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An overview of the refrigeration facilities in Portuguese agro-food industries: energy consumption and refrigerants

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Abstract

As part of a nation-wide survey aiming to characterize the energy efficiency in the Portuguese Agro-food industries, Project Inovenergy is looking upon equipment and behaviour in six Agro-food industry sectors: Meat, Fish, Milk & Dairy, Wines, Fruit & Vegetables and Food Distribution. The main purpose is to survey both active and passive components, which have an impact on the refrigeration energy inputs. After an extensive survey period where a total of 256 companies were visited, a database was established to generate Key Performance Indicators (KPI's), used as benchmarking tools, enabling managers to identify their companies' deviation from the national average, regarding the energy consumption. As the refrigeration-related costs can reach, in some of these industries, values as high as 60-70% [1], the Project Inovenergy will also release a "Best-Practice Guide", helping managers to reduce their companies' energy input, thus raising this industry's energy efficiency.

In this paper the main conclusions concerning energy intensity, specific energy consumption of refrigerated cold stores, average number, size, height, volume and its relation to each of the studied agro-food sectors will be provided.

1. Introduction

According to the statistics [1] Portugal still presents an energy dependence level higher than the European average. Recently, due to large investment in renewable energies, namely wind and hydro, the dependency rate fell to about 76.5% [2], but at a high cost for the end-users who saw the energy prices rise significantly. Furthermore, the constant price increase of oil, natural gas and coal, has further contributed to the loss of the national purchase power and the Portuguese industries' competitiveness.

Even though not being typically regarded as an "energy intensive" sector, the Agro-food industry, in accordance to a recent study carried out by the Spanish energy agency [3], was identified as being one of the industry sectors with the greatest potential to increase its energy efficiency. This seems to indicate that a great potential is to be unveiled and as one cannot act on what it is not known, Project Inovenergy aims at further contributing to the characterization and consequent recommendations geared towards raising this sector's energy efficiency.

2. Main objectives

The main objectives of this work are the publication of a set of preliminary indicators and technical characteristics that will be the cornerstone for a "Best-Practice Guide", training workshops directed to industries' energy managers and lastly, the development of an analysis tool based on a predictive algorithm. This online tool will provide, based on input data supplied by the end-users, a set of advised energy-efficiency measures, specific to each sector, and can also be used as a benchmarking tool, through the publication of a set of Key Performance Indicators (KPI's), that will further help energy managers act on their companies' energy consumption and established behaviours.

3. Results and discussion

Figure 1 shows the differences regarding the refrigerated volume and the total number of cold stores, characteristically used on each agro-food sector. It is noteworthy the high number of cold stores in the Meat sector, being the one that typically presents smaller cold stores.

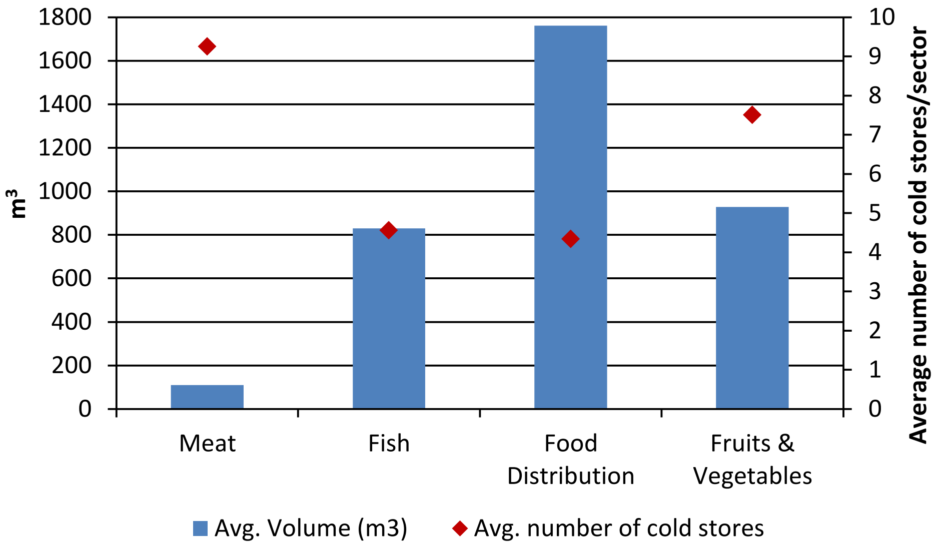

Figure 1 – Average number and volume of cold stores per agro-food sector

The area occupied by cold stores, whether refrigerated (positive temperature) or freezing storage (negative temperature), concerning the facilities' deployment area is presented in Figure 2. It is possible to verify that the Food Distribution and Fish sectors are those with larger area occupied by cold storage, regarding the facility's deployment area. This also means that in these sectors, lesser area is devoted to the processing and food products' transformation, in clear contrast with the Meat sector.

