited resources, lower priority given to energy issues, rather small energy-saving potential for a single company, and great heterogeneity of the small and medium-sized enterprises. However, the accumulative energy-saving potential for small and medium-sized enterprises can be quite high and achieved at very low costs, partly because most improvements are found in support processes and are relatively easy to implement. Various public policies such as industrial energy audit programs serve as a means for overcoming barriers to energy efficiency in the sector of small-and medium-sized enterprises. One example is the Swedish Energy Audit Program, a stand-alone audit program functioning between 2010 and 2014. The aim of this paper is to examine the program by means of process and impact evaluation. The results show that the program resulted in annual net energy efficiency savings equivalent to 340 GWh/year or 6% of the 713 participating companies' energy end-use. The implementation rate in the audit program was 53%. On average, the public cost of one implemented measure was € 700/measure. Derived in the amount of energy saved, the audit program annual cost effectiveness is € 7/MWh saved energy. This paper adds a significant scientific contribution due to the method used for evaluation. Multiple company visits and availability of quantitate data from 713 companies gave a possibility to address the additionality effects and estimate net energy savings more precisely.

Keywords: Energy audit policy program, small and medium-sized enterprises, energy policy, energy efficiency measures, energy policy evaluation.

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1. Introduction

The industrial sector accounts for 35-40% of total energy use in Sweden, where approximately 70% of industrial energy use comes from energy-intensive large companies and 30% from non-energy

intensive small and medium-sized enterprises (SMEs) (SCB, 2010). When comparing large energy-intensive companies and SMEs, the latter have not historically received much attention when it comes to improving energy efficiency (Ramirez et al., 2005). This is explained by reasons such as limited resources, lower priority given to energy issues, rather small energy-saving potential for a single company, and great heterogeneity of the sectors (Shipley, 2001). International research has categorized these reasons for non-action into the barriers to energy efficiency (Trianni et al., 2014; Trianni et al., 2015; Trianni & Cagno, 2011). Still, the accumulative energy-saving potential for SMEs can be quite high and achieved at very low costs. This is because most of the improvements have to be done in support processes and are relatively easier to implement than measures related to production processes, and partly because technologies and methods have been already developed for energy intensive industries. Also, in large and energy-intensive industry, the absorptive capacity in terms of energy engineering consultants are higher, thus leading to a theoretically higher relative energy efficiency potential among SMEs. The minimum estimated potential for improved energy efficiency among SMEs is 20% and even more (EC, 2006; Thollander, 2013; Thollander et al., 2015a).

Various public energy policies in the form of industrial energy programs serve as a means for overcoming energy efficiency barriers. They gained ground after the introduction of the European Energy End-Use Efficiency and Energy Services Directive (ESD) in 2006 aiming at energy efficiency promotion in order to fulfill the existing targets for CO₂ emissions reduction outside of the EU Emission Trading Scheme (ETS). Among other things, the ESD highlights the importance of performing energy audits for SMEs (European Union, 2006; European Commission, 2011). The ESD mentions the contribution of energy audits to the fulfillment of energy efficiency targets set by firms (European Union, 2006). Further, performing energy audits as well as implementing energy management systems are promoted by the Energy Efficiency Directive (EED) (EC, 2012).

Energy audits can be stand-alone or part of a broader program outlined, for example, in the form of voluntary agreements or implementation of energy management systems (Price & Lu, 2011). There are two examples of such energy programs in Sweden which were completed recently. The program launched by the Swedish Energy Agency (SEA), called the Program for Improving Energy Efficiency in Energy Intensive Industries (PFE), was run between 2005 and 2014. This is an example of a voluntary agreements program (VA/VAP) oriented towards electricity-intensive industrial firms which deploys an energy audit as a first step. Another example is an energy audit program targeting SMEs (mostly represented by non-energy intensive industries), the Swedish Energy Audit Program (SEAP), representing a stand-alone audit and functioning between 2010 and 2014. It is argued that broader energy programs are more appropriate for energy-intensive industries while stand-alone audit schemes are considered more suitable for less energy-intensive SMEs (Bertoldi, 2011). The energy audit program for SMEs is the focus of this study.

The aim of this paper is to examine the SEAP by means of process and impact evaluation. The process evaluation is based on the selected companies' experience of participating in the program and the impact evaluation is based on analyzing the data from the SEA on such aspects as the program's cost effectiveness and implementation rate of energy efficiency measures (EEMs).

The paper is outlined as follows. First, the background information is provided about energy audit programs, energy audit quality and the SEAP. Second, in the method part, the process of data collection is described. Third, the results part presents the findings of the study. This is followed by the

discussion part where the major findings and their implication are addressed and a conclusion part where applicability of the findings are highlighted.

2. Industrial energy audit programs for SMEs

The most common energy efficiency barriers for SMEs are related to insufficient information or costs of information gathering. The performed studies highlighted barriers common to SMEs such as scarce information regarding energy efficiency opportunities (Trianni & Cagno, 2012), costs of obtaining information about energy consumption of purchased equipment (Sorrell et al., 2000; Sorrell et al., 2004; Rohdin & Thollander, 2006), hidden costs (Trianni et al., 2013), lack of staff for analysis (Anderson & Newell, 2004), and lack of time or other priorities (Sorrell et al., 2000; Sorrell et al., 2004; Thollander et al., 2007). Since SMEs usually do not have resources to search for information about energy efficiency potential and means to reach it, supplying the right information can help to eliminate informational barriers.

Public policy intervention in the form of energy audits can serve as a means to overcome informational barriers (Schleich, 2004). For example, if energy efficiency investments are not made by SMEs because of insufficient information about available technologies, then by providing specific information by experienced energy consultants, it is possible to influence the companies' decision on implementing these technologies. Performing an energy audit is a first step in improving energy efficiency by SMEs (Caffal, 1995; Bunse et al., 2011). An audit in itself does not result in energy savings (Schleich, 2004; Backlund & Thollander, 2014a), but it helps to define the areas for improvement and potential more energy-efficient solutions. The external assistance of energy consultants thus partly replaces the lack of energy managers at SMEs (Fleiter et al., 2012a; Schleich, 2004). This is of particular importance for SMEs whose energy expenditures often represent only a small part of total costs and thus do not seem to be relevant for top management.

