Voluntary Energy Efficiency Programs: An Interim Evaluation of PFE in Sweden

Stenqvist, Christian; Nilsson, Lars J; Henriksson, Eva; Söderholm, Patrik; Wårell, Linda

2009

Voluntary Energy Efficiency Programs: An Interim Evaluation of PFE in Sweden*

Christian Stenqvist, Environmental and Energy System Studies, Lund University, +46-46-2229542, christian.stenqvist@miljo.lth.se
Lars J. Nilsson, Environmental and Energy System Studies, Lund University, +46-46-2224683, lars_j.nilsson@miljo.lth.se
Eva Henriksson, Economics Unit, Luleå University of Technology, +46-920-491430, eva.henriksson@ltu.se
Patrik Söderholm, Economics Unit, Luleå University of Technology, +46-920-492078, patrik.soderholm@ltu.se
Linda Wårell, Economics Unit, Luleå University of Technology, +46-920-492078, linda.warell@ltu.se

1. Background and Purpose

In Europe and elsewhere there exist a wide array of different policy instruments aiming to remove barriers against cost-effective investment in energy efficiency, not the least in the industrial sectors. Many of these policy initiatives take the form of various types of voluntary agreements, in which often industrial firms may get tax cuts if they pursue given measures to improve their energy efficiency. Still, our understanding of these programs is so far limited (see, however, Anderson and Newell, 2002), and there exists a need to develop tools with which their impacts and cost-effectiveness can be evaluated. This paper presents an interim evaluation of the Swedish Programme for improving energy efficiency in energy-intensive industries, the so-called PFE program. Specifically, we analyze how Sweden went ahead implementing PFE, give some insights into the policy process of the program, and elaborate on how the impacts from PFE and similar voluntary energy efficiency programs could be evaluated. Empirically we comment on both the impacts and the cost-effectiveness of the program.

Before the minimum tax directive (2003/96/EC) took effect in 2004, Swedish industries had enjoyed untaxed electricity for over a decade. While the introduction of the tax increased costs for many companies, energy intensive industries were eligible for exemption if they entered an agreement on energy efficiency. Sweden quickly implemented the directive and simultaneously launched PFE. Since its introduction, over 100 companies have entered the five-year voluntary agreement. The PFE program provides energy-intensive companies the opportunity of a tax exemption on electricity use. In return they have to introduce and obtain certification for a standardized energy management system and carry out an energy audit analysis. The latter is done to identify electricity-saving measures that are to be implemented if the investment payback period is three year or shorter. As a consequence, the program builds (at least implicitly) on the idea that the attention-raising effect of the energy management system will offset the impacts of the removed tax on electricity. Similar programs exist in other countries (e.g., Denmark, United Kingdom), and the lessons drawn from the Swedish case should therefore be of general interest. The PFE program is still ongoing, but with the data at hand we can still discuss the program's potential drawbacks and strengths given its current design.

The paper proceeds as follows. In the next section we provide a more detailed presentation of energy use in the Swedish industrial sector as well as of the current design of the PFE program. Sections 3 and 4 present an interim evaluation of, respectively, the process and the impacts of the program. In section 4 in particular we discuss a number of critical issues associated with the design of the PFE program – e.g., the presence of free-riders, and asymmetric information – and how these have influenced policy outcomes as well as the cost-effectiveness of the program. Section 5 provides some concluding remarks and implications.

2. Swedish Industrial Energy Use and the Design of the PFE-program

2.1 Industrial Energy Use in Sweden

During the last 30-40 years the Swedish energy system has made a notable shift away from oil as the dominating primary energy source. Nuclear power has been scaled up considerably and together with hydropower it accounted for 90 percent of total produced electricity (145 TWh) in 2007. The industry sector has also contributed to this development by shifting its energy end-use away from oil products towards more electricity, as is demonstrated in Table 1. The energy demanding pulp and paper industry has increased its use of biomass sources; in 2007, 78

* This paper has been prepared for the 10th European Conference *Energy, Policies and Technologies for Sustainable Economies*, Vienna, September 7-10, 2009. Financial support from the Swedish Energy Agency (AES research program) is gratefully acknowledged.

percent of fuel consumption was covered by internal biomass resources, primarily black liquor and bark (Wiberg, 2007). Moreover, an important policy impact of the green certificate system introduced in 2003 is an internal electricity production of 5.6 TWh (2007), which represents an increase by 40 percent since 2000. This is enough to cover 25 percent of total electricity consumption of the entire pulp and paper sector. The industrial use of natural gas and district heating have increased steadily since the 1980s when these energy carriers were introduced in the sector. Consumption of coal and coke has remained more or less constant owing to its function in reducing iron oxides in the blast-furnace process for iron manufacturing.

Table 1: Industrial Energy Consumption in Sweden, 1970-2006

Industrial energy use (TWh)	**1970**	**1980**	**1990**	**2000**	**2006**
Electricity	33.1	39.8	53	56.9	56.2
Oil products	74.2	54.8	20.8	21.6	20.2
Coal and coke	14.2	14.8	16.9	15.6	16.6
Natural gas	-	-	3.2	3.4	5.7
District heating	-	3.1	3.6	4.0	5.5
Biomass and peat	32.7	35.2	42.8	51.7	52.8
Total energy end-use	154.2	164.8	140.2	153.2	157.0

Source: SEA (2007a).

