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BRIEF COMMUNICATION

Portuguese SME toward energy efficiency improvement

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Abstract About 50 % of world energy consumption is due to industrial use (DOE/EIA 2011), with consequences in carbon dioxide emissions and climate change. Reducing energy consumption in industry is therefore an important strategy to achieve the target of energy policies in Europe, of reducing the energy consumption of 20 % by 2020. In order to identify the situation in Portuguese small and medium enterprises (SME) concerning energy efficiency, the project EFINERG involved several stakeholders and was developed and implemented in five sectors: food, agriculture and beverage; ceramics and glass; wood, furniture, and cork; metal industry; and textile and clothes. The objective was to analyze the situation mainly in SME with energy consumption between 250 and 500 toe, in order to provide SME the necessary conditions to adopt energy efficiency improvements, best practices, and technological solutions that answer the problems diagnosed. In the companies involved in the project, the barriers to energy efficiency were listed and classified according to different levels: information, organizational, training/behavioral, economic, and financial. The main barriers and the result of the discussion with the different stakeholders in order identify measures that can contribute to overcome the problem are also included.

Keywords Industrial energy efficiency · SME · Barriers · Energy management practices

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Introduction

With the rising price of energy and resources and the threat of its exhaustion, energy management began to be considered one of the main worries of industrial management (Petrecca 1992; Rohdin and Thollander 2006). Furthermore, different stakeholders showed their interest in analyzing and improving the impact of energy consumption of products and processes (Thiede et al. 2013).

About 50 % of world energy consumption is due to industrial use (DOE/EIA 2011), with consequences in carbon dioxide emissions and climate change (Chai and Yeo 2012). This process calls for the attention of industrial enterprises on the importance of energy efficiency (Worrell et al. 2009) considered at the same level as conventional fuels in the global energy balance (IEA 2013; Fleiter et al. 2012a). Reducing energy consumption in industry is therefore an important strategy to achieve the target of energy policies in Europe, of reducing the energy consumption of 20 % by 2020 (Trianni et al. 2013a, b).

Different studies underline the potential for improving the energy and resource efficiency in manufacturing companies in intervals that range from 10 to 40 % in possible energy savings (European Commission 2008; Thiede et al. 2013). This potential appears to be higher when considering SME once they represent the large majority of companies and have improved very little in the field of energy efficiency (Trianni et al. 2013a, b).

Portuguese situation is in accordance with the results presented by the studies at European level. More than 90 % of Portuguese industrial companies are SME, and in most of them, the level of entrepreneurial culture in what concerns energy efficiency aspects is low. However, Portugal is committed to European agreements to reduce 20 % of its energy consumption by 2020 in order to achieve the target of energy policies in Europe, and therefore, measures must be implemented (Backlund et al. 2012).

Although energy efficiency measures are recognized as an important matter and the possibilities of application are wide-ranging, it is still hard to convince companies' top management about its benefits. This is due mainly to the difficulty in demonstrating the resulting savings. Other barriers, which make the implementation of the energy efficiency concept difficult, must be identified. This project intends to identify the main barriers and also possible ways to overcome them.

Barriers to energy efficiency implementation

The motivations to energy efficiency can generally be categorized as either economic or environmental. The former translated in cost savings (especially when energy prices are increasing continuously) and productivity and the latter in lower pollutant emissions and consequently health benefits. The result of adopting a green economy is the increase of human well-being as well as social equity, while environmental risks and ecological scarcities are significantly reduced (Valdivia et al. 2013).

The factors that contribute to the non-adoption of energy efficiency measures are referred to as barriers (Apeaning and Thollander 2013). Different authors have been identifying barriers to industrial energy efficiency, even if this concept of a barrier to energy efficiency is not always clear.

Different taxonomies appear in literature and different approaches, some of them based in statistic methods (Giacone and Mancò 2012). In this study, the proposal of Sorrell et al. (2000) seems to be the one that better applies to the project reality. It classifies the barriers into the following categories: organizational, management, financing, government policy, economic, behavioral, training and knowledge, and technical (Sorrell et al. 2000; UNEP 2006).

Lack of employees' knowledge or aptitude, lack of physical space, and resistance to replace existing machinery are some of the obstacles in incorporating new technologies in an existing production process and thus constituting organizational barriers (Groot et al. 2001).

Hirst and Brown (1990) had already distinguished structural barriers (distortion and uncertainty about fuel prices, inadequate information, government fiscal and regulatory policies, codes and standards) and behavioral ones (attitudes of decision makers in what concerns energy efficiency, low priority given to energy issues, risk of energy efficiency investments and misplaced incentives for the implementation of energy efficiency measures).

Lack of information either at consumption patterns and efficiency measures levels, priorities, or lack of time (Harris et al. 2000) fall into management barriers. When speaking about lack of information, two different aspects can be considered (Schleich 2009):

- Levels and patterns of energy consumption—the availability of this information depends on the information systems, the energy metering, the detail of energy bills, how consumption is analyzed, and who does it (Trianni and Cagno 2012)
- Energy saving opportunities—lack of evaluation opportunities, availability of information on technologies' costs, and performance

Lack of time and staff has also been rated as an important barrier to the implementation of energy efficiency measures (Anderson and Newell 2004; Schleich 2009; Thollander et al. 2007; Cooremans 2011, 2012).

Another aspect to be considered is the importance of guaranteeing the continuity of business and the consequences if this does not happen—cost of production disruption, hassle, and inconvenience (Nichols 2000).

Profitability remains the biggest driver for any investment in industry; energy efficiency technologies and projects are no exception (Alcorta et al. 2014).

Financial and economic barriers, namely lack of budget funding, other priorities for capital investment

(Rohdin and Thollander 2006; Trianni and Cagno 2012), the difficulty of access to capital or a too long return on investment felt in different countries, appear as important barriers to the implementation of energy efficiency measures (Sutherland 1996; Harris et al. 2000; Nagesha and Balachandra 2006; O'Malley and Scott 2004; Trianni and Cagno 2012; Thollander et al. 2013) verified in foundry industries, in several European countries, that the driving forces related to financial aspects and organizational ones are the most relevant.

Companies usually classify energy efficiency projects with lower priorities when compared to other considered as strategic investments by being more promising or important (Sorrell et al. 2000; Trianni and Cagno 2012; DeCanio and Watkins 1998; Schleich 2009; Rohdin and Thollander 2006). Very often, the share of energy costs is rather low and this can be the reason why energy efficiency projects are not considered strategic (Cooremans 2007; Groot et al. 2001).

The strategic value of a measure depends not only on its benefits (energy savings, productivity increase, and reduction of local emissions) but also on the company's objectives.

Lack of capital makes the implementation of energy efficiency measures difficult (Fleiter et al. 2012b); therefore, the existence of subsidies or support programs may alleviate this problem. Even when companies have access to external funding, they prefer to use it with other projects rather than in energy efficiency ones (O'Malley and Scott 2004).