An international review of energy audit programs has been made by Price & Lu (2011), where they presented 22 energy audit programs launched in 15 countries. Seven of the analyzed programs are in the form of free or subsidized stand-alone energy audits and the rest are mandated or voluntary energy audits integrated in the broader framework of VA or energy management system implementation. One of the conclusions from Price and Lu (2011) was that in order to increase the adoption of EEMs, energy audits should be included in the broader energy programs (Price & Lu, 2011).

Even stand-alone energy audit programs are different in terms of the implementation rate of EEMs. For example, the free energy audits that have been provided by the US Industrial Assessment Center to more than 14,000 companies since 1976 have an average implementation rate of around 50% (Anderson & Newell, 2003; Muthulingam et al., 2009). Another example is the German KfW fund of Reconstruction Credit Institute providing grants for audits for SMEs and covering around 9,200 companies, which has shown a 77% implementation rate of EEMs (Gruber et al., 2011). The Australian Enterprise Energy Audit Program (EEAP) mandating energy audits by law resulted in an approximately 80% implementation rate at around 1,200 companies (Harris et al., 2000). In fact, an implementation rate as high as in the Australian program is rarely reached. This can be explained by the fact that the audits were partly subsidized and that relatively few measures were proposed, all quantified and supported by investment assessments (Thollander et al., 2007). The implementation rate for a Swedish

regional program, Project Highland, was much lower and equivalent to 22% or 40% if the planned measures were also included in the estimate (Thollander et al., 2007). The evaluation of the Swedish regional and German national energy audit programs has shown that the majority of the EEMs were proposed for generic (support) processes related to space heating, ventilation, compressed air systems, etc. For SMEs, support processes present larger aggregated energy use than production processes (Thollander et al., 2015a).

The overview of the current and past Swedish energy programs is given in Thollander et al. (2012b) where eight programs are presented. However, only Project Highland covered a large number of SMEs (340 companies). Project Highland was run in the south of Sweden from 2003-2008 and aimed at providing free energy audits performed by advisors from municipalities in order to increase energy awareness among SMEs (Bondesson, 2006). Of the 340 SMEs, 140 were industrial companies. The interviewed participants mentioned that the energy audits raised engagement in energy issues at the companies. The evaluation showed that giving the companies recommendations on how to improve energy efficiency is a very efficient method to eliminate barriers such as lack of interest in energy efficiency, risk for making investments in energy-efficient technologies, and lack of information (Bondesson, 2006). The evaluation of the program also showed its effectiveness in terms of public expenditures per unit of saved energy. The recommendations for program improvements concerned quantification of the proposed EEMs as well as investment assessment (Thollander et al., 2007).

The review of industrial energy and climate policies of Sweden and Japan (Thollander et al., 2015b) showed less law enforcement in Swedish industrial energy end-use (EEU) policy mix compared to Japan, with, however, rather low costs for its implementation due to availability of the regulations. Another essential issue highlighted in the review is insufficiency of standardized approaches for industrial energy policy evaluation, which can play a crucial role for the perceived success of industrial policies (Harris et al., 2000). Also, homogeneous categorization of energy data for evaluation of industrial EEU policies is a further important aspect which would enable comparison of energy policies among different countries (Thollander et al., 2015a).

3. Energy audit quality

Quality of energy audits is an important aspect of energy audit programs. An important factor is the level of detail with which the energy audit is performed. According to the classification used in ISO 50 002, there are three types of energy audits. Type 1 (walk-through audit) is characterized by low level of detail, rather short time expended and little money spent, and thus results in a less detailed report with general EEU data and most often low-cost energy efficiency improvement recommendations. This type is appropriate for smaller organizations or as a preliminary audit. Type 2 audit contains more information about a single site or process and implies an energy analysis with extensive measurements, detailed calculations on energy savings, and evaluation of energy efficiency improvement options. Type 3 audit is used for obtaining additional information associated with high-investment projects, for example. This type of audit requires longer and more accurate measurements and results in a more comprehensive energy analysis followed by a thorough report with more detailed calculations of savings and investment costs. The type of energy audit can be chosen according to a company's needs and available resources (ISO, 2014)

The quality of energy audits also depends on the competency of energy consultants performing them. Schleich (2004) argues that energy efficiency consultants from engineering firms appear to have higher quality than industrial associations providing more general information or utilities focusing only on tariffs. Thollander et al. (2007) stated that almost half of the EEMs suffered from lack of quantification and investment assessment due to the limited time for energy audits. The important criteria for making a good energy audit are thus skilled energy auditors with a good engineering background able to deliver the information to the customer, as well as energy audit tools and handbooks in order to support the auditors (Thollander et al., 2012a). Notably, other countries, e.g. Germany, require three years of work experience and an engineering degree to conduct governmentally subsidized energy audits (Fleiter et al., 2012b). Energy audit databases, follow-ups and dissemination of the audit results can also contribute to a higher level of quality of energy audits (Price & Lu, 2011; Blomqvist & Thollander, 2015).

4. The characteristics of the Swedish energy audit program

SEAP, the energy audit program analyzed in the current study, is a program launched by the SEA and offering monetary support from 2010 to 2014, mainly to SMEs to perform an energy audit (SEA, 2015). The “SME” category includes companies that have between 10 and 249 employees and a turnover in the range € 2–50 million (EC, 2003). Larger companies could apply for participation as well if they were able to prove the necessity of this monetary support for performing an energy audit. However, companies already participating in PFE could not apply for participation in SEAP. The subsidies could be given to companies with annual energy use higher than 0.5 GWh or minimum 100 livestock units in the case of farms.

The support given should cover half of the price for energy audit but a maximum of € 3 000. One company could not apply for support more than one time and companies with more than one facility could use the support at only one of them (SEA, 2015). An energy audit has to contain an overview of the company’s annual energy use specified in MWh per year and price for each energy carrier as well as EEMs proposed for different processes and process equipment (STEMFS, 2010). Those companies that received a subsidy had to present an energy plan where they listed the EEMs that they planned to implement within two years (SEA, 2015). There were no requirements on who had to perform energy audits and companies could choose to do it themselves or use external energy consultants; however, the SEA recommended the latter.

