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SURVEY OF ENERGY USE IN GROCERY STORES

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ABSTRACT

This paper presents the results of an energy use survey assembled for 93 grocery stores in south Texas. All stores were of the same chain. Several conclusions were drawn. Total electricity consumption per square foot is roughly 9 W/ft² for all stores, and varies by ± 2 W/ft². This seemed to be due to a set amount of refrigeration capacity in the stores. In this survey, stores built after 1979 had roughly 9% less energy consumption per ft² than those built before 1979. Heat reclamation from the refrigeration systems provided an adequate means of space heating most winter-time conditions. In many cases, stores used natural gas primarily for cooking. Grocery store energy use is divisible into components, some of which are dependent on store size and some of which are not, a more detailed analysis is required in order to determine key predictors of energy use.

INTRODUCTION

This paper presents the results of a survey assembled from 93 grocery stores, all of the same grocery chain, in the south Texas region. Approximately 3% of the United States' commercial building energy consumption is attributable to food sales facilities [CBECS, 1986], as shown in Figure 1. Previous work on this topic has been done by Claridge and Schrock [1989], Ruch *et al* [1991], and Claridge and Ruch [1991], Ruch D., Chen, L., Haberl, J., Claridge, D. [1991].

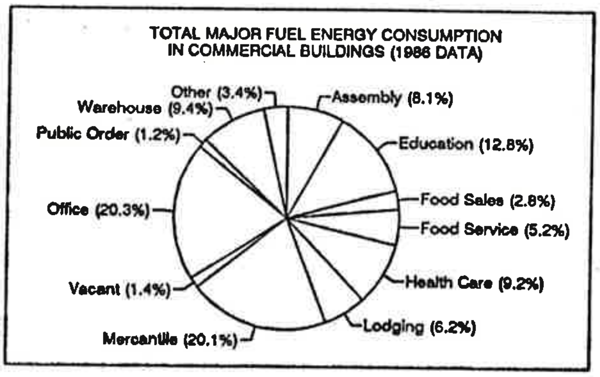

Figure 1: *Percentages of Total US Energy Consumption in Commercial Buildings*, [CBECS, 1986].

THE SURVEY STUDY

With the goals of identifying key predictors of energy use and discovering the potentials for energy-saving retrofit measures, a project to monitor and assess the energy use of typical urban grocery stores was initiated. As part of this effort, a database for 93 grocery stores in the south Texas area was developed. These stores are all owned and operated by a single national grocery retailer. In addition, a case study store was monitored. Insight gained from the case study and the survey is expected to be applicable to the 93 stores since most are of similar construction and geographic location. This paper details the database/survey portion of this project.

Data were obtained from recent annual utility billing reports for the 93 stores provided by the supermarket corporate management. Information was also obtained with a mail-in store survey questionnaire developed with the help of the regional chief facilities engineer of the retail chain. Data were compiled into a spreadsheet database, discussed with the chief facilities engineer, and spot-checked with visits to a local, case study store. Questionnaire and report parameters that were assembled into the database are listed in Table 1.

Table 1 - *Parameters Included in Store Database*

store location	annual electricity consumption per ft²
construction status	annual electricity cost
climatic zone index	annual electricity cost per ft²
floor area	annual natural gas consumption
hours per budgetary period	annual natural gas cost
store acquisition date	annual water consumption
recent store improvement date	annual water cost
source of heating	linear feet of freezers/coolers
installed refrigeration capacity	number of fluorescent lamps
annual electricity consumption	number and type of parking lot lamps
actual peak electric demand	method of thermostat adjustment
billed peak electric demand	method of inside lamp control
average daily electricity use	method of parking lot lamp control

Some parameters represented conditions as recorded during store construction. Others represented conditions at the time of the annual billing report. Refrigeration horsepower represented installed, rated capacity, and did not necessarily represent present operating conditions.