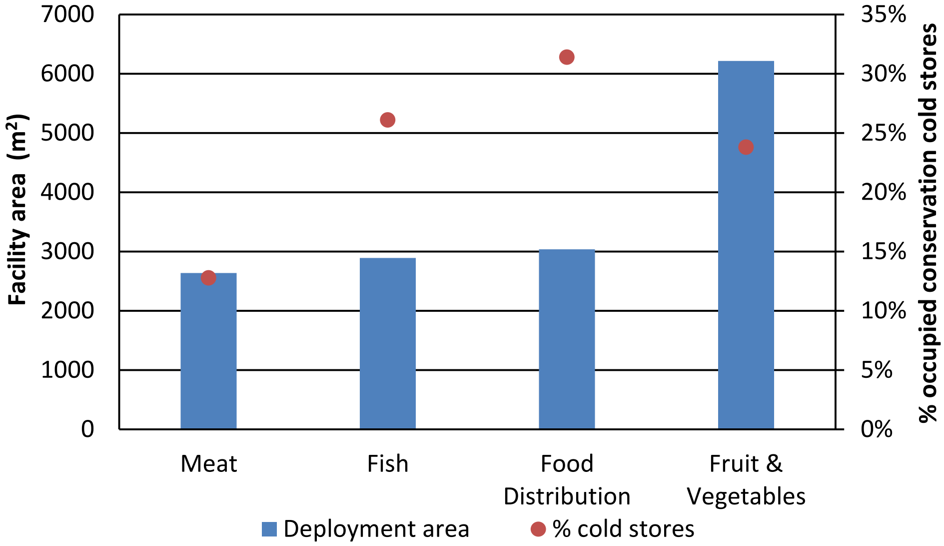

Figure 2 – Facility area and its relation to cold store area

Figure 3 shows the relation between facility area, contracted electric power and rated refrigeration plant capacity (in the cases where it was possible to obtain those data). It is quite visible that the cold storage area is larger in the Fruit & Vegetables sector, in agreement with Figure 1 where this sector presents the second highest cold store capacity. Even though the Meat sector presents the smallest number of cold stores it is evident that this is an energy intensive sector, given the highest rated electrical power, as confirmed by the results of Figure 4.

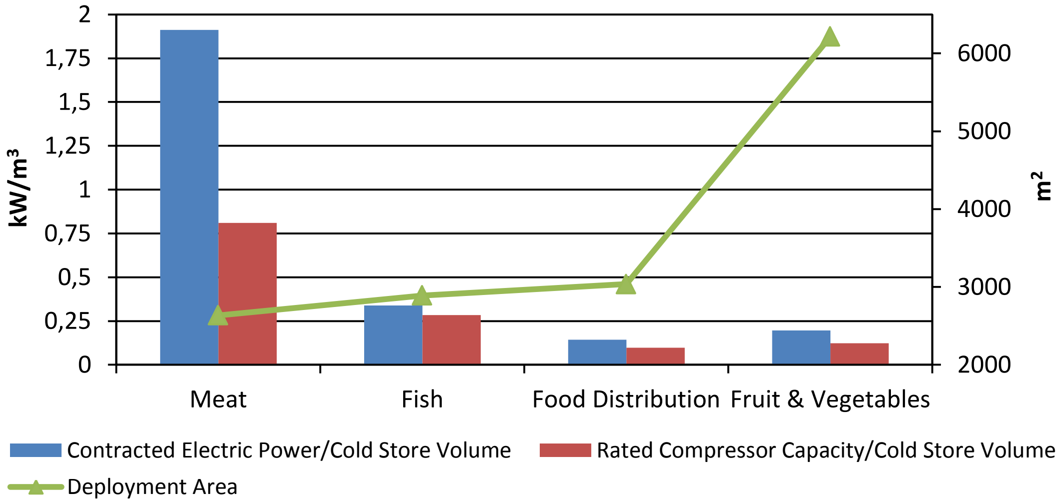

Figure 3 – Contracted electric power, rated compressor capacity and deployment area

