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Non-technological barriers to the diffusion of energy-efficient HVAC&R solutions in the food retail sector

Silvia Minetto[a,*], Sergio Marinetti[a], Pietro Saglia[b], Nina Masson[c], Antonio Rossetti[a]

[a] National Research Council, Construction Technologies Institute, Corso Stati Uniti 4 35127 Padova Italy
[b] University of Padova, Post-Graduate Course in Industrial Engineering, via Venezia 1 35131 Padova Italy
[c] shecco SPRL, Rue Royale 15 1000 Brussels Belgium

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ABSTRACT

SuperSmart is an European Union (EU) project aiming at speeding up the uptake of energy-efficient refrigeration, heating and cooling solutions for Europe's food retail sector, reducing its energy use, lowering its environmental footprint and increasing its economic benefits. The project pursues the removal of non-technological barriers to efficient heating & cooling in the European food retail sector and supports the introduction of a new EU Ecolabel for food retail stores.

Non-technological barriers have been mapped and categorized by preliminary interviewing food retail sector stakeholders. While highlighting a general positive attitude towards energy efficiency of the sector stakeholders, the results of the survey reveal the need for specific actions focused on improving the knowledge level of technical staff, from the planning and design stage down to servicing and maintenance. Raising awareness about available technology and financial support is also required. In general terms, barriers are always perceived as stronger when moving North to South, and West to East in Europe, thus emphasizing the need for homogenization of virtuous practices and attitudes throughout Europe.

Obstacles non technologiques è la diffusion de solutions CVC et frigorifiques è haute efficacité énergétique dans le secteur de la distribution alimentaire

Mots-clés: Froid commercial; Faible émission de CO2; Efficacité énergétique; CO2; Frigorigène naturel; Obstacle

1. Introduction

Food retail stores play a key role in people's daily life, having a significant relevance in the cold food chain. The number of grocery stores with a size ranging from about 400 m^2 to 2500 m^2, generically called supermarkets, has been increasing over the past decades across Europe mainly due to urbanization, to the emerging middle class and to the globalization of markets. In the last decade, changes in household composition, ageing population, interest in new health issues and environmental awareness have had an impact on the grocery retail market in Europe. Finally, the economic crisis, starting in 2008, has set new priorities such as lower price product availability (EY, Arcadia International, 2014).

Grocery stores do not have a negligible impact on the environment. Supermarkets consume about 3–4% of the annual electricity production in industrialized countries. These have been reported in different countries including 3% in Sweden (Sjöberg, 1997), 4% in the USA and France (Orphelin et al., 1999), 3% in the UK (Tassou et al., 2011), and 4% in Denmark (Reinholdt and Madsen, 2010). In addition to this, they are energy intensive buildings, having one of the highest specific energy consumption (defined as the energy consumption per sales or total area) related to the other commercial buildings in Europe, as documented in the UK (Galvez-Martos et al., 2013) and Norway (Enova, 2008). The impact of refrigeration and air conditioning in the overall store energy bill may depend on climatic conditions and social habits. It is generally acknowledged that refrigeration accounts for 30–60% of the supermarket energy bill, resulting in the highest energy consumption related to other systems, as demonstrated by Tassou et al., 2011 and

* Corresponding author.
E-mail address: silvia.minetto@itc.cnr.it (S. Minetto).

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Lundqvist, 2000. The energy intensity may range up to 700 kWh m^{-2} per year for a hypermarket, and up to 2000 kWh m^{-2} for a convenience store, as recently documented by the European Commission, 2016.

Three major categories of refrigeration systems can be identified in food retail stores: stand-alone systems (used for example for cold beverages), including emerging water loop self-contained systems, condensing units (for small supermarkets), and centralized systems. The most widespread centralized systems have a central refrigeration unit, located in a machine room, with refrigerant pipes connecting the unit to and back from cabinets and cold rooms. This solution is known as direct expansion configuration. In the very recent past, centralized refrigeration systems used high Global Warming Potential (GWP) refrigerants with the magnitude of the leakage rate estimated in the range of 3–22% of the total amount of charge that varies from hundreds to a few thousands of kg (IPCC/TEAP, 2005). The Regulation (Eu) No 517/2014, known as F-gas Regulation, represents a turning point, setting ambitious goals for the sector in terms of F-gases phase down and ban.

Low-GWP synthetic fluids (HFOs) are currently evaluated, mainly as short-term replacements of R404A, which is the most widespread fluid for MT (Medium Temperature) and LT (Low Temperature) commercial refrigeration systems (Mota-Babiloni et al., 2017). It is however becoming clear that drop-in is not straight forward (Domanski et al., 2017) and concerns about real environmental impact of new synthetics (KTH, 2015), future regulations and price and availability are increasing.

State-of-the-art systems take advantage of CO_2 as a refrigerant, confirming that the CO_2 transcritical booster system is the preferred lay-out all over Europe (Masson, 2016). The booster system is widely described in the technical literature (Ge and Tassou, 2011). It is a compact lay-out including LT and MT, sections, typically directly expanding (DX) refrigerant into display cases and room evaporators. In the reference lay-out, the MT section performs a simple vapor compression cycles, rejecting heat in transcritical or subcritical conditions depending on air temperature, while the LT section rejects heat to the low pressure side of the MT circuit. In the last years, different works demonstrate that the booster systems is competitive to conventional HFC systems in middle and cold climates, providing energy savings in the order of 20% on an annual basis when comparing to traditional HFC-based systems (Sawalha et al., 2017), even though the simple vapor compression cycle is adopted in the medium temperature branch. The standard CO_2 transcritical booster system shows also other important features, such as the possibility of integration of heating and air conditioning systems with the refrigeration system (Karampour and Sawalha, 2017). In the last years many efforts have been taken to move CO_2 application southward in Europe, where climate can be hostile to the simple CO_2 transcritical cycle. In fact, due to the peculiarities of the CO_2 transcritical cycles, throttling losses rapidly increase as the gas cooler outlet temperature increases (Cavallini and Zilio, 2006), thus penalizing COP and reducing cooling capacity at the same time. An increase of the system's energy efficiency can derive from different modifications of the original lay-out, which result in staged compression and expansion, such as the adoption of parallel compression (Minetto et al., 2005), mechanical sub-cooling (Llopis et al., 2016) or evaporative cooling (Fornasieri et al., 2008) and recovery of the expansion work replacing the expansion valve with ejectors (Elbel and Hrnjak, 2008). In particular, parallel compression is widely applied in order to compress directly the flash gas vapor from the receiver to the high pressure side and it perfectly fits with the integration of the air conditioning system (Karampour and Sawalha, 2016). In CO_2 systems the ejector can recover part of the expansion losses and convert it into pre-compressing work. The application of this element is significant due to the high value of the throttling losses in high pressure expansion valves when CO_2 systems operate in warm climates at transcritical conditions, which negatively impact on COP. Recent works demonstrate that its use could lead to an improvement of the system efficiency of up to 20% (Hafner et al., 2014). Overfed evaporators have also spread out as a simple and effective way of increasing evaporation temperature, and then reducing energy consumption, by proper use of evaporator heat transfer surface. This solution often combines with liquid recirculation by ejectors (Minetto et al., 2014).