Stores were indexed by climatic zones based on the annual wet-bulb degree hours above 66 °F. Ten zones were defined for the south Texas area -- zone #1 having the least degree-hours (least humid climate), and zone #10 having the most degree-hours (most humid climate), as shown in Figure 2 [Dubin and Long,

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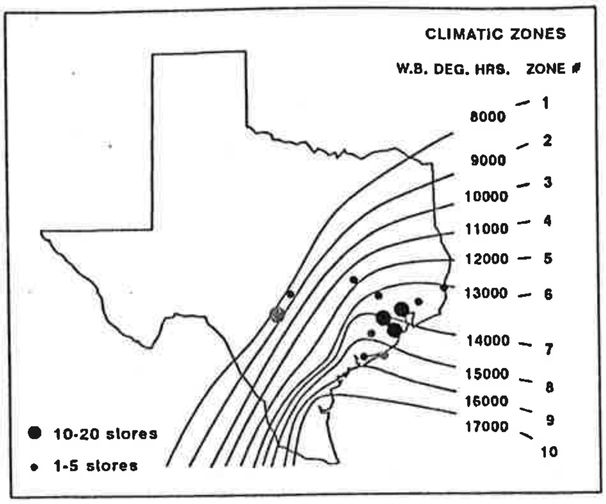

Figure 2: *Climatic Zones* -- The south Texas region containing the surveyed stores was divided into ten climatic zones, each based on the annual wet-bulb degree hours above 66 °F [Dubin and Long, 1978].

1978]. The second index used was a heating-type code which designated e for electric heating, g for gas, E for process reclaim heat with electric booster heat, and G for process reclaim heat with natural gas booster heat. These codes were used as data labels in Figures 4,5,7-9.

DISCUSSION OF RESULTS

Whole-building electricity use and store size were the most useful parameters. For the stores surveyed, the floor areas ranged from approximately 20,000 to 80,000 ft². The average store size was 43,000 ft², with 50% of the stores having floor areas between 41,000 and 47,000 ft² (see Figure 3a). Two other store sizes were also dominant -- one about 25,000 to 35,000 ft², and the other about 55,000 to 65,000 ft². While a number of the larger stores were built to more closely adhere to corporate specifications, some of the smaller stores were acquired from other retail chains, and do not meet all of the same standards.

Annual electricity consumption in 1990 ranged from about 1.5 to 6.0 GWh/yr (million kWh/yr), with 70% of the stores consuming between 2.7 and 3.7 GWh/yr, as shown in Figure 3b. Of the 68 stores using natural gas, approximately 70% consumed between 300 and 1,000 million Btu/yr (see Figure 3c).

Interestingly, one of the most revealing ways of looking at trends in the energy use was the use of simple scatter plots. An energy use index (EUI) was defined for electricity and natural gas consumption. An electricity EUI (W/ft²) was created for the annual electricity use (kWh/ft²-yr) to represent an average electricity intensity. EUIs were also defined for refrigeration nameplate capacity (W/ft²), and natural gas use (Btu/ft²-yr).

