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Impact after three years of the Swedish energy audit program

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ABSTRACT

The Swedish energy audit program is a publicly financed program, mainly targeting small and medium-sized firms to help them finance energy audits. By examining suggested and implemented energy efficiency measures from the energy audits conducted in 241 firms in the program, the aim of this paper is to examine the energy efficiency implementation gap and the cost efficiency of the program.

The audits show that the firms' average annual energy efficiency improvement potential is between 860 and 1270 MWh/year which corresponds to a total energy efficiency improvement potential of between 6980 and 11,130 MWh/firm. The implementation rate of the suggested energy efficiency improvement measures in the SEAP is 53%. The program has resulted in investments in energy efficiency improvements between €74,100and €113,000/firm.

1. Introduction

In 2006 the ESD (Energy Service Directive) [7,8] was launched by the EC (European Commission) and along with that an energy savings target of 9% in the European Union. Since then the even stricter 20-20-20 energy savings target was introduced in 2008 and policies to improve energy efficiency in order to save energy in all sectors of society have been analysed and implemented. Whether improved energy efficiency leads to energy savings, that is, reduced total energy demand, has been discussed (e.g. Ref. [15]) but improving energy efficiency is often argued as a no-regret measure.

One sector that has been pointed out to have large untapped potential for improved energy efficiency is SMEs (small and medium-sized enterprises) in the European Union. The challenge is that SMEs in Europe use large quantities of energy but the individual firms are often not energy intensive and since energy costs are relatively small for each firm they do not prioritize energy efficiency investments. The untapped potential has been explained further in numerous articles discussing barriers to energy efficiency in SMEs (e.g. Refs. [20,27,25]). The ESD and later the EED (Energy Efficiency Directive) [9] have advocated energy audits as a way to overcome barriers to energy efficiency and facilitate implementation of energy efficiency measures in the SME (small and medium sized firms) sector.

As a consequence of the European energy savings targets the SEAP (Swedish energy audit program) was introduced in 2010. The SEAP is a subsidy program that finances 50% of an energy audit up to €3000. All firms that use more than 500 MWh/year or farms with more than 100 livestock units may apply for the support. The SEA (Swedish Energy Agency) which is responsible for the program states that the energy audit report is supposed to function as a decision support to optimize firms' energy use. The audit report shall include energy use, how energy is distributed inside the firm and suggestions for energy efficiency measures.

By examining the reported energy audit data from the SEAP the aim of this paper is to examine energy efficiency improvement potentials presented in the audits, and the cost efficiency of the Swedish energy audit program.

2. Background

The prevailing consensus is that there is untapped potential for improved energy efficiency. The untapped potential for energy efficiency and by extension energy savings is commonly referred to as “the energy efficiency gap” [16,17] or the “energy paradox” [29]. However, the magnitude of this EE (energy efficiency) potential is debated. The barrier theory is the widespread explanation to the discrepancy to why the potential for improving energy efficiency remains so large. The barrier theory is a theory that combines technical knowledge, economic theory, psychology and organizational theory to explain why energy efficiency measures are not being implemented [23]. In 1997 Weber pointed out that barrier

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models assume that there is an ideal level of energy efficiency. Weber then categorized barriers to energy savings in four categories (institutional barriers, market barriers, organizational barriers and behavioural barriers) by asking the questions "what is the obstacle", "to whom is it an obstacle" and "what is it impeding" [23]. define a barrier as "a mechanism that inhibits a decision or behaviour that appears to be both energy efficient and economically efficient" [23]. define barriers in six broad categories: risk, imperfect information, hidden costs, access to capital, split incentives and bounded rationality. Policies focus on overcoming these barriers.

Numerous studies of barriers to energy efficiency in SME sectors have been done. Schleich et al. (2008) [20] investigated barriers in commerce and the commercial sector and found that conflict between investor user and lack of information about energy consumption patterns were the main inhibitors. In an investigation of barriers to industrial SMEs in Sweden by Ref. [25] other priorities and access to capital were ranked highest. In 2012 Trianni and Cagno cautioned against bundling up conclusions about barriers to energy efficiency in different sizes and sectors, since there are vast differences in behaviour between different sectors. Despite that they concluded that across sectors two problems were recurring, access to capital and lack of information.

