Cost-Effectiveness of Energy Programs involving Energy Eudits – Results from Sweden

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ABSTRACT

Energy programs including energy audits are cited as one of the most promising means to increase energy efficiency and reduce GHG emissions. From a public point of view, the cost-effectiveness of an energy efficiency program is of major importance if a program is to be considered or not. The aim of this paper is to outline results from the two largest Swedish energy efficiency programs, project Highland and the PFE (Program for improving energy efficiency in energy-intensive industry), in terms of the program's cost-effectiveness, in order to answer the research question where public money towards energy end-use programs should be placed from a cost-effectiveness point of view. Project Highland, involved small- and medium-sized industrial and service and sales enterprises, and the PFE involved electricity-intensive industries. Results indicate that the cost-effectiveness differs substantially between the two programs, and that the most cost-effective sector to target is small- and medium sized and non-energy-intensive companies using energy audits. The next most cost effective programs are LTAs (Long-Term Agreements) towards energy-intensive companies and, followed by energy audits towards small- and medium-sized and non energy-intensive service and sales companies. Analytic generalization of the paper's results indicates that a clean-cut energy audit program towards small- and medium-sized and non-energy-intensive industries is more cost-effective than an LTA towards energy-intensive industries.

Introduction

The threat of increased global warming resulting from the use of fossil fuels stresses decision-makers in formulating and adopting policies towards different sectors of the economy. In particular, reducing energy use through the adoption of energy policy instruments is of importance as reduced use of energy is one of the major means of reducing GHG (Green House Gas) emissions. As a means to increase energy efficiency in Europe, the EU launched the European Energy End-use Efficiency and Energy Services Directive in 2006, which propose a 9% reduction in the use of energy within the Member States to be achieved by the ninth year of application of the directive (EC, 2006). In addition to promoting energy services, the directive is addressing a number of other activities and services such as the availability of high quality independent energy auditing for smaller commercial customers. It also highlights the availability of energy efficiency funds which should be open to all market actors and include the promotion of energy audits and financial incentives for the adoption of energy efficiency measures (EC, 2006). Each Member State is obliged to formulate a NEEAP (National Energy Efficiency Action Plan) on how these targets are to be met. Beyond the targets for 2016 are the 2020-targets with the aim of reducing emissions of GHG with 20%.

Energy policy decisions-making in Western World Economies is inspired by mainstream economic theory which in short states that an energy policy should only be adopted in the case of the existence of market failures or market imperfections. Moreover, solely the existence of a market failure or a market imperfection may not justify adoption of a policy if it is not clearly shown that the policy is cost-effective. Apart from these theoretical implications of policy adoption, there is also the perspective of financial constraints when it comes to financing public energy policies. If there are several policy alternatives on how to increase energy efficiency, it is important for the authorities to evaluate where public money can be most cost-effectively invested, i.e. where does a policy have the largest net impact in relation to investments of public money.

In order to adequately design future programs, it is thus of importance to evaluate current programs in terms of the program's cost-effectiveness. The aim of this paper is to outline results from the two largest Swedish energy efficiency programs, project Highland and the PFE (Program for improving energy efficiency in energy-intensive industry), in terms of the program's cost-effectiveness. Project Highland, involved small- and medium-sized industrial and service and sales enterprises, and the PFE involved electricity-intensive industries. The aim was portioned into a research question:

Where should public money towards energy end-use programs be placed from a cost-effectiveness point of view?

The paper is unique as it draws attention to the timely topic of where public money invested towards increased energy efficiency optimally should be directed.

Method

An evaluation of energy programs consists of two phases: an information gathering phase and an analysis phase (Väisänen, 2003). For an energy audit program, typical questions that may be of interest are, for example: the impact of the program in terms of actual energy saved, the amount of public money invested per kWh saved, etc. (Väisänen, 2003). Evaluation of public energy policies, and not least industrial energy efficiency programs, is complex. Larsen and Jensen (1999) stated that results from an evaluation of energy audits may face a risk of being too optimistic or even giving a false-positive result, due to free-rider effects, as they are wrongly attributed to a given audit when in reality they would have been implemented anyway. In evaluating energy programs in terms of energy actually saved, a questionnaire is a common means of collecting the figures (Väisänen, 2003).