5. Methods

Evaluation of public policies aims to achieve reasoned decision-making by means of assessing the results of ongoing or completed action. Done in good time, the evaluation can help authorities to correct errors and support good practices (Vedung, 2007). In order to perform the impact and process evaluation of the SEAP, two methods have been used for this study. The first includes collection of data from all the energy audit reports and energy plans that have been submitted to the SEA and approved for the entire program period. The second method is the interviews and site visits to the premises of several selected companies that participated in the program. In this way, the analysis of data from the reports would enable a conclusion about such aspects of the impact evaluation as the

program's cost efficiency, gross and net energy savings, and implementation rate of suggested EEMs, while the interviews would help to make the process evaluation based on some aspects of the program theory as well as provide additional quantitative data about the actual energy savings and EEMs.

5.1. Process evaluation

The process evaluation consists of the quantitative and qualitative data gathered through the interviews during the company visits. The program theory played an important aspect during the process evaluation.

5.1.1. Program theory

Program theory as an evaluation method is used to explain why it is desirable to make a public intervention and what the necessary resources and possible effects are (ESV, 2012). The social relevance of the evaluation process is, thus, to analyze an effect from the intervention, paying attention to why it failed or succeeded. The persistent problem is to determine whether it is the program or something else that has caused the effect (Vedung, 2007) and therefore it is important to consider what external factors may affect the result (ESV, 2012). It can be problematic to make this distinction because the influence of public policy instruments is hard to "isolate." This calls for distinguishing between gross and net impact evaluation. Unlike gross impact calculations, net impact or net energy savings calculations cover additional aspects (free-rider, spill-over and double counting effects) (SEEAAction, 2012; Broc et al., 2009).

$$\text{Net energy savings} = \text{Gross energy savings} * \text{double counting coefficient} * (1 + \text{spillover effect} - \text{free-rider effect})$$

(formula 1)

where:

- double counting coefficient (0÷1) considering mutual energy savings from different EEMs or public programs;
- spill-over energy effect – indirect energy savings from EEMs or public programs;
- free-rider effect – energy savings by free-riders or those program participants who would have undertaken EEMs anyway.

In this study, free-rider, spill-over and double counting effects were addressed during the interviews with the SEAP participants. Also, changes in electricity prices can play an important role in evaluation of energy-oriented public policies. This factor, however, was not considered specifically in the interviews. It is important to note that all the calculations were based on final energy use of the participating companies.

5.1.2. Interviews

For this study semi-structured interviews were used consisting of a list of questions with a possibility to alter them depending on a particular context (Yin, 2006). Thus, a trade-off between flexibility and the importance of getting answers to all important questions was assured. In total, 37 Swedish companies were visited with the aim to interview an energy manager or top manager (a person that was in charge of work with the SEAP). The selection of respondents was based on the whole population, which includes more than 1,000 companies. However, only 760 energy audit reports were approved by the SEA. The companies vary in size, turnover, energy use and sector, which is why the selection criteria were energy use higher than 1,000 MWh/year and energy efficiency potential of

around 20% of energy use. Also, the intention was to visit the counties with largest number of applications (Figure 1) as well as the companies within the top sectors according to the number of applications (the European categorization NACE Rev. 2, Eurostat, 2008).

Figure 1. The number of visits made in different counties.

The top ten sectors applied for the SEAP are presented in Figure 2 starting from the sector “Real estate” (114 companies), followed by “Crop and animal production” (93 companies), and “Manufacturing of fabricated metal products” (85 companies). When choosing the companies for visits, priority was given to manufacturing industries, because they have higher energy intensity and were in the scope of the SEAP.

Figure 2. The top ten sectors that applied for the SEAP.

The aim with the interviews was to get an overview of how the SEAP functioned and what the main benefits were for the participants. The interview guide was divided into such areas as information about the company, EEMs, the company's opinion about the energy consultant's work, additionality (free-rider and spill-over) effects, barriers to energy efficiency, importance of energy issues, etc. There can be a risk that the answers of the interviewees are affected by their perception of what they think the interviewer expects to hear from them (Bryman, 2012), especially in a study like this when a governmental policy program is being evaluated. This risk cannot be eliminated but was accounted for by instructing the interviewees that interviewing researchers were not sprung from a controlling organization but an independent party and the study was conducted not to judge their work and deliver the results to the SEA but to find out the actual outcomes of the SEAP to improve future programs.

Every visited company's energy audit report was summarized in terms of its advantages and disadvantages and generally evaluated in order to estimate the level of quality of energy audit reports and thus the qualification of energy consultants. Quantitative data from the interviews served as a supplement to impact evaluation.

5.2. Impact evaluation

The companies that participated in the SEAP were obliged to submit their energy audit reports together with energy plans with the quantified EEMs to be performed within two years. In total, about 1,020 energy audit reports were received while 760 were approved. For this study, 713 reports were compiled and used for the analysis with the aim to calculate the program's cost effectiveness, net energy savings, and implementation rate of EEMs. The calculations are based on final energy use.

The companies' energy use can be categorized by unit processes (Söderström, 1996) as presented in Figure 3. For this study, only support processes were divided into particular categories due to the variety of production activities in the SME's sector.

Figure 3. Categorization according to the concept of unit processes.

The same categorization was applied for the EEMs suggested by the energy consultants. A detailed description of the measures under each category can be found in Backlund & Thollander (2014a). The

data from the energy audit reports were used to calculate the total energy savings and cost effectiveness of the program. Based on the results of the 37 company visits, the net energy savings were calculated according to Formula 1. Furthermore, an important factor to consider was the lifetime of EEMs. Following Stenqvist & Nilsson (2012) and Backlund & Thollander (2014), the same lifetimes of 12 and five years were assumed for investments in technical measures and management-related measures correspondingly. The shares of technical measures versus management measures were assumed at 64% and 36% (correspondingly) based on Backlund (2014).

In the cost effectiveness calculations, the net present value (NPV) of the SEAP's related costs and energy savings derived in EUR was used in order to take into account the value of cash flows over a period of time. The formula used for NPV calculations is:

$$NPV = \sum_{t=0}^N \frac{C_t}{(1+i)^t} \quad (\text{Formula 2})$$

where:

C_t – the net cash flow (in – out) at a specific time;

t – the specific time of cash flow;

N – the number of time periods;

i – the discount rate.

In the NPV calculations, the price of € 65/MWh of electricity and district heating (Nilsholgersson, 2014; Nordpool, 2015) and the discount rate of 6% were used.