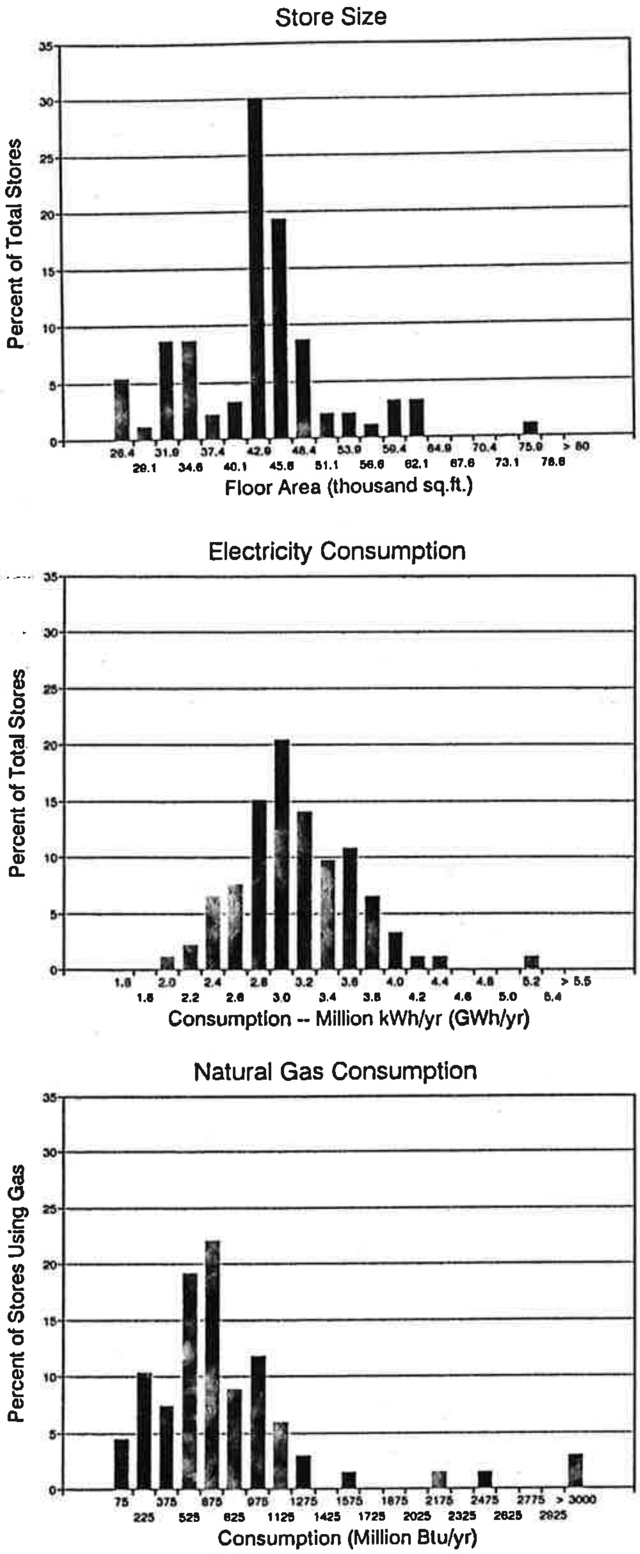

Figure 3 a,b,c: *Histograms of Store Size, Electricity Consumption, and Natural Gas Consumption*

As expected, Figure 4a shows an increase in electricity consumption as floor area increases. However, all stores tended to have electricity EUIs of roughly 9 W/ft², and varied to extremes by ± 2 W/ft², as shown in Figure 4b. The most noticeable change in EUI with respect to floor area seemed to occur between 40,000 and 50,000 ft². Stores smaller than 40,000 ft² had an average electricity EUI of 9.5 ± 1.7 W/ft² (± twice the sample standard deviation). Stores larger than 50,000 ft² had an average EUI of 7.7 ± 1.1 W/ft². Stores between 40,000 and 50,000 ft² had an average EUI of 8.2 ± 1.4 W/ft².

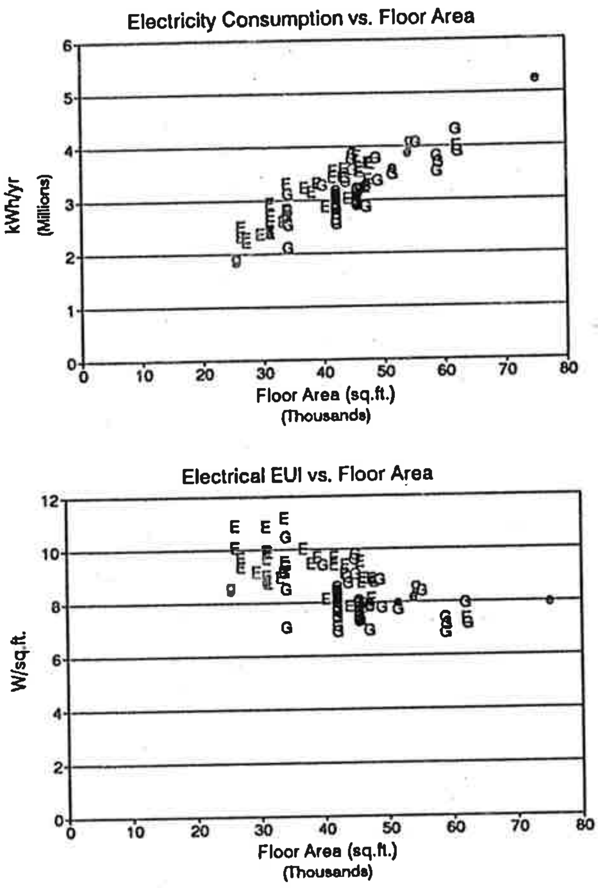

Figure 4 a,b: *Electricity Consumption and Electricity EUI vs. Floor Area* -- The data labels, e, g, E, and G, differentiate heating systems used, as explained in the text, and are used in all successive figures.