The evaluation made in this paper has been conducted through a literature review and energy program evaluation methodology. The evaluation of the project Highland was inspired by Yin (2003) and carried out as a multiple case study. Results from the industrial part of project Highland as well as results from the PFE were previously published in Thollander et al. (2007), while the service and sales part of project Highland has not been published previously. Results outlined in this paper follow the structure presented in Thollander et al., (2007), and includes clear indication of where the material is new research results and where it is collected from the literature review. A questionnaire was sent out by mail in 2006 from the Linkoping University, to firms which had taken part of the program before September, 2005, and was collected by the local authority energy consultant. A total of 64 industrial respondents and 37 service and sales companies received the questionnaire resulting in 47 and 28 replies respectively for industry and service and sales. The questionnaire covered questions regarding the degree of adoption of the proposed energy efficiency measures resulting from the energy audits. Moreover, in order to explain the non-adoption of the proposed energy-efficiency measures, the questionnaire also included a number of barriers to and driving forces for energy efficiency which the respondents were asked to rank. The barriers were derived from Sorrell et al. (2000) and the driving forces from Rohdin and Thollander (2006) and Rohdin et al. (2007). It should be noted that previous research of barriers to and driving forces for energy efficiency investments reveal different results depending on the sector, magnitude of energy costs, type of ownership of the buildings, size of the firm, etc (Schleich and Gruber, 2007, Sorrell et al., 2000). Moreover, results depend on current energy cost structures, economic growth, policy frameworks and regulations, etc. As these factors and other factors change, so will the barriers to and driving forces for energy efficiency (Bailey, 2001). Finally, it should be noted that a comparison between the two programs is not unambiguous as PFE deals with both strategic issues and energy audits, and project Highland included only energy audits. Another aspect of the comparison is that PFE focuses solely on electricity, while project Highland included all energy carriers.

Table 1. Swedish industrial energy efficiency programs (Thollander et al., 2007).

Energy program, year	Type of program	Number of companies	Quanti-tative evaluation	Qualitative evaluation	Subsi-diaries	Calculated energy efficiency potential
EKO-Energi, 1994-2001	Voluntary agreements	Approx. 70 large energy-intensive	N.a.	Increased priority to energy and environment	Public sponsore d audit	N.a.
PFE, 2005-	Long term agreements	Approx. 120 energy intensive	Electricity saving	N.a.	Tax discount	N.a.
SEA-seminars, 2006	Seminars, information	N.a.	N.a.	Increased awareness, low implementation	N.a.	N.a.
Project Highland, 2003-2008	Energy audits	Approx. 340 small and medium-sized	Energy (including electricity) saving	Barriers and driving forces, interviews	Public sponsore d audit	Electricity savings , total energy savings
Sparkraft, 2000-2003	Energy audits	Mainly service sector	N.a.	N.a.	Public sponsore d audit	N.a.
Oskarshamn, 2000-2001	Energy audits	9 largest companies in Oskars-hamn	N.a.	Barriers and driving forces	Public sponsore d audit	Electricity saving 48%, total energy saving 40%
Elost,	Energy audits	7	N.a.	N.a.	Public sponsore d audit	Electricity saving 58%
Energieffektiva VästraGötaland, -2005	Energy audits	9	N.a.	N.a.	Public sponsore d audit	Total energy saving 16%
Sustainable municipalities, 2004-2006	Energy audits	Approx. 40	N.a.	N.a.	Public sponsore d audit	Electricity saving 20-60%, total energy saving 30-38%

The evaluated programs

Thollander et al. (2007) makes a review of existing energy programs since 1990 in Sweden, see table 1. The review indicates that Project Highland and the PFE are the by far largest programs, in terms of participating companies, up until 2007, in Sweden for industrial and commercial customers.

PFE (the program for improving energy efficiency in energy-intensive industries)

The PFE (program for improving energy efficiency in energy-intensive industries) was initiated in 2005 and is an LTA (Long-Term Agreement) between the Swedish authorities and the electricity-intensive Swedish industry (Ottosson and Petersson, 2007). In the program, electricity-intensive firms are offered a discount of 0.55 €/MWh on the tax on electricity for Swedish industry if the company fulfils the requirements (Ottosson and Petersson, 2007). The requirements are the following: within the first two years, the participating companies must undertake an energy audit with a systems approach. The audit should result in a number of energy efficiency measures that could be implemented over the remainder of the period (the last three years), and the implemented measures should result in savings at least equivalent to the tax discount (Ottosson and Petersson, 2007). The program also includes mandatory elements such as the implementation of an energy management system, the introduction of standardized routines for purchasing of energy-efficient technologies and planning, energy systems, and plants (Ottosson and Petersson, 2007).