6. Results

In the following section, the results of the process and impact evaluation of the SEAP are presented.

6.1. Process evaluation

This subsection represents the quantitative and qualitative results of the company visits.

6.1.1. Quantitative evaluation of the visited companies

Figure 4 shows how many visits were made for a particular industrial sector in relation to the number of applications sent to the SEA for the SEAP support that was obtained from these sectors.

Figure 4. Industrial sectors visited and corresponding number of applications for the SEAP.

Where: A1 – Crop and animal production, hunting, etc.; C10 – Manufacture of food products; C11 – Manufacture of beverages; C16 – Manufacture of wood, products of wood and cork, of straw and plaiting materials; C20 – Manufacture of chemicals and chemical products; C22 – Manufacture of rubber and plastic products; C23 – Manufacture of other non-metallic mineral products; C24 – Manufacture of basic metals; C25 – Manufacture of fabricated metal products; C27 – Manufacture of electrical equipment; C28 – Manufacture of machinery and equipment; C32 – Other manufacturing; C33 – Repair and installation of machinery and equipment; E38 – Waste collection, treatment and disposal activities, materials recovery; F42 – Civil engineering; G45 – Wholesale and retail trade and repair of motor vehicles and motorcycles; G46 – Wholesale trade, except of motor vehicles and motorcycles; G47 – Retail trade, except of motor vehicles and motorcycles; H49 – Land transport and transport via pipelines; L68 – Real estate activities. (Eurostat, 2008)

6.1.1.1. Energy use of the visited companies

The EEU of the visited companies is presented in Figure 5 below.

Figure 5. EEU of the visited companies in corresponding industrial sectors.

As shown by the figure, there are also companies with very different EEU within a particular sector (SNI C, SNI G). EEU of eight companies exceeds 10 GWh/year. One company (Company 35) has an extremely high EEU (565 GWh/year). This company applied for the SEAP in order to get help within the area of support processes accounting for only 2.9 GWh/year of the company's total EEU, and thus only energy used in support processes was considered in the calculations. Average energy use among the companies (excluding Company 35) was 6.4 GWh/year. However, if not all eight energy intensive companies are taken into account this number was reduced to 2.4 GWh/year.

The total energy use in the 37 companies was around 260 GWh/year. In Figure 6, the EEU divided among different unit processes is shown. More than half of the EEU belongs to support processes while production processes account for 46% (Company 35's production processes are not included). Among the support processes, the major users of energy are heating (43 GWh/year), lighting (29 GWh/year) and ventilation (28 GWh/year) processes. The share of pumping is rather small because this process does not contribute to significant EEU at SMEs, and most often is represented by circulation pumps. In the studied energy audit reports for the 37 companies, pumping was not presented as a separate category in any of the cases and often was presented together with heating and ventilation unit processes. When pumping contributed to the core business at the studied companies its energy use was included in the production processes.

Figure 6. Energy use divided among unit processes (37 company visits).

6.1.1.2. Energy saving potential for the visited companies

The potential for improved energy efficiency in the visited companies is presented in Figure 7 by suggested and reported potential and compared to the outcome. It is worth noting that the suggested measures are the measures proposed by energy consultants in the energy audit reports. The reported

measures are the measures that the companies stated would be implemented within two years. The outcome represents the measures that as stated in the interviews have already been implemented or will definitely be implemented in the future (mentioned as “implemented” further on the figures). The energy efficiency potentials given in the energy audit reports are almost always higher than reported by the companies and implemented or stated to be implemented by the companies. Only in three cases did the companies report more measures than were received through the energy audits (Company 27, 24, and 18). The outcome was lower than reported in 10 cases, however, the total outcome for all the companies is higher than reported to the SEA in the energy plans. On average, the suggested measures represent a 17% energy-saving potential (35,5 GWh/year). While the companies reported implementing energy-saving measures which on average account for 9% of their total energy use (19 GWh/year), the outcome results in 13% potential which is equivalent to 26.8 GWh or 22% higher implementation rate than reported (spill-over effect).

Figure 7. Energy efficiency potential of suggested, reported and implemented measures from the 37 visited companies.

The number of measures suggested by the energy auditors in the energy audit reports, as well as the measures reported by the companies to the SEA and the real outcome (according to the interviews with the companies’ representatives) are shown in Figure 8 where it is also possible to see the spill-over effect. The same situation as with energy saving potential holds for the number of the proposed EEMs. An average number of EEMs suggested per company is 13, however, the companies stated that eight would be implemented while the number reported to the SEA was seven.

Figure 8. Number of suggested, reported and implemented measures from the 37 visited companies.

6.1.1.3. The SEAP's cost effectiveness based on the company visits

To get a better understanding of the SEAP, the cost effectiveness indicators were calculated not only for the entire data sample presented in the section "Impact Evaluation" but also for 37 visited companies. The calculations are based on the expenditures of the SEA during 2010-2014 which comprise the costs for the energy audit checks as well as administration, IT support, communication with regional energy offices, other communication and other public costs (Table 1). The total cost of the program is € 3,450 million.

Table 1. SEA's costs for the SEAP

SEA's costs	Total, thousand €	Per company, €/company
Administration	462	
IT system	107	
Communication via energy offices	602	
Other communication	21	
Other public costs	9,7	
Energy audit	2,247	2,960
Total SEA costs	3,450	4,540

The costs for the energy audits are € 2,247 thousand which implies an average cost of one energy audit of about € 2,960 considering 760 approved reports. Together with other costs, the total SEA's

expenditures for one company is about € 4,540. The average cost of an energy audit for the participating companies is around € 1,970/company, however, for the interviewed companies it is around € 3,960/company.

The public costs of one measure in the visited companies paid by the SEA range from about € 150/measure to € 2,400/measure as shown in Figure 9. On average one measure costs about € 600 for the SEA. In nine cases the public cost of one measure exceeded € 1,000. There is no information for 21 and 22.

Figure 9. Cost effectiveness of the SEAP derived in €/measure.