Lack of access to capital is a crucial barrier to the adoption of energy efficiency measures (Anderson and Newell 2004; Thollander et al. 2007), and the investment subsidies are positive measures that can contribute to the adoption of those measures. SME have greater difficulty accessing the same credit than large companies (Trianni and Cagno 2012) since financial institutions, especially in this situation of global financial crisis, tend to provide capital on the basis of the financial situation of the firm rather than on the possible profitability of a project (Trianni et al. 2013a, b). All the benefits resulting from energy efficiency must also be considered by financial institutions when evaluating investment projects (Worrell et al. 2003; Pye and McKane 2000; Mills and Rosenfelds 1996).

Companies' size has an important influence in modifying the barriers in the implementation of energy efficiency measures, being the smaller ones more affected by barriers than larger ones (Trianni and Cagno 2012; Schleich 2004). The smaller is the company, the lower is the budget for investment. SME are considered important for a smooth transition to a greener economy (Eurobarometer survey 2012).

Investment can not only be analyzed in the light of profit but also seen as a strategic one by contributing to develop a sustainable competitive advantage, this point of view greatly depending on the culture and priorities of the company's managers (Abdelaziz 2011; Cooremans 2011). Therefore, the implementation of energy efficiency measures may be within the company's sustainability objectives and those concerning a corporate image (Thollander and Ottosson 2008). Top management, while deciding about new products and processes, investments and policies must consider the three dimensions of sustainability, namely by using life cycle assessment with a special emphasis on the social economic impacts.

The potential for improving energy efficiency depends on several factors besides the size of the company: production type, energy intensity, and automation degree (Waide and Brunner 2011). Both the Energy Services Directive adopted in 2006 by the European Union and the 2020 primary energy target show the potential of energy savings in the industrial sector, namely in SME although they tend to face more technical and financial barriers than larger organizations.

Behavioral and attitude changes to energy consumption lead to energy efficiency, thus indicating the importance of training and sensitization in these areas (Owens and Driffill 2008; Stephenson et al. 2010).

A summary of different theoretical and empirical studies on barriers to energy efficiency is presented on Table 1.

The objective of this paper is to identify the situation in Portuguese SME with low energy consumption, in what concerns energy efficiency. It includes the discussion of the main barriers and identification of measures that can contribute to energy efficiency improvement.

EFINERG—goals and sectors involved

Some countries have developed policies in order to support companies to implement energy efficiency programs. In Portugal, the project Energy efficiency in SME (EFINERG) involved several stakeholders and was designed, developed, and implemented to identify

Table 1 Theoretical and empirical studies on barriers to energy efficiency

Barriers (according to Sorrell et al. 2000; UNEP 2006)	Studies on barriers to energy efficiency	
Organizational	Lack of employees' knowledge or aptitude	Groot et al. (2001)[a]
	Lack of physical space	
	Resistance to replace existing machinery	
Management	Distortion and uncertainty about fuel prices	Hirst and Brown (1990)[b]
	Inadequate information	
	Lack of information either at consumption patterns and efficiency measures levels,	Harris et al. (2000)[a]
	Priorities	
	Lack of time	
	Lack of information:	Schleich (2009)[a]
	Levels and patterns of energy consumption (information systems, the energy metering, the detail of energy bills, consumption is analysis)	Trianni and Cagno (2012)[a]
	Energy saving opportunities (lack of evaluation opportunities, availability of information on technologies costs and performance)	
	Lack of time	Anderson and Newell (2004)[a]
	Lack of staff	Schleich (2009)[a]
		Thollander et al.(2007)[a]
		Cooremans (2011 and 2012)[a]
	Energy efficiency projects are not considered strategic due to the share of energy costs being rather low	Cooremans (2007)[a]
		Groot et al. (2001)[a]
Financing	Lack of budget funding	Rohdin and Thollander (2006)[a]
	Other priorities for capital investment	Trianni and Cagno(2012)[a]
	Difficulty of access to capital	Sutherland (1996)[b]
	Long return on investment	Harris et al. (2000)[a]
		Nagesha and Balachandra (2006)[b]
		O'Malley and Scott (2004)[a]
		Trianni and Cagno (2012)[a]
		Thollander et al. (2013)[a]
	Energy efficiency projects with lower priorities in what concerns investments	Sorrell et al. (2000)[a]
		Trianni and Cagno (2012)[a]
		DeCanio and Watkins (1998)[a]
		Schleich (2009)[a]
		Rohdin and Thollander (2006)[a]
	Lack of capital	O'Malley and Scott(2004)[a]
	Lack of access to capital	Anderson and Newell (2004)[a]
		Thollander et al. (2007)[a]
Government policy	Government fiscal and regulatory policies, codes and standards	Hirst and Brown (1990)[b]
Economic	Importance of guaranteeing the continuity of business (cost of production disruption, hassle and inconvenience are possible consequences of a discontinuity)	Nichols(2000)[a]
Behavioral	Low priority given to energy issues	Hirst and Brown (1990)[b]
	Risk of energy efficiency investments,	
	Misplaced incentives for the implementation of energy efficiency measures	
Training and knowledge	Behavioral and attitude changes to energy consumption lead to energy efficiency thus indicating the importance of training and sensitization in these areas	Owens and Driffill (2008)[b]
		Stephenson et al. (2010)[a]
Technical	Production type	Waide and Brunner (2011)[a]
	Energy intensity	
	Automation degree	

[a] Empirical

[b] Theoretical

the situation in Portuguese SME in what concerns energy efficiency.

EFINERG approach considered energy efficiency in accordance with sustainability principles in order to meet the proposal of the Earth Summit (Rio+20 Conference) of a green economy. This approach proposes a life cycle vision on the products, services, and production processes (Glavic and Lukman 2007). The term life cycle refers to the integrated assessment of raw material production, manufacture, distribution, use, and disposal including all intervening transportation steps necessary or caused by the product's existence. The goal of life cycle assessment is to improve processes, support policy, and provide a sound basis for informed decision.

Both the questions related with energy use in the production processes in companies and those related with the products in the market were considered under the entrepreneurial energy efficiency. Energy consumption in society also has to do with the use of products offered by companies, as home appliances for example. Once the reduction of consumption in those equipments existent in the market depends on its conception, it is important to consider the energy efficiency since design phase. Also, the aspects linked with energy used in transports were considered—materials transport into the companies and products from the enterprise to final user. The energy needed for final deposit of products at the end of life was also taken into consideration.

EFINERG project dealt with energy efficiency study in five industrial sectors previously defined: food, agriculture, and beverage; ceramics and glass; wood, furniture, and cork; metal industry; and textile and clothes. These sectors were selected according to their representativeness in Portuguese industry and potential for energy efficiency improvement. The total amount of enterprises in those selected sectors represents 77 % of the total number of manufacturing industry in Portugal (INE 2011).

The project analyzed the situation in SME with energy consumption between 250 and 500 toe, in order to provide SME the necessary conditions to adopt energy efficiency improvements, best practices, and technological solutions that answer the problems diagnosed. In Portugal, enterprises with consumptions higher than 500 toe are subjected to specific legislation (management system of energy intensive consumption (SGCIE)) and must be submitted to periodic energy audits; therefore, they were not the main targets of this project.