Of the approximately 1,200 firms that are eligible for participation, only about 120 have joined the program (Ottosson and Peterson, 2007).

Project Highland

Project Highland was the largest Swedish energy program since the 1990 targeting the adoption of energy efficiency measures in Sweden, funded partly by the EU's Program Objective 2 South of Sweden. The program offered energy audits in six municipalities. A total of about 340 energy audits where conducted, of which approximately 140 audits, were directed towards the industrial sector and the rest towards the services and sales sector. The initiation of an audit was done by the local authority energy consultant in each municipality who offered public-sponsored energy audits to the enterprises within the municipality. The audits were then conducted by ESS (Energy Agency of South East Sweden), resulting in an individual energy audit reports where specific energy efficiency measures for each company were presented. (Thollander et al., 2007).

Thollander et al. (2007) shows the initiation of an audit in project Highland, see figure 1.

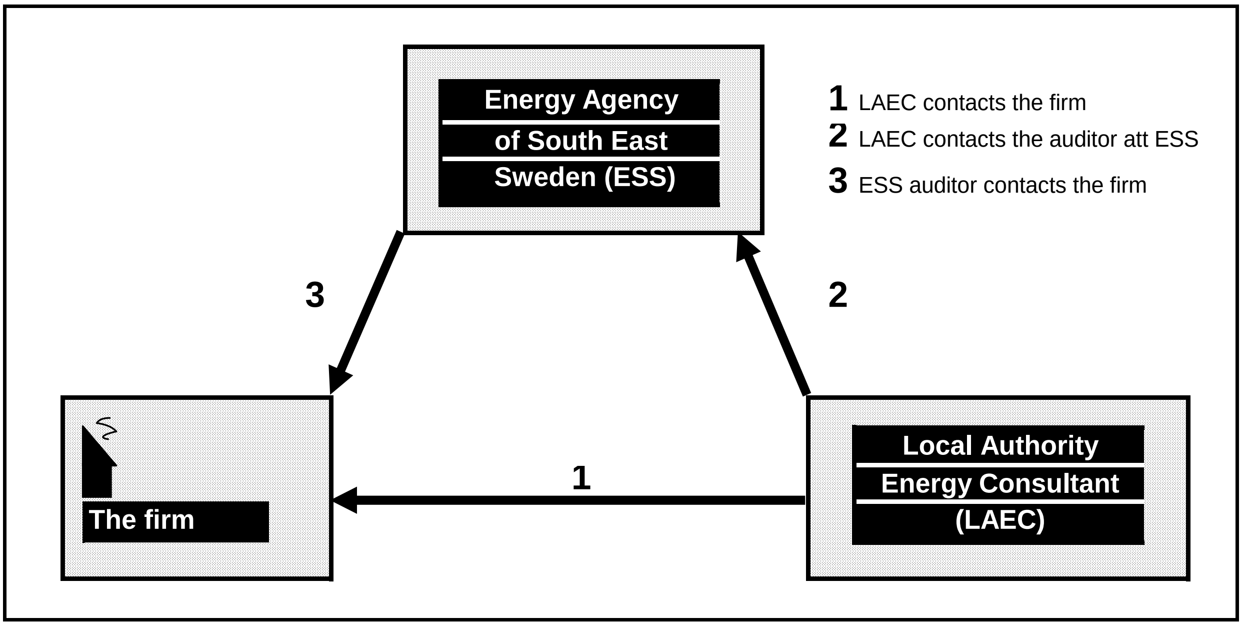

Figure 1. The beginning of an energy audit in project Highland (Thollander et al., 2007).

However, partly due to limited amount of time assigned to each audit, and partly due to the fact that the SEA (the Swedish Energy Agency) did not allow complete audits, due to a risk of competitive disadvantages for enterprises not included in the program, less than half of the recommended measures were quantified, i.e. only half of the proposed measures were quantified in terms of energy saved per year (Thollander et al., 2007).

Results

Figure 2 and figure 3 displays results from the evaluation of project Highland.