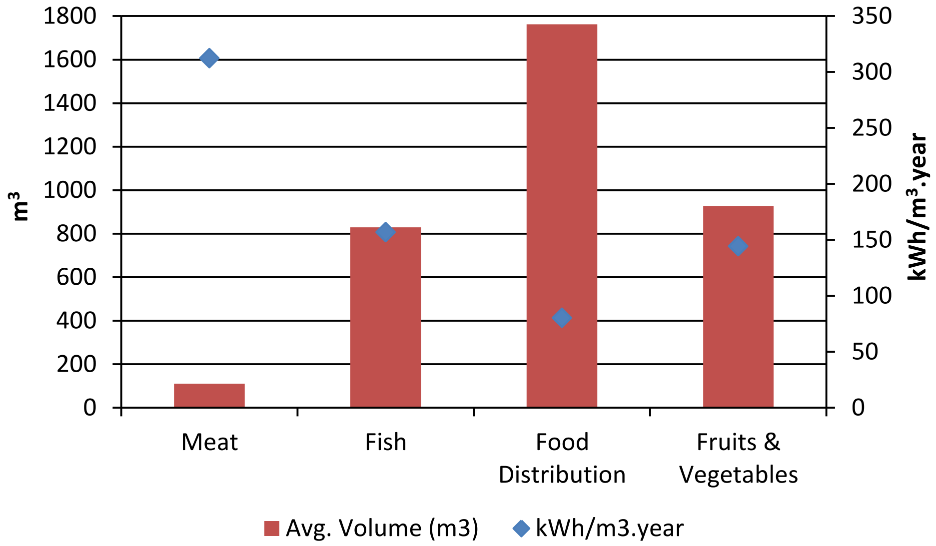

Figure 4 – Relation between average volumetric capacity and annual energy consumption

From the results of Figure 4 an inverse relation is verified between cold stores' average volume (capacity) and specific annual energy consumption. For better understanding the aforementioned phenomenon, cold stores were organized either in positive or in negative temperatures, as shown in Figure 5. It is observed that, unlikely what would be expected, sectors with the highest percentage of freezing storage are the ones with the best annual specific energy consumption, which seem to indicate that the temperature lift (difference between condensing and evaporating temperatures) is not that relevant.

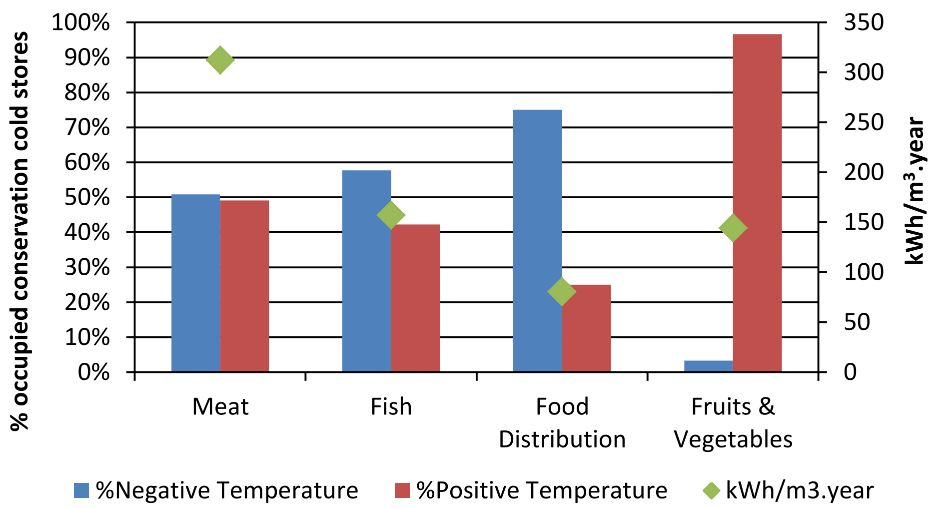

Figure 5 – Relation between temperature level and specific annual energy consumption

Meat sector is the most enlightening example of the inverse relation between annual specific energy consumption of the cold stores and their size. Due to the lesser volume, when accessing the cold stores, a higher air change rate occurs: the incoming warm moist air occupies more of the available volume, increasing the thermal load removed by the evaporators and requiring more defrost cycles to cope with the humidity increase. By the other hand, this factor is enhanced by the number of times the cold stores are accessed: whilst in freezing stores the product is stowed and kept for long-term storage (hence infrequently accessed), in refrigerated stores, the number of times the doors are opened is usually greater, thus contributing to a higher air change rate.