An output of this project was a proposal for energy efficiency strategy in SME directed toward companies but also public authorities.

Methodology—gathering information, survey, and stakeholders

In Portugal, the information about energy efficiency in companies with consumptions below 500 toe is not organized, therefore the need for a methodology which enables the diagnosis of the energy situation in those companies.

The Portuguese technological centers, with competences in each of the industrial sectors, selected the companies involved in the project assuring that they are representative of the sectors to be studied and that they would provide the requested information. Those companies received a final report concerning their energy performance.

The target companies were selected according to a preestablished set of criteria:

- SME
- Energy consumption (between 250 and 500 toe)
- Be located on the north, center or Alentejo region (rules of the financial support program)
- No previous actions, to improve energy efficiency had taken place
- Potential for improvement of the product's performance during its life cycle (not only what it consumes, but what can be saved concerning energy)
- Company's ability to interact in the project's portal
  - Internet access
  - At least one qualified technician to work within digital environment
- Sector's representativeness concerning energy consumption
- Company's representativeness concerning the sector's production process/product launched in the market

Another aspect considered, during the selection process, was the ISO 9000 or ISO 14000 certification because an easier information gathering could be expected.

An energy flash diagnosis was designed and applied in 125 companies, 25 by selected sector, to analyze the Portuguese situation concerning energy and energy efficiency in a 3-year period. This diagnosis was supported by a previously constructed checklist. This checklist consisted of four parts.

The first part has to do with a thorough identification of the enterprise: identification, size, location, sector to which it belongs, turnover, gross value added (GVA), contact person, activity, export share, logistics, number of employees, shifts, the way companies keep up with technological development, organization chart, and energy management.

The second one is directed to energy efficiency in the design phase according to a life cycle vision: knowledge about European directives, namely the ecodesign and the energy labeling ones, criteria for materials' and suppliers' selection, packaging definition, installation and maintenance, and end of life.

The third part deals with energy efficiency in the production process: audits, kind of energy used and its characterization, energy consumption, production data, higher energy consumers in the process, evaluation of critical items (electric energy network, use of renewable energies, driving force, air conditioned systems, lighting, refrigeration, freezing, thermal energy, boilers and furnaces), and relationship with workers. The aspects connected with human resources were considered in the questionnaire, namely the importance of workers training and motivation in energy efficiency, because this does not only depend on technological aspects but also on the human ones.

The fourth part analyzes the relationship with public policies and financial incentive systems.

In order to guarantee that all the questionnaires would be filled, elements from the project team conducted presentially, in each company, the interviews with staff with responsibilities in energy management, assigned by top management. Confidentiality about the information collected was guaranteed.

The information was gathered, analyzed, and discussed with several stakeholders involved with the energy efficiency subject, namely the entrepreneurial associations of the involved sectors, the Portuguese entrepreneurial association, technological centers, the national energy agency, the Portuguese institute for SME and innovation, and the national institute for research in energy. As a result of this discussion, those stakeholders agreed in several strategic recommendations about policies to be implemented in order to improve energy efficiency in Portuguese SME.

The resulting information is collected in the report of the flash diagnosis study in companies (IAPMEI and LNEG 2012).

Results and discussion

Some of the results obtained with the implementation of the project will be analyzed with some detail.

Companies and their worries

General description of the involved sectors

Most of the companies in the metal industry; wood, furniture, and cork; and food, agriculture, and beverage are located in industrial parks. Moreover, the ones from textile and clothes and ceramics and glass are in industrial zones. A minority of companies is still located either in urban areas or mixed ones which may indicate the need of promoting the relocation of those companies to already existing industrial parks.

The textile and clothes sector is the one with the highest percentage of exportation followed by the metal industry, ceramics, and wood, furniture, and cork ones. The lowest percentage for international markets is found in the food sector.

Figure 1 shows that when analyzing GVA, the lowest figures are in ceramics sector and the highest in metal industry and the same happens with invoicing. Anyhow, it seems that there is a decreasing tendency, in the analyzed period of time, in what concerns GVA except in the wood sector.

The ceramics presents a lower turnover relatively to the other studied sectors with a decreasing tendency between years 1 and 3. Metal industry shows the highest average turnover, and years 2 and 3 figures are lower than on the first year analyzed. In textile and clothes, wood, food, and agriculture sectors, the average turnovers in the third year are higher than in the second year which may indicate a slight economic recovery in these companies.

The lowest number of workers is found in the ceramics sector and the highest in the textile and clothes (Fig. 2). In textile and clothes, metal industry, and wood, furniture, and cork sectors, there is a decrease in the number of workers although for the last one, a small

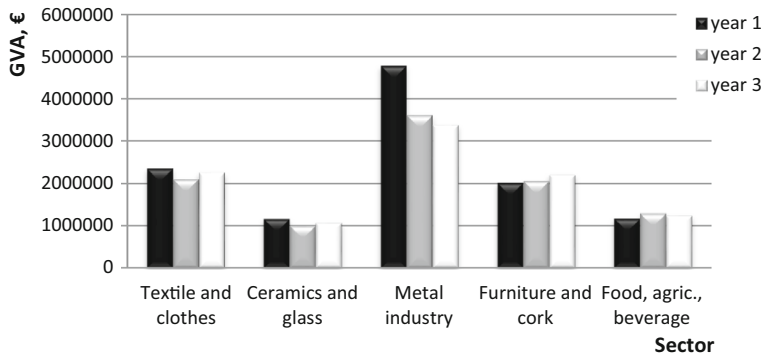


Fig. 1 Average GVA

increase is shown for the third year. In the ceramics and food and agriculture sectors, the number of workers has not changed during the 3 years analyzed.

The pictures above suggest the existence of a stronger structure in textile and metal industry sectors than in ceramics and food ones with a weaker one and therefore more vulnerable to external circumstances.

Energy consumption

Electricity is the type of energy with a higher weight in the consumption of companies from the different sectors except for natural gas in ceramics. This happens because most of the equipment installed in the target companies uses electric energy. Diesel is used in the transports in every sector. Propane is used in every sector but with low consumption, and, with a lower level, fuel oil is consumed in food and agriculture and textile and clothes sectors. Biomass has a low level of utilization, only in wood furniture and cork sector, and petrol is seldom used (Fig. 3).

In all the sectors, the driving force is the item with a higher weight in energy consumption, followed by lighting in textile and clothes, ceramics, wood, furniture, and cork. Gas furnaces are high energy consumers in ceramics and metal industry while boilers are in textile and clothes and food and agriculture (Fig. 4). Air conditioning and heating were referred by all sectors as high energy consumers but with lower percentages.

Energy efficiency in logistics

Assuming that the improvement of energy efficiency in logistics (materials, people and products transport) has to do with the existence of traffic managers, the control of empty return from the client, courses optimization with GPS, use of GPS by drivers, fleet localization system, and drivers' training, those items were considered in survey. The percentage of affirmative survey answers in all sectors about those items is shown in Fig. 5.