Swedish industry has a good record in terms of energy efficiency improvements. Industrial final energy consumption has remained more or less stable since 1970 whereas the total production value has increased by about 150 percent (SEA, 2007a). Considering the primary energy demand for electricity production the decoupling effect becomes weaker; a generation efficiency of 40 percent implies that primary energy use has increased by almost 40 TWh, or 20 percent, over the period due to the shift towards more electricity use. Studying electricity use independently, the trend towards decreased intensity does not start until the second half of the 1990s. The industry sector categorised with NACE code SNI 10-37 comprises both primary industry and manufacturing industry. Structural changes over the last decades have led less energy-intensive manufacturing industries to become more important to the national economy. In 2005 almost 50 percent of the industrial value added was produced in the manufacturing industry, including, for instance, the electronics and automotive industries (Johansson et al., 2007). This development has certainly enhanced the effect of an overall decrease in industrial energy and electricity intensities (Odyssee, 2007, p. 36).

2.2 The Swedish Program for Improving Energy Efficiency in Energy-intensive Industries (PFE)

On 1 July 2004, due to the adoption of the EU’s Energy Tax Directive, a tax of 0.5 Euro per MWh on industrial process-related electricity was introduced.[1] The Directive gives, however, the energy-intensive companies that are subject to the tax, the opportunity of removed taxation on their electricity consumption if they take action to improve their energy efficiency. As an instrument to promote this, the program for improving energy efficiency (PFE) came into force in January 2005. The aim of the program is partly to increase the efficiency of energy use among companies that consume large amounts of electricity. Participation is voluntary and companies which applied before 31 March 2005 were entitled to a tax reduction backdated to 1 July 2004 (SEA, 2005).

The Swedish Energy Agency is the supervising authority, and decides thus whether a company may participate in PFE. Most notably, only energy-intensive companies can participate and a company is defined as energy intensive if it meets at least one of the following criteria: (a) the cost of energy in the company amounts to at least 3 percent of the value of the output: and (b) the company’s energy, carbon dioxide and sulphur taxes amount to at least 0.5 percent of the added value. The program period starts on the date at which the company is accepted for participation and lasts for five years. During the first two years the company has to introduce and obtain certification for a standardized energy management system (EMS), and carry out an energy audit and analysis in greater depth than

[1] Manufacturing companies in the metallurgy, electrolysis and chemical reduction sectors were exempted from the tax.

the one described in the EMS.[2] In addition, the audit and analysis within the PFE program must be carried out from a system perspective and must cover both the short and the long term. It must also include measures to improve electricity efficiency. The purpose of the energy audit and analysis is to enable the company to monitor its energy consumption and identify measures to improve the efficiency of its electricity consumption. The company will prepare a list of the measures to be implemented in subsequent years, and all projects with a pay-back time of less than three years should be implemented (although projects with even lower rate-of-returns can also be pursued on a voluntary basis). The list is to be submitted to the Swedish Energy Agency. During the first two years the company also has to introduce standard procedures for the procurement of high-consumption electrical equipment. As a consequence, by acknowledging the life cycle cost when new equipment is being bought, the company will give greater preference to energy-efficient products. Finally, the company has to introduce procedures for project planning.

When a company has participated in PFE for two years, it must submit its first report to the Swedish Energy Agency to demonstrate how the program requirements have been met. During the following three years the company should implement the identified measures and continue to apply the energy management system, as well as the procedures for procurement and project planning. They also have to assess and demonstrate the effect of these procedures. At the end of the programme period the company must submit its final report. In this report the company should analyze its actual electricity consumption during the period and the actual impacts of the measures. If the company has achieved an improvement in electricity efficiency which broadly speaking is equivalent to the improvements that would have been achieved if the tax had been imposed, then the company will have fulfilled its obligations under the program.

PFE can be described as a voluntary agreement implemented in conjunction with a tax policy in that it allows exemption from the minimum tax. The agreement can only be signed and entered by individual companies.[3] The scheme is supported by an act (SFS 2004:1196) that defines the binding commitments of all parties. It is not possible to negotiate the terms of the agreement since these have been set already in the stage of planning for PFE. During this planning process, however, policy makers have worked in close contact with industry representatives to reach mutual understanding (Ds 2001:65, p. 55). The threat in case of non-compliance is that the tax must be paid.

Between 1150 and 1300 companies with a total electricity consumption of about 42 TWh are eligible for PFE (SEA, 2005). In the beginning of 2007, when 117 companies (consuming roughly 30 TWh per year) participated in the program. 98 of these had submitted their first report to the Swedish Energy Agency. According to the reports they are planning to carry out almost 900 different measures at an estimated investment cost of SEK 1.3 billion (Ottosson and Pettersson, 2007). The Swedish Energy Agency expects PFE to reduce companies' electricity consumption by 1 TWh annually compared to the reference year (i.e., 2003).[4] Assuming an average electricity price of 0.40 SEK per kWh this corresponds to annual cost reductions of SEK 400 million. In addition, the companies are granted a yearly tax relief of about SEK 150 million (SEA, 2007b). A large part of the tax exemption is expected to be offered to a small number of companies with high electricity use. For instance, a group of six companies, each using more than 1 TWh per year, will be able to benefit SEK 55 million, while a group of 1059 eligible companies, each using less than 10 GWh per year, would benefit only a total of SEK 10 million if they participated (SEA, 2005).