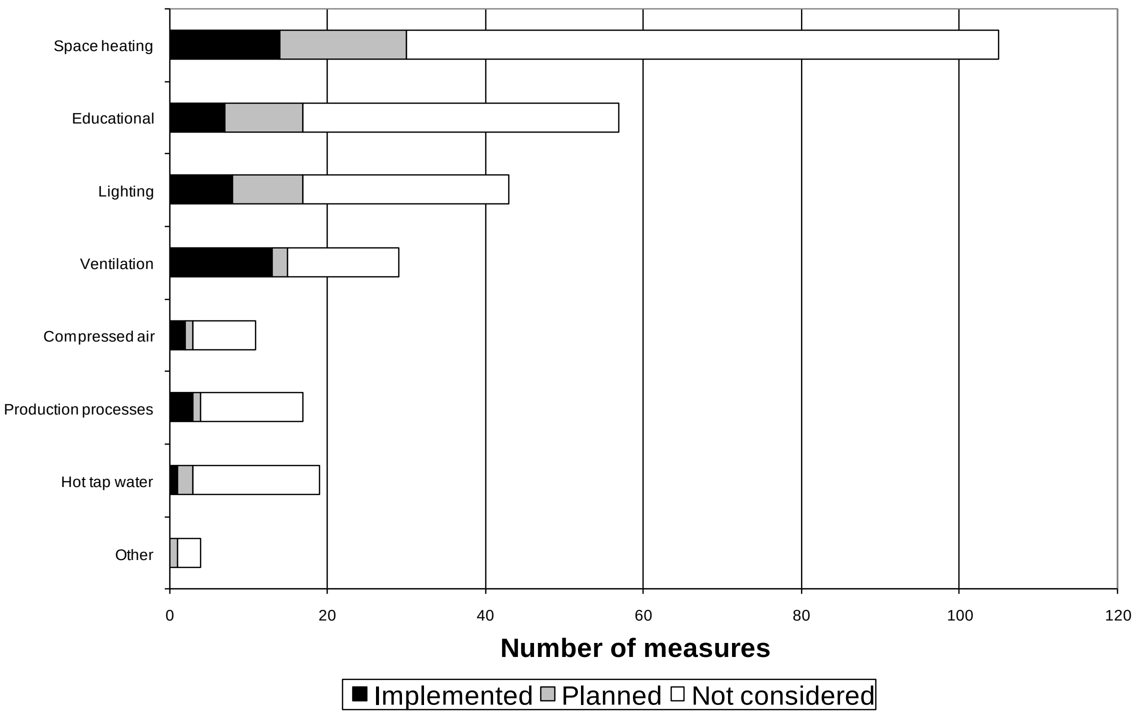

Figure 2. Number of implemented, planned and not considered measures for the different generic processes for the 28 evaluated service and sales enterprises within project Highland.