All of the previous described solutions are already present in the European market, but they are not yet widespread, especially in Southern Europe. The EU funded MultiPACK project (Multipack, 2016–2019) is currently demonstrating and building up confidence for standardized integrated cooling and heating packages installed in high energy demanding buildings. The project will scientifically support the introduction of innovative packages, with all parts made in Europe, applying the natural working fluid CO_2 and the latest efficiency enhancing technologies, such as two-phase ejectors, heat recovery and Heating, Ventilation and Air Conditioning (HVAC) integration. It will finally validate in the field the suitability of the CO_2 refrigeration technology for warm climate applications.

Despite the increasing number of supermarkets adopting energy-efficient, natural refrigerant-based units, there are still obstacles to their adoption.

In the last years, many steps have occurred towards low carbon solutions in commercial refrigeration, as widely documented by Masson, 2016. With respect to CO_2 solutions, with 5500 transcritical units counted in 2016, the diffusion of energy-efficient and natural refrigerant-based solutions is still under expectations, especially in some areas, such as South Europe. The reason is then to be ascribed to non-technological barriers. These barriers slow down the natural evolution and improvement of the new technologies proposed by the market. This hindrance leads to a lack of knowledge as regards the behavior of the specific technological solution, gained only through field experience. While CO_2-based refrigeration solutions have consolidated in North Europe in the last ten years, the need for more complex cycles to meet competitive energy efficiency in South Europe has been initially perceived as a technological barrier

The technology to build and manage energy efficient systems exists, residual non-technological barriers still slow down its adoption. Technicians might not be aware of solutions or feel inadequate, contractors might dislike being pioneers and end users worried about reliability and price.

While the existence of these barriers and their effect on the market is unquestionable, to the authors' knowledge there is no comprehensive picture of the actual situation in the European area available in the open literature. There is not a systematic work addressing the impact and the importance of each single aspect of non technological barriers (social, organizational, etc.) over the different climates and economical areas in the EU. This work aims to provide this piece of information that is currently not available.

2. Methodology

The European project SuperSmart has been created in order to understand non-technological barriers and to remove them all over Europe.

The first part of the SuperSmart project identifies key non-technological barriers for the food retail stores heating and cooling systems.

Starting from the literature related to barriers in the energy sector [25,26] and from the project partners' technical and market experience and knowledge, the barriers are grouped into awareness, knowledge, social, organizational and legislative. Considering the lack of a consolidated background and terminology, each group is

then analyzed in order to provide the stakeholders with proper introduction to the topic, to reduce effort in understanding, to avoid communication barriers and to improve the future success and relevance of the survey.

Translating the barriers description and the survey itself from English to French, German, Spanish, Italian and Serbian prevented the linguistic barrier.

2.1. Awareness barrier

The availability of new technologies gives many possible choices to the supermarket stakeholders. However, they are not always aware of the different opportunities and how they can fit their sites. The awareness barrier also relates to lack of knowledge regarding the positive impact an adoption of efficient technologies can have on the business case for operators.

2.2. Knowledge barrier

Target groups involved in the choice and utilization of efficient heating and cooling solutions in supermarkets often lack the necessary knowledge to operate in the best way. As technologies evolve towards more efficient solutions, system complexity increases and interdisciplinary knowledge is required in order to fully understand the integration of subsystems and implication of specific choices on the final energy bill.

2.3. Social barrier

The social barrier relates to the bias of some target groups towards changes under multiple aspects, such as technology, planning procedures and collaboration necessary to implement energy-efficient solutions. For instance, moving from a well know technology to a new one, may arise concerns in planners: while they are sure they can achieve their goal with usual solutions they are experienced in, new technologies are perceived as risky.

2.4. Organizational barrier

The organizational barrier refers to the relation between two or more stakeholders involved in planning or operating a supermarket, which impedes the adoption of more efficient heating and cooling solutions. This kind of barrier often relates to conflicting interests. Each supermarket stakeholder has his/her own interests, which may interfere with the interests of other stakeholders.

2.5. Legislative barrier

Although major parts of supermarket systems and subsystems are actually affected by relevant EU regulation in terms of environmental sustainability, as for example air conditioning and ventilation, lighting, electrical appliances and building materials, there is a lack of legislation considering key components of the supermarket or the food retail store as a whole. Ecodesign for Commercial Refrigeration (refrigerated display cases) is still at the consultation forum and proposal status (Ares, 2016); unlike other systems relevant to the food retail sector, such as EN13215:2016 for remote condensing units or EN14825:2012 for heat pumps for space heating and cooling, centralized refrigerating units are not affected by similar regulations, as recently described by Minetto et al., 2017. Consequently, there is no strong legislative incentive towards energy-efficient supermarkets as a whole and neither against inefficient ones, except for some national regulations. These regulatory standards can be a key driver for sustainability; however, cost increase related to standards is to be kept under control in order to avoid a loss of competitiveness.

Within the legislation barrier the F-gas regulation, EPBD Directive and the EU Ecolabel were specifically questioned.

The European Union aims at controlling emissions of fluorinated greenhouse gases (F-gases), including hydrofluorocarbons (HFCs), and with the Directive 2006/40/EC for mobile air conditioning appliances and the F-gas Regulation for the all other applications where F-gases are used. The F-gas Regulation tends both to reduce the leaks from equipment that contains F-gases and to avoid the use of F-gases where environmentally superior alternatives are cost-effective. Some of the adopted measures for leakage reduction includes containment of gases and proper recovery of equipment, training and certification of personnel handling these gases and a labeling of equipment containing F-gases. The recent update of the F-gas Regulation strengthens the existing measures by three main actions:

- limiting the total amount of the most important F-gases, the HFCs, that can be sold in the EU from 2015 onwards and phasing them down in steps to one-fifth of 2014 sales in 2030;
- banning the use of F-gases in many new types of equipment where less harmful alternatives are widely available, such as household refrigerators or supermarkets;
- preventing emissions of F-gases from existing equipment by requiring checks, proper servicing and recovery of the gases at the end of the equipment's life.

Food retail sector stakeholders have been specifically questioned to evaluate the impact of the new F-gas Regulation on their business.