[2] Participating companies use the Swedish Energy Management System standard SS 62 77 50. This document will eventually be replaced by the recently launched European standard EN 16001.

[3] There exist other examples of sector-based voluntary agreements, where the signatory is an industry sector association, e.g., the Long Term Agreements on Energy Efficiency of the Netherlands (Nuijen and Booij, 2002).

[4] The reported measures indicate gross electricity savings in the range of 700 to 800 GWh; additional savings are expected to arise from the adoption of EMS and altered routines.

3. Process Evaluation

The analysis of the PFE process builds on the process-oriented Theory-Based Evaluation (TBE) approach. Theory should be understood as "the set of beliefs and assumptions that undergird program activities," (Weiss, 1997, p. 503). Thus, the program theory constitutes the basis for how program activities are expected to bring about desired changes. Advocates of TBE claim that it is superior to a traditional impact evaluation in that it can answer to not only if, but also why, targeted impacts are achieved. In case there is no evident impact the evaluator, by using TBE, should be able to answer to where in the chain of program activities that the policy failed to function as expected. This in turn can support program administrators in determining what specific modifications that are needed for an effective operation. For the evaluator TBE calls for a system analytic procedure of: assessing the program by separating its components, examine these, and communicate the interpretations. In the following we analyze two program components that both are of essential importance for understanding – and evaluating – the results of PFE: (a) participation admission; and (b) the objective of the program.

First, in Figure 1 we show the number of companies eligible for participation in PFE grouped by total electricity consumption as well as the number of participating companies categorized in the same manner.[5] The data presented builds on those 90 companies that had submitted their second-year report as of March 2007. Figure 1 shows that less than ten percent of the target group is participating in PFE: large electricity consumers, however, will receive large tax cuts and are therefore overall keener to join the program. Naturally, a similar picture of self-selection emerges if we instead categorize firms by total electricity costs.

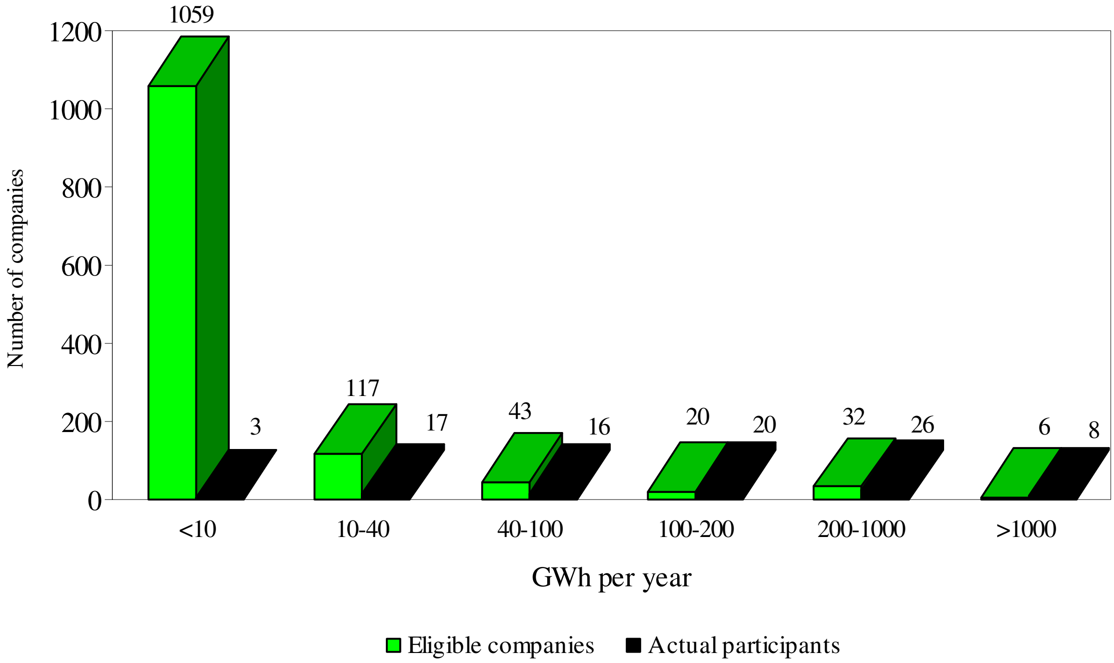

Figure 1: Eligible and Participating Companies in PFE Categorized by Electricity Consumption

Sources: SEA (2005, 2009).