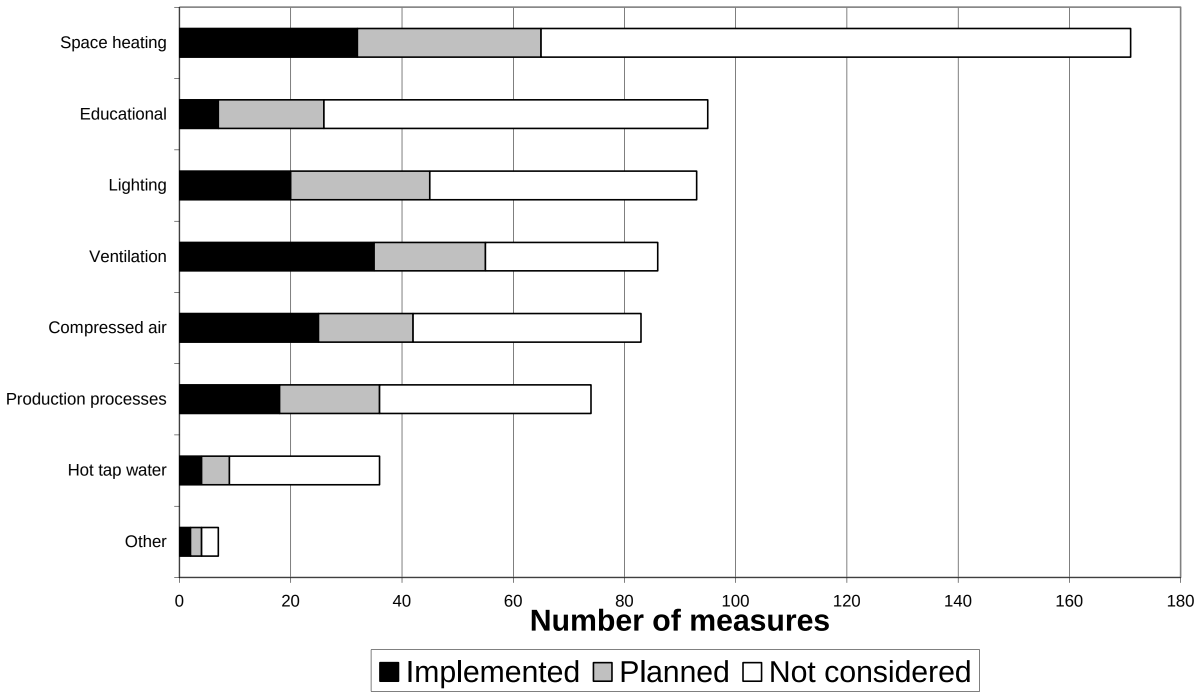

Figure 3. Number of implemented, planned and not considered measures for the different generic processes for the 47 evaluated industrial firms within project Highland (Thollander et al., 2007).

Results indicate that the degree of implementation for the two sectors, industry and service and sales, differs substantially. While the relative percentage of proposed measures is equivalent, the degree of adoption of measures are higher for the industrial sector.

In table 2, results in terms of potential savings are outlined (Thollander et al., 2007).

Table 2. Energy saving potential of project Highland (partly based on Thollander et al., 2007).

Results from project Highland, MWh/year	Evaluated industrial firms (Thollander et al., 2007)	Evaluated service and sales firms
Use of electricity	100 343	6 118
Electricity saving potential	21 262	1 140
Use of other energy carriers	81 348	5 911
Saving potential, other energy carriers	18 627	2 087
Total energy use	181 691	12 029
Total energy saving potential	39 889	3 227

Table 2 clearly indicates that the saving potential in absolute figures are higher among the industrial enterprises than among the service and sales enterprises. Moreover, the actual energy use targeted in the audits towards the industrial sector is higher than the audits towards the service and sales sector. This fact will affect the outcome of the cost-effectiveness of the audits as the cost for the audits did not differ substantially between audits made in service and sales firms versus audits made in industrial firms.

Table 3, presents results from the previous evaluation of the industrial part of project Highland together with the evaluation results from PFE, and new results for the service and sales sector from project Highland (Thollander et al., 2007).

Table 3. Key figures for project Highland and PFE (Results from the PFE and industrial firms from project Highland has previously been published in Thollander et al. (2007).

	Service and sales firms in project Highland	Industrial firms in project Highland[a]	PFE[a]
Number of firms	28	47	98
Electricity savings (GWh/year)	0.2/0.35[b]	4/10[b]	-/765[b]
Total energy savings, including electricity (GWh/year)	0.35/0.7[b]	7/16[b]	-/808[b]
Total electricity saving (%)	3/6[b]	4/10[b]	-/2.5[b]
Total energy savings (%)	3/6[b]	3.8/8.8[b]	-/0.8[b]
Number of measures	48/90[b]	142/281[b]	-/872[b]
Subsidy, including program administration (EUR)	42 600	81 600 (adm.+audit costs)	70 200 000 (adm.+tax discount)
Cost-effectiveness for solely electricity measures (kWh/EUR)	4/7[b]	47/125[b]	-/11[b]
Cost-effectiveness for all measures (kWh/EUR)	8/15[b]	86/195[b]	-/11[b]

When comparing the cost for the programs with the actual savings achieved it is important to note that the PFE solely deals with electricity. Results are shown in table 3. When comparing the cost-effectiveness for solely electricity measures, PFE reach figures in the magnitude of 11 kWh/EUR and the industrial part of project Highland show figures of 47 kWh/EUR (implemented) and 125 kWh/EUR (implemented and planned) (Thollander et al., 2007) while the service and sales part of project Highland show figures of 4 kWh/EUR (implemented) and 7 kWh/EUR (implemented and planned). When all energy carriers are included in the project Highland figures, the industrial part reaches 86 kWh/EUR (implemented) and 195 kWh/EUR (implemented and planned) while the service and sales sector reach figures in the magnitude of 8 kWh/EUR (implemented) and 15 kWh/EUR (implemented and planned).