The relevance that cold store sizes have on energy intensity is quite clear in Figure 6, which presents the annual specific energy consumption by cold store sizes, divided into three categories.

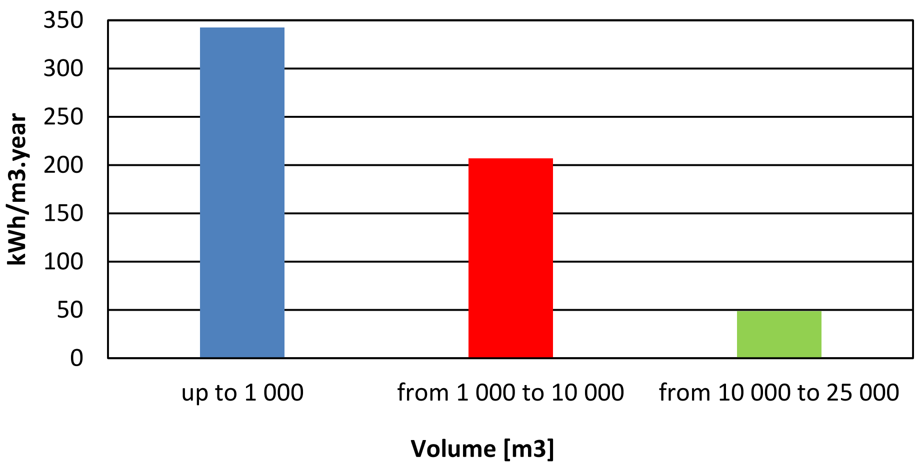

Figure 6 – Annual specific energy consumption by categorized cold store size

3.1 Refrigerant survey

As part of the "walk-through" energy audits, the refrigerants used in the refrigerating systems were pointed out (see Figure 7). During the survey, it was not possible to obtain the refrigerant's quantities. Therefore, one could not perform a quantitative analysis on the Ozone Depleting Potential (ODP) and the Global Warming Potential (GWP), hence only a qualitative analysis was executed.

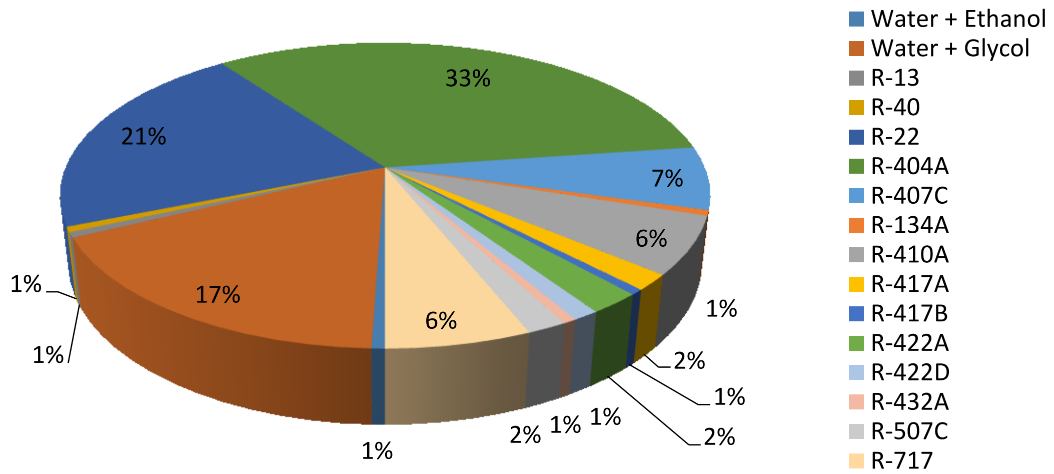

Figure 7 – Primary and secondary refrigerants

The forefront of the surveyed refrigerants is R-404A, an HFC (hydrofluorocarbon), with an expressive 33% (40% for primary refrigerants – see Figure 8). The second most used is R-22, an HCFC (hydrochlorofluorocarbon) refrigerant, which is being currently phased-out due to its environmental impacts. The third corresponds to a secondary refrigerant, glycol-water, which has much of its relevance due to the Fruit & Vegetables and Wines sectors (44 and 12%, respectively).