Whether the fact that companies with lower electricity demand have chosen not to join PFE should be considered a failure or not depends on the perspective adopted. Staff at Swedish Energy Agency would like to see as many as possible in the program (SEA, 2008). In terms of electricity use however, the few participating companies use almost 90 percent of the eligible electricity, and PFE therefore comprises most of the saving potential. On the other hand, as we have pointed out elsewhere (Henriksson and Söderholm, 2008), it is more like-ly that the energy

[5] Among companies consuming more than 1000 GWh per year, eight out of six eligible companies are participating in PFE. This might seem contradictory, but is nevertheless the conclusion when analyzing the number of participating companies based on company registration number in combination with their stated electricity consumption.

management systems could do a good job in detecting cost-effective energy efficiency measures in the non-participating compa-nies. This is due to their lack of prior experience of energy efficiency improvements compared to the energy-intensive ones (see also section 4.2). The way participation is currently set up does reduce the costs for administrating the program. Supposing that the 1250 eligible companies would have joined PFE, the administrative burden would have increased several times. In this sense the tax incentive has been successful in attracting a significant share of eligible electricity use, and thereby potential savings, while keeping the administrative burden at a low level. For non-participating companies the tax incentive is often judged insufficient to cover the costs involved in complying with program requirements (Sjögren et al., 2007). If policy makers desire a higher rate of participation the economic incentive probably needs to be modified.

Second, essential for the program's success are the goals to be achieved. The second-year report has been an important program component in serving as an intermediate checkpoint; this *ex ante* assessment provides the basis for the expectations on successful program results. In the reports the companies had to confirm their compliance with the program requirements as formulated in the PFE Act (SFS 2004:1196 11 §), A main requirement is that the sum of the listed electricity-saving measures should be expected to (at least) lead to the amount of savings that would have been achieved if the EU minimum tax had been applied during the same period. In lack of other quantitative targets this has become, also in a national context, the criterion for what level of savings PFE is supposed to achieve. Although the Swedish Energy Agency is responsible for making this judgment, as a part of the second-year report, the companies were asked if they could comply with the requirement. All companies (with one exception) answered that they could. It should be pointed out, though, that the way in which the companies interpreted the requirement, and thus how they argued for compliance, varied widely. Indeed, there is no clear-cut answer on how to understand the issue and neither has the Agency provided any definition or guidelines.

Theoretically the above requirement implies that the own-price elasticity of electricity demand needs to be assessed; the higher this is the more difficult it becomes to fulfil the requirement and the higher expectations need to be put on the effectiveness of the energy management systems. For the industry sectors participating in PFE electricity demand has been estimated to be relatively price inelastic, and much closer to zero than -1.00 (e.g., Sjögren et al., 2007). This implies that the assumed tax increase of 0.5 Euro per MWh would have had only a moderate effect on electricity savings. Still, this assessment is complicated by the issue of whether the estimated elasticities are to be interpreted as short- or long-run price responses. From an energy efficiency policy perspective the long-run electricity demand elasticities ought to be of most interest. In a recent paper (Henriksson and Wårell, 2009), we derive an explicit long-run cost function for the Swedish mining industry (using data over the time period 1990-2005),[6] and find that in the long-run a one percent increase in the price of electricity appears to induce a 1.75 percent decrease in electricity use for this industry. This more pronounced price effect implies that the tax exemption may have had a far from insignificant effect on electricity consumption in the participating mining companies.

Many companies have, without framing it in terms of price elasticities, interpreted the requirement as a demand to report saving actions as if they were facing a unitary demand elasticity of -1.00. In their own words, if electricity cost savings due to the reported actions are equal to, or exceed, the cost savings due to the tax exemption, the above requirement is met. If all companies, and indeed the Swedish Energy Agency, were to make this interpretation there would be a problem with fulfilment. Assuming a general electricity price of 0.40 SEK per kWh, about 20 percent of the companies will profit more from the annual tax exemption than from the gross annual electricity savings (that are expected to result from reported actions). The hard-to-grasp program requirement has led companies to make individual assumptions about their achievements. In conclusion, the PFE program lacks a well-defined baseline scenario, implying also that the policy target (which should guide all future evaluations of the program) is unclear.

[6] Specifically, in this paper we first estimate a short-run variable cost function with capital included as a quasi-fixed variable. Since the lower boundary of a set of short-run cost functions confines the long-run cost function, we can compute the long-run cost function with capital as a variable factor and the price of capital as an independent variable (Henriksson and Wårell, 2009).

4. Impact Evaluation

4.1 Brief Theoretical Remarks: The Case for Market Failures in Industrial Energy Use

Before discussing the impacts and the cost-effectiveness of the PFE program it is useful to discuss the possible types of market failures that may motivate policy intervention targeting increased energy efficiency, thus action beyond those measures already taking place in the private market. In the paper we define 'free-riders' as those companies who would have implemented the energy efficiency measures even in the absence of the support from the policy program (e.g., Vreuls et al., 2008).

