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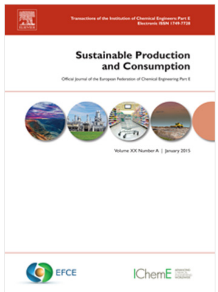

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ANALYSIS OF THE POTENTIAL OF SPANISH SUPERMARKETS TO CONTRIBUTE TO THE MITIGATION OF CLIMATE CHANGE

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Abstract:

The commercial sector is part of the so-called diffuse sectors for the purposes of meeting the targets for reducing greenhouse gases which Europe has set as 10% by 2020, Climate and Energy Package. Within the commercial sector, the entire supermarket type establishments have one of the highest rates of energy consumption per square meter in all commercial and industrial sectors. This paper presents for the first time the results of emissions related to energy consumption assessment study for supermarkets in Spain. All consumptions are considered, including lighting, cooling system, heating, ventilating and air conditioning (HVAC), bakery ovens, hot water, plugs and others. The results indicate that the cooling system has the largest contribution to most environmental impacts. For example, the global warming potential (GWP) over the 20-year lifetime of a supermarket is 6 kt of CO_2 eq. Around 50% of the GWP is from the cooling system, 30% from lighting, 10% from bakery ovens and 8% from HVAC. The measures proposed leads to an overall reduction of the impacts. For instance, the GWP reduces by 44% for the cooling system, by 44% for the lighting, by 11% for the HVAC and by 1% for bakery ovens. The results also highlight that these actions have an amortization period of four years and applied to 50% of large Spanish supermarkets would allow to obtain a 14% annually of the need to reduce GHG emissions generated by diffuse sectors of Spain (258,832 ktCO_2/year), agreed in "Objective 20-20-20" by the member states of the European Union by the year 2020.

Highlights

- Supermarkets are the commercial models with the highest growth and energy consumption.
- Adoptions of energy saving measures in supermarkets are economically profitable.
- Supermarkets could contribute significantly to GHG reduction.
- The biggest energetic savings of a supermarket are obtained in the refrigeration and lighting.

Keywords

Supermarkets; Energy saving; Greenhouse gas emissions reduction; Heat recovery; Residual fluid.

Abbreviations

COP: Coefficient of Performance.

CO_2: Carbon Dioxide.

GHG: Greenhouse Gases.

SNAP: Selected Nomenclature for Air Pollution.

UNFCCC: United Nations Framework Convention on Climate Change.

HVAC: Heating, Ventilation and Air Conditioning.

1. Introduction

The global warming related to CO_2 (carbon dioxide) emissions, coupled with steeply rising energy prices and the recent global financial institutional melt-down are causing massive societal concerns and give rise to increasing demand for ways to improve societal and individual energy efficiency and for ways to shift increasingly to alternative, low or non-carbon based energy systems (Dovì, V. G., 2009). The commercial sector belongs to the SNAP (Selected Nomenclature for Air Pollution) category 02 of the Spanish inventory of greenhouse gas emissions (GHG). In 2009, this group produced 7.7% of the total GHG emissions in Spain, (Ministerio de Agricultura, Alimentación y Medio Ambiente de España, 2015), being an important generator of GHG, which contribute to the so-called diffuse emissions to the problem of climate change. Retail trade in the EU-27 shows a significant turnover, with almost constant growth (European Commission, 2008), with supermarkets being the first sales channel and a consolidated model in continuous growth, currently counting with more than 18,000 stores (The Nielsen Company, 2013) that have a great potential for generating greenhouse gas emissions, since they are energy-consuming establishments over long periods of time in many ways (heating, cooling, lighting, etc.) (Tassou, S. A., et al., 2011). A number of studies have been conducted to estimate the environmental impacts from the construction sector. In Europe, these include studies of office buildings (Cabeza, L. F., et al., 2014 and Asdrubali, F., et al., 2013), universities (Lukman, R., et al., 2019 and Sartori, I., et al., 2017), apartment buildings (Gustavsson, L., et al., 2010 and Blengini, G.A., 2009) and houses (Asif, M., et al., 2017, Bribián, I.Z., et al., 2009, Hacker, J., et al., 2008 and Monahan, J., et al., 2011). As far as the authors are aware, only one study has been conducted in the UK supermarket sector (Tassou, S. A., et al., 2011). Supermarkets have a high energy intensity due to the high energy consumption in relation to their commercial area. The electric bill of Spanish supermarkets exceeds one thousand three hundred million euros (Clúster d´Eficiència Energètica de Catalunya, 2012). Supermarket-type establishments have been consolidated in all developed countries and are experiencing rapid growth in developing countries. Legislation is one of the means to improve energy efficiency by companies that own the premises and commercial facilities. To this effect, the approval of the Technical Building Code in Spain was an important step, especially in terms of measures to be adopted in new buildings (Sanz, J. L., 2008). In addition to legislative measures, the implementation of voluntary actions aimed at reducing energy consumption has a clear effect on climate change mitigation. However, the implementation of this type of measures by the commercial sector is still limited, even though they entail economic savings in the medium term. Perhaps some barriers to deal with the economic investment that may initially involve the adoption of voluntary measures may be found in the lack of information, the lack of environmental awareness and the failure to consider the environment as an opportunity and competitive advantage for companies, or the lack of a policy that encourages companies (Meath, C., 2016). Business model innovation is increasingly recognised as a key to delivering greater social and environmental sustainability in the industrial system (Bocken, N. M. P., 2014).