As shown in Fig. 5, in every sector, the items with higher number of affirmative answers are the existence of traffic managers and the control of empty vehicles returning from the clients. Only wood, furniture, and cork and food and agriculture sectors expressed their interest in optimizing the routes with GPS. As to the use

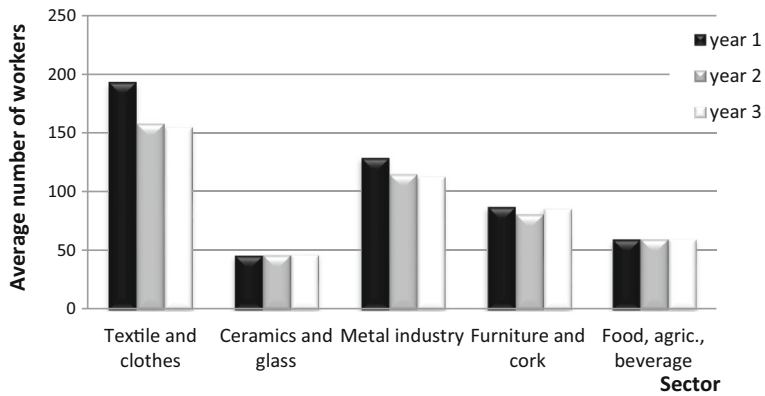
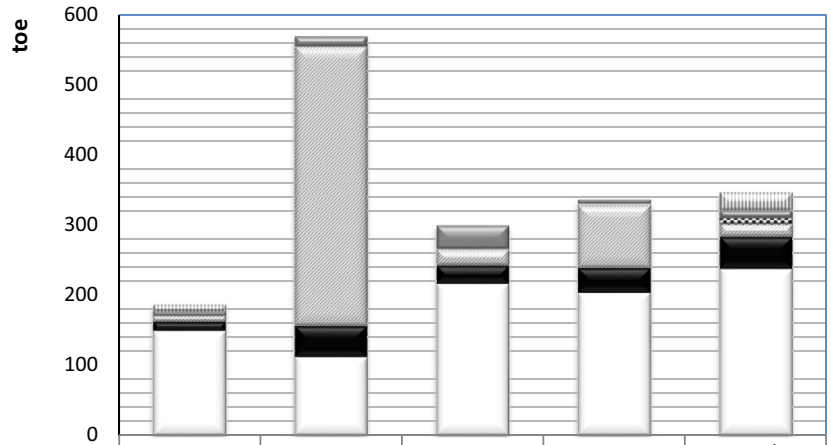


Fig. 2 Average number of workers



	Textile and clothes	Ceramics and glass	Metal industry	Furniture and cork	Food, agriculture, beverage
Fuel oil	10	0	0	0	25
Propane	6	14	34	6	11
Petrol	0	0	1	2	0
Biomass	0	0	0	0	8
Naural gas	8	397	23	89	18
Diesel	13	45	26	36	46
Electric energy	149	112	216	203	237

Fig. 3 Average consumption of the different types of energy

of GPS by drivers, only 20 % in the wood, furniture, and cork sector do it and in all the others, the percentages are very low. The localization systems do not exist in the textile and clothes sector, and for the others, they vary from 5 % to a maximum of 15 % in the wood, furniture, and cork sector. Specific and regular training of drivers have very low expression except for the metal industry where 25 % of the companies declared to do it. The smaller number of affirmative answers about worries in transportation appears in ceramics.

Energy efficiency at product level

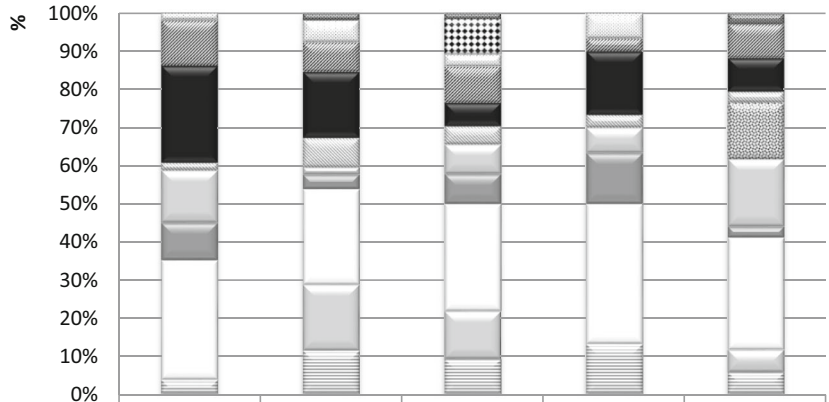
Companies can contribute to society energy efficiency through the characteristics of their products and their impact in energy consumption either directly (energy consumer equipments) or indirectly (products that can contribute to the decrease of energy consumption, as is the case of construction products, for example, coatings, that increase energy savings in buildings).

Besides the consequences of processes and management in energy efficiency, companies, by putting their products into the market, will influence energy efficiency in society in a wider way, as they can influence in a positive or negative way, the reduction of energy consumption in the activities involved.

With this purpose, the companies were inquired about the criteria used in their product design, namely about those having to do with raw materials, suppliers, package, installation, use, and end of products life. The resulting information is shown in Fig. 6.

The main worries expressed by companies (29 % of the answers) have to do with criteria used to define packaging (Fig. 6). Those criteria are related with the use of recycled and recyclable materials, minimization of the quantity of necessary materials, minimization of storage area, avoiding dangerous and scarce materials, avoiding material diversity, and minimization of energy use for storage and handling.

About 28 % of the companies also considered the criteria for raw material selection, namely those concerning



	Textile and clothes	Ceramics and glass	Metal industry	Furniture and cork	Food, agric., beverage
others	0	7	4	0	7
kitchen, wc	0	0	24	0	0
compressed air	6	20	8	14	0
air conditioning	33	27	24	7	20
lighting	72	60	16	36	20
electric furnace	6	27	12	7	7
cold oven	0	0	0	0	33
boiler	39	7	20	14	40
heating	28	13	20	29	7
driving force	89	87	72	79	67
gás furnace	0	60	32	0	13
hot oven	11	40	24	29	13

Fig. 4 Higher energy consumers in the production process

waste minimization, use of local resources, storage optimization, energy spent on the process, and also the use of recycled, recyclable, and dangerous materials.

The criteria for suppliers' selection were considered by 23 % of the companies, and preference is given to the certified, national, nearest, and older ones or those involving a shorter distance for transportation.

Product installation and use aspects were considered only by 14 and 3 % of the inquired companies. Other aspects were also considered in the design process: waste and emissions prevention, easiness in preventive maintenance, availability of use instructions stick on the product or in the internet, repair, and cleaning easiness.

Other aspects related to the use of the product were also considered in the design process: available information on energy performance, renewable energies to feed the product, integration of automatic functions for energy saving, reduction of energy consumption in the product utilization, energy needs, and consumables' minimization.