Jaffe and Stavins (1994) identify a number of market failures that may motivate targeted policy action in the energy efficiency field. New information often possesses substantial public good characteristics and therefore leads to important positive spillover effects. This means that a single firm cannot generally reap the entire benefits of its investment in new knowledge, and it does therefore not have enough incentives to undertake such activities. An important policy lesson from this is that even if policies to correct for environmental externalities are in place, the level of investment in new knowledge may be suboptimal (and too low). However, although the social benefits of such information activities are higher than the private ones, it must also be acknowledged that this is the case for many such activities throughout the entire economy (including many energy projects). Moreover, for different reasons the presence of *asymmetric information*, implying that one actor holds information but faces too few incentives to transfer this to other actors although this would increase overall economic efficiency, may conistute an important market failure in industrial energy use. One example is the principal-agent problem where the principal (e.g., the CEO) is unable to perfectly monitor the agents' (e.g., the engineers) performance and introduce enough incentives for the agent to pursue all profitable energy saving projects. The existence of so-called split incentives implies in turn that the benefits of energy efficiency investments cannot be appraised by a concerned actor (Sorrell et al., 2004). For instance, if a department of a company are not held accountable for its specific energy use there is a clear lack of incentive to improve energy efficiency.

While the above assumes perfectly rational (i.e., profit-maximizing) firms, we need also to pay attention to the potential bounded rationality of firms. The latter implies that individuals within firms will economize on scarce cognitive resources by utilizing routines and rules of thumb and will tend to make satisfactory decisions rather than expend time and effort searching for the optimum decision (Simon, 1957; Foss, 2003). According to the organization and management literature, this leads to path dependent behaviour. The notion of path dependencies recognizes that "history matters". Thus a firm's previous investments and its repertoire of routines constrain its future behaviour (Teece et al., 1997). In other words, firms continue to perform business as usual. This can be because of sunk costs or technical interrelatedness, i.e., whole systems are seldom replaced at once which raises the probability of continuing doing the same (Lambert and Tikkanen, 2006). Organizations develop patterns of behaviour, often referred to as routines or set of rules, to respond to problems as they arise. Once a set of rules is developed it is reinforced by, for instance, in-house training and incentive structures. Thus, bounded rationality can induce rules following behaviour which can lead to path dependence (Heffernan, 2003). According to this strand of literature a set of rules or problem solving techniques within the firm will persist since they are costly to change but also because the system itself is not questioned. This may motivate the use of policy instruments that raise attention to energy use issues.

4.2 The Gross and Net Impacts of the PFE Program

The data analysis presented in this section is based primarily on data from the companies' second-year reports, and more specifically on the list of program results that has been compiled and communicated by the Swedish Energy Agency (SEA, 2009). Currently, the Swedish Energy Agency is expecting annual electricity savings of at least 1 TWh, which corresponds to about 3 percent of the electricity consumption during the base year (i.e., 2003 for most of the companies). This impact is best interpreted as the gross impact, i.e., the energy savings without taking into consideration the fact that also other driving forces could have played a role in determining reported outcomes. Table 2 compiles the reported (planned) measures as of March 7, 2007. In total 860 measures were reported. The large variety of measures has been subdivided into types of end-use technologies. It can be noted that measures related to pumping systems are common which reflects the large participation of the pulp and paper industry that uses pumping equipment throughout their mills.

In another paper (Stenqvist and Nilsson, 2009) we discuss in detail how the annual savings reported in Table 2 can translate into longer-term impacts. It is particularly useful to distinguish between a case which assumes that the measures implemented have a limited lifetime during which they result in electricity savings, and a case which assumes that there is no deterioration in technical performance and at time for replacement, equipment with equal energy performance can be reinstalled (i.e., the annual savings remain unchanged over time).[7] Factors influencing the end of performance include: intended design lifetime, economic reasons, or social/behavioural manners (CEN, 2007). The lifetime issue has special importance in relation to the Energy Service Directive (ESD) that allow for already existing policies, and early actions implemented after 1995 (or even 1991), to contribute to the saving target of 9 percent conditional a lasting effect exists by 2016 (Annex I 2006/32/EC). Hence, the lifetime of any realized savings will be a critical factor in determining Member States´ target achievement.

Table 2: Reported Energy Efficiency Measures Categorised by Type

Type of measure	Number of measures	Reported savings in GWh	Share of reported savings (%)
Production processes: Site-specific measures that commonly involve optimization of motor-related processes	243	353.9	48.8
Pumping systems: Commonly including measures like variable speed drive control and shifting equipment	214	142.4	19.6
Compressed air systems: Sealing of air leakage is a common measure. This category also includes measures on compressors and vacuum systems	78	75.8	10.4
Other electricity efficiencies: Common are measures related to the control of motor heaters and electrical boilers	47	42.5	5.9
Industrial motors: Changes to motors with higher efficiency and control of motor-driven equipment	85	30.4	4.2
Fan systems: Typically time and demand control	58	22.7	3.1
Space heating and ventilation: Often measures on heat recovery and time-controlled ventilation	50	20.9	2.9
Indirect electricity efficiency: Commonly phase compensation	18	20.6	2.8
Cooling systems	19	10.1	1.4
Lighting systems: Time and presence controlled lighting are common measures	48	6.7	0.9
Total	**860**	**725.9**	**100.0**

Source: SEA (2009).