This article analyses the potential for the reduction of greenhouse gases that the introduction of energy saving and efficiency measures has in the Spanish supermarket park through the study of a significant sample of establishments. The analysis was carried out both for new buildings and for the renovacions of the existing establishments, since this last segment presents a great improvement capacity, taking into account the majority of the Spanish trades have an average age of over 10 years (The Nielsen Company, 2013). A series of proposals for measures of energy saving and efficiency of application to this type of establishments have been analysed, presenting the potential of different actions based on technological advances, the use of residual energies, and the development and application of a catalog of good practices in the use of energy, all of them tested in real supermarkets. The various measures to improve energy efficiency have been quantified, reflecting the necessary investment, economic and energy consumption savings, reduction of CO_2 emissions and periods of recovery of investment or amortization. The proposed solutions focus on the areas of the highest consumption: refrigeration installation, lighting installation, installation of air conditioning and ventilation, installation of domestic hot water and in the use of residual heat. Comparative analyses of the proposed measures have been carried out according to economic and environmental parameters to facilitate decision making in the adoption of one or other saving measure.

2. Material and methods

2.1. Supermarket model analysed

The analysis of the commercial sector has focused on medium and large supermarkets, with an exhibition and sale area between 400 m^2 and 2500 m^2, as they have the highest operating margins to reduce energy consumption (Tassou, S. A., et al., 2011) and constitute about 70% of the commercial area of Spanish supermarkets and hypermarkets (The Nielsen Company, 2013). The study contemplated the type of commercial establishment more widespread in Spanish level, surpassing 40% of the market share (The Nielsen Company, 2013). Currently, the number of supermarkets of this type in Spain exceeds 8000 establishments with a tendency to grow in the coming years. This is a detriment to traditional commerce and establishments of less than 100 m^2, whose number continues to decrease. Likewise, hypermarkets with an exhibition and retail sales area of more than 2500 m^2 with much lower growth (The Nielsen Company, 2013). A study of energy consumption has been carried out in 150 supermarkets in the north of Spain all included in this area. Two hundred technical projects of energy-consuming facilities in supermarkets have been considered. The most common facilities of a "type" supermarket have been defined, the services that these types of shops offer to the public have analysed the energy consumption in the different areas of the supermarket, sectorising the power dedicated to each purpose.

2.2. Distribution of energy consumption in a supermarket type

The consumption of a supermarket is distributed among the different areas of the supermarket, which includes the public courtyard, butchery, deli, fish market, greengrocers and bakery, as well as warehouses, engine rooms, changing rooms, public toilets and offices. To obtain a pattern of distribution of the electric energy consumed by the different areas identified in the supermarket associated with lighting, air conditioning and ventilation, cooling system, bakery ovens and domestic hot water, a statistical analysis of the consumption of electricity has been carried out, obtaining average values. The energy intensity (kWh/m^2 selling area) considering the surface and the use of the establishments has also been calculated.

2.3. Identification of measures to be taken and quantification of associated energy savings

In this study, a methodology has been used to analyse a series of saving and energy efficiency measures that can be appreciated in the different facilities and equipment identified in most of the establishments studied. These measures, more efficient and innovative, avoid unnecessary energy consumption or reduce the energy consumption necessary for the normal development of the supermarket activity. The savings achieved with these measures are obtained by comparing the actual results of energy consumption with those obtained by using the models of facilities traditionally used in Spanish supermarkets. In this way, measures are proposed for lighting, cooling, air conditioning, ventilation and bakery ovens.

2.3.1. Lighting proposals

As shown in Figure 1, in a supermarket-type commercial establishment, the energy consumption by lighting accounts for 29.68% of the total energy (Ríos, J. C., 2015). The traditional lighting model employs for fluorescent lighting and halogen spotlights and does not use on/off control systems. Table 1 shows the distribution of the average electricity consumption in the lighting of the supermarkets studied.