The cost effectiveness of the SEAP derived in the amount of public costs spent per saved energy is shown in Figure 10. This indicator ranges from € 1 to 280/MWh, however, Company 15 and 22 differ significantly from the rest (€ 150 and 280/MWh respectively). This is explained by that the EEMs suggested for these companies result in quite low energy savings. On average the cost effectiveness of the SEAP is equivalent to € 6/MWh or € 5,7/MWh if Company 15 and 22 are excluded. It is worth noting that the cost effectiveness calculations for 37 visited companies are not based on NPV (the discount rates and EEMs' lifetime are not considered). The NPV calculations are made for the entire program.

Figure 10. Cost effectiveness of the SEAP derived in EUR/MWh from the 37 visited companies.

Reversing the numbers above it is possible to calculate the energy saved per public money (Figure 11). This indicator ranges from 4 to 1,150 kWh/€, however it is significantly higher for Company 2, 17, 31 and 36, exceeding 400 kWh/€. The average energy saved per public money invested is around 165 kWh/€ or 150 kWh/€ if Company 2, 17, 31 and 36 are excluded.

Figure 11. Energy efficiency savings per money spent from the 37 visited companies.

6.1.2. Qualitative evaluation of the visited companies

Each energy audit report was thoroughly read before the company visit and positive and negative aspects were highlighted. One general conclusion was that the quality of auditors' work varied extensively. The positive points mentioned in the same reports were clear allocation of EEU, detailed list of EEMs with motivation explanation, heat use presented in the form of a heat balance with the possibility to see excess heat areas, transparent analysis of energy use and measures with explanations, comprehensive measurements of energy use with analysis and comments, attention not only to technical measures but also organizational and behavioral aspects, explanation of what is lacking for more extensive energy analysis, as well as detailed profitability calculations. However, there were also negative comments such as energy and profitability calculations lacking explanation, energy balance not presented or not detailed enough, only adjustment measures given, lack of measurements, or short report without graphic presentations. In 27 cases, it was possible to find other energy efficiency improvement possibilities during the site visits.

6.1.2.1. Audit quality in the visited companies

On a question about the quality of energy audits, five out of 37 company representatives had some negative remarks. One reflection was that the company expected more serious measures in order to focus on higher energy-saving potential. There were also less satisfied companies mentioning that the audit reports were too basic: "It was not the best business for us, disappointment. The audit included only obvious measures." "The energy audit did not suit our activities, only basic measures." Four interviewees mentioned that their energy audit reports contained only basic recommendations, as if consultants used existing templates. However, the rest of the respondents were satisfied or very satisfied with the energy audits. The recommendations they got were clarified, five respondents mentioned that they could use them as decision support and two mentioned that the audit was an eye-opener and helped to embrace the whole situation.

The energy auditor competence was judged by 27 respondents. Only three of them mentioned that the auditor's competence was not at a high level. One respondent explained that an energy auditor was quite young and inexperienced, another respondent did not like the correlation between the price for consultancy work and the audit result they obtained and finally, the third respondent mentioned that the auditor's knowledge about the production processes was insufficient. The rest estimated the auditors' work as good or (in five cases) very good. One company got help not only with showing improvement potential but also with understanding the results of the audits. It was mentioned that an auditor needs to have great communication skills. Several respondents stated that their auditor's work was trustworthy and inspiring and they recommended auditors to peers. Some companies were introduced to recent technological trends in lighting and HVAC in Sweden which was also appreciated.

6.1.2.2. Energy strategy of the visited companies

The visited companies were part of a bigger company group in 22 cases, and individual companies in 15 cases, while one company was a municipal organization. On a question about the importance of energy issues for a company, only five companies answered that energy is not that important and is not on an everyday agenda and only the companies' activities are prioritized. All these five companies were private. However, only two companies mentioned that they have joint work on energy issues on a company group level and that is why it is hard to make a conclusion that being part of a company

group results in higher energy ambitions. Those companies who answered that energy is a very important question justified it by the fact that energy costs represent a significant part of their expenses and continue to increase. Also, energy-related aspects are recognized as important along with environmental, health and safety issues. Finally, it was stated that many customers put pressure on a supplier by means of their energy requirements.

On a question about pay-off time for energy investments, 23 respondents said that pay-off requirements for energy investments are no different from other investments related to production or maintenance. They mentioned that if measures save a lot of energy they try to implement them and that pay-off is not important but saved kilowatt-hours are. However, the measures with pay-off of less than three years are preferred, as mentioned by three respondents. Six interviewees mentioned pay-off less than 10 years as acceptable. Five respondents said that energy investments are not as prioritized as production or safety/environmental investments, and in the case of energy investments, pay-off is always a decisive criterion as well as being important to agree on energy investments with top management in order to put them on a priority list.

6.1.2.3.   Additionality effects

In 23 cases out of 37, energy efficiency actions apart from those recommended in the energy audits were implemented. In several cases, the recommendations from energy audits that the companies had not reported as implemented were implemented anyway. However, in the majority of the cases, after launching work on the measures from the audit the companies found some additional areas for improvements as well (the spill-over effect was estimated to be 22%).

Free-rider effects could be analyzed in 26 cases while 11 companies could not give an answer to this question. Out of these 26, only three companies stated that they would have made an energy audit even without participation in the SEAP, and one stated they had to do it due to the need to change their boiler. Thus, 88% of the responding companies would not have done an energy audit without governmental support. These 23 companies explained that the support from the SEA was a good argument to show to top management to perform analysis of their energy use. Some companies had discussed the possibility of performing an energy audit but it seemed too expensive, and the audit triggered the process. Some areas for improvement had been known but they could not estimate the whole improvement potential. Ten companies could give the estimated percent of the measures they would have taken even without the participation in the SEAP (Figure 12). On average 58% of the EEMs were known, however they were not highly prioritized and without an energy audit they would not have been done in the immediate future. The free-rider effect was estimated to be 15%.

Figure 12. Percent of EEMs that were known or would have been found without energy audit from the 37 visited companies.

Nineteen companies stated that the energy audit helped to overcome the barriers to energy efficiency. Figure 13 shows what barriers to energy efficiency were mentioned during the interview (some companies mentioned several barriers). As can be seen, lack of knowledge is mentioned by 13 companies. Other barriers include lack of interest from top management, lack of time, other priorities, lack of staff responsible for energy use, other priorities for capital investments, and lack of access to capital. Six respondents said that the energy audit did not contribute to reduction of the energy efficiency barriers. One of them mentioned that even after the energy audit there are barriers left related to difficulties in finding information about energy efficiency opportunities.