When performing a gross-to-net impact conversion the evaluator typically seeks to answer the question: how much of the reported energy savings would not have been made in the absence of the policy program? In the second-year reports the participants state for each electricity saving measure whether it was identified through the energy audit or if it was known already prior to the start of PFE. Out of the total saving potential of 726 GWh, 47 percent were reported to having been identified through the energy audits, thus providing support for the existence of imperfect information in company-decision making. Consequently, assuming honest reporting, a minimum of 47 percent of the electricity savings from reported actions can be attributable to PFE. Out of the remaining 53 percent it can be assumed that some measures would have been implemented also in the absence of PFE. Many of these latter measures have payback times from zero up to two years, thus being profitable also in the absence of any policy

[7] Stenqvist and Nilsson (2009) also consider a case in which PFE – through the introduction of energy management systems and altered company routines – deliver additional electricity savings above those already reported. It should be noted that such additional savings are needed to achieve the expected outcome of 1 TWh decreased electricity use annually.

incentives. With this reasoning the free-rider coefficient will lie in the range 0–0.5. Neglecting other potential correction factors (e.g., multiplier effect and double-counting factor) the net electricity savings from reported measures will thus lie in the range 363-726 GWh. See Stenqvist and Nilsson (2009) for further discussions about the gross and net saving impact of PFE. In sum, while it is clear that the net impact of PFE is lower than the gross impact it should also be acknowledged that PFE has put focus on energy efficiency issues both by identifying previously unattended measures and by obligating previously known measures to be implemented. One should also note that the three-year pay back period used in PFE is typically longer than that applied by most industrial firms. Thollander and Ottosson (2009) show, for instance, that about 80 percent of surveyed pulp and paper mills normally use a pay back period of less than three years.

A lower rate-of-return requirement can be motivated if the social benefits of the realized energy efficiency projects exceed the corresponding private benefits, and the pay back period (less than three years) stipulated in PFE is (as noted above) generally longer than the private requirements adopted by most industrial companies. Although a sharp divergence between the social and private benefits of energy efficiency measures are unlikely to exist universally, given the fact that energy carries a positive price, one should note that there are many potential sources for significant spillover effects including the possibility that more energy-efficient equipment would become the standard choice in various applications (see Stenqvist and Nilsson, 2009).[8] These impacts are however difficult to quantify, and no attempt has yet been conducted.

Finally, it can be noted that the problem of split incentives may exist in the Swedish industry given that at least a third of the companies in the pulp and paper industry do not allocate energy costs to the respective production sites based on sub-metering (Thollander and Ottosson, 2009). However, there is yet no evidence of the PFE program having an explicit impact on this situation, but the implementation of energy management systems may promote the introduction of improved monitoring.

4.3 The Cost-effectiveness of the PFE Program

In this subsection we comment on the cost-effectiveness of the PFE program. This implies analyzing whether the program induces behaviour leading to an outcome in which the achieved energy efficiency improvements take place where they are the least expensive. Account needs also to be taken of the administrative costs associated with the program. Interviews with the companies participating in PFE show that the program has induced these to allocate a large share of their investment funds on energy efficiency improvements, and the companies confirm that the program has raised overall competence levels with respect to energy use and savings (Hammes, 2006). This has led companies to in part question its existing repertoire of routines and “rules of thumb”, thus indicating the presence of firm-specific information asymmetries, although it does not tell us whether addressing these is overall economically efficient.[9]

Still, the PFE program does not necessarily address any information asymmetries cost-effectively, in part due to the self-selection mechanism of the program (Glachant, 1999). The presence of firm-government information asymmetries imply that electricity taxes could do a better job in energy-intensive companies while an energy management system could be more effective in companies with a low energy-intensive production process due to the lack of prior experience of energy efficiency measures.[10] The current set-up of PFE induces the reverse situation. Moreover, although firm-internal information asymmetries may well exist in the participating energy-intensive companies – implying that energy management systems could do a good job in detecting cost-effective

[8] The scope for targeting energy efficiency *per se* in energy policy may also be motivated by previous failures to internalize the environmental externalities generated, for instance, by the industry’s polluting activities.

[9] The reason for this is simply that the re-allocation of investments towards increased energy efficiency may crowd out other productive investments.

[10] This is also confirmed by the experiences from the PFE program. Hörnsten and Selberg (2007) report that about 70 percent of the participating companies claim that the energy auditing has been useful, and companies within the food processing industry have found it the most useful. The food processing industry is a less energy-intensive subsector, and therefore lacks prior experience of energy management. The second-year report (SEA, 2009) shows that this sector reported the largest percentage electricity savings, 6.3 percent compared to the average of 2.3 percent for all PFE companies.

measures – this is likely to be even more true for the non-participating companies (again due to their comparatively low accumulated knowledge in the energy efficiency field).

One should note however that since a significant share of total industrial electricity use is represented in the participating firms the ineffectiveness arising as a result of the missed-out opportunities may not be too large. The key to cost-effectiveness lies primarily in whether the attention-raising effect of the energy management system is able to identify inexpensive (otherwise unattended measures), and thus offset (and exceed) the impacts of the reduced tax on electricity. As was noted above this depends largely on the estimated long-run own-price elasticity of demand, as well as on the presence of significant information-related market failures in the industry's use of electricity.