It was initially thought that the latent load on the stores' air-conditioning systems would be a significant determinant of the electricity consumption. Thus, the whole-store electricity EUI was plotted against the climatic index (see Figure 5).

Stores in the more humid zones tended to show only slightly greater EUIs than those in the dryer zones. While this may well be due to an increased latent air-conditioning load in the more humid climates, the increase does not seem significant. Also, since this climate index considers only wet-bulb temperature, stores closer to the Gulf of Mexico (which may have higher latent loads, yet lower outside dry-bulb temperatures than stores which are farther inland) may not be represented as well as they could be with a dry-bulb temperature index. The interaction between wet- and dry-bulb temperatures in this region may mask the effect either temperature would otherwise have, alone, on the stores' air-conditioning. Constant lighting and miscellaneous loads may also make it difficult to see a climate effect when only whole-building EUIs are considered. Ruch *et al* has shown that it is possible to use the slope of a consumption vs. temperature curve to determine how much dry-bulb temperature may influence a store's energy consumption.

In Figure 5, a more significant pattern can be seen in the plot of gas use versus climate index. Stores in the drier, northern zones tended to have higher gas EUIs (Btu/ft²-yr) than do the other stores. Stores in the more humid zones (higher zone indices) tended to show only slightly greater electricity EUIs (annual, averaged W/ft²) than those in the dryer zones.

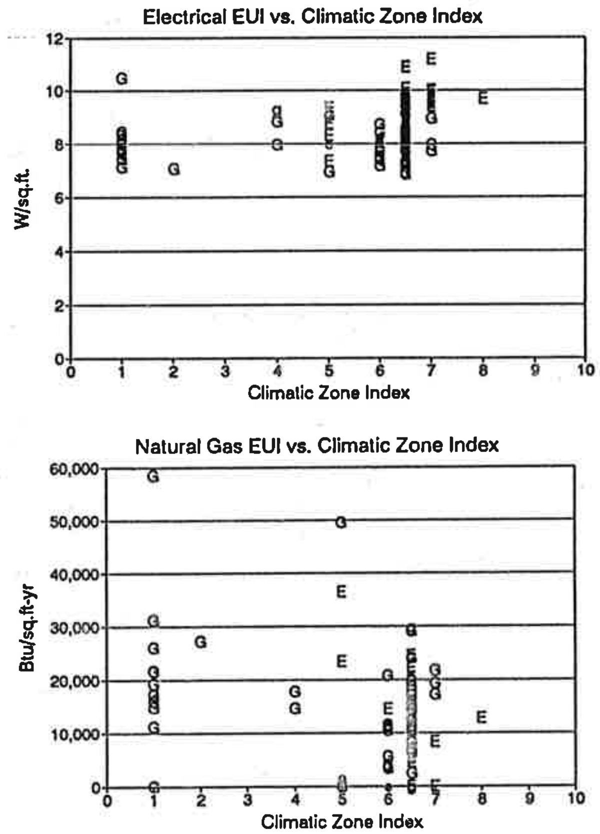

Figure 5 a,b: *Electricity and Natural Gas EUIs vs. Climatic Zone Index*

All but six of the stores used waste heat recovered from the condensers of the refrigeration system to provide space heating. They were equipped with either gas-fired or electric booster heat for use when the reclaim heat was not adequate (see Figure 6).

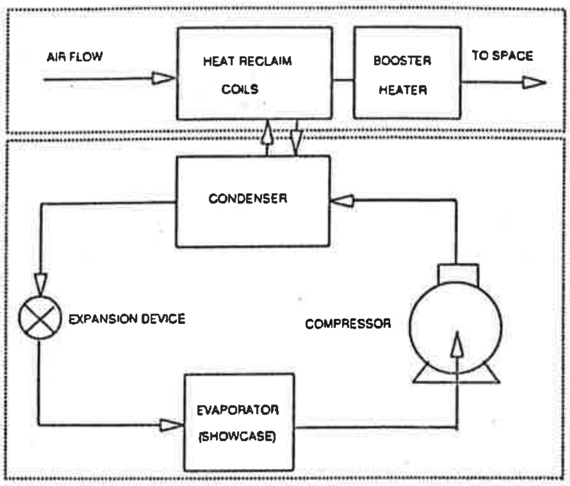

Figure 6: *Heat Reclaim System Schematic* -- Shown here is a typical heat reclamation system installed in many stores. Heat is extracted from the condensing units of the refrigeration system, and used for space heating.