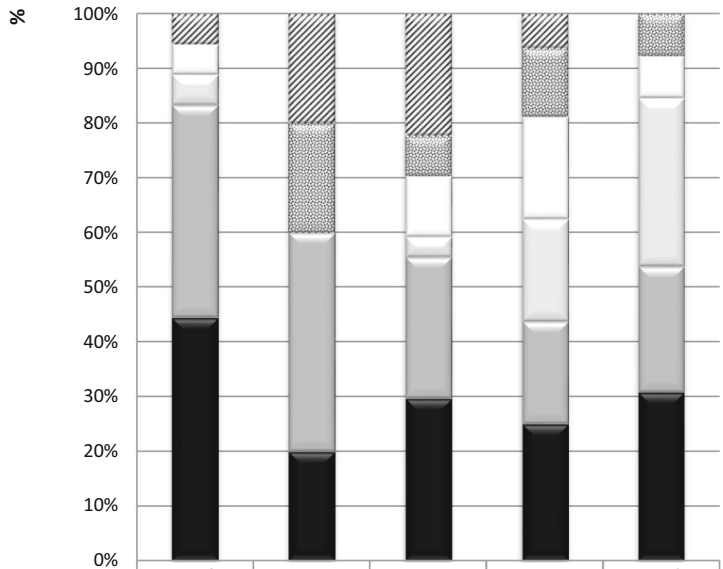
Only 3 % of the answers show the consideration, in the design process, of aspects related to the product end of life, such as easiness in dismantling, information about materials, on how to correctly disassemble, recycle or direct, and also on the consumed energy to reconvert materials.

Although companies consider some aspects related to products energy efficiency in society, this subject is not yet part of SME culture which shows lack of training and general information on those matters.

Barriers to energy efficiency improvement and suggestions to overcome them

According to Sorrell et al. (2000), a barrier is defined as a postulated mechanism that inhibits a decision or behavior that appears to be both energy and economically efficient.

Identifying and understanding the main barriers to energy efficiency is an important step in order to find the



	Textile and clothes	Ceramics and glass	Metal industry	Furniture and cork	Food, agric., beverage
drivers training	6	7	24	7	0
fleet localization system	0	7	8	14	7
GPS drivers using GPS	6	0	12	21	7
courses optimization with GPS	6	0	4	21	27
empty return	39	13	28	21	20
traffic manager	44	7	32	29	27

Fig. 5 Specificities of transportation by own fleet

measures to overcome them (Trianni et al. 2013a, b). Special attention must be paid to the difference between perceived and real barriers or the results of measures' implementation may be inefficient as stated by Cagno et al. (2013).

Most of the studies stress the fact that the barriers to energy efficiency in developing countries are similar to those in industrialized nations but typically more pronounced. The most common barriers cited are imperfect information and access to capital (UNIDO 2011).

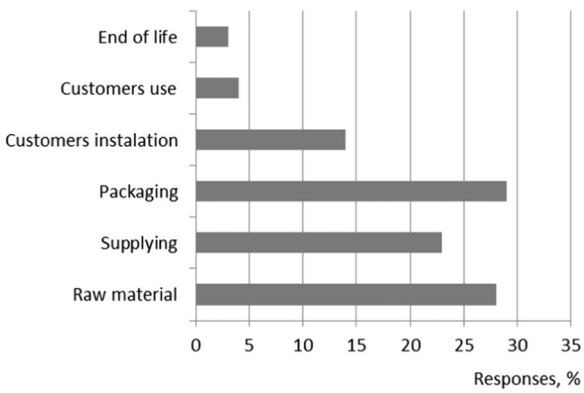


Fig. 6 Aspects related to the phases of product life

In the companies involved in the project, they were listed and classified according to different levels: information, organizational, training/behavioral, economic, and financial as to Sorrell et al. (2000).

Energy efficiency is on the focus of national energy policies and is considered as a keystone to mitigate climate change and for sustainable development (Pérez-Lombard et al. 2013).Some proposals for energy efficiency improvement in SME are made, directed toward companies but also public authorities, where some policy measures are suggested in order to make the implementation of energy efficiency measures easier and overcome the identified barriers.

Information barriers

Information sources used by SME about technological development and incentive systems were identified,

once the lack of information is commonly considered as one of the barriers to energy efficiency improvement as it implies that technologies are not fully available as stated by Cagno et al. (2013).

In 2010, a survey conducted in 12 European countries in SME (Eurochambres - Change 2010) showed the need of overcoming information barriers.

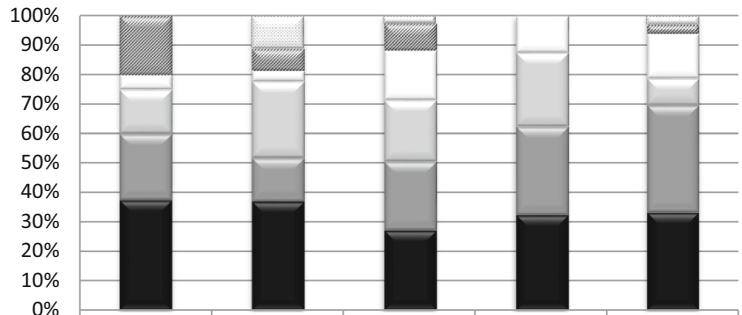
In Portugal, fairs and entrepreneurial associations are the main sources of information about technological development (Fig. 7). If companies are sensitive to what they see in the fairs, they are still more to demonstration activities given by other companies. Technological centers also play an important part in this process. The importance of universities and research centers is emphasized by metal industry, followed by wood, furniture, and cork and food and agriculture, while ceramics and textile and clothes sectors presented very low percentages. Textile and clothes sectors considered suppliers an important partner, but all the other sectors considered it irrelevant. Ceramics and food are the sectors that use in a lower level the information sources available.

Companies answered that information about incentive systems (Fig. 8) was provided mainly through entrepreneurial associations (57 %), Portuguese Institute for SME and Innovation (IAPMEI) (47 %), consultants and technological centers or other entities from the scientific and technologic system (30 %). Other sources, with a lower importance in the knowledge transmission about these schemes, were referred: seminars and workshops (22 %), sites of the support programs (20 %), press (17 %), television (12 %), and other companies (13 %). Networks also play a part in this transmission in 8 % of the inquired, and about 1 % of the companies get this information through the internet.

Information and economic barriers are the main constraints to the adoption of energy efficiency measures. According to Trianni et al. (2013a, b), the same problem arises in Italian SME.

In order to overcome the information barriers, several stakeholders can play an important part, once the problem can be studied from different perspectives at different levels (micro, meso, and macro) (Sudhakara Reddy 2013).

In Portugal, the national scientific and technological system, which includes state laboratories, universities, and technological centers, may produce and transfer knowledge into companies. Therefore, those entities are well positioned to provide technical and scientific support by helping the companies in the identification of improvement opportunities and by designing research, development, and innovation projects for better energy efficiency. They can also facilitate the dialogue between companies and public entities in order to adopt measures promoting higher energy efficiency levels. Also, the participation in collaborative networks will enable to share knowledge with companies. Therefore, the integration of these entities for collective efficiency is highly recommended.