The 2010 Energy Performance of Building Directive 2010/31/EU is one of the main legislative acts to reduce the energy consumption of buildings. The EPBD requires that:

- energy performance certificates are included in all advertisements for the sale or rental of buildings;
- EU countries establish inspection schemes for heating and air conditioning systems or put in place measures with equivalent effect;
- all new buildings are nearly zero energy buildings by 31 December 2020;
- EU countries set minimum energy performance requirements for new buildings;
- EU countries have to draw up lists of national financial measures to improve the energy efficiency of buildings.

Food retail stakeholders answered to specific questions on the expected impact of the EPBD on their business.

3. Survey

The adopted methodology included an interview performed to food retail sector stakeholders, held in the form of survey. Answers were first collected on paper during a dedicated workshop held in Barcelona on 18.04.2016 under the ATMOsphere 2016 Conference; the survey was then available online from 18.04.2016 to 17.06.2016 on the project website www.supersmart-supermarket.org in different languages.

3.1. Survey contextualization

3.1.1. Food retail sector stakeholders

Stakeholders are identified within target groups directly or indirectly related to planning, designing, installing, operating, maintaining and refurbishing heating, cooling and refrigeration systems for food retail stores. Each group has an active role in promoting or impeding the adoption of efficient solutions and their behavior depends on non-technological inputs. Fig. 1 presents the identified stakeholder categories.

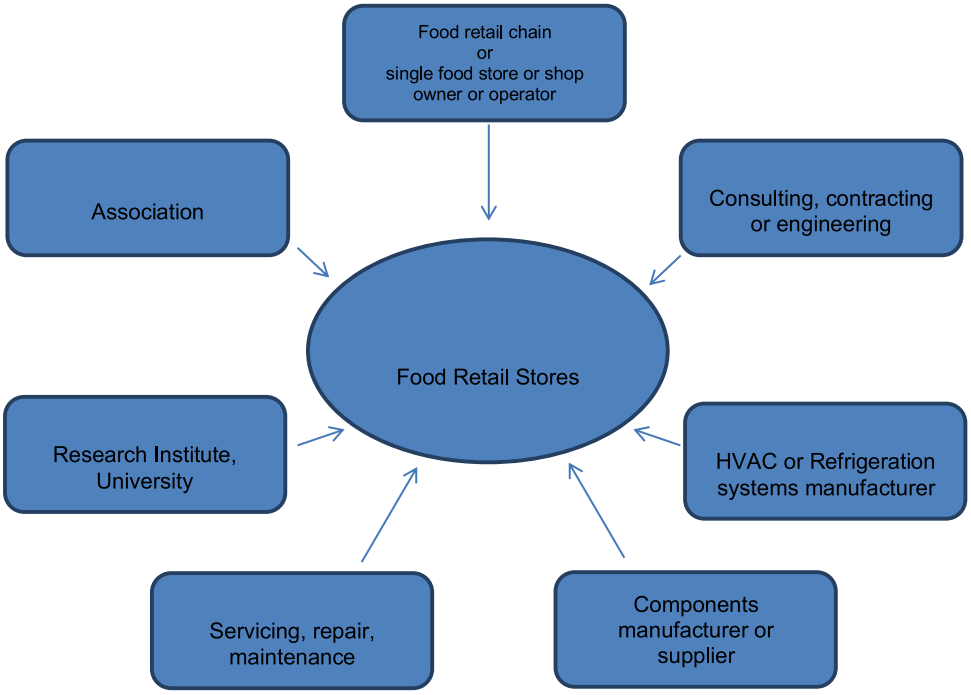

Fig. 1. Food retail store energy systems stakeholders.

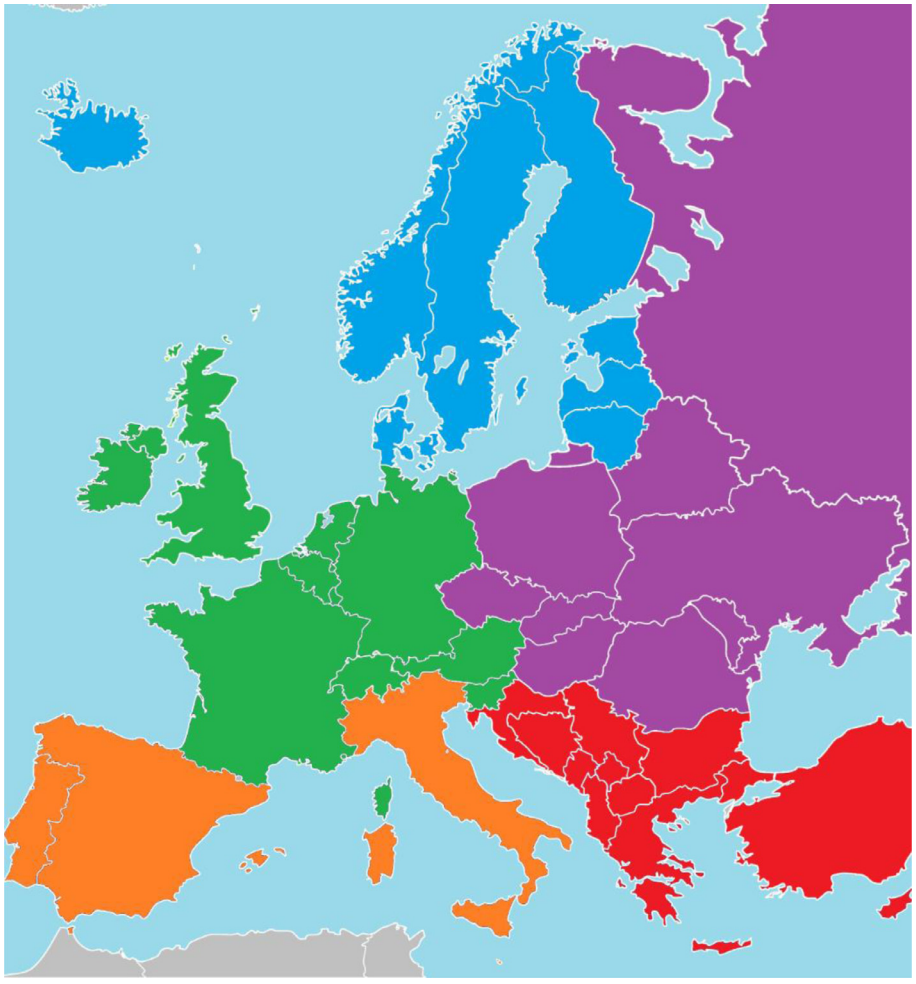

Fig. 2. European regions.

