Sustainable Production and Consumption xx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Sustainable Production and Consumption

journal homepage: www.elsevier.com/locate/spc

Research article

Analysis of the potential of Spanish supermarkets to contribute to the mitigation of climate change

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ARTICLE INFO

Article history:
Received 13 September 2017
Received in revised form 13 February 2018
Accepted 18 February 2018
Available online xxxx

Keywords:
Supermarkets
Energy saving
Greenhouse gas emissions reduction
Heat recovery
Residual fluid

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 metre 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.

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 et al., 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 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 et al., 2014; Asdrubali et al., 2013), universities (Lukman et al., 2009; Sartori and Hestnes, 2007), apartment buildings (Gustavsson et al., 2010; Blengini, 2009) and houses (Asif et al., 2007; Bribián et al., 2009; Hacker et al., 2008; Monahan and Powell, 2011). As far as the authors are aware, only one study has been conducted in the UK supermarket sector (Tassou 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 Éficiència Energètica de Catalunya, 2012). Supermarket-type establishments have been consolidated in all developed countries and are experiencing rapid growth in

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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

https://doi.org/10.1016/j.spc.2018.02.003
2352-5509/

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, 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 et al., 2016). Business model innovation is increasingly recognized as a key to delivering greater social and environmental sustainability in the industrial system (Bocken et al., 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 renovations 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 catalogue of good practises 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 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, sectorizing 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 Fig. 1, in a supermarket-type commercial establishment, the energy consumption by lighting accounts for 29.68% of the total energy (Ríos, 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.

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 vapour lamps or metal halide lamps, are used to keep

Please cite this article in press as: Ríos J.C., Roqueñí N., Analysis of the potential of Spanish supermarkets to contribute to the mitigation of climate change. Sustainable Production and Consumption (2018), https://doi.org/10.1016/j.spc.2018.02.003.