Barriers for non-implementation

In figure 4, results from the questionnaire concerning barriers and driving forces for project Highland are outlined (Thollander et al., 2007). It should be noted that no such study regarding barriers and driving forces have been conducted for all the companies involved in the PFE. An exception to this is Thollander and Ottosson (2008)'s study regarding barriers to and driving forces for energy efficiency in the Swedish pulp- and paper industry, a sector which constitutes about half of the companies involved in the PFE. In figure 5 the barriers and drivers for the service sector are presented. A discussion of the results regarding barriers and drivers for the two sectors is found in the discussion section.

[a] Thollander et al. (2007).
[b] Implemented/planned & implemented.

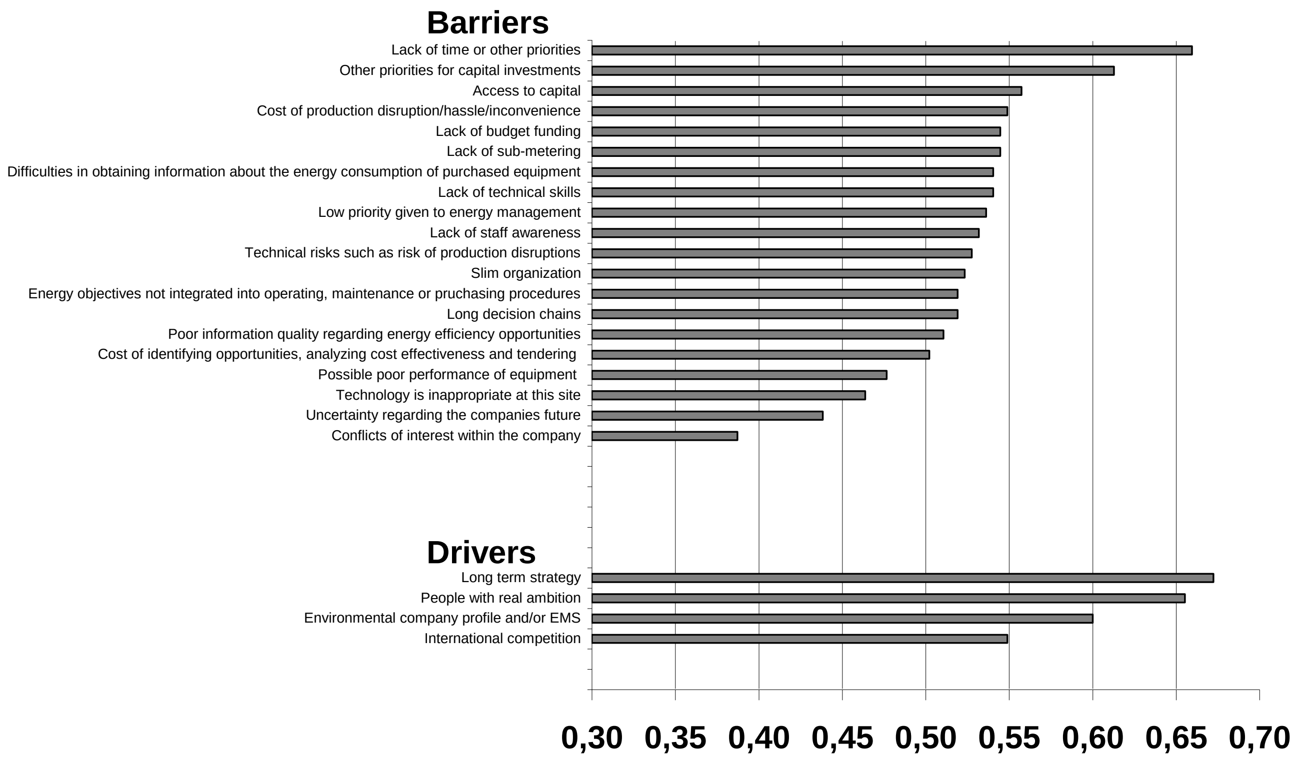

Figure 4. Ranked results of barriers to and driving forces for energy efficiency at the 47 evaluated manufacturing firms in project Highland (Thollander et al., 2007).