3.1.2. European regions

According to the actual adoption of energy-efficient and natural refrigerant-based solutions across Europe, it becomes evident that geography and therefore climatic conditions play an important role. Therefore, another division is proposed that involves the geographical area of interest where the stakeholders operate. In Fig. 2, there result five regions in Europe: North, Centre West, Centre East, South West and South East, including Turkey. This division mainly takes into account the climate conditions, which are mostly affecting the HVAC&R systems' energy consumption and the adopted technology both for HVAC&R systems and building construction. At the same time, geographic division often corresponds to commercial areas for system manufacturers and suppliers. Secondly, the geographic perspective includes also social and cultural aspects, which are relevant to the topic. In fact, some factors, such as shopping habits, food traditions and average income, influence the adoption of specific solutions and the resulting energy consumption. On the other hand, there might be significant differences within the same geographical region, for example in terms of regulation. Many differences also derive from food traditions in terms of diffusion of "modern retail" that consists in a large and diverse store format offering a wide assortment of goods. This format is sometimes integrated into a sophisticated supply chain, with ownership concentrated in a small number of national or international retail groups.

3.2. Survey structure

The first section of the survey asks respondents to identify their business sector and role in the organization, together with the geographical location of their activity. Moreover, respondents have to indicate only those European region(s) they are familiar with. Food retail chains or shop owners respond to dedicated questions, intended to investigate the average size of their shops and their prevalent ownership model. In the second part of the survey, respondents' attitude towards low carbon solutions is analyzed. Gained experience in energy efficiency and low environmental impact systems is investigated. In the third part of the survey, a general assessment of the magnitude of the identified non-technological barriers is carried out by asking about the importance of each of them, jointly with the difficulty in removing the respective barrier and the potential impact deriving from its removal. Questions on each specific barrier are then presented to understand where the major obstacles lie. The respondents' general attitude about the EU F-gas Regulation (Regulation (Eu) No 517/2014) and the Energy Performance of Buildings Directive (Directive 2010/31/EU) is also registered. In a specific section regarding the EU Ecolabel, respondents are asked how they feel an EU Ecolabel that might affect their business. In the end, respondents are encouraged to express the willingness to be kept informed about the SuperSmart project or to actively participate.

The survey is reported in Annex 1.

3.3. Survey validation

Data coming from the online survey were first validated based on the time spent on the survey and technical figures on the connection sessions, to avoid, for example, multiple attempts from the same address.

4. Survey outcomes

Answers are segmented by business sector and geographical areas of competence. Quantitative answers were processed computing the average and the mode, as well as the percentage of maximum score in order to convey information related to the score distribution.

Table 1
Business sectors represented in the survey.

Value	*Percent (%)*	*Count*	*Completed survey*
Food retail chain/Single store owner	6.8	12	5
System manufacturer HVAC	13.1	23	18
System manufacturer Refrigeration	29.0	51	26
Components supplier	31.8	56	36
Consulting, contracting, engineering	19.3	34	18
Servicing, repair, maintenance	11.4	20	13
Association	4.0	7	5
Research institute / University	15.3	27	14
Other	6.8	12	4

Table 2
Coverage of the North, Central West and South West in terms of declared business sector knowledge and experience.

Value	*Percent (%)*	*Count*	*Completed survey*
North	57.2	99	53
Central West	56.6	98	53
Central East	35.3	61	33
South East	36.4	63	36
South West	50.3	87	53

The total number of respondents is 300; 96 of them came to the last page of the survey (completion rate 32%). Amongst the 204 partial completions, 82 respondents provided a significant number of answers, together with identification of their business. Based on the evaluation of the number of answers, in relation to the business sector, the total number of valid questionnaires resulted in 178.

4.1. Business sector, geographic location and role in the organization

Geographically 79% of the participants belonged to a European organization (global headquarters located in Europe), while 10% worked for US companies. The largest group of respondents (52%) was managerial (Fig. 3), while 35% belonged to the technical area (designers, researchers, technicians). Regarding the European organization headquarters, a significant share of German (19.7%) and Italian (15%) organizations were represented (Fig. 4). In general, societies coming from the North, Central and South West Europe are well represented in the survey, while there is no relevant representation of companies based in East Europe. This result is actually not surprising as major players of the food retail business are based in West Europe. Table 1 represents these sectors amongst the respondents (multiple choice is allowed), showing that an important role is played by refrigeration and components manufacturers and suppliers. These companies are often based in Germany and Italy, thus providing explanation for the previously presented geographical distribution of European headquarters location. Food retail chains are represented by 12 respondents, mainly covering managerial roles (Table 1). Despite the small number of respondents, in comparison with other business segments, the presence of respondents from major multinational players provides significant coverage of the sector. Their EU headquarters are based in Central West and South West Europe, but they declare knowledge of the entire EU market; this aspect guarantees a good exposure for all regions. The represented end users (food retail chains) administrate 100% stand alone sites (none inside shopping malls) and near 78% of them state that the predominant ownership model equals one that is totally owned and operated by the owner stores. The average size of the stores represented is almost equally distributed amongst small, medium and large sites, with a negligi-

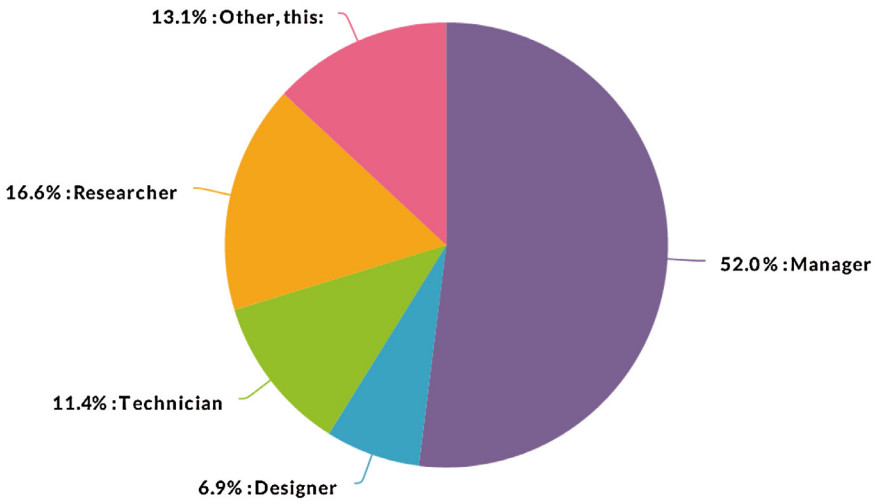

Fig. 3. Role in the organization.