In discussing the cost-effectiveness of the program we need also to comment on the administrative costs of the program. For the Swedish Energy Agency PFE has imposed annual costs of about SEK 7 million on average. Program participation also demands extra time and effort, and 80 percent of the participating companies report that the energy auditing demanded between two and twelve man-months in internal staff. For those companies that used consultants to carry out the energy audit, costs have commonly been between SEK 100000 and SEK 500000 (Hörnsten and Selberg, 2007). Nutek (2008) estimates that the particpants' total administrative costs for coping with the program requirements have equalled about SEK 130 million. Stenqvist and Nilsson (2009) estimate that overall the total societal costs of compliance equal about SEK 1300 million, which corresponds to an annulized cost of SEK 192 million per year (assuming a 4 percent interest rate and an 8-year depreciation period). This implies a unit cost of SEK 0.26-0.53 per kWh electricity saved depending on the presence of free-riders.[11] In the lower end of this range, which reflects a low free-rider effect, the per unit cost of electricity savings compare favourable with establishing new generation capacity.

5. Concluding Remarks and Implications

The process evaluation presented in this paper shows that the question of goal achievement in the PFE program rests on shaky grounds merely because no real effort has been made to translate the vague program target into something uniformly understood by participating companies and other possible stakeholders. Since no clear targets have been formulated for PFE it is not possible to judge success based on target achievement. Still, acknowledging the often low reported own-price elasticity of electricity demand it is likely that the sum of the reported saving actions will exceed what would have been achieved with the minimum electricity tax. This picture could change, though, if one considers the presence of long-term price elasticities, indicating firm responses to price changes when also capital equipment can be altered. Nevertheless, with its blend of policy instruments, limited free-rider effects, and potential for spillovers, PFE should be capable of creating more creative impetus for energy efficiency improvement than the relatively small cost difference. Participating companies typically state that the program has been helpful in putting energy issues on the agenda and in organising energy management efforts. In addition, one should acknowledge the potential long-term effects of voluntary energy efficiency programs; the Swedish PFE program introduces a systematic way of organizing energy use in the company and thus raises the attention towards efforts that may generate future cost savings in the energy field.

The presence of information inefficiencies and asymmetries represent one of the major motives for policy intervention in the industrial energy efficiency field, but the substitution of energy management systems for electricity taxes does not necessarily address these asymmetries cost-effectively. In part this conclusion arises from the fact that the set-up of voluntary energy efficiency programs offering tax rebates (such as PFE) only induces energy-intensive companies to participate in the programs, and these companies generally have paid relatively much attention to energy efficiency measures in the past. In addition, for these companies the presence of firm-government asymmetries is likely to be significant. While this paper has only focused on the general issues that need to be raised in addressing the cost-effectiveness of voluntary energy efficiency agreements, future research efforts also need to establish the empirical significance of the trade-off between the negative effects of the

[11] It should be noted that this *average* cost does not indicate whether the PFE-program induces a cost-effective allocation of energy efficiency measures across firms, thus a situation in which the *marginal* costs of electricity savings are equal across all measures undertaken.

information asymmetries on the one hand and the advantages of an EMS (in identifying previously overlooked energy saving opportunities) on the other.

In sum, considering the present EU energy saving targets, the development of policies for improved energy efficiency in industry as well as monitoring and evaluation to assess program impacts is becoming increasingly important. This paper contributes to this process through an in-depth understanding of PFE, and more broadly to voluntary agreements of a similar kind. Our analysis of the Swedish PFE program supports the call for more in-depth *ex ante* and *ex post* evaluations, and highlights a number of issues that have been largely neglected in previous process and impact evaluations of PFE and similar programs. These include, no the least, the need to identify a relevant baseline scenario taking into account the presence of free-rider and spillovers; without this the policy target will remain unclear.

References

Anderson, S. T., and R. G. Newell (2002). Information Programs for Technology Adoption: The Case of Energy-Efficiency Audits, Discussion Paper 02-58, Resources for the Future, Washington, DC.

CEN (2007). Saving Lifetimes of Energy Efficiency Improvement Measures in Bottom-up Calculations: Final CWA Draft (CEN WS 27). Internet: www.monitoringstelle.at/fileadmin/dam/spritspar/downloads/Dokumente/009_CWA_27_final-_draft_NEN.pdf.

Ds 2001:65. *Principförslag till program för långsiktiga avtal*, Fritzes, Stockholm.

Foss, N. J. (2003). "Bounded Rationality in the Economics of Organisation: "Much Cited and Little Used," *Journal of Economic Psychology*, Vol. 24, pp. 245-64.

Glachant, M. (1999). "The Efficiency of Policy Instruments for Regulating Industrial Pollution: A Coasean Approach," Working Paper, CERNA, Ecole Nationale Supérieure des Mines de Paris.

Hammes, J. (2006). *Styrmedlens interaktion. En analys av hur sex ekonomiska styrmedel bidrar till klimatmålet och till försörjningstrygghet*, ER 2006:37, Swedish Energy Agency, Eskilstuna, Sweden.

Heffernan, G. M. (2003). "Path Dependence, Behavioral Rules, and the Role of Entrepreneurship in Economic Change: The Case of the Automobile Industry," *The Review of Austrian Economics*, Vol.16, No.1, pp. 45-62.