According to talks with the facilities engineer, stores in zones 4 to 7 only called for gas booster heat about 1% of the time (or less); the majority of their gas usage went to cooking. Stores in the more inland regions (zones 1 and 2) made significant use of their booster heating, which accounted for their greater gas usage compared to stores in other zones.

As shown in Figure 7a, stores built by the corporation, after about 1979, are larger than those built prior to that year ("construction date" actually refers to the date each store was acquired and/or built). As shown in Figure 7b, newer stores use less electricity per ft², and employ heat reclaim from the refrigeration compressors and natural gas booster heat for space heating. These buildings were built to new corporate engineering specifications. A appreciable decrease in electricity EUI (W/ft²) is seen after 1979, which corresponds to the beginning of a new energy conservation policy. New stores average 8.3 W/ft², while older stores average 9.1 W/ft², a difference of about 9%. As shown in Figure 7c, stores using gas, built after about 1983, tend to use less gas per ft².

Typical energy-saving measures employed since 1979 by this grocery store chain include better insulation (an R-4 increase), the changeover from incandescent to fluorescent lamps, installation of energy-efficient ballasts on fluorescent lamps, the changeover from electric to gas-fired booster heating (or elimination of booster heating altogether), and better sealing of building entrances using vestibules. In addition, an effort was made to ensure that buildings were built to standard corporate design specifications.

It was considered whether the lack of electric heating in gas-boosted stores explained their lower electricity consumption. However, discussions with the chief facilities engineer of the store chain revealed that stores using heat reclaim from the compressors (92% of the stores) rarely need booster heat. It is estimated that electric booster heating is needed about two days per year, if at all. And indeed, at the case-study store located 50 to 100 miles north of most of the other stores, the fraction of booster heat time is only 1% of the HVAC system's operating hours [Ruch *et al*, 1991]. According to the chief facilities engineer, booster heating is no longer installed in new stores built between climatic zone 6 and the Gulf coast. Thus, since booster heating is so rarely used, it is unlikely that the absence of electric heat in gas-boosted stores is the primary cause of the reduction in their electricity consumption.