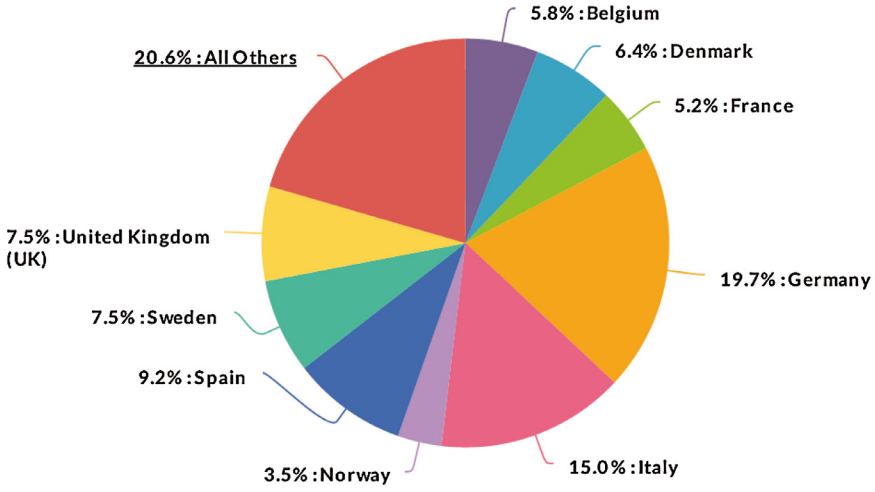

Fig. 4. The headquarters location for European respondents.

Table 3
Stakeholders' attitude towards energy efficiency (score 1–5).

	Top score (%)	*Average/Mode*
Food retail chain/Single store owner	100	5.0/5
Consulting, contracting, engineering	50	4.1/5
Association	50	4.3/5
Servicing, repair, maintenance	47	4.0/5
System manufacturer: HVAC	45	4.0/5
Components supplier	41	4.2/4
System manufacturer: Refrigeration	36	4.1/4
Research Institute / University	33	3.9/5

ble predominance of hypermarkets (>4500 m^2). Again, despite the limited number of representatives from food retail chains in the survey, they provide a good representative sample of the EU market.

Moreover, there is a good coverage of the North, Central West and South West regions in terms of declared business sector knowledge and experience (multiple choice is allowed) from all stakeholder categories, as can be seen in Table 2.

4.2. Attitude towards low carbon solutions

The importance of energy efficiency for different stakeholders is presented in Table 3, where the percentage of respondents attributing the top score (5) is listed, together with the average score (1–5). What is clearly emerging from the table is that the closer the stakeholder is to the final complete supermarket installation, and therefore to the energy bill, the higher is the importance they give to energy efficiency. In fact, all respondents from food retail chains give five stars to energy efficiency, while HVAC&R systems and components suppliers are more reluctant. People providing consultancy and contracting are also very much concerned about energy efficiency; the explanation might lay on the fact that normally they are considered by the storeowner or manager as the personal responsible for the overall energy performance of the site. Near 50% of respondents from all categories recognize LED lighting and high-efficiency motors as the widespread energy saving solutions. Also, close to 30% of those surveyed have experienced, directly or indirectly, A class HVAC systems. In a second analysis, a list of solutions for energy efficiency they practiced in a direct or indirect way is provided. 25% report system monitoring, control and optimization and 22% (from all stakeholders group) state closure of display cabinets, such as doors and lids (data not shown).

Over 50% describe modifications to the refrigeration system under different aspects such as components, refrigerants (natural R290 and R744) or integration with HVAC. Heat recovery is practiced by over 70% of the respondents, thus confirming that it is becoming a widespread solution. The direct use of renewable energy sources by the respondents shows that there is a widespread use of them (Fig. 5), with an important relevance of air source heat pumps (over 60%). Fig. 6 shows the experience with natural

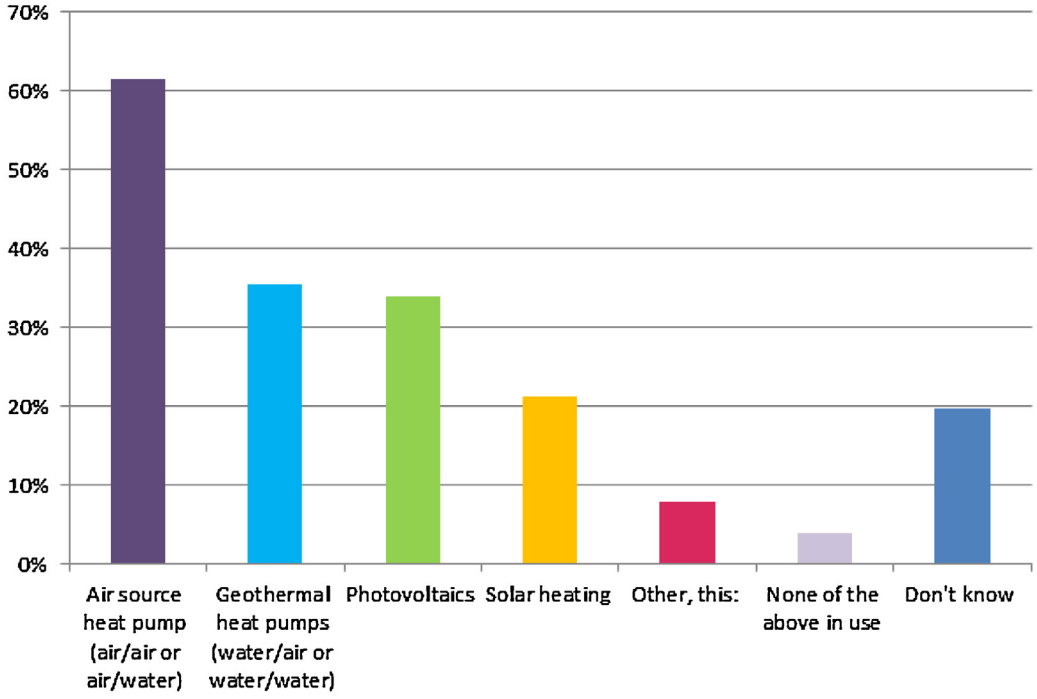

Fig. 5. Experience with renewable energy sources.

