The University Of Sheffield.

E-Futures

Research Councils UK Energy For a Low Carbon Future

Mini Project No 2

Acquiring data for energy modelling of supermarkets

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1. Acquiring data for energy modelling of supermarkets

The goal of this mini project was to have a closer look at the available data for the modelling of the energy performance of supermarkets. The result of this study is intended to form the basis not only for simple supermarket models in the next mini project, but also for identifying the more specific data requirements for the PhD project.

This report summarizes the work done during this project including a description of the methodology developed. The second part of the report is on preliminary data analysis, which is then commented on in the final section headed 'conclusions', which also suggests further work.

1.1 Methodology

Based on a preliminary literature review and discussion with the supporting company, which specialises in energy saving in supermarkets, and the academic supervisor for this mini project the model in Figure 1 was developed. This model aided the decision of what data to collect and how to approach this selection task. After deciding which store to concentrate on, the store was visited and data from the installed sub-meters was collected.

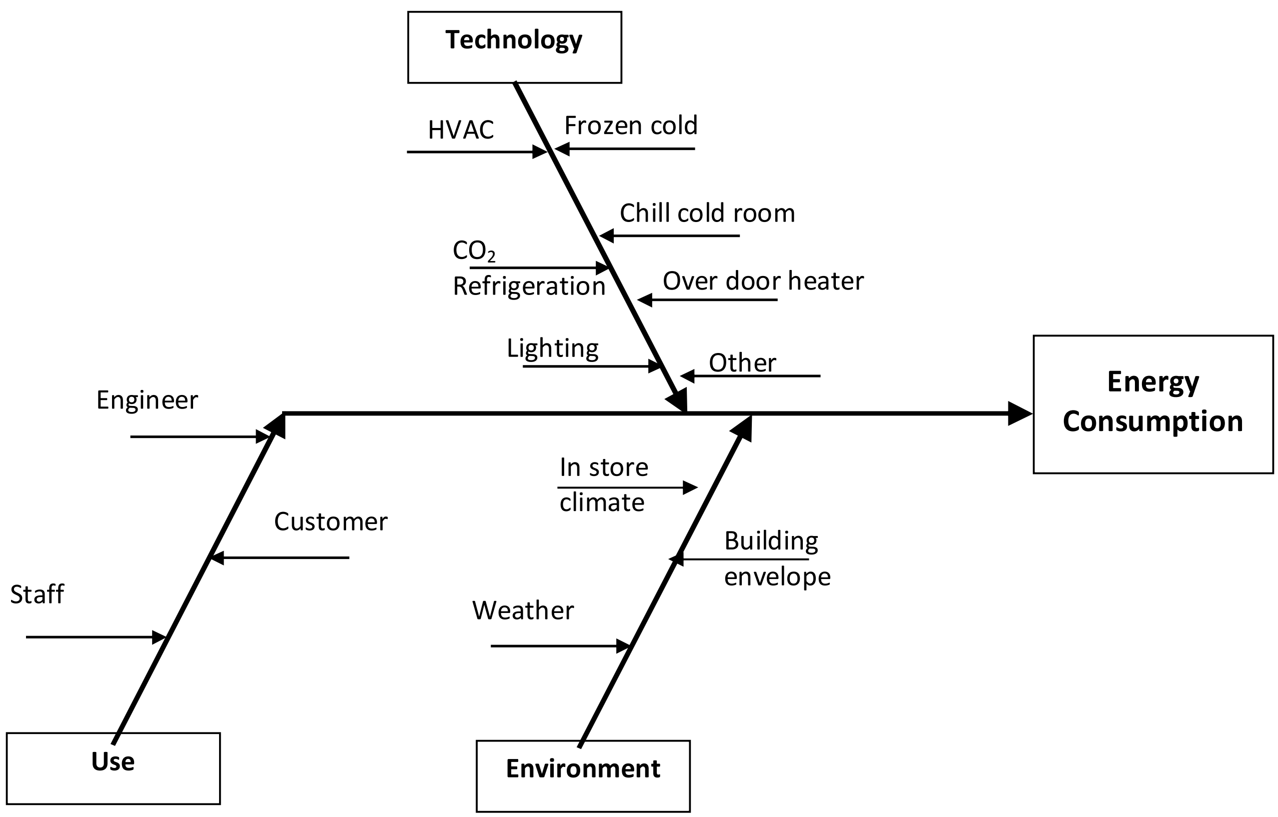

Figure 1: Factors influencing energy consumption

As Figure 1 indicates, the factors which influence the consumption of energy were divided into three categories: Technology (i.e. what type of equipment is installed), use (i.e. how the equipment is used and maintained) and environment (although the in-store climate is affected by the outside weather and the building envelope, other factors impact on it as well). Considering these factors lead to the following questions, which helped with choosing an appropriate site:

- Is sub-metering available?
- What sort of weather data is available?
- Is technical data available with respect to electricity, gas and water consumers (i.e. equipment)?
- Is behavioural data available relating to customers, staff and management?
- What is the attitude of the store management toward such an investigation?
- Is the store within reasonable travel distance?