	Average installed power values (kW)	Percentage of electricity consumption (%)
Public area	51	67
Spotlight furniture and exhibition areas	5.5	7
Sections of fresh produce (butchery, deli, bakery, fishmonger and greengrocers)	11.5	15
Warehouses, cleaning rooms and garbage disposal	1.5	2
Machine room	1.1	1.5
Public toilets and dressing rooms	1.5	2
Entrance	0.5	0.5
Advertising lighting	3	4
Emergency lighting	0.6	1

Table 1. Average values of installed power and distribution of electricity consumption in the lighting of a supermarket.

In any commercial establishment, the lighting of the exhibition areas of the product being sold is a prominent element in marketing policies, so energy-efficient lighting solutions must consider the required lighting levels, together with the criteria of rationality in the use of energy. The implementation of energy saving systems, in the lighting of a commercial establishment, that have been evaluated are the following:

a) *The electrical installation*: it has been proposed to design the installation in such a way that the different areas of electrical consumption of the centre are efficiently segmented, allowing different ignitions depending on the needs of each area of the trade.

b) *The control systems of lighting on and off*: this section is closely linked to a design of the electrical installation sectorized by uses. Control of the ignition times, replacing the traditional switches with presence detectors, timers or programmers and light sensors, which facilitate the switch-off of the illumination when no person is in the illuminated area, as well as the ignition control now results indispensable.

c) Use of electronic ballasts: ballasts are elements which form part of some lighting system used in fluorescence lamps, mercury sodium vapor lamps or metal halide lamps, are used to keep the current flow stable. Replacing the traditional electromagnetic ballasts of fluorescent tube lamps for electronic ballasts reduce the energy consumption of the ballast itself.

b) *Lamps and luminaires*: it is very important to select the type of technology that best suits your business needs. Aspects such as the longer life span, the luminous flux of the lamps and luminarias, the consumed electric power and the colour of the light, are aspects that must be considered in the selection of the illumination. Light-emitting diodes or led lamps, constitute the latest novelty when considering low energy consumption. Due to the greater energy efficiency of this type of devices, the consumption is much smaller than in other types of existing lamps on the market. In addition, the life span of LEDs is much greater and the waste generated during its manufacture and disposal, after use, is less than with other type of lamp.

2.3.2. Refrigeration proposals

The refrigeration systems currently used in supermarkets are mainly two types:

- Each refrigerator unit has its refrigeration system with its independent charge of refrigerant, being fed directly by an electrical outlet of the electrical network of the supermarket.

- The installation has a specific machine room which is isolated from the rest of the supermarket and where multi-circuit or refrigeration plants, condensers, coolant reservoirs, etc. are located. Refrigerators, evaporators and pipes that conduct the refrigerating fluids from the engine room are located in the sales room.

The machine room model presents electrical consumption substantially lower than the sum of the consumption of each refrigerator unit with independent cooling. There is also the disadvantage of a greater load of refrigerant and as the length of the distribution pipes is greater there is an increased risk of leakage of the refrigerant to the atmosphere. The use of independent cooling cabinets with few meters of exposure and storage of refrigerated or frozen product is not advisable in shops. Centralized refrigeration systems or specific machine rooms result more efficient (Tassou, S. A. et al., 2011). The measures of saving in the energy consumption of the evaluated refrigeration installations are as follows:

a) The insulation for both cooling and freezing cabinets, that exposes the product in supermarkets, is more efficient by using cabinets equipped with doors and glass covers that prevent the cold loss. These cold losses not only increase the consumption of energy by the refrigeration plant, but also increase the consumption of electricity in the air conditioning systems, especially in cold periods.

b) The replacement of multi-circuit refrigeration facilities for refrigeration plants, allowing the differentiation of the cooling systems according to the service temperatures. The cold store of a supermarket consists of different cooling cabinets and chambers that store the product at different temperatures. There are chambers for frozen dough to be used in the bakery and furniture for frozen products that require temperatures below -20 ºC. There are also meat and fish chambers, as well as cooling cabinets that require temperatures between 0 ºC and 3 °C. One of the ways of saving energy has been to group the services into two independent refrigeration systems (Tassou, S. A., et al., 2011), one for temperatures below 0 ºC and one for temperatures equal to or above 0 ºC. As the cold requirement for the different cabinets differs according to the temperature, therefore it is not simultaneous, the separation of the service in several systems allows the consumption of less energy. Since in many occasions part of the compressors can be switched off, only working if necessary. In this way and due to the simultaneity coefficient of the installation, a smaller number of compressors will be needed to give service to all the chambers and cooling units included in a single cooling system. The cooling plants have been equipped with:

- Electronic expansion valves and floating condensation systems. The use of the floating condensation enabled to regulate the operation of the refrigerators as a function of the temperature used to transform the refrigerant as it passes through the condenser, from gaseous state to high pressure and liquid temperature. It has been favoured that the condensation pressures are lower when the temperature of the outside environment is lower. By means of the electronic control of the expansion valves, the cooling system was adapted to the temperatures in the condenser allowing the refrigerant fluid to change phase, thus, the lower the condensing temperature, the less the compressor works. Thus increasing the energy savings.