Figure 8 shows the results with the secondary refrigerants excluded from the analysis. The major change in comparison to Figure 7 is that now the third place is occupied by R-407C followed by R-717 and R-410A, both weighing in at 7,4%. By examining the refrigerants per sector it is observed the predominance of the R-404A in all the sectors, with exception of the Wine sector (Figure 9).

In regards to the environmental impacts, being R-404A and R-407C HFC's and R-717 an inorganic refrigerant, their impacts on ODP are null, but in terms of GWP, the two HFC's still pose some threat (seen in Table 1).

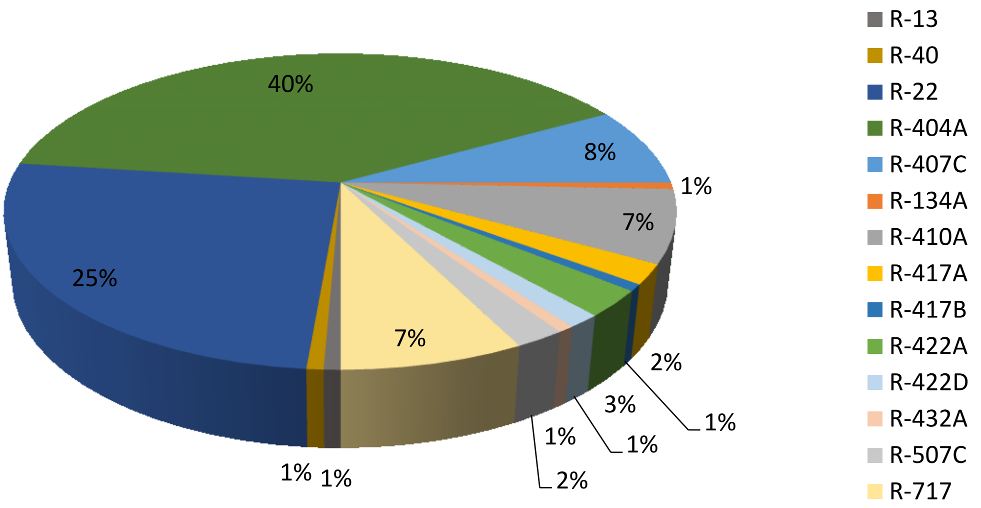

Figure 8 – Primary refrigerants

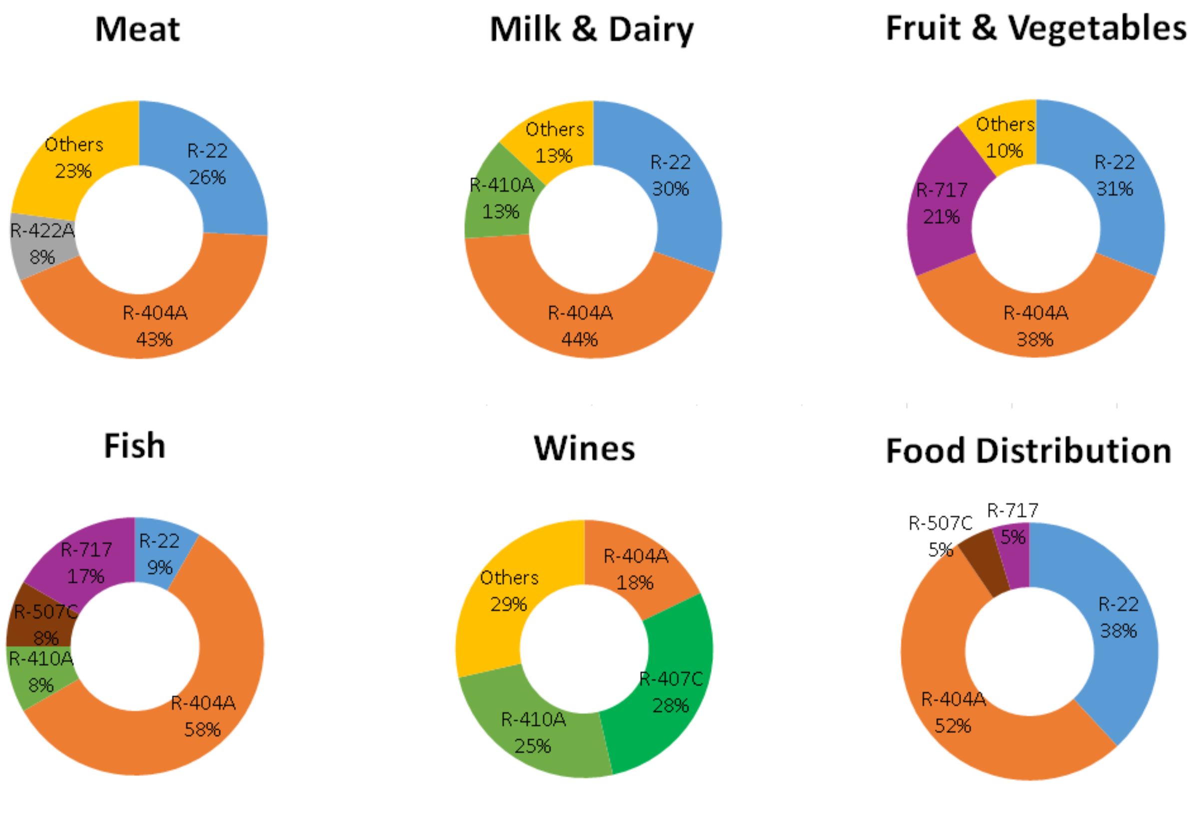

Figure 9 – Top most-used refrigerants in agro-food industry

Table 1 – Environmental impacts of various refrigerants

	Ozone Depleting Potential ODP	**Global Warming Potential GWP**		**Ozone Depleting Potential ODP**	**Global Warming Potential GWP**
R-13	1	14400	R-417A	0	2346
R-22	0,05	1810	R-417B	0	3027
R-40	0,02	13	R-422A	0	3143
R-134a	0	1430	R-422D	0	2729
R-404A	0	3922	R-432A	0	1,64
R-407C	0	1774	R-507C	0	0,85
R-410A	0	2088	R-717	0	0

R-22 still is the second most-used refrigerant, despite being a transition refrigerant whose adoption on new systems was already banned by the Kyoto Protocol. Even though having a low ODP – the lowest among HCFC's (see Table 1) is to be phased out progressively. Therefore, as its quantities will become scarcer, its price will steadily rise. Companies must look at this inevitability not as a financial burden, but as an opportunity to go "greener", opting by the R-22 replacement with competing refrigerants with not only lower ODP and GWP, but also with the more favourable thermodynamic properties. As seen in Table 2, refrigerants used in similar systems and operating under the same conditions can have a great impact on energy efficiency.

Table 2 – Coefficient of Performance (COP) of different refrigerants

Refrigerant Comparative Performance		
N.º	**Name**	**COP**
R-717	Ammonia	4,84
R-290	Propane	4,74
R-600	Butane	4,68
R-22	Chlorodifluormethane	4,65
R-134a	Tetrafluorethane	4,6
R-407C	R-32/R-125/R-134a (23/25/52)	4,51
R-410A	R-32/R-125 (50/50)	4,41
