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ScienceDirect
Energy Procedia 75 (2015) 2569 – 2574
Energy Procedia

The 7th International Conference on Applied Energy – ICAE2015

Diffusion of motor systems energy efficiency measures: an empirical study within Italian manufacturing SMEs

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Abstract

Energy efficiency is a crucial issue for increased industrial sustainability and competitiveness. In the present study we have conducted an investigation about the diffusion of energy efficiency measures within motor systems, which are responsible of about 74% of all industrial consumption of electric energy in Italy. Starting from a selection of nine measures that range from substitution of equipment to management and maintenance of motor systems, we have also tried to find out the problems (barriers) that firms experience in the implementation of such specific measures, and the drivers they perceive to be more effective to overcome barriers. Results show that maintenance measures are mostly diffused, whilst the substitution of equipment with innovative technologies such as inverters or AFDs is still limited. Moreover, beside economic issues, that are even more critical for smaller enterprises, organizational issues emerge. Additionally, the presence of an energy manager points out a greater relevance of technology barriers and leads the firms to have a better knowledge about interventions and devices, that can be used to enhance the level of energy efficiency of electric motors. Finally, the diffusion of inverters and AFDs is limited to larger motors (mostly between 10 and 100 kW), thus tending to disregard the many small motors installed in the production system.

Peer-review under responsibility of Applied Energy Innovation Institute

Keywords: industrial energy efficiency; motor systems; barriers; drivers; manufacturing firms.

Introduction

The environmental problems caused by GHG emissions have led the policy-makes to have a greater awareness about energy efficiency. The industrial sector is one of the field in which it is possible to obtain the best results in terms of energy efficiency, especially because energy efficiency can be an opportunity for firms to be more competitive on international market [1]. This is particularly true for countries like Italy in which the energy price is 25% higher than European average. Additionally, countries like Italy strongly rely on foreign energy sources (the import is about 80%) [2], therefore increased energy efficiency may also offer interesting geo-political advantages [1]. In industrial sector, there is a wide

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1876-6102
Peer-review under responsibility of Applied Energy Innovation Institute
doi:10.1016/j.egypro.2015.07.302

usage of electric motors. Almost every type of machine in every sector is equipped with at least an electric motor. According to recent research conducted by ENEA in Italy, electric motors cover the 74% of all industrial consumption of electrical energy. Compressors, pumps and ventilators are the machinery most frequently present in industries [3].

For this reason, we have conducted a wide investigation in Northern Italy about the implementation of energy efficiency measures (EEMs) concerning motor systems, understanding their diffusion, the barriers hindering their adoption, as well as the drivers and stakeholders that might be more important for promoting them in industry. The investigation is the largest so far conducted, to authors' awareness, in Italy, also considering the specific set of energy efficiency measures among motor systems that have been considered.

Research methods

First, when considering energy efficiency in motor systems, we should refer to an effective "system" made by several components, which does not merely imply the substitution of a piece of the equipment, rather managing and maintaining all the technology. After an extensive review of the major scientific and industrial literature about EEMs on motor systems, we have adopted the classification offered by the US Industrial Assessment Center [4], from which we have extracted nine EEMs, that best cover the most relevant components in motor systems, as well as are interesting in terms of managing and maintaining the technologies. The list of EEMs is as follows: (i) install soft start to eliminate nuisance trips; (ii) install motor voltage controllers on lightly loaded motors; (iii) use multiple speed motors or AFD; (iv) size motors on the rated load; (v) utilize energy-efficient belts and other improved mechanisms; (vi) develop a repair/replace policy; (vii) avoid rewinding of motors; (viii) establish a preventative maintenance program; and (ix) establish a predictive maintenance program.

Second, when dealing with motor systems, it is crucial to gather information about a certain number of parameters, such as: number of motors installed, power, working hours per year, age/efficiency class, voltage and current type, where they are installed (for core production processes or ancillary systems), etc. In fact, the adoption of the aforementioned EEMs may vary according to such parameters. Third, the diffusion of such EEMs may vary according to several firm's characteristics, such as firm size, industrial sector, energy/non energy intensive enterprise, presence in the firm of an energy manager, having recently conducted an energy audit, having implemented EEMs for specific energy efficiency purposes.

In this regard, a questionnaire had to be properly designed covering the full set of information described. Therefore, our questionnaire has been structured with close questions, taking about 15 minutes to be compiled by a person knowledgeable of energy efficiency issues, and has been sent via e-mail (after some preliminary tests to plant directors). The diffusion of the aforementioned EEMs in motor systems has been asked with a 4-point fixed Likert scale ranging from 1 "not implemented" to 4 "extensively implemented". Barriers and drivers to the implementation of EEMs have been asked according to several categories offered by recent studies in literature [5-6], with a 4-point Likert scale from 1 "not important" to 4 "very important".