- Floating evaporation systems to electronically control the evaporation temperature of the cooling systems were installed. By using these systems, we achieved that when the cold demand permitted, it could increase the evaporation pressure, reducing the need for cold production in the evaporators and thus saving energy. These systems produced their greatest savings in periods when the establishments were closed to the public.

- Frequency inverter for compressors and condensers. That allowed to vary the frequency of feeding the fans of the compressors, evaporators and capacitors, depending both on the cold needs of the installation and the temperatures of the external environment within the condensation process. The speed of the fans did not have to be constant, but could vary depending on the different cold needs, allowed more fans to be operational at the same time at lower service speeds, saving on the energy consumption of the system.

2.3.3. Proposals for air conditioning and ventilation

It details the saving strategies that are proposed for their efficiency in the design of the commercial establishments analysed, improving the feeling of comfort for clients of these establishments, while at the same time it is possible to obtain a reduction in the cost caused by the electrical consumption of the air conditioning and ventilation.

a) Correct regulation of air conditioning equipment: the energy consumption of the air conditioning system increases between 5% and 8%, for each extra centigrade degree of heating or air conditioning (Ríos, J. C., 2015). Therefore, adequate regulation of the operating temperature, humidity and air intake parameters were essential in reducing the energy consumption of the installation.

b) Use of Inverter technology in air conditioning equipment: air conditioning equipment with inverter technology, allow the electronic regulation of the operation of the of the air-conditioning system compressors, depending on the comfort temperature set for the room to be air-conditioned. By regulating the power of the compressor motor, the traditional start-up and shut-down cycles of traditional air conditioning systems are avoided, avoiding the high energy consumption that occurs during the start-up periods of the equipment. It also increases the feeling of comfort by the user, as there are no sudden changes in the temperature of the air-conditioned room. Such equipment can operate at lower outdoor temperatures while maintaining its yield and the distribution of air within the premises is more uniform.

c) Exploitation of the enthalpy of outdoor air: a savings system which could be interesting and whose use is compulsory in certain types of air conditioning installations, is the so-called free cooling. It consisted in taking advantage of the air from the outside of the trade to cool the supermarket, partly avoiding the operation of air conditioning systems and thus saving energy. To carry out this, sensors were necessary to register the enthalpy of indoor and outdoor air of the premises and by means of an electronic control to allow the entrance of air from the outside to the interior of the supermarket, passing through a filtering of previous impurities, when conditions were favourable. The free-cooling system was highly recommended in the following cases:

- Temperature of the air outside the supermarket is lower than the temperature in the interior, as the thermal load stored inside the supermarket is high. With the free-cooling system, air was pumped into the supermarket, with no need to be cooled, this reduced the temperature of the store.

- The temperature of the air outside the supermarket is higher than the temperature of the air expelled by the air conditioning system. In these cases, by means of a system of gates, the air that was to be expelled was used to be recirculated to the air conditioning equipment and to reduce the energy consumption in the cooling process.

d) Installation of heat recuperators in air conditioning systems: this enables the use of air energy from the air conditioning process which normally is totally evacuated outside the supermarket to preheat the cold air that the equipment takes from outside. In this way, the energy consumption needed to condition the interior of the establishment was reduced. The heat recovery system was more efficient when there was great difference in temperature between the air-conditioned environment of the supermarket and the outside environment.

e) Energy utilization of the residual hot air from refrigeration condensation to increase the efficiency of the air conditioning: in the processes of industrial cold generation residual hot air was obtained, which, instead of being totally discharged outside the supermarket, was partly recovered to improve the performance of the HVAC (Heating, Ventilation and Air Conditioning) equipment and thus reduce its energy consumption. In order to carry out this, the external air conditioning units were located inside the same engine room as the industrial cold condensing units that feed the islands, cabinets and refrigerated murals, which generated hot air both in summer and winter. The applied and analysed design placed motorized dampers in the air discharge ducts of the condensing units of the refrigeration system, so that when the temperature of the engine room fell from 10 ºC the hot air was discharged in the room itself where the air conditioning units are located. This, on the one hand does not penalise the condensation of the cooling system, while on the other hand, improves the conditions of air intake by the air conditioning equipment, as they achieved increases in the temperature of air intake on the order of 10 °C. In this way, the COP (Coefficient of Performance) of the installation was increased, therefore, the electrical consumption of the heat pumps decreased. In winter, when the temperature at which the air pumps take the air was rather low, then this system was highly recommendable (Ríos, J. C., 2015).