Henriksson E., and P. Söderholm (2008). "The Cost-effectiveness of Voluntary Energy Efficiency Programs," Paper presented at 31st IAEE International Conference, Istanbul, 18-20 June .

Henriksson, E., and L. Wårell (2009). "Electricity Demand and Factor Substitution in the Swedish Mining Industry – An Econometric Approach," Paper presented at Securing the Future and 8th ICARD Conference, Skellefteå, 23-26 June.

Hörnsten, P., and A. Selberg (2007). *Utvärdering av PFE, energieffektivisering i energiintensiv industri*, Rapport till Energimyndigheten, Demoskop.

Jaffe, A. B., and R. N. Stavins (1994). "The Energy-Efficiency Gap. What Does It Mean?" *Energy Policy*, Vol. 22, N0. 10, pp. 804-810.

Johansson B. et al. (2007). "Policy instruments and industrial responses – experiences from Sweden," Paper presented at the 2007 European Council for an Energy-Efficient Economy (ECEEE) summer study "Saving energy – just do it!". Panel 7, pp.1413-1421.

Lambert, J., and H. Tikkanen (2006). "Changing Sources of Competitive Advantage: Cognition and Path Dependence in the Finnish Retail Industry 1945-1995," *Industrial and Corporate Change*, Vol. 15, No. 5, pp. 811-846.

Nuijen, W. C., and M. Booij (2002). *Experiences with Long Term Agreements on Energy Efficiency and an Outlook to Policy for the Next 10 Years*, Internet: www.senternovem.nl/LTA/publications/lta/index.asp.

Nutek (2008). *Näringslivets administrativa kostnader på energiområdet*, Report from the Swedish Agency for Economic and Regional Growth R2008:10, Stockholm.

Odyssee (2007). *Evaluation of Energy Efficiency in the EU-15: Indicators and Measures*, ADEME/IEEA, Paris.

Ottosson C., and K. Petersson (2007). "First Results from the Swedish LTA Programme for Energy Efficiency in Industry," Paper presented at the 2007 European Council for an Energy-Efficient Economy (ECEEE) summer study "Saving energy - just do it!". Panel 7, pp. 1517-1525.

Simon, H. A. (1959). "Theories of Decision-making in Economics and Behavioural Science," *American Economic Review*, Vol. XLIX, pp. 253-283.

Sjögren H., M. Stenkvist, and H. Åkesson (2007). *PFE: Effekter av elskatt*, Report produced by ÅF-process on the commission by the Swedish Energy Agency.

Söderholm, P., and H. Hammar (2005). *Kostnadseffektiva styrmedel i den svenska klimatpolitiken? Metodologiska frågeställningar och empiriska tillämpningar*, Occassional Studies No. 8, National Institute of Economic Research, Stockholm.

Sorrell, S et al. (2004). *The Economics of Energy Efficiency – Barriers to Cost-effective Investment*, Edward Elgar, Cheltenham.

Stenqvist, C., and L. J. Nilsson (2009). "Process and Impact Evaluation of PFE – A Swedish Tax Rebate Program for Industrial Energy Efficiency," Paper presented at the ECEEE 2009 Summer Study.

Swedish Energy Agency (SEA) (2005). *Skattebefrielse på el – för effektiv energianvändning i industrin,* ET 2005:03, Eskilstuna, Sweden.

Swedish Energy Agency (SEA) (2007a). *Energiläget i siffror*, ET 2007:50, Eskilstuna.

Swedish Energy Agency (SEA) (2007b). *Två år med PFE. De första redovisade resultaten*, ET 2007:10, Eskilstuna, Sweden.

Swedish Energy Agency (SEA) (2008). Personal communication with the Swedish Energy Agency: Camilla Ottosson and Eva Albäck, February 26, 2008.

Swedish Energy Agency (SEA) (2009). *List of reported actions (as of March 7, 2007).* Internet (August 25, 2009): www.energimyndigheten.se/sv/Foretag/Energieffektivisering-i-foretag/PFE/Om-PFE/Resultat-fran-programmet/.

Teece, D. J., G. Pisano, and A. Shuen (1997). "Dynamic Capabilities and Strategic Management," *Strategic Management Journal*, Vol. 18, No. 7, pp. 509-533.

Thollander, P., and M. Ottosson (2009). "Exploring Energy Management in the Swedish Pulp and Paper Industry," Paper presented at the ECEEE 2009 Summer Study.

Vreuls, H., S. Thomas, J. S. Broc (2008). *General Bottom-up Data Collection, Monitoring, and Calculation Methods*, Report prepared within the framework of the EMEEES-project for the European Commission within the Intelligent Energy for Europe (EIE) programme. Available online at (20 March 2009): http://www.evaluate-energy-savings.eu/emeees/-en/publications/reports/EMEEES_Bottom_up_draft_overview081006.pdf

Weiss, C. (1997). "How Can Theory-Based Evaluation Make Greater Headway?" *Evaluation Review*, Vol. 21, pp. 501-524.

Wiberg, R. (2007). *Energiförbrukning i massa- och pappersindustrin 2007*, ÅF-IPK on behalf of the Swedish Forest Industries Federation, Stockholm.