	Textile and clothes	Ceramics and glass	Metal industry	Furniture and cork	Food, agric., beverage
others	0	20	8	0	7
suppliers	44	13	28	0	7
universities	11	7	52	36	33
technological centers	33	47	64	71	20
industrial associations	50	27	72	86	80
fairs	83	67	84	93	73

Fig. 7 Technological development

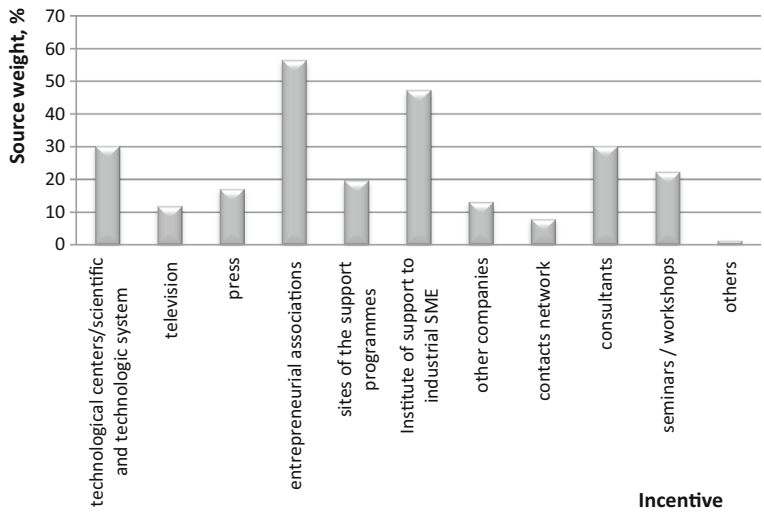


Fig. 8 Information sources about incentive schemes

Other stakeholders that will help to attain better results in this process are the different business associations as well as consumers and media, and therefore, it is highly desirable that they are involved in this process. They can perform an important part not only in the effective dissemination of energy legislation, energy technological innovation, and success stories concerning energy consumption reduction but also on the development of projects and sensitization activities for entrepreneurs on energy efficiency.

Another very important aspect is the effective involvement of companies, in a global way, so that entrepreneurs and their collaborators know and adopt proactive measures concerning energy efficiency and innovation. The collaborators' motivation, from the top management to the shop floor, is an incentive to the implementation of an energy efficiency attitude in a company.

Therefore, the recognition of economic benefits resulting from the adoption of energy efficiency measures, as well as the interest showed by the government on this subject through the launching of effective measures, may stimulate the uptake of efficiency energy actions in companies, in addition to the availability of the right information, for the right person on the right time. This implies the correct identification of when, how, and what kind of information is needed, as well as who needs it, and the need to reinforce energy efficiency skills turning to the entities belonging to the scientific and technological system and the update knowledge about newer solutions for energy efficiency.

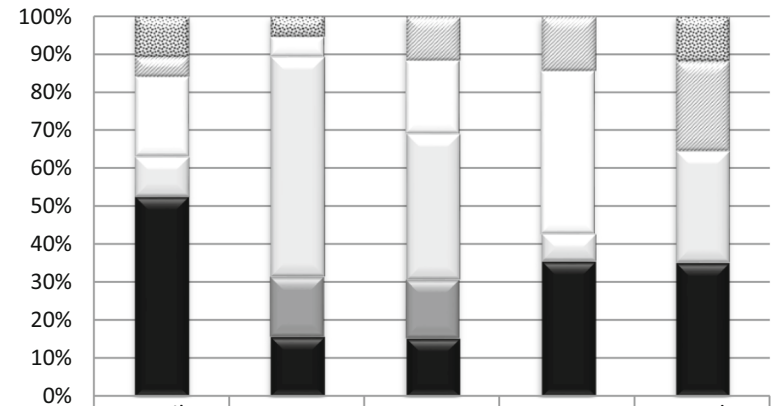
Management/organizational barriers

The responsibility by energy management in companies is supported by different kinds of entities, as the analysis of Fig. 9 shows. Administrative departments play this task in most of the companies from textile and clothes and food and agriculture sectors. As to ceramics and metal industry, this task is played by management departments and in wood, furniture, and cork by technical and administrative departments. This means that there is not an energy manager mainly dedicated to energy efficiency.

In some companies, especially in food and agriculture sector, external entities do it. The creation of the function Energy Manager in companies will help to implement good housekeeping in energy consumption monitoring, the systematic identification of energy efficiency improvement opportunities, and the implementation of energy efficiency measures according to their viability studies. In 2013, Thollander in his studies in several European countries had already concluded about the high importance of the organizational aspects.

Energy management in companies comprises several tasks, namely invoices and contract analysis in every sector. Either occasional or regular measuring is rarely considered in the five sectors. In 5 % of the companies from ceramics and food and agriculture, there is no activity connected with energy management, as shown is Fig. 10.

A high level of proactivity from SME is required in order to attain a better definition of the adjustment of



	Textile and clothes	Ceramics and glass	Metal industry	Furniture and cork	Food, agric., beverage
not done	11	7	0	0	13
external entities	6	0	12	14	27
technical	22	7	20	43	0
management	11	73	40	7	33
production	0	20	16	0	0
administrative department	56	20	16	36	40

Fig. 9 Responsibility by energy management in companies

energy efficiency programs and needs identification. Only with this data it is possible the correct offer of expertise services oriented toward specific subsectors instead of general skills. The promotion of technical partnerships with other entities, namely enterprises, governmental entities, and research institutions should also be explored. The development and use of cost-benefit models and tools and the necessary information about energy consumption in the company must also be considered, so that they will help companies in the decision-making process.

Consultancy companies involved in the different areas of the company and in this particular case linked to energy efficiency, either directly or indirectly, such as energy audits, ecodesign, design, fashion, marketing, architecture, and life cycle assessment, must also be considered. The same applies to raw materials and technology suppliers.

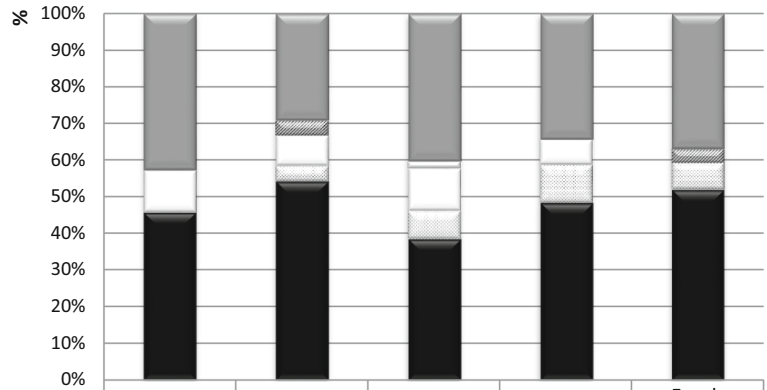
Another aspect that can be developed at management level in order to make the overcome of barriers easier is the increase of proactivity in the interactions with the entities that represent enterprises, namely at associative level, that can facilitate the rational use of the available support tools for implementation of energy efficiency namely in what concerns technology transfer to companies through the establishment of contracts and licenses.

Training/behavioral barriers

Beyond several cultural aspects, training and motivation of collaborators involved in the process industries definitively contribute to SME energy efficiency as stated by Rohdin and Thollander (2006) in non-energy-intensive companies. Specific competences have to be available to implement energy efficiency (Cagno et al. 2013). Therefore, it is important to know the level of collaborators training and motivation in order to overcome possible existing barriers in Portuguese SME.