2.3.4. Proposals in bakery ovens

In the bakery shop of an average supermarket, two electric ovens with an average power of 30 kW each are installed (Ríos, J. C., 2015). These ovens are used for baking bread, pastry and other baked goods that are sold daily in the establishment. During the baking of the bread dough, water is added to the oven chamber to maintain the dampness of the dough. Due into the high temperatures, which are generated inside the oven, some of the water is turned steam. To collect the excess water, from the baking process, there is a steam evacuation system. The steam passes through a vapor condenser, which basically consists of a cold-water basin placed in the oven. A system has been designed in which the heat of the steam is used to preheat domestic hot water, destined to the consumption in the supermarket. This enables to heat water, for later consumption, in a more economical way and reduce the clean water consumed in the supermarket. As supermarkets are usually located in the commercial lowlands of existing buildings, the generation of domestic hot water is usually not supported by any source of renewable solar thermal type plates. Therefore, this system was a clean source of thermal energy, an energy saving generator and also avoided clean water waste.

3. Results

The electricity consumption of supermarkets depends on the establishment format, the age of the establishment, the geographical area in which it is located, the commercial practices implemented, such as opening and closing times, and the equipment used for the preparation, conservation and food exposure. In the supermarkets studied, electrical consumptions ranged between 440 and 600 kWh/m^2 were observed. Table 2 shows the average electrical consumption obtained in the supermarkets analysed, depending on the size of their shopping area.

EXHIBITION AND SALE AREA (m^2)	ELECTRIC CONSUMPTION (kWh/m^2)
400-1000	600
1000-1500	540
1500-2000	490
2000-2500	440

Table 2. Electric consumption of a supermarket depending on the area of exposure and sale.

Figure 1 reflects the average percentages of electric consumption of the different areas of consumption of the supermarket. The refrigeration systems being those where more electrical energy with a percentage of around 50% was required, followed by the lighting that consumes around 30%. The other consumptions are dedicated to air conditioning, bakery ovens, and the consumption of small equipment.

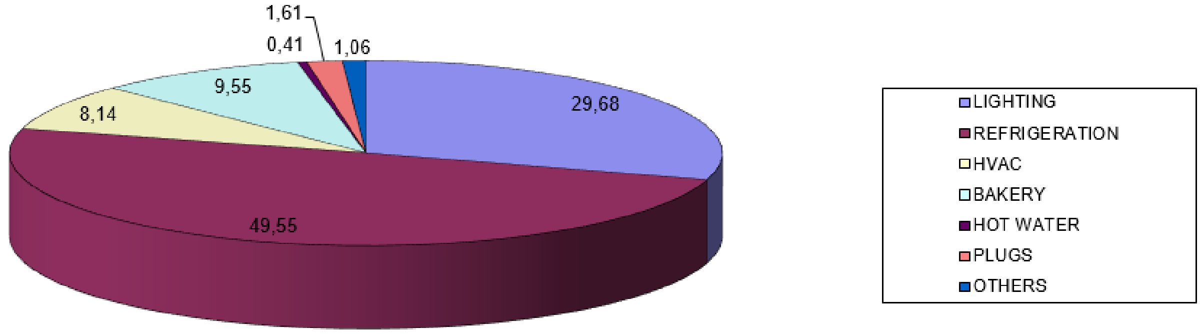

Fig. 1. Percentage distribution of electricity consumption in a supermarket.

The investment required to implement the evaluated measures in a large supermarket, with about 2000 m^2 of floor space, amounts to 160 k€. The amortization period of the investment was 4 years, achieving a reduction in energy consumption of 475,800 kWh/year, a reduction of greenhouse gas emissions of 161 tCO_2/year and a saving of 61 k€/year. The GHG emissions factor used was the energy mix of 2013, according to official values issued by the National Energy Commission of Spain, which was 0.34 $kgCO_2$/kWh (IDAE, 2013; Centro Español de Metrología, 2014) and the price of electricity at the time of this analysis of 0.13 €/kWh. Following, different comparative analyses are presented, which allow to classify the impact of the different proposed measures, the improvement of energy efficiency, in commercial installations according to economic, temporal and environmental parameters. In this way, it is intended to facilitate the decision making at the time of adopting a new improvement, in the function of the values obtained per square meter of useful commercial area. The actions of the application of lighting control systems (presence detectors) in the areas of occasional and restricted occupancy and of the use of the illumination carried throughout the supermarket are concentrated on two unique measures. Energy saving achieved by using the residual heat of bakery ovens to reduce energy consumption in domestic hot water amounts to 2700 kWh/year, with savings in emissions of 918 $kgCO_2$/year. The investment required to implement the measure amounts to 2000 €, generating economic savings of 440 €/year, with a payback period of less than five years.

