Energy and Buildings 68 (2014) 172–182

Contents lists available at ScienceDirect

Energy and Buildings

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

An empirical study of electricity and gas demand drivers in large food retail buildings of a national organisation☆

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ARTICLE INFO

Article history:
Received 20 April 2013
Received in revised form 4 September 2013
Accepted 9 September 2013

Keywords:
Supermarkets
Food retail
Energy consumption
Empirical analysis
Energy end-use demand
Regression

ABSTRACT

Food retail buildings account for a measurable proportion of a country's energy consumption and resultant carbon emissions so energy-operating costs are key business considerations. Increased understanding of end-use energy demands in this sector can enable development of effective benchmarking systems to underpin energy management tools. This could aid identification and evaluation of interventions to reduce operational energy demand. Whilst there are a number of theoretical and semi-empirical benchmarking and thermal modelling tools that can be used for food retail building stocks, these do not readily account for the variance of technical and non-technical factors that can influence end-use demands.

This paper discusses the various drivers of energy end-uses of typical UK food retail stores. It reports on an empirical study of one organisation's hypermarket stock to evaluate the influence of various factors on annual store electricity and gas demands. Multiple regression models are discussed in the context of the development and application of a methodology for estimating annual energy end-use demand in food retail buildings. The established models account for 75% of the variation in electricity demand, 50% of the variation in gas demand in stores without CHP and 77% of the variation in gas demand in stores with CHP.

1. Introduction

Currently in the UK there are more than 9000 food retail stores with sales floor areas of more than 280 m^2. Most of these stores are operated by the four largest supermarket multiples: Tesco (29.7%), ASDA (17.7%), Sainsbury's (17.0%) and Morrisons (11.8%) [1,2]. The remaining 23.8% are shared by smaller chains such as Waitrose and Iceland [2]. The energy consumption of these stores is important for the profitability of their organisation as their operating margins are generally low at an average of 4.2% in 2005 [3]. Additionally the consumption is important for national CO_2 emission targets where the food retail sector accounts for more than 3% of the total electricity consumption in the UK and approximately 1% of total UK CO_2 emissions [4]. Considering both these issues, along with the relative homogeneity of management structures and energy end-uses in food retail organisations, minimising and managing energy demand is an important opportunity for both business competitiveness and national targets.

Strategic financial planning in the sector's large organisations typically takes account of future demands for gas and electricity. Future demands and financial implications are estimated for different time frames, such as the months or year ahead, and account for increasing energy prices, changes in store sizes and reductions due to investment in energy efficiency initiatives applied across an organisation's building stock. Projected energy demands are used for multiple purposes including the identification of the operational efficiency of individual stores indicating generally where inefficiencies lie and when faults occur. With such multiple purposes and scope of applications, the energy demand tools-developed to estimate future demands-need to be able to provide insights on many technical and non-technical factors that influence gas and electricity demand. The aim of this study is to identify and interpret the implications of key factors influencing the aggregated annual electricity and gas demand, in a sample of large food retail stores of a national food retail organisation. This

Abbreviations: AHU, air handling unit; CDD, Cooling Degree Days; CHP, combined heat and power; HDD, Heating Degree Days; HVAC, heating, ventilation and air-conditioning; MPAN, Meter Point Administration Number; SFA, sales floor area.

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http://dx.doi.org/10.1016/j.enbuild.2013.09.015

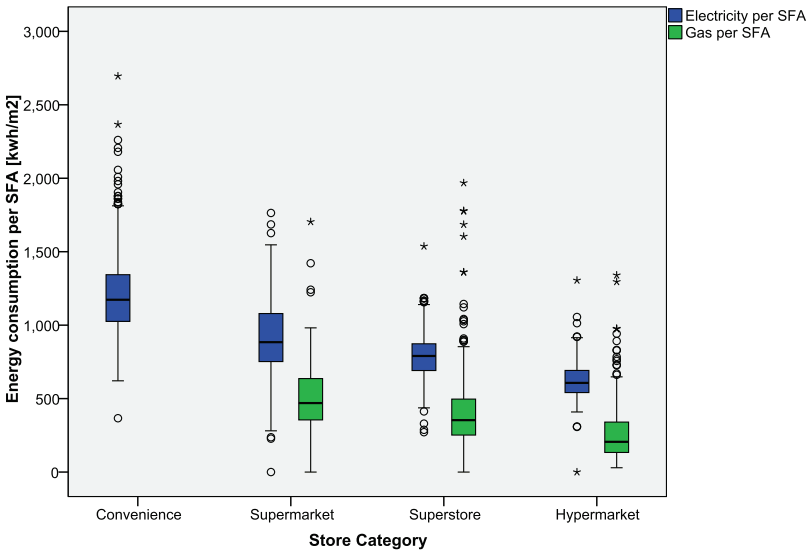

Fig. 1. Electricity and Gas Intensity of for each store category.