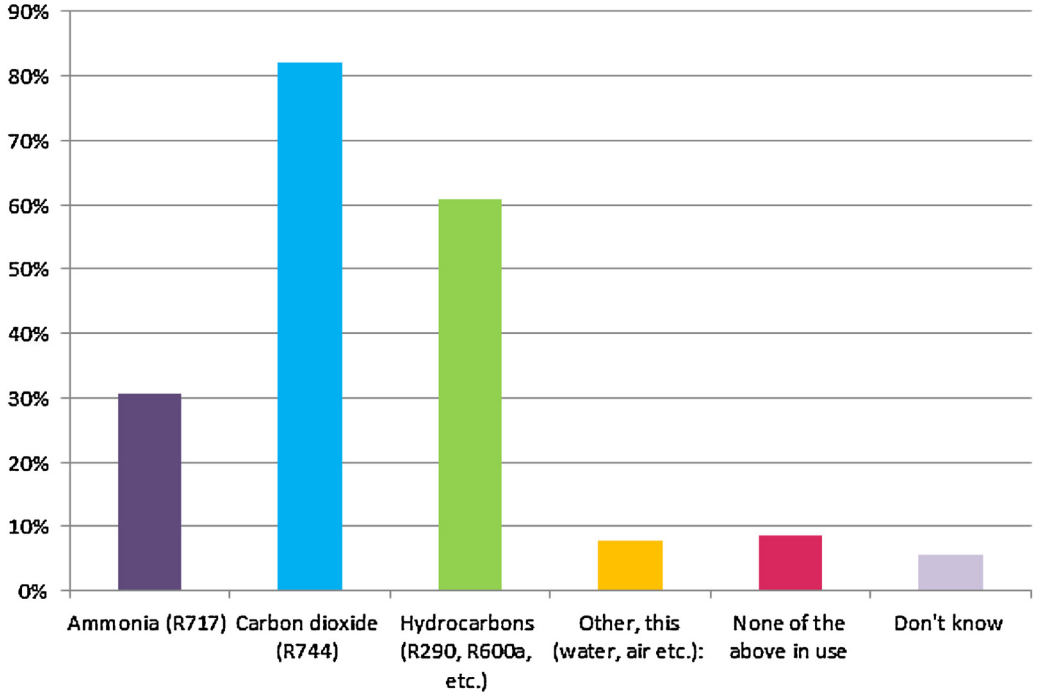

Fig. 6. Experience with natural refrigerants.

refrigerants. Carbon dioxide is the most common natural refrigerant (81%), followed by hydrocarbons (60%). Finally, while energy efficiency is considered important by almost all interviewed stakeholders, 51% of them expect the payback time for energy-efficient solutions to be within 3 years, while 42% can accept 6 years as a reasonable timeframe (data not shown).

4.3. Non-technological barriers results

Respondents are initially asked to rate the importance of each proposed non-technological barrier in the EU regions they experience in their business. A 1–5 score system, where 1 means “not important” and 5 means “very important”, was used.

In the following sections, the results of the survey for each kind of non-technological barrier are presented.

4.3.1. Awareness barrier

The awareness barrier gets a slightly increasing score ranging from 2.5 to 3.3, moving from North to south and West to East (Table 4). The increase is more evident when the mode is considered, instead of the average. The North region does not experience the proposed awareness obstacles as being as important as

Table 4
Rating the barriers for energy-efficient cooling & heating you experience in your European food retail business / in that of your European customers and partners, from weak barrier (1) to strong barrier (5).

	Top score (%)	Average / Mode				
		North	Central West	Central East	South East	South West
Awareness	10	2.5/1	2.8/2	3.1/4	3.2/4	3.0/3
Knowledge	15	2.8/1	3.0/4	3.3/3	3.3/3	3.4/4
Social	11	2.3/1	2.8/3	3.3/4	3.5/3	3.4/4
Organizational	16	2.9/1	3.1/3	3.0/3	3.3/4	3.3/3
Legislative	13	2.8/1	2.7/3	2.8/3	2.8/3	2.9/3

Table 5
Rating of the proposed awareness barriers for energy efficient heating & cooling in the European food retail business, from weak barrier (1) to strong barrier (5).

	Top score (%)	Average / Mode				
		North	Central West	Central East	South East	South West
Lack of awareness of available technology at decision making level	2	2.2/1	2.4/2	2.9/4	2.9/2	3.2/3
Lack of awareness of financial support (by banks, financial bodies or govt. funding) or reward schemes for energy efficiency	3	2.6/3	2.8/2	3.2/3	3.1/3	3.2/3
Lack of awareness of possible financial savings from energy efficient solutions	4	2.4/1	2.8/3	3.1/4	2.9/1	3.2/4
Lack of awareness of the environmental benefit of energy efficient systems	3	1.9/1	2.4/2	2.6/1	2.7/1	2.9/1

Table 6
Rating of the proposed knowledge barriers for energy efficient heating & cooling in the European food retail business, from weak barrier (1) to strong barrier (5).

	Top score (%)	Average / Mode				
		North	Central West	Central East	South East	South West
Lack of training programs	3	2.8/1	2.8/3	3.0/3	3.5/3	3.5/3
Lack of experienced trainers	3	3.0/2	3.2/4	3.3/4	3.7/5	3.7/5
Lack of free or low-priced educational material, easily available	6	2.8/1	2.8/2	3.0/3	3.4/3	3.2/3
Lack of education material for different technical knowledge levels	3	2.7/1	2.8/3	3.1/3	3.4/3	3.2/3

the South West area, where nearly all the same suggested barriers have the same relevance (Table 5). Amongst the comments, one respondent belonging to the Consulting, Contracting and Engineering group claims that the lack of awareness on the potential attractiveness of energy efficiency towards customers is a barrier. According to him, this obstacle is experienced as very important in South West Europe (5), important in Central West (4) and not really important in the North (1).

4.3.2. Knowledge barrier

The knowledge barrier is considered less important (average score 2.8, mode 1) in the North than in the rest of Europe (score 3.0–3.4, mode 3–4) (Table 4). The proposed knowledge barriers are perceived more relevant when moving southward; amongst them, the lack of experienced trainers is considered the biggest hindrance (Table 6). The lack of training interest is also proposed as a barrier in South West Europe, together with the absence of skilled specialists in Central and South regions. Considering the ratings with reference to the role in the organization, in the North, consultants, contracting and engineering respondents recognize the greatest importance of the knowledge barrier, while in the rest of Europe refrigeration systems manufacturers and components suppliers provide the top score. End users, such as food retail chains, are mainly concerned about the lack of experienced trainers in West (Central and South) Europe. An interesting suggestion is given by a refrigeration system manufacturer, who recognizes the lack of unbiased third party data to compare alternative technologies as a very strong knowledge barrier (score 5). This statement emphasizes the need for a shared and repeatable metrology for comparing different systems under the same boundary conditions (Minetto et al., 2017). Besides, there is a general need for training all major food retail sector stakeholders all over Europe, with limited difference moving from North to South (Table 7). In particular, servicing, repairing and maintenance staff rate the importance of training highly, especially in South Europe (average score 4.3). Regarding the importance of receiving training, it is worth noting that some stakeholder groups underestimate their own need for training, attributing a lower score to themselves than what they received in Table 7 as an average score by all respondents. For instance, servicing, repairing and maintenance staff rate 3.5 (vs 4.0 average) the importance of being trained, while attributing 4.4 to consulting, contracting and engineering staff (vs 3.9

Table 7
Rating the importance to be trained about energy efficient heating & cooling solutions by different stakeholders, from low importance (1) to high importance (5).