One of the conclusions of the survey made in 12 European countries in 2010 (Eurochambres - Change 2010), in order to identify characteristics that enable SME to improve energy efficiency or prevent them from doing so lead to the lack of energy efficiency expertise in SME.

Most companies consider that their workers are duly motivated for the functions they perform and for the



	Textile and clothes	Ceramics and glass	Metal industry	Furniture and cork	Food, agric., beverage
contracts analysis	83	47	84	71	67
others	0	0	4	0	0
no activity	0	7	0	0	7
regular measuring	22	13	24	14	0
occasional measuring	0	7	16	21	13
invoices analysis	89	87	80	100	93

Fig. 10 Tasks performed in energy management in the companies

questions about energy efficiency related to their tasks. One of the problems faced, which Cagno et al. (2013) also highlighted, is the difficulty to evaluate the difference between perceived and real barriers. When looking at each of the involved sectors, textile and clothes consider that their workers are totally motivated; metal industry 96 %; ceramics 80 %; wood, furniture, and cork 79 %; and only 67 % in food, agriculture, and beverage. However, the existence of motivation programs, such as posters, written information, lectures, courses, or others, is not a usual practice.

Figure 11 shows that 71 % of the companies in the wood, furniture, and cork sector, 53 % in the food, agriculture, and beverage, 52 % in metal industry, 40 % in ceramics, and 39 % in textile and clothes make an effort as to their workers' motivation, but there is a large number of companies with no investment in this area.

Workers training for the functions they perform is a normal procedure within the companies: about 80 % of the companies in the textile and clothes, ceramics and glass, and food, agriculture, and beverage sectors consider that their workers are duly trained in order not to waste materials and energy in the functions they perform; 86 % of the companies in the wood, furniture, and cork sector, and 67 % in the food, agriculture, and beverage have the same opinion.

Here, the collaboration between different stakeholders as enterprises, the entities from the national scientific and technological system and the sector associations can play an important part in overcoming the barriers resulting from inadequate training. One of the first steps is a correct identification of real training needs with the consequent implementation of specific courses in energy where sector associations can play an important part in its promotion. In some particular aspects, the recourse to mandatory rules for energy efficiency emanating from legal government departments may be considered necessary. The scientific and technological entities should promote energy efficiency R&D projects with companies and the implementation of its results in industrial companies.

Economic and financial barriers

Numerous studies have shown the potential for industry to cut its energy costs by installing more efficient equipment that offers competitive payback periods, but the realization of this potential is hindered by numerous obstacles (Brown et al. 2014).

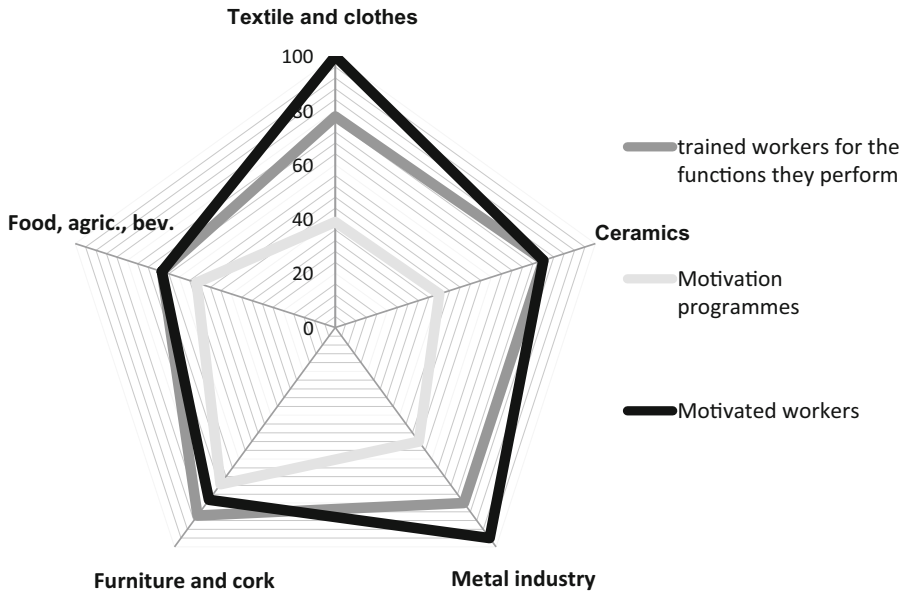


Fig. 11 Workers' training and motivation

The need to reduce energy costs is normally a motivation reason to implement energy efficiency measures, and the opposite happens with energy low costs. In the companies where the project was implemented, the percentage of energy costs related to total costs is low, between 0 and 43 % (only in one company) as Fig. 12 shows, being most of them between 0 and 5 % and seemingly with a low relation with companies' energy consumptions.

DeCanio (1993, 1998) as well as Cagno et al. 2013 underlined the low priority given to energy efficiency

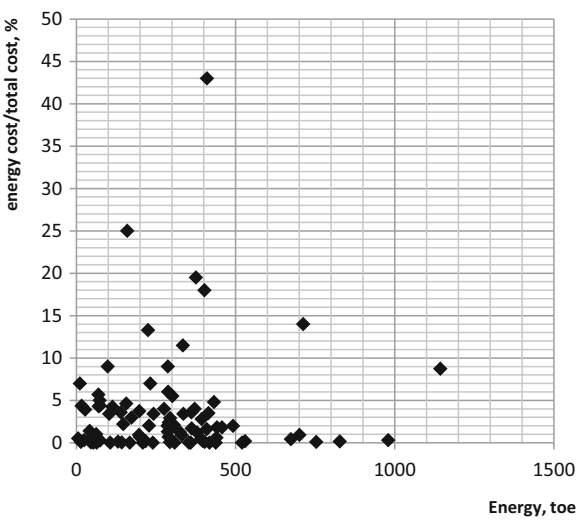


Fig. 12 Weight of energy costs' related energy consumption

aspects reinforcing what the International Energy Agency (2007) had already stated especially when the energy costs represent a low amount when referred to total production costs.

In average terms among the involved sectors, this indicator presented the highest values for ceramics and food, agriculture, and beverage (Fig. 13). On the other hand, the percentage for transportation costs in relation to total costs is even lower than the one with energy (Fig. 13), being similar when considering wood, furniture, and cork sector and food, agriculture, and beverage sector. The higher percentage for food, agriculture, and beverage may result from the need of product refrigeration during transportation.

Being the companies' economical-financial capacity, one possible constraint to investment in energy efficiency, Portuguese government makes financial instruments available, in order to support the necessary investments, although the appliance to this kind of incentives has not produced yet the expected results.

The involved companies were questioned on their idea about the incentive schemes by individual positioning to a statement list in a 1 to 4 scale (1, total disagreement; 2, partial disagreement; 3, partial agreement; 4, total agreement). Figure 14 shows the resulting information from the companies of the five sectors, knowing that 54 % of the inquired companies had already applied to at least one incentive scheme.