The questionnaire has been sent to more than 2,300 companies in Lombardy region, and we received 154 full questionnaires, thus with a response rate of about 6,7%. Although information has been anonymously treated, in case of further clarification needed, a short telephone interview has been conducted.

Interestingly, Figure 1 (a) and (b) report respectively the distribution of the sample by size and sector. Moreover, 20% of the sample is composed by energy intensive firms, 34% has conducted an energy audit in the last 3 years, and 14% has an energy manager within its staff. Additionally, more than half of the sample (about 55%) has conducted from 1 to 5 interventions for energy efficiency purposes. Regarding some features of the motor systems, most of the equipment is deemed to work for about 8 hours a day, and the largest share of enterprises has installed motors with a nominal power lower than 100 kW.

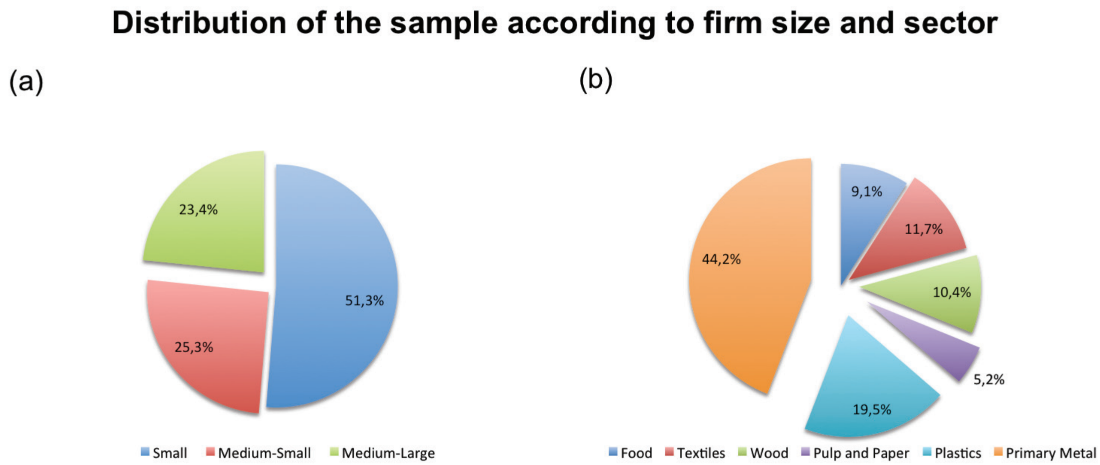

Fig. 1. Distribution of the sample according to some relevant firm characteristics: (a) firm size; (b) sector

Results

When considering motor for the main production process (Fig. 2a), we can note that the most diffused EEMs are referred to maintenance programs, both preventive and predictive, which have an average score of 3.15 and 2.73. Additionally, as shown in Fig. 2b in which we report the frequency analysis of the responses, EEMs requiring a greater technological change have been ranked at lowest positions. Indeed, in 60% of the cases the installation of soft start resulted to be barely implemented. Similarly, the diffusion of energy-efficient belts and other improved mechanisms has shown to be scarce for about 60% of the cases. For what concerns EEMs for ancillary systems (Fig. 2c and 2d), the picture looks quite similar. Nonetheless, in ancillary systems, we can note that EEMs with strong technological change result to be less diffused compared to process systems. This could be expected as ancillary systems are often considered to be somehow "invisible", i.e. not immediately under the focus of operations managers and maintenance managers. Such results are quite new in literature, that have not so far considered a possible difference in the diffusion of motor systems measures between process and ancillary systems. Therefore, starting from our sample of SMEs, we can conclude that the priority is usually given to update and enhance the efficiency of equipment directly related to production processes.

The whole sample has shown to mostly suffer from economic barriers, which have an average of 3.05 (Table 1). Only economic barriers present an average over 3, which can be considered as a threshold of really critical barriers. Organizational barriers rank second, with an average of 2.55. The findings seem to indicate that the uptake of EEMs in motors systems, beside economic issues, can be primarily jeopardized by organizational issues: this indicate that the whole production system should be involved in the process, especially considering the production disruption, and, considering that motors are behind all processes, this could be an effective problem. Such results are novel, as industrial (and scientific) literature has so far paid little attention to point out either the production disruption caused by the implementation of motor systems technologies or the needed time to substitute even "standard" equipment (as motor systems). For what concerns drivers (Table 1) and most relevant stakeholders, we found that external economic support is perceived as largely needed, followed by external information. To do so, the main stakeholders identified are Governmental bodies, technology suppliers and Industrial Associations and Groupings. Again, the findings are interesting for policy-making purposes and industrial decision-makers, and not aligned with previous literature: although energy efficiency motors are quite known and considered a "standard" energy-efficient technology, still final users perceived additional information as crucial in order to implement them, e.g. in order to reduce their (still existing) uncertainty about their energy performance.