	Top score (%)	*Average / Mode*				
		North	*Central West*	*Central East*	*South East*	*South West*
Food retail chains and supermarket owners	8	3.6/4	3.6/4	3.7/3	3.7/5	3.7/5
System manufacturers and component suppliers HVAC&R	5	2.9/1	2.9/3	3.1/5	3.4/5	3.2/5
Consulting, contracting, engineering staff	9	3.8/5	3.9/5	4.2/5	4.0/5	4.0/5
Servicing, repair, maintenance staff	11	3.7/5	3.8/5	3.8/5	4.3/5	4.3/5

Table 8
Rating of the proposed social barriers for energy efficient heating & cooling in the European food retail business, from weak barrier (1) to strong barrier (5).

	Top score (%)	*Average / Mode*				
		North	*Central West*	*Central East*	*South East*	*South West*
Concern about possible investment increase and long payback time	6	3.4/5	3.5/4	3.7/4	3.7/5	3.9/4
Concern about new solutions leading to too many technical changes at the same time	4	2.8/4	3.4/4	3.5/3	3.7/3	3.8/5
Concern about new systems being less reliable than H(C)FC ones	6	3.0/4	3.4/4	3.5/5	4.0/4	3.8/5
Concern that energy efficient systems do not perform as promised	4	3.0/4	3.2/3	3.2/3	3.5/3	3.9/4
Concern about higher maintenance for new solutions or increased installation time	4	2.9/4	3.1/3	3.4/3	3.4/3	3.7/3
Concern about availability of trained technicians for installation/maintenance of the new systems	7	3.2/5	3.3/4	3.4/3	4.1/5	4.0/5
Concern about consumers not valorizing improved environmental impact of supermarkets	4	2.6/1	2.8/3	2.9/2	3.2/4	3.4/5

average), who are probably considered responsible for the system design and complexity. On the other hand, consulting, contracting and engineering staff are very convinced about the importance of being trained and attribute a score of 4.3 to themselves (vs 3.9 average). System manufacturers and component suppliers in HVAC&R consider the importance of own training being quite low (2.7 average), while they think it is very important to train both consulting, contracting and engineering on one hand and servicing, repairing and maintenance staff on the other. The general outcome is that it is very important to train people who design, commission and service the plant, while there is more confidence in the competence of single component suppliers or HVAC&R unit designers and procedures.

4.3.3. Social barrier

The social barrier increases its relevance from North (score 2.3, mode 1) to other areas (score up to 3.5 mode 4) (Table 4). The proposed social barriers are felt to gain in importance when moving South, with an almost uniform increase of 0.8–1.0 points (in a 1–5 range) from North to South (Table 8). The fear of not having sufficiently trained technicians, which was also identified by many respondents as a knowledge barrier, is considered to be the worst social barrier, especially in the South. Secondly, the concern about possible investment increase and long payback time get the most uniform score all over Europe. In the South, there is also a general misgiving about new systems not performing as well as the old ones or not being equally reliable. This feeling might derive both from the concern about the region's low knowledge levels, as well as the hot climate, which is a bigger challenge in the South than in the North. Suggestions are provided by respondents about other social barriers, such as the creation of new personal relationship with new market players. Also, one respondent from the consulting, contracting and engineering group claims that energy efficiency might be perceived as temporary fashion. Furthermore, financial conflict of interests is also proposed as a social barrier.

4.3.4. Organizational barrier

The organizational barrier follows almost the same trend of the social barrier, but with a reduced span: from 2.9 to 3.3. (Table 4). Top score to the proposed organizational barriers is mainly provided by components and systems suppliers, all over Europe (Table 9). This means that they feel somewhat unable to sell their products due to this kind of barriers and the cause mainly lies within the planning, building and running a store. On the other hand, end users (food retail chains) do not consider these barriers particularly important.

4.3.5. Legislative barrier

The legislative barrier has the same relevance when the average is considered (score 2.8) between all the areas, while mode is uniform to the value of 3, except in north were it drops to 1 (Table 4). The legislative barrier is described as the lack of legislation that considers the supermarket system as a whole. This fact

Table 9
Rating of the proposed organizational barriers for energy efficient heating & cooling in the European food retail business, from weak barrier (1) to strong barrier (5).

	Top score (%)	Average / Mode				
		North	Central West	Central East	South East	South West
Conflicting interests of stakeholders involved in planning or operating a supermarket	6	3.3/5	3.2/2	3.6/4	4.0/5	3.7/5
Lack of an "Energy Manager" for supermarket life time	5	3.0/2	3.0/2	3.4/3	3.7/5	3.5/5
Lack of distributed responsibility chain for setting up an "integrated, efficient solution"	3	2.9/3	3.0/3	3.3/3	3.6/3	3.4/3
Lack of an energy rewarding/payback scheme between system owner and system operator	6	3.1/5	3.3/4	3.4/5	3.9/5	3.8/5
Short term view for energy efficiency investments	6	3.2/5	3.2/2	3.8/5	3.6/3	3.5/5

Table 10
Rating of the proposed challenges under the F-gas Regulation for energy efficient heating & cooling in the European food retail business, from weak barrier (1) to strong barrier (5).

	Top score (%)	Average / Mode				
		North	Central West	Central East	South East	South West
Complexity in record keeping for HFCs systems	4	2.9/3	2.8/3	3.0/3	3.1/4	3.5/3
Lack of qualified personnel for system servicing	4	2.8/3	3.2/3	3.4/3	3.5/3	3.7/5
Lack of awareness of possible alternatives to F-gases when planning the future installations	4	2.9/1	2.9/4	3.3/3	3.6/4	3.5/5
Lack of/limited availability of suppliers for HFC-free systems	2	2.4/1	2.5/1	2.8/3	3.0/3	2.9/3

Table 11
Rating of the proposed challenges under EPBD for energy efficient heating & cooling in the European food retail business, from weak barrier (1) to strong barrier (5).

	Top score (%)	Average / Mode				
		North	Central West	Central East	South East	South West
Complexity in the legislative framework (EU vs national)	4	3.1/3	3.4/3	3.3/3	3.6/5	3.7/5
Complexity in the key roles for the Directive implementation (Local authorities, ESCOs, …)	5	3.2/4	3.5/3	3.4/3	3.8/4	3.7/5
Lack of qualified designers and consultants	4	3.0/2	3.2/3	3.4/3	3.5/3	3.4/3
Unclear/Unstable energy price	2	2.5/1	3.1/4	3.3/3	3.0/3	2.9/3
Fear of increase in the required financial effort	5	3.0/3	3.4/5	3.3/4	3.3/5	3.9/5

hinders the promotion of energy-efficient supermarkets as a whole and does not punish inefficient ones. Questions are posed about the major legislative EU acts promoting environmentally friendly technologies in the food retail HVAC&R systems.