Table 3 details the measures to improve energy efficiency, reflecting the savings of energy consumption by the surface of the supermarket.

DESCRIPTION OF THE MEASURES	ENERGY SAVING kWh/yearxm^2
Temperature control for air conditioning (per °C of variation)	0.65-2.41
Detectors of presence in zones of occasional and restricted occupation	5.57
Sensors with photoelectric cells in buildings with skylights	19.46
Sensors with photoelectric cells in commercial premises of residential buildings	5.34
Free-cooling and air conditioning heat recovery systems	1.50-6
Electronic ballasts	13.31
Air conditioning with inverter technology	17.05
Closed cooling cabinets, with doors or glass covers	39.17
Use of residual hot air from refrigeration increasing the performance of the air conditioning	1.58

LED lighting throughout the supermarket	60.78
Cooling plants replacing multi-circuit installations	62.30

Table 3. Comparative analysis of savings obtained with the application of measures to improve energy efficiency in a supermarket.

Figure 2 shows the different measures of energy efficiency improvement analysed in the supermarket, reflecting the percentages of reduction of CO_2 emissions achieved with each measure.

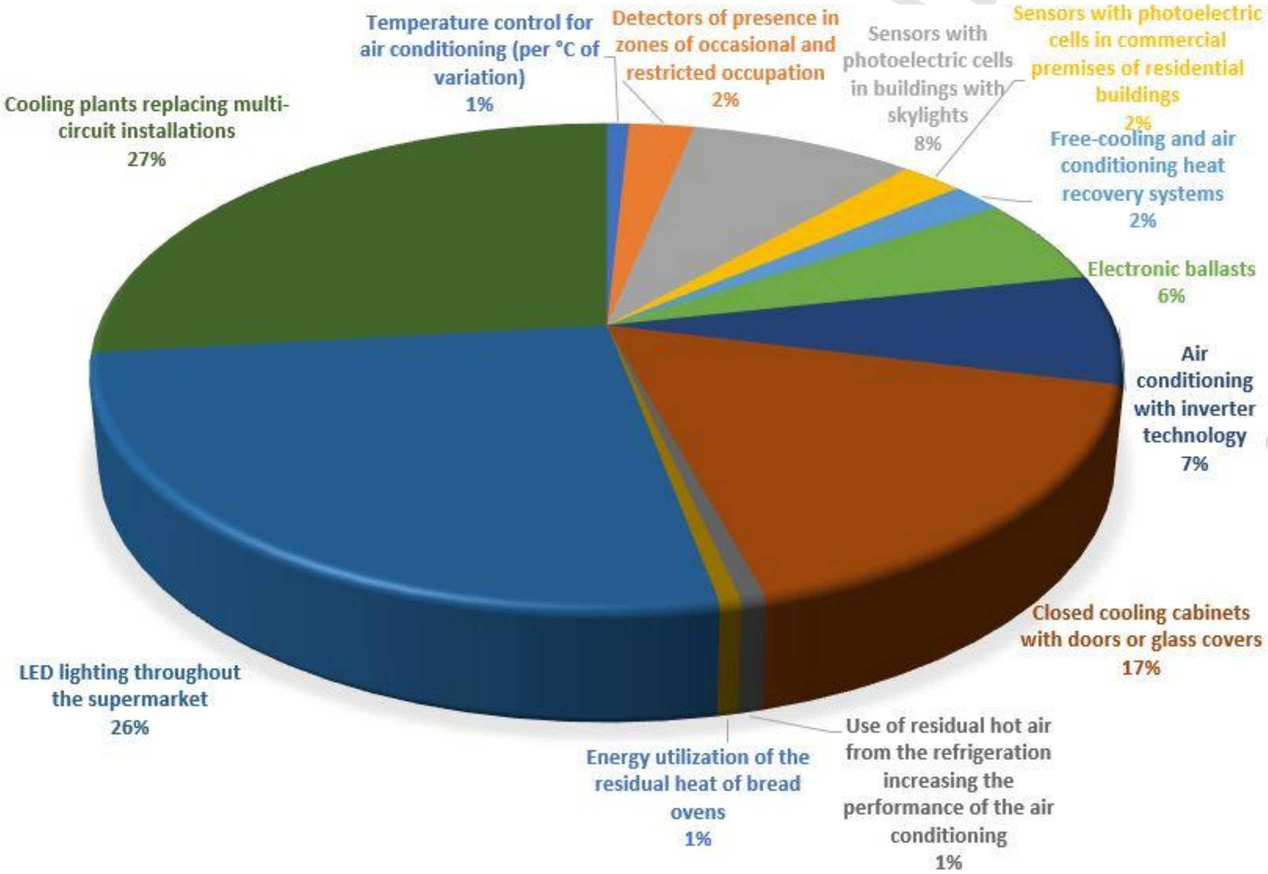

Fig. 2. Percentage of reduction of CO_2 emissions obtained with the application of measures to improve energy efficiency in a supermarket.