Figure 13. Barriers to energy efficiency that were overcome by means of an energy audit.

One aspect related to additionality that was also asked during the company visits was what other types of support for SMEs could have affected the outcome of the program (for example, participation in energy efficiency networks). Thirteen companies could answer this question. They stated that energy efficiency work is also promoted by other types of support presented in Table 2.

Table 2. Other type of energy support used by the visited companies.

Respondent	Other type of support in energy work
Company 4	Network (collaboration between university and industrial association)
Company 5	Sector association
Company 6	Local network
Company 12	Municipal energy advisement
Company 13	Investment support from the county board
Company 17	Internal network
Company 19	Local network
Company 25	Activities on community level
Company 27	Sector association
Company 28	Sector association
Company 30	Environmental network organized by industrial association
Company 33	Sector association
Company 36	Environmental organization that puts a requirement on energy audit and energy plan

It is hard to estimate the extent to which these types of support affected the outcome in reality, and when comparing these companies to the results presented in Figures 13-15, there was no direct correlation followed. For example, the same companies stated that they would not have performed an energy audit in the immediate future or to the same extent without the support from the SEAP. The effect on the outcome might somehow be reflected in greater implementation rate of EEMs. Ten out of these 13 companies have implemented additional EEMs, which is a good indicator. At the same time, in another 16 companies the implementation rate was also higher than reported to the SEA.

6.1.2.4. Further work in the visited companies

20 companies see the need to make an energy audit again, out of 25 companies who answered this question. Also, it was mentioned that the need for an energy audit can arise if there are changes in production or rebuilding. Four of the 20 respondents that see the need for further energy analysis stated that it would be in a simpler form next time. Five respondents said that a more detailed, deeper audit will be needed in the future for already defined areas with potential for improvement, which can help avoid overlooking accustomed conditions and keep awareness at a high level. Several respondents stated that an energy audit will be needed again in several years. Some mentioned every three to five years, "in several years," or "not very often." Five respondents answered that they will not need analysis of their energy use in the future. One respondent stated that it would not be needed because now they are aware of what they should do. Another respondent explained that their facilities are newly built and they do not have energy-intensive processes. Two respondents answered that continuous maintenance would be enough. Thus, the majority of the interviewees understand the need for continuous analysis of their energy use. As mentioned by one of them, the technology as well as knowledge in the field of energy efficiency is developing quite fast so there is a need for continuous update.

6.2. Impact evaluation based on the SEAP's data base

In the following section, the results of the impact evaluation of the SEAP based on 713 approved energy audit reports are presented.

6.2.1. Energy use, saving potential and deployment levels

The impact evaluation of the SEAP is based on the data from 713 companies. The energy use of the companies participating in the analysis is 5,370 GWh/year. In total, the energy savings account for 589 GWh/year, which represents 11% of the energy use. The savings for different unit processes are presented in Figure 14. Thus, the highest energy savings are in Ventilation (26%) and Space heating (24%), followed by Production processes (22%) and Lighting (8%).

Figure 14. Energy saving potential for different unit processes.¹

The EEU as well as savings for each particular sector are presented in Figure 15. The most energy is used in such sectors as D35-Electricity, gas, steam and air conditioning supply, C24-Manufacturing of basic metals, C16-Manufacture of wood and products of wood, C25-Manufacture of fabricated metal products, and C22-Manufacture of other non-metallic mineral products. The energy savings potentials for these sectors are 1%, 3%, 18%, 16% and 16% respectively. The small potential for sectors D35 and C24 can be explained by the fact that the measures were suggested for their support processes whereas the majority of energy is used in production processes. Another explanation can be that some companies that applied for the money support are quite energy-intensive for the SEAP and eventually should have participated in the PFE instead. The average energy saving potential for all the sectors is 21%, which is within the range of potential stated in Thollander et al. (2015a).

¹ This figure is built on the data from 454 companies because for the rest of companies there was no proper allocation of EEU among the unit processes.

Figure 15. EEU in different sectors and corresponding energy savings.

Energy savings per company are presented in Figure 16. The highest energy savings are found in the following sectors: C15-Manufacture of leather, C11-Manufacture of beverages, B7-Mining of metal ores, C16-Manufacture of wood and products of wood, and M71-Architectural and engineering activities. However, sectors B7, C11, C15, M71 are presented by only one or two companies. Thus, the highest potential is found (apart from C16) in such sectors as C10-Manufacture of food products, C22-Manufacture of rubber and plastic products, and C20-Manufacture of chemical products.

Figure 16. Energy savings per company for various sectors.

Investment costs are shown in Figure 17. Major costs are found in the sector L68-Real estate activities because it is presented by 15% of the companies. This sector is followed by C25-Manufacture of fabricated metals and C10-Manufacture of food products.

Figure 17. Investment costs of EEMs in different industrial sectors

Average investment costs calculated per one company are about 21 thousand €/company (excluding the real estate sector).

6.2.2. The SEAP's cost effectiveness based on the SEAP's data base

The ex-ante evaluation of the SEAP made in 2010 predicted that the program would result in improved energy efficiency of 700-1,400 GWh/year or 780-1,560 MWh/year per company (Thollander & Dotzauer, 2010). Another ex-ante gross impact evaluation of the SEAP was performed in 2012 based on 130 energy audit reports approved by the SEA. The energy savings for these reports are 20% of the total energy used by the companies or 120 GWh, which is equivalent to € 15 million investment costs. The average expenditures of a company for implementation of the measures are 125 EUR/MWh saved. The program's cost-efficiency calculations showed the figures 119-237 kWh/EUR (Karlsson et al., 2012). The evaluation of the German program shows the following figures: total energy saved 1055 GWh/year, energy saved per company 117-197 MWh/year (considering both only reported implemented and implemented together with suggested measures), 240-555 kWh/EUR public costs (Gruber et al., 2011; Fleiter et al., 2012b). It is important to note that in the German evaluation, the savings calculations were made based on NPV.

The gross impact evaluation of the SEAP after three years of the program's lifetime was made by Backlund & Thollander (2014). The evaluation was based on 241 approved energy audit reports. The companies' energy plans submitted to the SEA reporting system consist of a total savings potential equivalent to 91.7 GWh representing 55% implementation rate (Backlund & Thollander, 2014). The average energy efficiency improvement per company was stated to be 460-660 MWh/year.