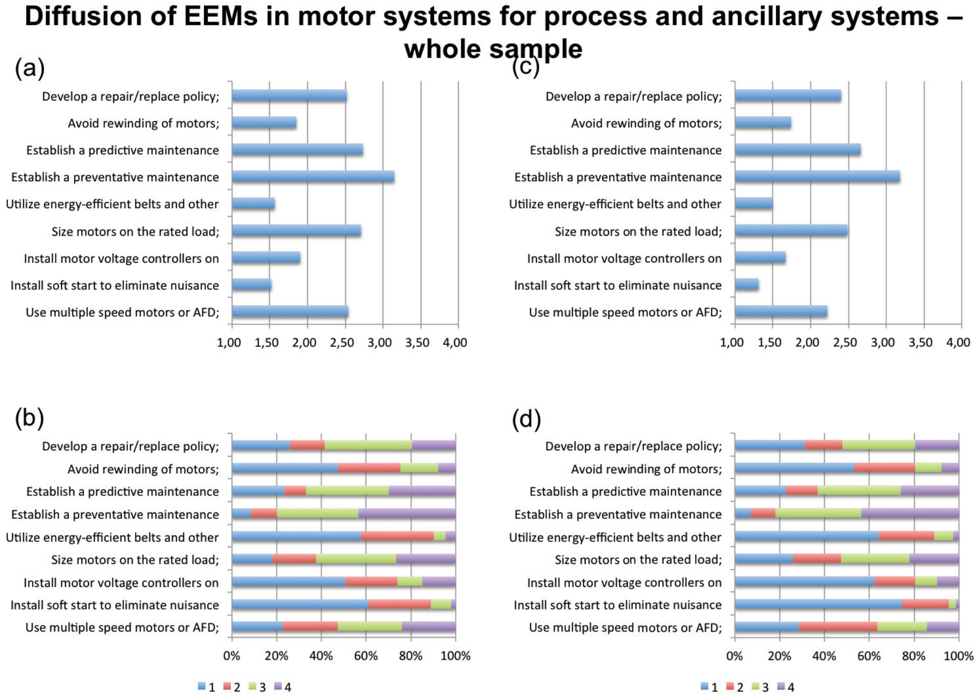

Fig. 2 Diffusion of motor system EEMs in process and ancillary systems – whole sample. (a) process systems: values on average. (b) process systems: frequency analysis. (c) ancillary systems: values on average. (d) ancillary systems: frequency analysis

Table 1. Barriers and Drivers for energy efficiency – whole sample

Barriers	Average	Drivers	Frequency
Economic	3,05	Regulatory - internal	38
Organizational	2,55	Regulatory - external	77
Information-related	2,19	Economic - internal	64
Behavioral	1,56	Economic - external	145
Competence-related	1,73	Informative - internal	57
Awareness	1,88	Informative - external	113
Technology-related	1,76	Vocational training - internal	59
		Vocational training - external	64

The analysis has then dealt with clusters of enterprises according to the main firm characteristics, as detailed in Section 2. Considering that large differences between motor EEMs for processes with respect to those for ancillary systems cannot be appreciated, in the following, we will limit to present the discussion for motor EEMs in process systems. By looking at firm size (Fig. 3a) we can note that larger differences might be appreciated for EEMs like the adoption of AFDs or variable load, as well as policies for reparation and maintenance, which result less diffused for smaller enterprises. The result looks pretty aligned if we consider that, the smaller the size, on the one side larger economic budget for energy efficiency could be expected (AFDs could be really expensive in some cases); on the other side, stronger policies for maintenance require that the enterprise is more "structured", in terms of procedures, routines, etc. This is quite in contrast with what commonly happens in smaller enterprises, where maintenance is often made by an external stakeholder, which is involved almost exclusively in case of failures. By looking at barriers, large differences cannot be appreciated, with the exception of larger economic barriers for smaller enterprises, which was somehow expected and aligned with previous literature. Nonetheless, we should note that, differently from previous Italian studies in which information-related barriers were considered as of minor importance for larger enterprises, in the present study focused on motor systems technologies all clusters have highlighted the relevance of information barriers (with average values always over 2). Regarding drivers, larger enterprises have highlighted the need to increase their internal activities of information and training. This finding seems particularly interesting for policy-making purposes: although the limited sample, we could start observing that, despite the usual greater relevance of external driving forces, larger enterprises have begun seeing the opportunity to develop internal driving forces to promote the adoption of EEMs, and particularly for motor systems. Additionally, it seems worth noting that they have not have highlighted a greater relevance of economic drivers, rather information-related ones: such finding looks pretty interesting by showing again that the promotion of EEMs can be obtained by a particular blend of driving forces, and not just through economic subsidies.