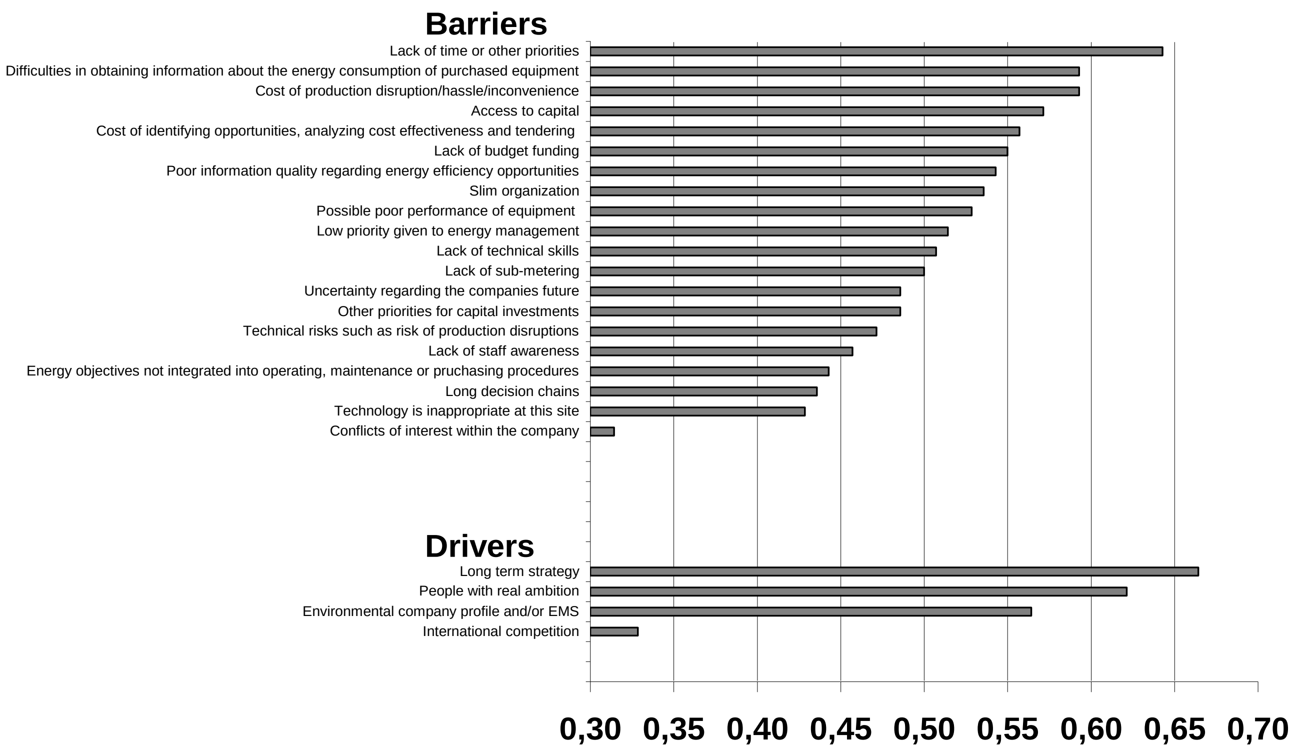

Figure 5. Ranked results of barriers to and driving forces for energy efficiency at the 28 evaluated firms within the service sector in project Highland.

Discussion

In order to validate the findings, comparable figures for Finnish (4 900 companies) and Norwegian (530 companies) industrial energy audit programs were collected (Väisänen et al., 2003). Results are shown in table 4.

Table 4. Cost-effectiveness for project Highland, PFE, Finnish Motiva, and the Norwegian Energy Audit Program (Results from the PFE and industrial firms from project Highland has previously been published in Thollander et al. (2007).

	Service and sales firms in project Highland	Industrial firms in project Highland[c]	PFE[c]	Finnish Motiva[d]	Norwegian Energy Audit Program[d]
Cost-effectiveness for all measures (kWh/EUR)	8-15[e]	86/195[e]	-/11[e]	-/555[e]	-/333[e]

The Finnish program show figures in the magnitude of 555 kWh/Euro while the Norwegian program shows figures of 333 kWh/Euro (Väisenen et al., 2003). Both the Finnish and the Norwegian programs were mature and this reduces the overhead costs of a program (Väisenen et al., 2003). For example, the Finnish program had overhead costs of 15% project Highland showed figures of about 50% (Väisenen et al., 2003, Thollander et al., 2007).