To keep a record of the progress a simple database was created and the survey was started with an internet search on which stores were within 2h travel time. This identified 68 possible sites. In addition to the location and travel distance, the store type and size were also recorded as this was an indication of the complexity of the modelling task later on. After that, a website which allows access to available sub-meter data was surveyed and the results were also recorded in the database. A discussion with an engineer of the supporting company also indicated that there was a further site with installed sub-metered not mentioned on the energy data website. Next, the availability of technical documentation was examined by logging onto another web resource, which should hold all the technical documentation for a given supermarket. Although there was a lot of information available, not all was filed correctly and some important technical information was not available from it at all. The database was discussed with the academic supervisor and an engineer from the supporting company and this lead to the decision to research a supermarket in Hull more closely.

This research included a site visit, examining technical documentation and downloading data from the 13 sub-meters installed in the distribution boards of the supermarket. During the visit to the supermarket the technical details were explained by an engineer from the supporting company, who also provided further technical documentation. In addition to this the store management was met, who were very cooperative and allowed the Energy Champion to be interviewed. The downloaded data analyse was started and preliminary results were discussed with the academic supervisor.

1.2 Analysis

Meter	System
Pwr01	Refrigeration system No 1 and associated cases
Pwr02	Refrigeration system No 2, associated cases, bakery and cold room
Pwr03	Back of building, roller shutter, scissor lift, trailor socket
Pwr04	Sales floor lighting and power
Pwr05	Café
Pwr06	Heater and air conditioning
Pwr08	Refrigeration pack No 1 and CO2 pump
Pwr09	Freezers (sales area) A & B
Pwr10	Refrigeration pack No 2 and CO2 pump
Pwr11	Freezer (sales area) C
Pwr12	Cold room (freezer)
Pwr13	Cold room (chilled)
Pwr14	Main incomer

Remark: Pwr07 not used

Table 1: Power sub-meters

The supermarket researched has thirteen sub-meters and two temperature/humidity sensors (one for outside and one for inside). The sub-meters measure the electricity consumption of the systems detailed in Table 1.

Meter	External temperature		External humidity		Opening hours		Internal temperature		Internal humidity	
	R^2 liner	R^2 square	R^2 liner	R^2 square	R^2 liner	R^2 square	R^2 liner	R^2 square	R^2 liner	R^2 square
Pwr01	0.4675	0.5071	0.028	0.0565	0.2837	0.2846	0.7376	0.7415	0.0045	0.1902
Weekdays	0.7681	0.8255	0.0144	0.0156			0.6518	0.6702	0.2004	0.2013
Pwr02	0.2918	0.3038	0.0147	0.0359	0.5166	0.5185	0.7361	0.7369	0.0029	0.1846
Weekdays	0.7691	0.7781	0.006	0.0072			0.7647	0.7656	0.1995	0.208
Pwr03	0.1203	0.1231	0.005	0.011	0.5344	0.5355	0.0393	0.1137	0.2181	0.2423
Weekdays	0.4255	0.4403	0.0261	0.027			0.1854	0.1869	0.1466	0.1762
Pwr04	≈0	≈0	0.0066	0.0316	0.8615	0.8623	0.2993	0.3748	0.1831	0.2932
Weekdays	0.0084	0.0306	≈0	0.0201			0.0248	0.0381	0.0559	0.187
Pwr05	0.0044	0.0096	0.0089	0.0549	0.7169	0.7197	0.2325	0.3122	0.2101	0.3127
Weekdays	0.0153	0.0194	0.002	0.0624			0.0032	0.004	0.0281	0.0357
Pwr06	0.298	0.3256	0.0398	0.0628	0.2039	0.2074	0.0107	0.0927	0.2056	0.2115
Weekdays	0.4333	0.4629	0.0817	0.1007			0.3203	0.3514	0.0685	0.0698
Pwr08	0.5341	0.5748	0.0263	0.0524	0.2137	0.2147	0.7431	0.754	0.0148	0.0195
Weekdays	0.782	0.8363	0.0151	0.0159			0.6756	0.6934	0.2049	0.2059
Pwr09	0.2107	0.2132	0.0647	0.0781	0.1356	0.1357	0.2558	0.2673	≈0	0.09
Weekdays	0.2419	0.2433	0.0181	0.0183			0.0876	0.0878	0.0659	0.0661
Pwr10	0.419	0.4285	0.0112	0.03	0.3931	0.3934	0.7913	0.7925	0.0029	0.1954
Weekdays	0.8069	0.8143	0.0042	0.0044			0.7857	0.786	0.2252	0.2384
Pwr11	0.072	0.0116	0.0115	0.0166	0.1629	0.163	0.203	0.2135	0.0134	0.0543
Weekdays	0.0007	0.0137	0.0528	0.1024			0.0538	0.0565	0.0037	0.0037
Pwr12	0.0005	0.0175	0.0024	0.0054	0.014	0.0152	0.0343	0.0836	0.0251	0.0632
Weekdays	0.0038	0.0043	0.0009	0.001			0.0023	0.0923	0.0006	0.0033
Pwr14	0.0027	0.0289	≈0	0.0271	0.763	0.763	0.3732	0.4092	0.1271	0.2515
Weekdays	0.0248	0.1111	0.05	0.0544			0.1827	0.2172	0.0082	0.0097