6.2.2.1. SEAP's gross and net energy savings

In the SEAP in total, as was already mentioned, the suggested EEMs result in energy savings equivalent to 589 GWh/year or 314.5 GWh/year when considering only those measures that were reported to the SEA as to be implemented within two years. A total of 5,941 EEMs were suggested whereas 3,234 measures were reported to the SEA to be implemented in the next two years, which represents a 53% implementation rate. On average 4.5 measures were implemented per individual company (considering only reported measures).

Taking into account a spillover effect of 22% and a free-rider effect of 15% (derived from the company visits), while neglecting a double counting, the net energy savings (according to Formula 1) increases to around 630 GWh/year for the suggested measures and to around 340 GWh/year for only the measures that were reported to the SEA. Thus, the average energy savings per one company are equivalent to 440 MWh/year (considering only the measures that were reported).

6.2.2.2. NPV of the SEAP's public and private expenditures

As already mentioned, the SEA's average cost for one energy audit is about € 2,960. Together with other costs spent on the program, SEA's average expenditures for one company are € 4,540. Total SEA expenditures for the program was € 3.45 million. However, taking into account the approximate lifetime of EEMs and the discount rate of 6%, the NPV of public cash flows calculated by Formula 2, this means € 2,665/company or € 2 million in total.

The average cost for an energy audit for the participating companies was € 1,970/company. Thus, the total average costs of an energy audit in one company are € 6,510 of public and private expenses. The total investment costs in EEMs by the companies were € 164 million or 214 thousand €/company or invested € 520/MWh. Considering only private costs without SEA support, the costs for one company were 216 thousand €/company (investment costs together with energy audit costs). According to Formula 2, the NPV of one company's cash flow was on average 127 thousand €/company or € 96 million in total. Thus, the average payback time for one measure was 7.6 years, considering only the planned measures corrected for additionality effects.

6.2.2.3. NPV of energy savings

The total net energy savings of 340 GWh/year derived in monetary form result in NPV of € 13 million if only measures reported to the SEA are implemented, and € 24 million considering all the suggested measures in the SEAP. In this calculation, free-rider and spill-over effect were considered as well as using € 65/MWh electricity and heat price.

The SEAP's cost effectiveness expressed in costs for one measure was around € 700/measure. The SEAP's annual cost effectiveness expressed in costs of energy saved is € 7/MWh (considering net energy savings). This results in 140 kWh/€ saved energy. The ex-post evaluation of the SEAP's total duration shows less savings than predicted in the ex-ante estimate as well as less energy saved per unit of public funding. The cost effectiveness indicators are however in line with Project Highland's, and equivalent to € 5.1-11.6/MWh. However, the numbers in the two referenced evaluations do not consider NPV of the cash flows whereas in this work they are based on the NPV calculations.

7. Discussion

This study was performed on 713 energy audit reports out of 760 reports approved by the SEA (a total of 1,020 companies participated in the SEAP). Thus, 25% of the cases did not proceed further (where 40% withdrew their participation application at their own request). According to the SEA's survey the reasons were: lack of time and resources, a person responsible for the SEAP left the company, too much administrative work, other more important investments, economic difficulties, problems with energy auditors. The rest were not approved by the SEA because the companies did not complete their progress reports or energy audit reports did not meet the SEA requirements and the companies did not want to pay for the supplementary work.

The interviews with the companies showed, in turn, that the overall quality of the energy audits was good and the companies were satisfied with their results. The energy audit results served as an eye-opener and helped in seeing the whole picture of a company's energy performance. They can also be used as decision support for making energy efficiency investments and prioritizing them among other investments, even though the majority of the companies mentioned that pay-off requirements for energy investments are no different from other investments related to production or maintenance. According to the company visits, it was possible to find further energy efficiency improvement areas in the majority of cases.

As for the spill-over effect, it was noticed that the majority of the visited companies implemented energy efficiency actions apart from the ones proposed by energy experts. Some EEMs that the companies had not reported as to be implemented were implemented anyway, resulting in 22% higher implementation rate. Free-rider effects were estimated to be quite low (15%). Only three companies said that they would have made an energy audit without monetary support from the SEA. This support was a good motivation to perform energy use analysis in their facilities which would otherwise seem costly. 58% of the suggested EEMs were known but there were no plans to implement them and energy audits triggered the work. Double counting or mutual energy savings caused by participation in other public programs was hard to estimate, and the scientific literature provides no guidance in this regard on how to make adjustments, calling for future research to be conducted in this area. This might somehow be reflected in a stated larger implementation rate of EEMs than what is actually the case.

The majority of the visited companies stated the importance of further energy audits. These audits would be needed though after some period of time. Alternatively, performing more detailed investigations for already defined areas may be needed (type 3 energy audits according to the ISO 50 002 classification scheme).

Analyzing the quantitative data from the approved reports, it was found that only 22 % of energy savings belong to production processes, which does not show that the potential in this area is small but rather indicates that support processes were the focus for the energy auditors. Among the support processes, the largest energy saving potential is found in Space heating (24%), Ventilation (26%), and Lighting (8%). Regarding the industrial sectors, the highest potential for energy efficiency improvement is found in Manufacture of food products, Manufacture of rubber and plastic products and Manufacture of chemical products.

630 GWh/year are the total net energy savings from all EEMs suggested in the analyzed 713 energy audits, which is 12% of the total energy used by these companies. However, the implementation rate

of the EEMs is 53% (3,234 reported measures out of 5,941 suggested) which is about 4.5 measures per company. The EEMs reported as to be implemented result in energy savings equivalent to 315 GWh/year (6% of total EEU). However, 37 visits to participating companies revealed 22% higher implementation rate than reported. These 37 visited companies represent 5% of the 713 companies' energy use and their energy saving potential is equivalent to 6% of the total energy saving potential. Considering additionality effects calculated based on the company visits, the net energy savings from the reported measures increases to 340 GWh/year. Per company, the average energy savings are equivalent to 440 MWh/year.

The results of the NPV calculations of the public and private cash flows as well as the cash flows of the SEAP's energy savings are presented in Table 3.

Table 3. The NPV of public and private cash flows and cash flows of the SEAP's energy savings.