Table 4 details the different measures of energy efficiency improvement analysed, reflecting the necessary investment, economic savings and periods of recovery of investment or amortization. The measures are arranged from shortest to longest repayment periods. Within the same year of amortization are arranged from less to greater economic investment needed to implement the measure. In this way, the table begins with the measure which requires less investment and is amortizable during the first year of its commissioning.

DESCRIPTION OF MEASURES	INVESMENT €/m^2	ECONOMIC SAVINGS €/yearxm^2	AMORTIZATION PERIOD years
Temperature control for air conditioning (per °C of variation)	0	0.08-0.31	1

Detectors of presence in zones of occasional and restricted occupation	0.13	0.73	1
Sensors with photoelectric cells in buildings with skylights	2	2.53	1
Sensors with photoelectric cells in commercial premises of residential buildings	3.20	0.69	1
Free-cooling and air conditioning heat recovery systems	0.49	0.20-0.78	2
Electronic ballasts	2	1.73	2
Air conditioning with inverter technology	7.30	2.22	3
Closed refrigerated furniture, with doors or glass covers	11.20	5.09	3
Use of residual hot air from refrigeration increasing the performance of the air conditioning	0.73	0.20	4
LED lighting throughout the supermarket	25.22	7.89	4
Cooling plants replacing multi-circuit installations	26.79	8.10	4

Table 4. Comparative analysis of the necessary investment, the period of amortization and the economic saving obtained with the application of improvement measures of the energy efficiency in a supermarket.

4. Discussion

Supermarkets have a high capacity to contribute to the mitigation of climate change due to the reduction of their emissions as a result of energy saving. The commercial sector presents a high consumption of energy in the development of its activity. It deals with the supermarket sector in a clear business expansion with a marked growth in energy expenditure and production of greenhouse gases. The possibility of saving and improving energy efficiency in the reforms and constructions of the new commercial establishments is evident. The adoption of improvements in the design of the commercial establishment and its facilities and even with the use of certain residual energies, vary in degree of profitability depending on whether they are adopted for the new or renovated comercial premises. The adoption of measures to improve energy efficiency, novelties in the design of facilities and the physiognomy of trade have been, for years, slowed down by the fear of modifying commercial patterns deeply rooted in the culture of the different commercial chains. At present, the increase in the price of energy, which penalizes the benefits obtained, the increasing competition in the sector, which motivates the adoption of improvements in design and comfort and the greater importance given by customers to the environmental sensitivity of commercial firms, has facilitated the adoption of measures in establishments, aimed at achieving savings in energy consumption and also the corporate image improvement. The study of the results obtained in the construction and start-up of the trades described, allows to obtain according to the fields of activity the following conclusions:

- To reduce the energy consumption caused by the heat transfer between the trade and its environment, an efficient design of the establishment with high levels of thermal insulation is essential.

- The reduction of energy consumption in lighting installations must be based on three complementary aspects: firstly, a correct architectural design of the commercial space will allow better use of natural light, for which it is necessary that the installations are carried out in phases, with independent electric circuits, allowing to have zones lit and others switched off depending on the intensity of natural light that can penetrate at any moment into the trade. Secondly, unnecessary energy consumption should be avoided by the installation of presence detectors that keep the light on only when people are detected in the room or timed pushbuttons that allow the lighting time of the luminaires to be regulated. It is recommended to install it both in new buildings and in existing supermarkets, it is especially advisable to use these systems in warehouses, public toilets and changing rooms. Use of programmers of time of on and off or light detectors for the ignition of the advertising signs placed outside the premises. Thirdly, we have analysed the replacement of traditional lighting with fluorescence, incandescent or halogen lamps for lighting with electronic ballast and lamps of low consumption, taking into account the advantage that the new technology LED has over other types of lighting, paying special attention to the selection of a quality product, bearing an energy label, tested tests and marks that guarantee the technical characteristics. Reaching the greatest savings in the sales area, due to the large area of action, with optimal values in the relationship between the savings obtained and the investment required. One of the most important factors of this type of technology is its long service life span, which makes maintenance costs lower. Another positive aspect in addition to its lower energy consumption is the absence of heat transfer to the environment, which avoids increases in consumption by the air conditioning systems in the warmer periods of the year.