Remark: Pwr13 needs to be re download

Yellow: $0.3 < R^2 \leq 0.65$, green: $0.65 < R^2$

Table 2: Square of correlation coefficients

The data analysis started with downloading data from these sub-meters and temperature/humidity sensors for the period from 1 Jan 2012 to 18 April 2012 in 15-minute intervals and then the data was aggregated for each day. For the energy consumption data this meant taking the difference of the reading at 23:45 and at 00:00 hours and for the humidity and temperature reading a daily average was calculated. In order to see if there was a correlation between any of the independent variables (external temperature and humidity and opening hours and to a lesser degree internal temperature and humidity) and the energy consumption, x-y plots were produced in Excel. This analysis also differentiated between weekday data (i.e. Monday to Friday) and daily data (including the weekends). The R^2 values[1] of these plots are listed in Table 2. Where the R^2 value was between 0.3 and 0.65 (corresponding to a correlation coefficient between 0.55 and 0.8) the cell is shaded yellow any R^2 value greater that 0.65 was shaded green.

[1] R^2 is the square of the correlation coefficient, indicating that there might be a relationship between two sets of data

Table 2 indicates that there is a relatively strong relationship (R>0.8) between the external temperature on weekdays and the sub-meters Pwr01, Pwr02, Pwr08 and Pwr10. All of these meters include one of the two refrigeration systems. Similarly strong relationships can be found between the internal temperature and the same sub-meters for both weekday and daily data. The same table also shows that there seems to be a medium strength relationship (medium strength means here $0.55 < R \leq 0.8$) between the opening hours and the readings from Pwr02, Pwr03, Pwr10 and an even stronger relationship between the opening hours and Pwr04, Pwr05, and Pwr14. Except for Pwr10 these meters include lighting circuits and other devices in the sales area normally operated only during (or just before or after) opening hours. Only a weak correlation between humidity data and the electricity consumption data could be found (with the exception of Pwr05 where R equals 0.56).

1.3 Conclusions

During this mini project the aim of investigating how readily available data for energy modelling was pursued. As a first step a model of different major factors of energy consumption was developed, which divided these factors into technology (what is used?), environment (where is it used?) and use (how is it used?). Next, six questions were asked to guide with the selection of data sources. These lead to the selection of a relatively simple supermarket in Hull.

The data of electricity consumption obtained from this supermarket was compared with temperature and humidity data (both internal and external) and opening hours. It was found that for sub-meters including refrigeration systems a correlation factor of 0.5 or greater could be calculated with respect to the (internal or external) temperature. For meters measuring sales floor consumption a correlation factor of 0.7 or greater was computed for opening hours.

The findings so far indicate that this supermarket is likely a good starting point for the development of energy models for supermarkets. The question not investigated in this mini project was: What behavioural data is available and accessible?

Regarding the data analysed the following, tentative conclusions can be drawn:

1) There is a relationship between temperature and the energy consumption of refrigeration efforts. Having said this, some inconsistencies exist between the correlation with external and internal temperature, for example Pwr01 shows a stronger correlation between the weekday data and external temperature, whereas for Pwr02 the difference is only slight.
2) Sub-meter data including sales floor lighting and equipment (including Café) show a medium or stronger correlation between opening hours and electricity consumption.

In order to gain further insight into the behaviour of this supermarket further work should include:

- Check data consistency (this could be done by comparing cascaded sub-meter data and technical data of the installed equipment).
- Recheck consumption data to ensure that the correct sub-meter data was analysed (e.g. the data for Pwr13 is likely to be incorrect).
- Establish where the temperature/humidity sensors are sited (only positive values for the outside temperature were available). It could be also checked against official data (e.g. from the Met office).
- Investigating the relationship between external temperature and humidity and internal temperature.
- Investigate if body counts (i.e. for customer and staff) are available.
- Collect data for the building envelope (in particular the thermal conductivity values).
- Some of the sub-meter readings may depend on more then one variable (e.g. Pwr02 which seems to depend not only on the temperature, but also on opening hours).