4.3.5.1. F-gas regulation. The strongest barrier under the F-gas Regulation is identified in the lack of qualified personnel for system servicing (Table 10), which is evaluated as being of importance especially in South West Europe (average score 3.7). This barrier is somewhat classified as a knowledge barrier and many similarities can be found with the lack of qualified and experienced technicians that was claimed before. Also, the lack of awareness of possible alternatives to HFCs is a medium strength barrier in South Europe. At last, there seems to be a good awareness level of the existence of suppliers for HFC-free systems.

4.3.5.2. EPBD directive. The complexity in the legislative framework is considered an important barrier all over Europe, getting a quite high score (3.7) in the South West Europe (Table 11). The rating for lack of qualified designers and consultants can be classified as a knowledge barrier. The fear for the increase in the financial effort is very high in South West Europe (score 3.9).

4.3.5.3. EU ecolabel. Table 12 shows the expected impact of the EU Ecolabelling on all the proposed items, that gets a score from 2.7 to 3.3 in a 1–5 range. All respondents, except food retail chains, are quite confident that it could improve their own financial success and sales number. The cautious rating (2.4) given by food retail chains is very important, as they supposed to be the final group implementing the Ecolabel and it well fits together with their feeling that the EU Ecolabel will provide almost no added value to their customers (score 2.2). However, they are the most

Fig. 7. Expected benefit from the removal of each of the barriers (score 1–5).

Table 12
Rating of the expected impact of a future Ecolabelling for food retail stores, from weak effect (1) to strong (5) effect (only food retailer chains are responding).

		Average / Mode							
	Average / Mode	*Food retail chains*	*System manufacturer HVAC*	*System manufacture Refrigeration*	*Components supplier*	*Consulting, contracting engineering*	*Servicing, repair, maintenance*	*Association*	*University and Research Institute*
My food retail business	3.0/3	3.0/3							
The European food retail sector in general	3.2/3	3.0/4	2.8/4	2.8/4	3.1/4	3.4/4	2.9/3	2.5/3	3.6/3
The carbon footprint of my products and services	3.3 / 4	3.8/4	3.0/4	3.1/4	3.0/2	3.2/4	3.3/4	2.4/1	3.4/5
My financial success / sales numbers	3.1/3	2.4/1	3.3/3	3.2/4	2.8/3	3.3/3	2.8/3	2.4/2	3.8/4
The value added I can provide to my customers and partners	3.2/4	2.2/1	3.3/2	3.3/5	3.1/3	3.2/3	3.1/2	2.4/2	3.9/4
The additional training needs for my staff members	3.0/3	3.2/3	2.2/1	2.6/3	2.8/4	3.1/3	3.1/3	2.2/3	4.0/4
My every day workload	2.7/3	2.0/3	1.8/1	2.4/1	2.6/1	2.8/2	2.6/2	1.8/2	2.9/3

aware group regarding the impact on the carbon footprint of their services (score 3.8). They also assert that the Ecolabel would not overload too much their everyday workload and they are aware of the need for training for their staff. System manufactures and components suppliers are quite positive with respect to the impact of the Ecolabel on sales numbers and the added value of their products. They also seem to be quite ready for the label, as they do not foresee too much impact on the need for training or everyday workload. Servicing, repairing and maintenance stakeholders think that the EU Ecolabel could have an impact (score 3.3) on the carbon footprint of their services and that it will require more training for themselves, although the impact on their workload won't be so relevant. Associations are very cautious and they do not think that the EU Ecolabel might have any significant impact on any of the proposed items. Very high scores are given by the universities and research institutes that imagine an important influence of the EU Ecolabel on their financial success through the added value they can provide.

4.4. Suggestions

About the active participation, 62% of the respondents are interested in participating more actively in the project by being involved in the expert panels, thus influencing the uptake of efficient heating and cooling technology in the food retail sector and the introduction of an EU Ecolabel for food retail stores. The percentage

of interest in the food retail sector is near 100%, while the largest number of respondents not willing to be actively involved lies in the refrigeration systems manufacturer group.

The interest in the SuperSmart project, which is high amongst respondent: near 80% of those who completed the survey declaring the willingness to be kept informed about the survey results and the project progress, reflects the perceived importance of low carbon technologies for the food retail stores, which is widespread across Europe and amongst all identified stakeholders. While industrial stakeholders (HVAC&R systems and component manufacturers and suppliers) are approached at the technical level, food retail chains are more difficult to be involved and the participation has to occur at managerial level. Energy efficiency is important for the business of all involved stakeholders and it acquires top relevance for food retail chains. There is already a general experience in energy-efficient technologies (LED lighting, doors on display cases, heat recovery), in renewables (mainly air source heat pumps) and in the use of natural refrigerants (CO_2 and hydrocarbons). When analyzing non-technological barriers, there is a general increasing trend in the perceived obstacles when moving from North to South in Europe: this is valid for all proposed barriers and stakeholders. Fig. 7 provides the importance of the benefit that might derive from the removal of each of the barriers, separately in the European regions. Suggestions on which action to implement for successfully address each barrier can be then derived from Tables 5 to 11, where the perceived rating of the impact of each proposed barrier can be turned into the expected benefit that can be derived from the removal of the barrier itself.

5. Conclusions

A survey was submitted to stakeholders within the European food retail sector, focusing on groups that are related to energy systems (HVAC&R). The survey aimed at identifying their attitudes towards energy efficiency, obstacles to the adoption of state-of-the-art technology, problems with the European regulations and feelings towards a future EU Ecolabel. The entire Europe is well represented in the survey answers and the highest number of respondents belongs to manager category, followed by the technical area. The general attitude towards energy efficiency is very positive amongst all the stakeholders groups. The level of experience in energy efficiency and low carbon technologies is generally high: 70% of respondents apply heat recovery, 60% utilize renewable energy sources and 81% use CO_2 as a refrigerant. In inquiring about the non-technological barriers, which are previously identified by the SuperSmart project consortium, an increase in the perceived obstacle in each barrier is elucidated. This phenomenon shows an increase that goes from North to South Europe. The legislative barrier is considered the most difficult to remove, together with the social one. Awareness and knowledge barriers are regarded as the easiest to remove. In analyzing the awareness barrier, the lack of awareness of financial supports to implement energy efficiency measures is viewed as the most important aspect in this barrier. The lack of experienced trainers is considered the knowledge barrier with the highest impact as compared to other options in the same category. Considering the social barrier, the fear of not having enough trained technicians is viewed as the worst type of social barrier, especially in the South. The organizational barrier is perceived as an obstacle mainly by components and system suppliers, all over Europe. Finally, in analyzing the legislative barrier, the judgments towards the F-gas Regulation and the EPBD were collected. Regarding the F-gas Regulation, the major obstacle is identified in the lack of qualified personnel for system servicing, in particular in South West Europe. For the EPBD Directive, the complexity in the legislative framework is considered a relevant barrier all over Europe.

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Supplementary materials

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