NPV	€, thousand
NPV public per firm (total costs for SEAP)	2.7
NPV private per firm (costs for audit + investment costs)	127
NPV public total (total costs for SEAP)	2,025
NPV private total (costs for EA + investment costs)	96,387
NPV of suggested savings	23,883
NPV of reported savings	12,747

On average, an individual company invested around € 520/MWh in EEMs. The SEA subsidized around € 700 per measure reported to the SEAP. Derived in the amount of energy saved, the SEAP's cost effectiveness is € 7/MWh or 140 kWh/€ saved energy per public costs.

A simplified comparison of these results with the international evaluations of several energy audit programs is given in Table 4 including the US IAC, (Anderson & Newell, 2003; Muthulingam et al., 2009), the EEAP Australia (Harris et al., 2000), Project Highland (Thollander et al., 2007), and the KfW fund (Fleiter et al., 2012b). Only actual savings are presented in Table 4 and only cost effectiveness indicators related to the public expenses.

Table 4. The comparison of several evaluations of the international energy audit programs.

	No. of companies	No. of measures	Energy savings, GWh/year	Cost-effectiveness, EUR/MWh	Specific savings, kWh/EUR	MWh/measure	MWh/year per company	Payback, years
US IAC	14,800	55,500	18,833	n/a	n/a	303	1,278	1.1
EEAP Australia	1,200	5,640	4,167	n/a	n/a	736	3,469	1.3
Project Highland	139	142	76	7.5	86	535	547	n/a
KfW fund	9,292	14,500 (1.7/company)	1,055	1.8-4.1	240-555	70	120	6.1
Ex-post SEAP	760	3,234 (4.5/company)	340	7	140	104	440	7.6

The oldest and largest American audit program accounts for the greatest energy savings, followed by the Australian program. The comparison of the programs' cost effectiveness is complicated however by the fact that different approaches were used during the program evaluations. The American program was evaluated based on the database records while the Australian evaluation was conducted through phone interviews with 100 participating companies. The German evaluation is based on online surveys and statistics from the KfW. The total energy savings were not reported in the German program and thus were estimated from the surveys. Additionality effects were not considered in the first mentioned programs nor were the programs' cost effectiveness indicators calculated in these energy audit programs. In the American program, the implementation costs were estimated while for the Australian program an average value of implementation was estimated. Free-rider effect was partly covered in the evaluation of Project Highland, however, no indicators were proposed. Also, the cost effectiveness calculations of Project Highland were not based on NPV calculations and thus did not account for the discount rates and lifetimes of measures. Additionality effects as well as NPV calculations were considered in the German program. Thus, only the German energy audit evaluation program and the present evaluation study seem to have indicators calculated in a similar manner. Comparing the German audit program and the SEAP, the first appears to be more cost effective in terms of kWh energy saved per public expenses whereas the number of EEMs as well as energy savings for an individual company is higher for the SEAP. The pay-off time for the German program is also one year shorter but the public costs were much higher.

8. Conclusion

The evaluation performed in this study shows the overall results of the SEAP. The process evaluation helped to obtain qualitative data in the form of the participants' reflections about the program. In order to shed light on whether it is the SEAP or something else that caused the effect, additionality effects were included as well. The impact evaluation based on the analysis of approved energy audit reports helped to estimate the energy efficiency improvement potential, the areas for improvements as well as the amount of energy saved per public money spent.

The interview study with the companies showed that the overall energy efficiency awareness among the visited companies is quite high and energy is considered to be an important issue among them. The visited companies mentioned that participation in the SEAP helped reduce barriers to energy efficiency. They mentioned lack of knowledge, lack of interest by top management, lack of time, other priorities, lack of staff responsible for energy, other priorities for capital investments, and lack of access to capital. However, the awareness of the companies that withdrew their applications for participation in the energy audit program can be considered low. This means that barriers to energy efficiency remain for these companies, which is proved by the fact that many companies declined to participate in the project, not even considering the companies that did not apply for the program at all. As shown, customer pressure can play an important role and put energy requirements on companies. Other mentioned drivers for increased awareness of energy efficiency are energy cost reductions and that energy is a part of corporate quality work.

One important finding was that in the majority of cases it is possible to find further energy efficiency improvement areas, underlining the requirement to support energy auditors with such standardized energy audit tools as an EEMs database, for example. This kind of database based on previous audit results can show what other EEMs were implemented in similar industrial sectors by similar companies.

Another important finding is that the companies see the need for further energy audits, which proves again that an energy audit is only the first step on the way to increased energy efficiency at SMEs. The interviewed companies recognized an importance of energy management measures and measures requiring behavioral changes. However, energy management practices for SMEs are relatively undeveloped and there is a need for further work in that area. Also, since energy efficiency has not been prioritized among SMEs despite the existing potential and since the companies often do not know that they have this potential for improvement, there is an obvious need for energy-related education among SMEs. One possible way to help SMEs can be engaging them in energy efficiency networks (Paramonova et al., 2014) where they can learn from each other's experiences. Such networks can also help to establish energy management practices at SMEs and combined with the aforementioned database tool to reduce energy efficiency barriers related to SMEs.

Overall, the SEAP can be considered cost-effective even though it resulted in less energy savings that predicted in the ax-ante evaluation. Also, the satisfaction of the interviewed participants is at a high level. According to the evaluation results, the SEAP appears to be less cost effective than the German audit program in terms of kWh energy saved per public costs. However, this kind of conclusion should be carefully made since the total energy savings from the German program were not reported by the participating companies but estimated from the results of the surveys. The number of EEMs as well as energy savings for an individual company are higher for the SEAP. This parameter should also be compared carefully since the categorization of EEMs can be different in the programs.

This paper adds a significant scientific contribution due to the method used for evaluation. Multiple company visits and availability of quantitative data from 713 companies gave a possibility to address the additionality effects and estimate net energy savings more precisely. More consistency in evaluation methods is needed if the evaluation results are to be comparable among programs and countries. A common categorization of energy-related data can be defined already at the energy audit stage. This would not only enable the comparison of the evaluation studies but also would increase

the quality of energy audits. Assuring the proper recording and reporting of the outcomes of energy audit programs is very important to make a qualitative evaluation study. In turn, the evaluation studies should also be properly designed, performed, recorded and reported in order to help policy makers improve similar forthcoming programs.

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