The perception of the potential for improving energy efficiency and the academic discourse on market barriers depend greatly on methodology and theoretical background [17]. describe three different types of potential. *The hypothetical energy efficiency potential* is the energy efficiency level that would be reached if all of the most energy-efficient technologies were implemented, regardless of risk, costs or maturity level and the energy system optimized. *The technological energy efficiency potential* is the potential where the benefit of a measure exceeds its investment cost. These potential studies are often done with bottom up calculations. *The economic energy efficiency potential* is the most limited potential because it also accounts for hidden costs, risks and opportunity costs. Economic potentials are often based on top-down calculations [17]. The difference in estimation hence lies in the view of costs and benefits. The costs, for the individual firm, of implementing an energy efficiency measures are the investment costs for the technology, capital costs and all the overhead costs or hidden costs that the implementation requires such as evaluation, making the decision, etc. The main benefit of an investment in energy efficiency for a profit-maximizing firm is reduced use of energy and reduced energy costs. To individual SMEs energy costs do not always have a large impact on financial result and therefore investing in energy efficiency measures is not always a priority. However it can be argued that energy use has social costs since not all negative externalities are included in the market price. When the benefits exceed the costs, implementation is efficient.

2.1. Energy audit programs

An energy audit is a type of indirect energy service [21]. The service in itself does not improve energy efficiency but is considered an important step towards investing and implementing energy efficiency measures. Energy audits have been put forth both in political directives [7–9] and scientific literature [19,3] as a means to overcome barriers to energy efficiency and increase the deployment of energy efficient technologies. For an international overview see Ref. [18] who provides information about energy audit programs in fifteen counties and stress the importance to consider country specific conditions when designing a national energy audit program [4]. state that energy audits and monitoring energy use is the first step towards increasing energy efficiency within a firm [28]. mentions energy audits as a way to increase diffusion of energy services, a market that has been highlighted as a tool to facilitate implementation of energy efficiency measures [7,8]. [1] describe it as a key ingredient for decision making in energy management.

The barrier theory, which is often used to explain why implicit discount rates are higher for energy efficiency measures than other kinds of investment, refers to lack of information as one of the most important barriers. The SEA argues that the energy audits from the SEAP are supposed to function as decision-making support for firms to implement and invest in energy efficiency measures.

This study draws on the experiences from previous studies of energy audit programs [14]. evaluates an Australian energy audit program and found that implementation rates of energy efficiency measures were estimated as high as 80% [2]. evaluated the effects of energy audits offered by the US Department of Energy's Industrial Assessment Center. Adaptation rates of 53% of suggested measures were found, which represented 46% of total energy efficiency improvements. Anderson and Newell estimated that a firm's threshold payback time for energy efficiency investments is about one to two years. They also concluded that despite having received information about energy efficiency opportunities; implicit discount rates remained high relative to market interest rates. Tonn and Martin (2000) [35] investigated decision making in the same program and found that the program had a significantly positive effect on energy efficiency decision-making in the participating firms.

In Germany [11] described the German energy audit program as successful with implementation rates of 77% of suggested energy efficiency measures [25]. evaluated Project Highland, a regional energy audit program in Sweden, where adaptation rates were estimated to be around 40% [25]. found that the largest energy efficiency improvement potential in Project Highland was in the support processes, especially in space heating, and few of the suggested measures in the energy audits were targeting production processes. In a later analysis of the previously mentioned German energy audit program [10], came to the same conclusion that the largest implementation of energy efficiency measures was in the support processes. Furthermore [10] also concluded that high investment costs impeded adoption of energy efficiency measures and that lack of capital slows down energy efficiency measure adoption. This is a result that corresponds with previous conclusions from studies on barriers to energy efficiency (e.g. Ref. [5]) [10]. also found that company size did not affect implementation rates. This contradicts the results from a study by Ref. [31] who recognized that characteristics of firms such as firm size, tangibility of the sector, perceived financial benefits, innovation orientation and ownership structure affect environmental management practices in Dutch SMEs.

2.2. The SEAP

The SEAP is mainly targeting SMEs since its extent limits the character of the energy audit. However, large firms with more than 250 employees and a turnover of more than €50 M are welcome to apply for the support if they can ensure that the SEAP will have a decisive impact on the conduct of the energy audit, and that the firm has not taken part in the Program for Improving Energy Efficiency in Energy-Intensive Industry, a policy directed towards electricity-intensive companies, see Ref. [24]. The energy audit can be conducted by internal staff but the SEA recommends consulting external help. The energy audit shall audit the firm's total energy use to get an overview of the energy flows. Firms with several plants at different locations can choose to target one plant but the individual firm can only apply for the support once.

After the audit is performed, an interim report from the audit must be turned in to the SEA in order for firms to receive the financial support. This is an interim report that shall contain the

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