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Enhancing energy efficiency in supermarket refrigeration systems through a robust energy performance indicator

Salvador Acha [a,*], *Yujia Du* [b], *Nilay Shah* [a]

[a] *Centre for Process Systems Engineering, Department of Chemical Engineering, Imperial College London, London SW7 2AZ, UK*
[b] *Energy Futures Lab, Imperial College London, London SW7 2AZ, UK*

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ABSTRACT

Supermarket chains require benchmarking and analysing refrigeration performance in order to manage their energy efficiency investments. This paper contributes in robustly assessing refrigeration system energy and carbon performance in which commonly believed drivers are used to conduct correlations. Based on this, refrigeration connected load, store opening hours and external temperature were found to construct a more representative energy performance indicator (EPI) than other metrics. By using such an indicator, it is possible to identify poor performing systems from an estate portfolio and thus select sites suitable for energy saving measures. Furthermore, energy impact from introducing natural refrigerants is examined using empirical data from a UK supermarket chain. It was found that CO_2 systems have different seasonal performance than HFC systems, nonetheless on an annual basis no system has a clear edge over another. Lastly, other initiatives such as cabinet night blinds and suction pressure optimisation achieved 10% and 7% energy reduction respectively.

Amélioration de l'efficacité énergétique dans les systèmes frigorifiques de supermarché grâce à un indicateur de performance énergétique robuste

Mots clés : Indicateur de performance énergétique ; Rideaux de nuit ; Optimisation de pack ; Conduites des systèmes de conditionnement d'air split ; Efficacité énergétique de supermarché ; Analyse de système frigorifique de supermarché ; Intensité d'échange ; Analyse de coût sur le cycle de vie ; Frigorigène ; Système de conditionnement d'air split

* *Corresponding author.* Centre for Process Systems Engineering, Department of Chemical Engineering, Imperial College London, London SW7 2AZ, UK. Tel.: +44 (0) 7838818934; fax: +44 (0) 20 7594 3379.
E-mail address: salvador.acha@ic.ac.uk (S. Acha).
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Nomenclature

BAU	Business As Usual
CDD	Cooling Degree Days
CO_2	Carbon Dioxide
CL	Connected Load
CRC	Carbon Reduction Commitment
EPI	Energy Performance Indicator
EUI	Energy Utilization Indicator
FA	Floor Area
GHG	Greenhouse Gasses
GWP	Global Warming Potential
HFC	Hydrofluorocarbons
HVAC	Heating, Ventilating, and Air Conditioning
kW	Kilowatt
kWh	Kilowatt-hour
Po	Pressure Optimisation
SFA	Sales Floor Area
R^2	Correlation
TEC	Total Energy Consumption

1. Introduction

Supermarkets are among the most energy intensive buildings. In the UK, they are responsible for 3% of the total energy consumption and 1% of the total greenhouse gas (GHG) emissions (The Carbon Trust, 2010). Specifically, the refrigeration sector accounts for 30% to 60% of the total electricity use in food retail buildings and thus can be attributed a large proportion of the indirect carbon emissions. In addition, direct carbon footprint from refrigerant leakage solely accounts for about 40% of the total carbon footprint of a store, owing to the use of hydrofluorocarbons (HFC) refrigerants which have very high global warming potential (GWP) (Tassou et al., 2011).

In line with the GHG emission targets set by the UK government (Department of Energy & Climate Change et al., 2013), major food retailers including Asda, Tesco, Sainsbury's and Morrisons have published sustainability plans with commitments to reduce operational GHG emissions (Asda Stores Limited, 2012; J Sainsbury plc, 2012; T. PLC, 2013; Wm Morrison Supermarkets PLC, 2011). However, a review of these reports suggests programmes are mainly focused on on-site renewable generation and carbon offsetting activities, which often have higher capital investment and positive marginal abatement cost (Caritte et al., 2013). Alternatively, a much more cost effective way to mitigate carbon emissions is for these businesses to manage their energy consumption more efficiently, which has been discussed in Geller et al. (2006), Laustsen (2008), Mills (2010), and Perez-Lombard et al. (2008) and supported by regulations such as Carbon Reduction Commitment (CRC) Energy Efficiency Scheme and Display Energy Certificate (Department of Energy & Climate Change, 2011; Environmental Agency, 2013). On account of the competitive environment of supermarket business, stores are often opened at a fast speed without correct commissioning, resulting in issues regarding equipment performance, energy metering and system control. This combined with a lack of energy awareness and communication among facility managers, maintenance team and store staff, makes many supermarkets perform poorly in terms of energy efficiency, which could go unnoticed for a prolonged time before being acknowledged (Acha et al., 2013; Escrivá-Escrivá, 2011; The Carbon Trust, 2012). This is particularly relevant for refrigeration systems, as the biggest energy user they are subject to large energy reduction potential as pointed out in Bahman et al. (2012), Little (1996), Tassou et al. (2011), and The Carbon Trust (2010). Thereby, low cost sustainability initiatives among supermarkets should focus more on improving the energy performance of their existing systems.

The purpose of supermarket refrigeration is to keep the temperature of the refrigerated goods at the designated level so as to slow down the rate of deterioration of perishable food or to keep cold beverages chilled (Food Standards Agency, 2007). A refrigeration system utilises the evaporation and condensation of refrigerants to achieve the transfer of heat from the refrigerated space (low temperature) to a heat sink (high temperature), which is normally the air outside the building (Westphalen et al., 1996). Common systems utilise HFC refrigerants which are potent GHGs. However, due to the concern of climate change, natural refrigerant systems are receiving more attention in recent years (Bansal, 2012; Cecchinato et al., 2012; Sawalha, 2008; Suamir et al., 2012).

Most of the energy consumption by refrigeration systems lies on refrigeration packs (racks of compressors) and is mainly influenced by two aspects: a) the amount of heat gained in cabinets, and b) the rate of heat rejected at condensers. The first one is affected by the designated cabinet temperature requirement, the rate of product replacement, cabinet aisle temperature, and indoor humidity. The second one is dependent on the surface area of the condensers, the rate of air flow and outdoor air temperature (The Food and Drink Federation, 2007).

This paper focuses on different steps to achieve refrigeration energy reduction in food retail businesses, as illustrated in Fig. 1. The work begins with a characterisation of refrigeration energy demand by detailing main factors that drive it, such as opening hours and trading intensity. These factors were then analysed for correlation with refrigeration energy demand and the most relevant were chosen to construct the Energy Performance Indicator (EPI), which was then used to rank a group

Fig. 1 – Steps of energy reduction planning for retail buildings.