Notably, the cost-effectiveness of the clean-cut energy audit program, project Highland, towards industrial small- and medium-sized non-energy-intensive companies is significantly higher (4-17 times higher) than figures for the LTA-program, the PFE, towards electricity-intensive companies. When comparing the cost-effectiveness of the clean-cut energy audit program, project Highland, towards industrial small- and medium-sized service and sales companies, it is clear the these figures are lower than both results from the industrial part of project Highland (91-96 % lower) as well as the PFE (60 % lower).

The companies within both the service sector and the industrial sector, within project Highland, ranked *Lack of time or other priorities* as the largest barrier when considering implementation of energy efficiency measures. This barrier reflects that the energy issue is not core business and it may also indicate that the energy issue has a low priority within the organizations. For the industrial companies within project highland this is also supported by the second largest barrier which was *Other priorities for capital investments*. In the service and sales sector, this barrier was followed by the information related barrier, *difficulties in obtaining information about energy consumption of purchased equipment*. When considering this, it is important to note that the companies have received energy audits within the program. For the industrial companies this barrier was not ranked as high, as it was found in 7th place. This is in line with the more general trend that the industrial companies in general rank information related barriers such as *difficulties in obtaining information about the energy consumption of purchased equipment*, *poor information quality regarding energy efficiency opportunities*, *cost of identifying opportunities*, *analyzing cost effectiveness and tendering* lower than the companies within the service and sales sector. This may be explained by the fact that the understanding of energy issues is greater within industrial companies that have a higher degree of engineers and technicians within the organization than within the service and sales sector. It may also be argued that this is a part of the explanation for the lower total implementation rate as a result of the auditing program for the companies within the service and

[c] Thollander et al. (2007).
[d] Väisenen et al., 2003.
[e] Implemented/planned & implemented.

sales sector. *Lack of sub metering* was in both service and sales and industry ranked as a relatively large barrier, and this is connected to the problem of not being able to properly measure the effect of an energy efficiency measure. This is a large problem, especially in organizations with strict investment criteria where it needs to be possible to evaluate the effect of an energy efficiency investment.

From an energy auditing perspective it is interesting to note the low rating for the barrier *technology is inappropriate at this site* which indicates that the auditing program has been effective in terms of reducing the perceived heterogeneity. Heterogeneity is often cited to be a major barrier for general information campaigns when site-specific information is not given.

Another interesting find is that the service sector rank *uncertainty about the company future* far higher than the small- and medium-sized enterprises within the industrial part of the study. A positive mind set for the company's future is of course a prerequisite for investing in energy efficiency improvements.

Even though the differences between the service and sales sector and the industrial sector are large in terms of what barriers the company representatives perceive as significant, the drivers for energy efficiency is similar. Both sectors ranked long-term energy strategy followed by people with real ambition highest. This followed by environmental company profile and/or EMS and international competition. The fact that many of the companies within the service sector are acting on a strictly local market is seen in the low rating for international competition.

Conclusion

The aim of this paper was to outline results from the two largest Swedish energy programs, project Highland involving small- and medium-sized industrial and service and sales enterprises and the PFE (Program for improving energy efficiency in energy-intensive industry), involving electricity-intensive industries, in terms of the programs' cost-effectiveness, in order to answer the research question where public money towards energy end-use programs optimally should be placed from a cost-effectiveness point of view. Results from this paper shows that public money, from a cost-effectiveness point of view, was more effective when directed towards industrial small- and medium-sized and non-energy-intensive enterprises using energy audits (project Highland), followed by directing an LTA (the PFE) towards energy-intensive industry. The least optimal means of placing public money in energy end-use programs was to approach small- and medium-sized and non-energy-intensive service and sales enterprises (project Highland). Based on these findings, together with results from the barrier part of the evaluation, it may be questioned weather a clean-cut energy audit program is an optimal policy means for the type of service and sales enterprises that was included in the evaluation.

Analytic generalization of the paper's results indicates that clean-cut energy audit programs towards small- and medium sized and non-energy-intensive industry is more cost-effective than LTA-programs towards energy-intensive industry followed by clean-cut energy audit programs directed towards small- and medium sized and non-energy-intensive service and sales enterprises.

It should be noted that this analytical generalization is based on multiple case studies in one country, and a limited number of evaluated companies. It is therefore strongly suggested that further research is conducted in this area, using both multiple case study methodology and other approaches, both in Sweden and internationally.

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