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A review of barriers to and driving forces for improved energy efficiency in Swedish industry– Recommendations for successful in-house energy management

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ABSTRACT

From an environmental point of view, reduced use of energy remains a cornerstone in global greenhouse gas mitigation. However, without full internalization of external costs, greenhouse gas mitigation as such may not be highly prioritized among business leaders. Rather, it is the magnitude of production costs and ultimately the size of market revenue that articulates success or failure for business leaders. Nevertheless, reduced energy use or improved energy efficiency can have a vast impact on profitability even for companies with low energy costs, as the reduced energy costs directly lead to increased profits. In this paper, a review of ten years of empirical research in the field of industrial energy management in Swedish industry is presented. Based on the review, the paper proposes success factors for efficient energy management, factors which could help guide individual energy managers as well as policy makers in order to close the energy efficiency and management gaps. The paper also presents an overview of important industrial energy management tools, which would facilitate in-house energy management in industry.

1. Introduction

Reduced energy use and improved energy efficiency are important actions towards a low-carbon economy. Approximately 80% of total global primary energy supply emanates from fossil fuels, and industry accounts for 33% of total final use of fossil fuels [1]. Improved energy efficiency in industry is vital not only from an environmental point of view, but also from a company point of view, since increased energy prices and costs for emitting greenhouse gases affect a company's competitiveness on the market. Even for companies with low energy costs, reduced energy use or improved energy efficiency can have a vast impact on profitability, as reduced energy costs directly lead to increased profits. However, companies often fail to implement energy efficiency measures despite a positive rate of return. This is referred to as the energy efficiency gap [2–4]. Why companies reject implementing profitable measures for improved energy efficiency has been the subject of research since the 1970s. In general, research on barriers and driving forces study investment decisions of profitable technological energy efficiency measures. However, Backlund et al. [2] proposed to also include managerial measures, when discussing potentially profitable energy efficiency measures. Adding the energy management gap (managerial measures) to the energy efficiency gap (technical measures) results in an *extended energy efficiency gap* [2]. Industrial energy management practices are the key to reducing both the energy efficiency and energy management gaps. However, research on improved industrial energy efficiency in industry primarily focuses on technological and system improvements, while energy management and organisational issues, such as new procedures and improved operation strategies, have so far only been scantily covered in the academic literature [5]. While there is a vast potential for improved energy efficiency in technology, the full energy efficiency potential, as stated by Backlund et al. [2], is found in combining technology with management.

The research on barriers and driving forces for improved industrial energy efficiency is a valuable source of information in trying to find common causes and solutions to close or reduce the energy efficiency gap. Even if it is not possible to generalise from individual case studies, analysing empirical findings from several case studies could reveal general patterns and help to identify success factors for efficient energy management in industry. The success factors would serve as a general guideline to achieve efficient management of industrial energy systems. Sweden has a unique tradition in working with industrial energy management practices. It is therefore of interest to compile and analyse findings from consecutive research on energy management practices in Swedish industry.

Previous research has concluded that there is great potential for energy efficiency improvement (see e.g. [6–8]) and that a majority of industrial firms do not practice successful energy management (see e.g. [8–10]). Therefore, this paper reviews more than ten years of empirical research in the field of barriers to and driving forces for improved energy efficiency in

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Swedish industry. Unlike previous research conducted on barriers, drivers and energy management, this paper takes a longitudinal approach, meaning that it covers all studies in the area, conducted in one specific region (Sweden), over a period of several years. Based on the reviewed studies, the paper will propose success factors for efficient energy management that could guide individual energy managers as well as policy makers in their work to close or heavily reduce the energy efficiency and management gaps. The paper will also present an overview of important in-house energy management tools. Energy managers in industry can use these tools to facilitate their work with improving the company's energy performance.

2. Methodology

The review in this paper includes empirical studies of barriers to and driving forces for improved energy efficiency in Swedish industry conducted between 2004 and 2016. To our knowledge, these are the only scientifically published empirical studies on such barriers and driving forces in Swedish industry. The first scientific study on barriers to improved energy efficiency studied eight Swedish non-energy intensive industrial companies [11]. Since then, consecutive research has been carried out including a large number of industrial companies:

- Eight Swedish non-energy intensive manufacturing companies [11]
- 27 Swedish foundries [12]
- 40 Swedish pulp and paper mills [13]
- 47 Swedish industrial SMEs [14]
- 21 Swedish industrial companies [15]
- 65 European foundries (including 20 Swedish foundries) [16,17]
- 23 Swedish iron and steel mills [8]
- 11 Swedish iron and steel mills [18]
- 105 Swedish industrial companies that participated in the Swedish Energy Audit Programme [19]

The scientific studies on barriers to and driving forces for industrial energy efficiency, conducted in Sweden, have resulted in a total of about 300 interview and questionnaire responses. In general, these research studies were conducted using a case study approach, with semi-structured interviews and/or questionnaires. The questions in the questionnaires addressed to what extent the respondents agreed that the factors presented impeded (or promoted) energy efficiency improvements at their company. They were asked to rank the factors from 'do not agree at all' to 'totally agree' on a 5-point Likert scale.