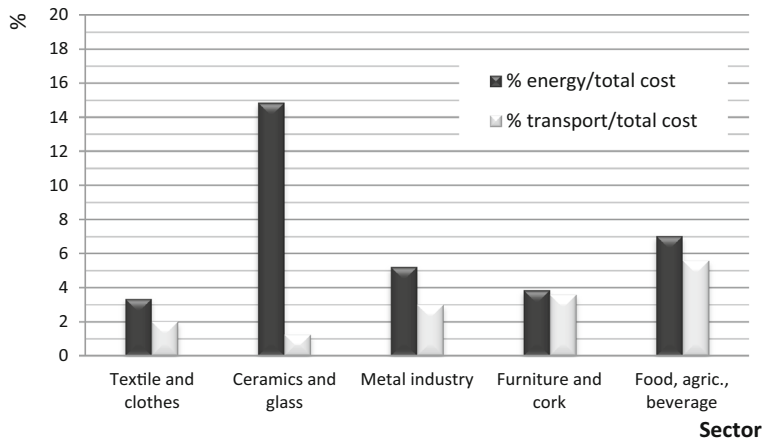


Fig. 13 Weight of energy and transportation costs in relation to total costs

The analysis of Fig. 14 shows that the opinions of those companies that have already applied for incentives and those that have not do not coincide. Those that have never applied refer more than the others the hard work to apply, that the incentives are thought for larger companies, and for those that already know the procedures. On the other hand, those that have already applied consider in a more positive way the transparency of incentive assignment, the opportunity of renewing the company, that the work in applying pays, and that the incentives answer to companies' financial difficulties and to the need to improve performance. Also, those that have already applied perceive in a positive way the easiness in accessing and filling the forms and that is worth applying. The opposite happens with those that have never applied.

The ideas with a bigger agreement are related with incentive benefits, namely in what concerns the opportunity to renew the company.

When barriers exist and restrain firms from investing, there is a potential role for the government (Groot et al. 2001) since financial institutions seem not to be fully aware of the potential financial benefits of lending to energy efficiency projects (Alcorta et al. 2014). The already mentioned survey in 12 European countries found out financing as the main obstacle to energy efficiency investment. Although financial tools and incentives already exist, it is desirable to create specific tools to support activities in the energy area, namely those concerning financial support for energy auditing, for the implementation of energy efficiency measures and renew older equipments and to adequate the existing incentive schemes to the real entrepreneurial needs. Also, the access to financial support namely as far as the bureaucracy work is concerned must be simplified. An adjustment of legislation to economy evolution is also needed, one of the possibilities being the creation of new incentive lines to the funding in which tax burden

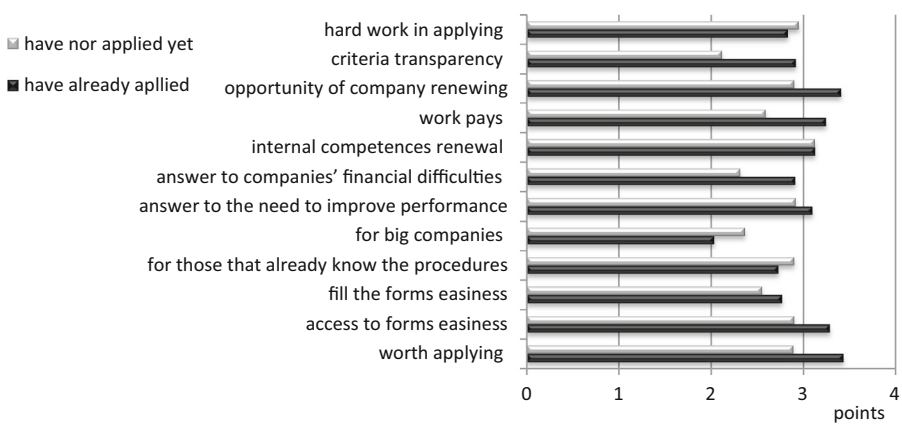


Fig. 14 Companies' opinions about incentive systems

benefits could be considered indexed to the improvement of ecological or the carbon footprints.

Conclusions

Energy efficiency issues are not identical for all the SME coming from the five Portuguese industrial sectors that were studied. In fact, some of them show a higher awareness to this problematic than others, as can be stated by measures already implemented, namely at logistics and product levels. Some of the sectors involved in this project showed a stronger internal structure, this being the case of the textile and of the metal industry, both with a lower dependency on energy sources and a smaller relationship between energy and total costs. They also search, more frequently than others, for several information sources and show a higher level of collaborators' motivation. On the other hand, the ceramic and food sectors presented either a weaker global structure or a lower adaptation capability to external conditions. Here, the use of information sources is lower and the relationship between energy and total costs is higher, being most of the times associated to the dependency of a single energy source.

Globally, the main information sources used by Portuguese SME are entrepreneurial associations as well as the Portuguese Institute for SME and Innovation.

Companies' perspective toward the use of criteria that leads to the improvement of products' energy efficiency during their life cycle is quite reduced. Although some attention is paid to products' packages, raw materials, and their suppliers, the same does not apply to the necessary energy to install, use, or at the end of life of the products.

The responsibility of energy management in these companies is mostly assigned to top management administrative elements. This shows that companies are more worried with costs than with technical aspects of energy use, since that responsibility is very seldom given to technical or production collaborators. When economic problems, associated to energy use, arise, more attention is given to invoice and contract analysis than to control and measurement activities.

Entrepreneurial associations are the main sources of information about technological development and about the incentive systems that enable Portuguese SME to overcome information barriers. Management/organizational barriers are basically the results of the inexistence of an energy manager mainly dedicated to energy efficiency although some situations were detected where external entities provide this expertise.

Motivation and training for energy efficiency use is considered a natural thing, and there are no big efforts to implement its improvement. Most companies consider that their workers are duly motivated and trained in order not to waste materials and energy in the functions they perform. However, the existence of motivation programs, such as posters, written information, lectures, courses, or others, is not a usual practice.

As to economic and financial barriers, it was stated that the need to reduce energy costs is normally a motivation reason to implement energy efficiency measures, but, in most of the companies involved in this project, the energy low costs found, when compared to total costs, are a demotivation factor. In many industrial companies, energy expenditures are often less than 5 % of total production costs (Cagno et al. 2013). Due to economic and financial difficulties, companies consider the importance of incentive benefits, namely in what concerns the opportunity to renew the company. However, they do not always make use of financial incentives systems due to their lack of confidence in the assignment processes, this being more frequent with companies that have never applied to those incentives.

Limitations and future research

This approach offers a perspective that includes economic, environmental, and social sustainability aspects concerning the energy efficiency problematic.

Future research in this direction is needed in order to advance and validate those results that were based on literature review and surveys in only five sectors. Therefore, further studies may be needed for other sectors in order to understand the complex mechanisms of energy efficiency implementation due to different singularities, approaches, and problems that may occur. Also, new tools to quantify barriers need to be studied, developed, and applied.

Another important aspect is that attention must be paid to the links between barriers, energy management and audits, policies, and programs in order to improve energy efficiency in industry.

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