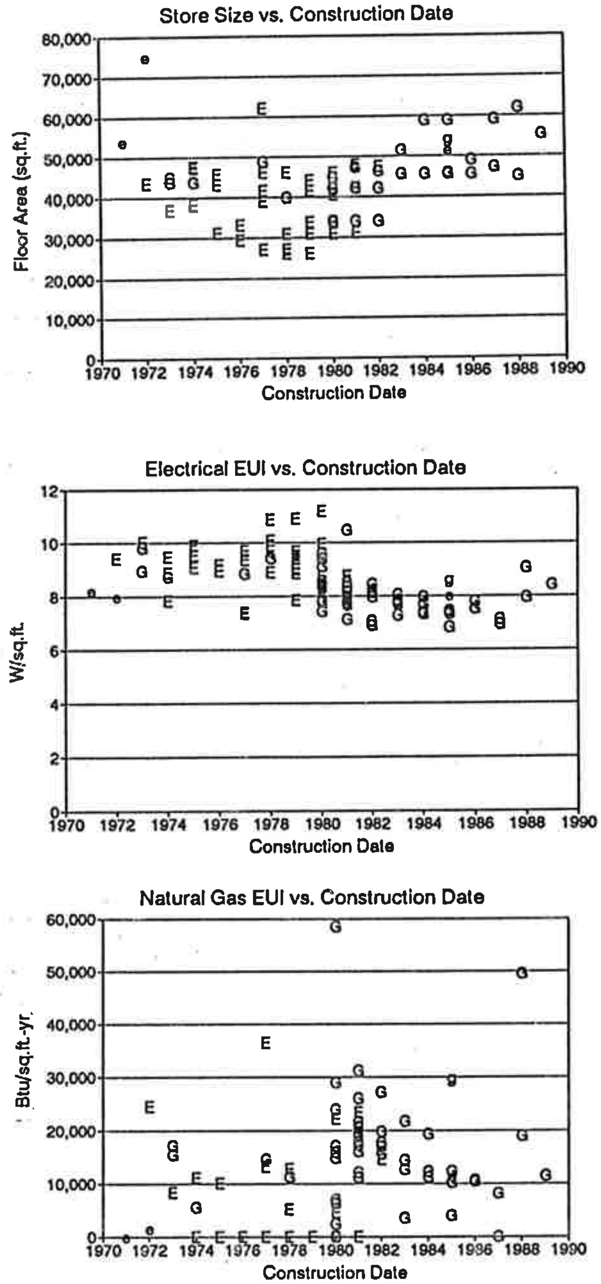

Figure 7a,b,c: *Floor Area, Electricity and Natural Gas EUIs vs. Construction Date* In 7c, one data point, at 120 thousand Btu/ft²-yr, has been excluded from the plot as an outlier.

Figure 8a shows that there has been only a slight variation in the installed refrigeration capacity over the last twenty years. The variation tended to follow the same pattern as store size. As shown in Figure 8b, the refrigeration nameplate EUI (W/ft²) has been fairly constant over the years, though a slight decrease is seen after about 1983. This corresponds to the point at which the corporation began to build larger stores which stock a considerable amount of merchandise that does not require refrigeration.

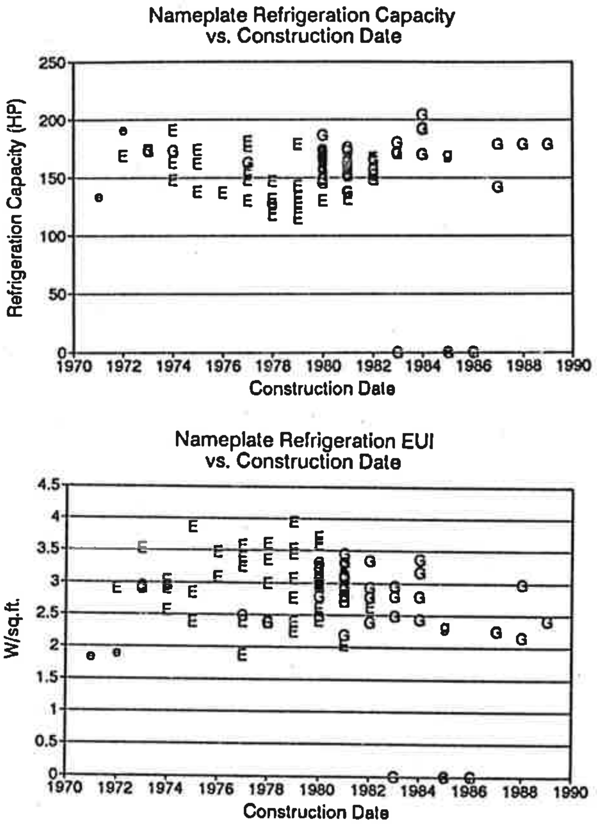

Figure 8 a,b: *Nameplate Refrigeration Capacity and Refrigeration EUI vs. Construction Date* -- Connected, nameplate horsepowers were taken from corporate utility reports.

Figure 9 shows that larger stores, while having slightly more installed refrigeration capacity, have lower EUIs (W/ft²) than smaller stores. Again, this is an indication that, in larger stores, the additional space is used to stock non-refrigerated products. The most noticeable change in refrigeration EUI with respect to floor area seemed to occur between 40,000 and 50,000 ft². Stores smaller than 40,000 ft² had an average refrigeration EUI of 3.3 ± 0.7 W/ft², while stores larger than 50,000 ft² had an average EUI of 2.2 ± 0.5 W/ft². Stores between 40,000 and 50,000 ft² had an average EUI of 2.8 ± 0.6 W/ft². As seen in Figure 9b, stores tended to have EUIs that decrease with increasing store size, most noticeably between 40,000 and 50,000 ft².