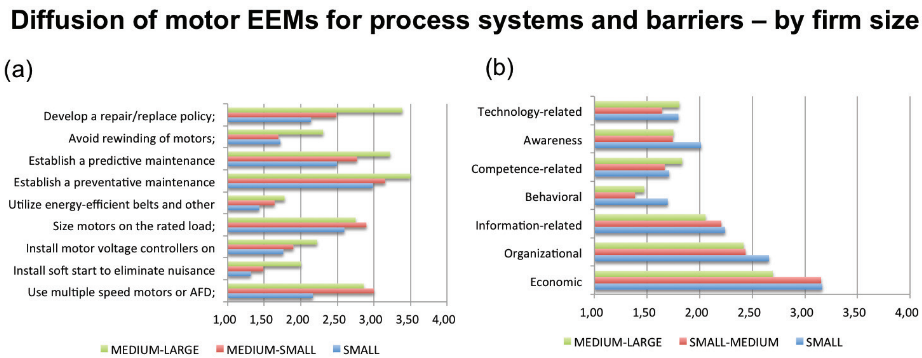

Fig. 3 Motor system EEMs in process systems by firm size. (a) Diffusion. (b) Barriers.

Despite the analysis by sector and energy intensity has not shown particularly interesting findings, some considerations from the presence of an energy manager in the company can be drawn. In fact, as shown in Fig. 4(a), having an internal energy manager in the company seems to be correlated to a greater diffusion of motor EEMs. The trend can be observed for all selected EEMs, and results to be particularly strong in case of more complex EEMs. Here the presence of personnel knowledgeable about motor systems seems to play a crucial role; additionally, as shown in Fig 4(b), larger technology-related barriers are found in case of presence of an energy manager. Here the findings seem to suggest that greater competences can allow a better understanding of the technology-related issues, which are typical for EEMs implying a strong technological change (e.g. installation of soft start, controllers). Additionally, the presence of an energy manager has a moderating effect of economic and organization barriers.

Clustering enterprises by motor size has not allowed pointing out large differences, although some exist. Nonetheless, thanks to further insight in some of the companies (through a telephone interview), it has been possible to further explore this issue: respondents have highlighted that, in case of inverters or AFDs, as well as for voltage controllers, they are more diffused for larger motors (size between 10 and 100 kW installed). This could be reasonably explained by the fact that such technologies are expensive (although with relevant returns in terms of energy saving): therefore, they diffusion can be found, at this primary stage, among the largest energy consumers within the plant, i.e. larger motors.

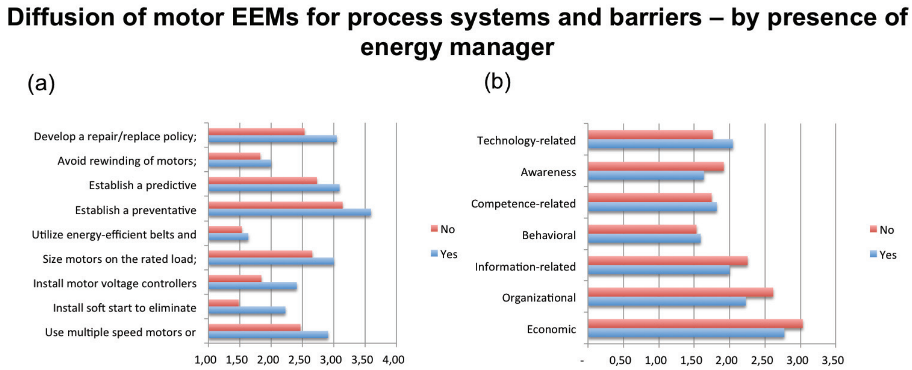

Fig. 4 Analysis of motor systems EEMs by presence of an energy manager . (a) Diffusion (b) Barriers.

Conclusions

Enterprises have shown a greater diffusion of EEMs requiring very low direct implementation costs, and with lower direct impact on motor systems. Among them, maintenance EEMs are the most diffused. Furthermore, the diffusion of motor EEMs in the investigated sample is deeply affected by several firm characteristics, as well as some motor systems characteristics. Additionally, despite the usual common tendency of blaming economic issues, the investigation seems to show that barriers to the adoption of EEMs are not fully understood yet, especially in smaller and less structured enterprises for which organizational issues emerge. Finally, the presence of personnel knowledgeable about energy efficiency issues (i.e. energy manager) is able, on the one hand, to increase the diffusion of motor EEMs; on the other side, it can better differentiate barriers, pointing out technological issues that may arise in case of specific EEMs. Future research efforts could be devoted in investigating how to diffuse motor EEMs in case of lower load motors (i.e. of few kW), which represent the vast majority of installed motors in a production system, as in the present sample we have observed that such EEMs are actually mostly diffused among motors of greater size.

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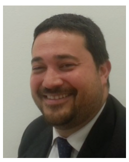

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