R-404A	R-125/R-143a/R-134a (44/52/4)	4,21
R-744	Carbon Dioxide	2,96

4. Conclusions

In this work, the results of a preliminary survey were obtained, for the different agro-food sectors, with the intent to define a set of indicators and technical features. The resulting sets will be used as baselines in the identification and promotion of energy efficiency solutions.

This preliminary analysis shows that the Meat sector presents the highest number of cold stores per industrial unit, simultaneously having the smallest size/capacity. In opposition, the Food Distribution sector presents the lesser number of cold stores, but being the one with largest store capacity. Given the lesser area dedicated to cold storage, one can conclude that the Meat sector is the one with greater areas devoted to food processing and, consequently, with greater manpower requirements. On the opposite side, the Food Distribution sector provides the majority of its space to food preservation with lesser space dedicated to food processing.

An important conclusion to be referred is the inverse relation between annual specific energy consumption of the cold stores and their size, mainly observed in the Meat sector: lesser volumes and frequently accessed stores (particularly the refrigerated ones), lead to higher air change rates and, consequently, to higher energy consumption. This observation also allows to conclude that temperature lift has an insignificant impact when compared to influence of the air change rates.

Lastly, a survey of the most-used refrigerants was performed, R-404A in the top spot, an HFC which complies with the Kyoto Protocol impositions. Still the second-most used refrigerant, R-22, is an HCFC currently being phased out. This forced retrofit must be further studied, and it should be seen as an opportunity to make a wiser choice in the refrigerant selection: preferring those with more favourable thermodynamic properties and lowers GWP and ODP, thus raising energy efficiency and minimizing its environmental impacts, effectively going “greener”.

5. Acknowledgments:

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6. References:

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