Table 1
Retail store categories.

Category	Sales floor area (m^2)
Convenience store	<280
Supermarket	280–1400
Superstore	1400–5750
Hypermarket	>5750

will inform the further development of new energy budgeting and management tools for the organisation.

Related studies reported in the literature tend to focus on detailed levels of analysis and factors to establish causal links with end-use demands, for example [5–8]. This study backtracks somewhat to investigate demands and drivers at the aggregated annual level. In doing this, causal links are suggested where their relative significance is evaluated in the context of the range of functions of such models.

The organisation's retail building stock studied here is comprised of four different store formats, which can be aligned with the common categories based on sales floor areas as shown in Table 1 [9]. Whilst there is a high degree of heterogeneity across the store categories, this reduces when inspecting the stock within each category. Store formats differ in terms of size, location, proportion of total floor area for different functions (e.g. frozen food, non-food, home delivery, back office, stores), external lighting provision, in-store services (e.g. in-store bakery, fish/meat/delicatessen counters), opening times, building type (e.g. new build, redevelopment from previous different use) and on-site services (e.g. petrol station, car wash, home delivery, click and collect). As a result of these differences the composition and intensity of energy end-uses varies across the store categories but have comparatively less within each category.

Convenience stores are the most common category of stores in the organisation's stock, numbering more than 2000 (more than 50% of the total stock) [10]. They are usually found close to the consumer; either located within a town centre, close to apartment blocks, or as part of petrol filling stations. Their product ranges, and thereby also in-store services, depend on the local market demand. They are typically closely related to their location in urban centres and are mostly chilled-food dominated as they bring the classic lunch meal to their customers. These stores are electrically heated.

Supermarkets are the most individual store category. These stores are usually found within town centres and the building types vary from new, purpose built stores to refurbished buildings such as churches. Similar to superstores these stores include a mixture of in-store services, depending on their location and market demands. Typically they have an in-store bakery but not any fish, meat or delicatessen counters and are a mixture of gas and electrical heating with some having a small number (i.e. one or two) ceiling mounted, cassette type cold air recirculating units for local cooling.

Superstores are the second most common store category, and are found closer to the consumer, usually at the edge of the town centre, and are typically built for purpose. In rare cases some of these stores were acquired from previous owners and refurbished to meet the organisation's design standards. These stores include a mixture of in-store and on-site services, as well as a mixture of construction types, as they can be timber framed, or simple steel framed retail sheds. The majority of these stores are heated by a central gas system, and approximately 15%[1] of them have a combined heat and power (CHP) plant. Cooling is provided by centralised constant volume air conditioning systems.

Hypermarkets are the largest retail stores within the studied stock. These are usually located outside town centres - normally at the edge of the town- and are designed for purpose, thereby maintaining the organisation's and national building standards at the time of construction. Being the largest stores of the stock, they contain the full range of in-store and on-site services, such as petrol filling station, in-store bakery, fish; meat & delicatessen counters as well as significant non-food sales area, including clothing departments and electronics departments. Although all hypermarkets have similar product lines, the proportional composition of these varies. In general, these stores have similar on-site electrical and gas end-uses; therefore have a lower relative variance in average Electricity and Gas Intensity. Approximately 75% of all hypermarkets are open 24 h a day. The majority of these stores are heated by a central gas fired low temperature hot water (LTHW) system with 15% having a CHP engine installed that generates electricity and heat. Cooling is provided by centralised constant volume air conditioning systems with vapour compression chillers.

This study is the first stage of a larger project, which seeks to develop an energy-forecasting tool for the organisation's entire stock of food retail buildings. This study focuses on hypermarkets

[1] Iain Black, Mechanical Engineering Manager, Tesco PLC, Personal communication, 2/10/2012.