It is highly desirable to replace the old air conditioning systems with constant compressor in high-efficiency equipment equipped with inverter technology in all newly built premises. It is also convenient to replace the electric air curtains at each entrance door to the supermarket for internal units of ducts to perform the functions of air sweeping and zoning the service. On the other hand, the use of the hot air generated by the condensing units of the industrial cold installation, increasing the performance of the air-conditioning units and decreasing the energy consumption and the production of CO_2, is more efficient in the more severe temperatures in the cold periods of the year, however its installation is interesting in all establishments. The design of the air conditioning in zones avoids the transfer of air from unheated areas to the heated areas, allowing the different machines to work independently, increasing the control of the different temperature needs of the areas to be climatized. These zones must have a correct regulation of the operating temperatures, the parameters of humidity and air intake, since, for each extra degree centigrade of heating or air conditioning, the energy consumption increases by 5-8%. For this purpose, the use of home automation management systems, which also regulate the periods of on and off, avoiding unnecessary consumption are recommended. Positive air pressure must be favoured to prevent air from being easily introduced from the exterior into the interior of the trade and thus increase the need for air conditioning.

It is advantageous to incorporate air heat recovery systems from the air conditioning process, to preheat the cold air that the equipment takes from the outside, as well as the use of free cooling systems that take advantage of the outside air of the trade to cool the supermarket. This reduces the consumption of energy needed to condition the interior of the establishment, reaching at certain times of the year energy savings of 20%. From the analysis of the refrigeration systems, it is concluded that there is a need to reduce the use of autonomous cooling cabinets, due to its high consumption of energy and heat transfer to the supermarket, the advantage of using centralized systems and differentiated by temperature ranges, whenever space is available outside the trade, axial capacitors located outdoors are advisable, as they consume much less energy than the centrifuges. Make sure that the machine room is close to the refrigerating units, in order to avoid loss of load and to reduce the risk of leakage of refrigerant, likewise for the cold rooms and the distribution pipes to the furniture, the machine room must be well thermally insulated, so as not to penalize the consumption of air conditioning.

Avoid old multi-circuit installations, since they have high energy consumption and have more possibilities of leakage of refrigerant and replace them for refrigeration plants in which expansion valves with electronic regulation, condensation and floating evaporation, compressors and capacitors with frequency inverters are employed.

The suitability of the use of cooling cabinets equipped with glass doors and lids has been proven, reducing energy losses, with an average savings of 25% in energy consumption and an increase in sales of refrigerated products.

It has been found that in all existing establishments, where space is available to locate a water tank of 300 litres and in all newly constructed supermarkets, it is interesting to have an environmentally friendly and even economical system of the heat from the steam generated by the bread ovens. In addition to reducing the energy consumption required to heat locally consumed domestic hot water, the consumption of drinking water from the network and the production of CO_2 is reduced.

As future research and work lines, the development carried out in this article can be considered to obtain the savings achieved in the hypermarkets and supermarket formats of smaller size, as well as the analysis of the savings obtained according to the physiognomy of the commercial establishments in search for optimal energy consumption designs. Expanding the actions of energy saving and efficiency to the whole value chain, including the effect of the transport of goods, the emissions generated by the treatment of waste from commercial establishments and the labeling with the CO_2 generated by the products marketed.

5. Conclusions

The investment required to implement the measures described, in a large supermarket with about 2000 m^2 of floor space, was 164,600 €. The amortization period was four years, resulting in a reduction in energy consumption of 475,800 kWh/year, a reduction of GHG emissions of 161,770 kg CO_2/year and a saving of 61,850 €/year.

If the intervention capacity with the savings measures described in this work reached 50% of the large supermarkets existing in Spanish territory, it would allow savings compared to the traditional configurations in the design of this type of commercial establishments of 98.960 M€/year, a decrease, in energy consumption of 761 MWh/year and would avoid the generation of 258,832 ktCO_2/year. This would be equivalent to 14% annually of the need to reduce GHG emissions generated by diffuse sectors of Spain, agreed in "Objective 20-20-20" by the member states of the European Union by the year 2020. Leave the car at home 1,726 Mkm/year (considering that an average vehicle generates 150 gCO_2/km) or planting 26 million trees (the United Nations Framework Convention on Climate Change (UNFCCC) estimates that a tree absorbs an average of 10 kg CO_2/year).

With the adoption of the measures indicated, the ecological footprint of the product sold in supermarkets would be reduced and a more environmentally friendly, sustainable development aimed at the economy for the common good would be achieved.

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