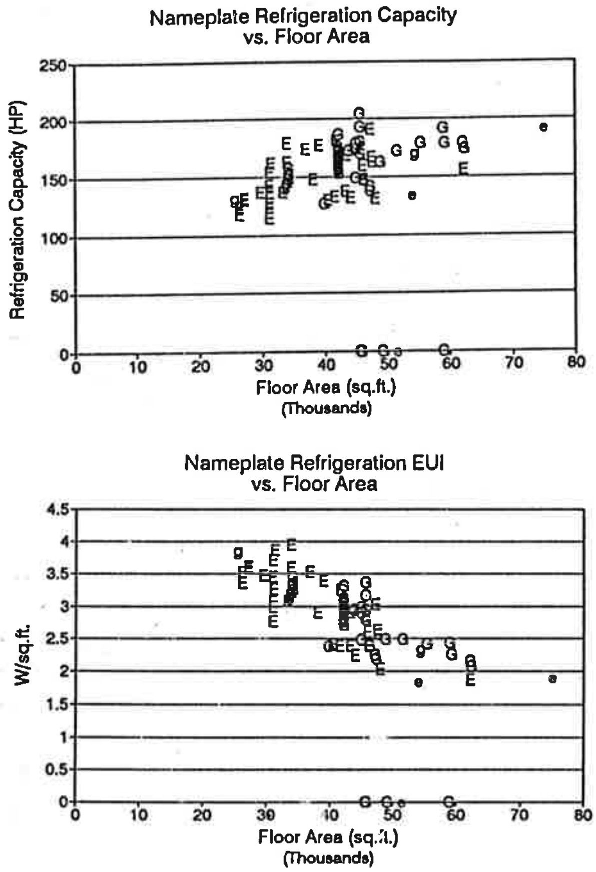

Figure 9 a,b: *Nameplate Refrigeration Capacity and Refrigeration EUI vs. Floor Area*

Discussions with the stores' engineering personnel have revealed other possible reasons for the trends that are displayed in Figure 9. Even the smaller stores seemed to have a minimum amount of refrigeration, roughly 100 to 150 hp. As the stores become larger, an increasing amount of floor space is devoted to items that do not require refrigeration until the stores reach about 50,000 to 60,000 ft². At this point, it is speculated that additional energy-consuming subsystems, such as salad bars and stand-alone display cases, are added which tend to level-out refrigeration EUI (W/ft²) vs. floor area.

While whole-building energy consumption, floor size, and construction date tell us general characteristics about the store buildings, specific information is difficult to glean from the data without detailed knowledge of the equipment in the store. The energy-using components of a store do not all share the same characteristics with respect to floor area. While some components, such as air-conditioning and lighting, are intuitively functions of floor area, refrigeration capacity and other miscellaneous loads are not.

CONCLUSION

From the data collected in the south-Texas database of 93 grocery stores of the same chain, several conclusions are drawn.

1.) Total electricity EUI is roughly the same for most stores, about 9 W/ft², and varies to extremes by ± 2 W/ft². Stores smaller than 40,000 ft² had an average overall EUI of 9.5 ± 1.7 W/ft², while stores larger than 50,000 ft² had an average EUI of 7.7 ± 1.1 W/ft². Stores between 40,000 and 50,000 ft² had an average EUI of 8.2 ± 1.4 W/ft². With most of the stores in the same geographic area, it seems unlikely that variations in climate-dependent loads explain this. Rather, this seems to be due to a set, proportionate amount of refrigeration capacity for all stores. As floor areas increase, electricity and refrigeration EUIs decrease, but less so for small and large stores than for those between 40,000 and 50,000 ft².

2.) In this survey, stores built after 1979 have roughly 9% less energy consumption per square foot than those built before 1979. This is due to at least two reasons. First, stores built after 1979 were larger. These stores used their additional space to stock merchandise that did not require refrigeration. Second, stores built after 1979 included a significant number of energy-saving measures.

3.) In the south-Texas region, heat reclamation from the refrigeration systems provides an adequate means of space heating for most winter-time conditions.

4.) Stores which use natural gas require less gas per square foot when it is used primarily for cooking. Too few stores in this survey use enough gas for heating to warrant any conclusion about heating gas use.

5.) Because grocery store energy use is divisible into components, some of which are dependent upon store size and some of which are not, a more detailed analysis, such as the case-study section of this project, is required in order to determine key predictors of energy use. The database section of the project provides a good foundation on which to apply the results of the findings in the case study.

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