The success factors for efficient in-house energy management were identified using an inductive approach initiated in the very first study [11] and based on the empirical findings in the reviewed research studies. Barriers and driving forces identified in the research studies were analysed to reveal patterns, which together with results from the in-depth interviews (conducted in the reviewed studies) motivated the formulation of the success factors. The development of the success factors has been a continuous process during the years 2004–2013. During the in-depth interviews in study [15], the energy managers reviewed and commented on the developed success factors and their affirmative response can be seen as a validation of the factors. Succeeding studies (included in our review) further confirmed the formulated success factors.

The major model for understanding improved energy efficiency and energy management in industry is that information is diffused into a company executive and, if an affirmative decision is taken, transformed into an implementation. This input-output model was used when analysing the various tools for energy management in relation to different barrier categories.

3. Barriers to and driving forces for improved energy efficiency in Swedish industry

There are four principal means of achieving reduced energy costs on the demand side: (1) energy-efficient technologies; (2) load management; (3) change of energy carrier; and (4) energy-efficient behaviour (energy conservation) [20]. Barriers to the adoption of cost-effective energy-efficiency measures in industry can be categorized into economic (which could further be divided into market failure and non-market failure), behavioural and organisational factors [21,22]. Cagno et al. [23] extended this categorisation and divided barriers into technology-related; organisational; information; economic; behavioural; market; competence; awareness; and government/politics.[1] There have been several attempts to categorize driving forces for improved energy efficiency. For example, Thollander and Ottosson [13] divided driving forces into market related, current and potential policy instruments, and organisational and behavioural factors. Thollander et al. [17] categorized driving forces into financial, informational, organisational and external. In a recent study [26], the authors classified driving forces according to the type of action the driving force represents, i.e. regulatory, economic, informative and vocational training. In order to harmonize the presentation of research undertaken on both barriers to and driving forces for energy efficiency, this paper categorizes barriers according to the taxonomy developed by [23] and driving forces according to the taxonomy proposed by [17].

In the following section, a review of the field of barriers to and driving forces for energy efficiency in Swedish industry is outlined. Table A1 in Appendix presents barriers to improved energy efficiency, identified in different industry sectors in Sweden. As can be seen in Table A1, the behavioural barrier 'Other priorities for capital investments', the organisational barrier 'Lack of time or other priorities', and the economic barriers 'Technical risk such as risk of production disruption' and 'Lack of access to capital' were considered very important in most of the studies. In addition to the empirical studies presented in Table A1, there is research which has investigated barriers to improved energy efficiency without ranking the barriers. One study showed that barriers to improved energy efficiency in the Swedish iron and steel industry were 'Lack of time', 'Lack of personnel', 'Information not clear by the technology supplier', 'Risk of production disruption', 'Other priorities for capital investments', 'Lack of people with higher education in the energy field', and 'Lack of awareness of the potential of engaging employees' [18].

In order to improve energy efficiency, it is crucial to reveal and understand factors inhibiting this process, but also factors promoting improvements. Johansson [18] asked energy managers in the Swedish iron and steel industry to mention factors that they had experienced as driving forces for improved energy efficiency at their companies. Without order of precedence, the driving forces mentioned were 'Cooperation within the corporate group', 'Networking with other energy managers', 'Well-prepared pre-studies', Cost reduction from lowered energy use', 'People with real ambition', 'Senior management prioritises energy issues', 'The energy manager has knowledge and experience of production processes', 'Awareness of employees', and 'Compliance with regulatory issues'. Table A2 in Appendix summarizes driving forces for improved energy efficiency found in Swedish industry. As can be seen in Table A2, 'People with real ambition' (behavioural), and 'Long-term energy strategy' (organisational) were considered very important driving forces in a majority of the Swedish studies.

4. Tools for industrial energy management practices

In order to facilitate the company's work with energy management, different tools are available. By implementing and using these energy management tools, some of the barriers to improving industrial energy efficiency could be overcome. However, it is important to emphasize that the tools alone do not provide success as such, but energy management is primarily a leadership issue [20]. The review of driving forces for improved energy efficiency presented in Table A2 (Appendix) revealed that several of the top-ranked driving forces for energy efficiency improvements in industry are related to in-house industrial management, e.g. 'Long-term energy strategy', 'Commitment from top manager' and 'People with real ambition'. Therefore, the tools for industrial energy management presented in this paper are primarily delimited to site-specific tools, which can be used by

[1] There are other ways of categorizing barriers, please see e.g. [24,25].