ENERGY USE, INFORMATION, AND BEHAVIOR IN SMALL COMMERCIAL BUILDINGS

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PU/CEES Report No. 240

July 1989

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ABSTRACT

To explore behavioral effects on energy use in small commercial buildings, owners and managers of 40 small businesses were interviewed. These energy decision-makers were found to have very poor information on energy consumption and energy-using equipment. One striking example is that not one of the managers asked was aware that they paid a demand (kW) charge, even though this charge represented, on average, 43% of their electricity bills. Similarly, only 40% of those with natural gas heating systems were aware that they used gas for heating. Energy-efficient technologies, such as clock thermostats and high-efficiency lights, are not used by these business managers because of a lack of awareness and a perceived difficulty of control.

It is argued that programs to encourage energy efficiency in these buildings should recognize non-financial determinants of behavior, including convenience, comfort, and appearance. These programs should target decision-makers--contractors in the case of retrofits and occupants in the case of operational improvements. Small businesses are more willing to consider energy use when equipment is already being replaced for other reasons, so programs should intervene at the time of retrofits and remodels. The lack of information on energy use and energy-using equipment available to small businesses suggests that improved user information is a necessary component of an energy efficiency program. To further investigate the information component, graphical feedback was developed to display historical and comparative energy information. This graphical feedback was experimentally presented to a subset of store managers and their reactions were evaluated in open-ended interviews.

The experiment compared different time periods of feedback and found that the preferred time period was a function of the responsibilities of the user. For example a store manager preferred daily feedback, since it provided information on equipment operation, which was her responsibility. In contrast, a store owner preferred monthly feedback so he could compare energy costs with other costs, which were billed on a monthly basis. Respondents saw both dollars and kWh as useful, but usually preferred dollars. Demand charges were not well understood, and were difficult to communicate even with our graphical methods. Managers saw inter-store comparisons as valuable, but potentially misleading due to variations in the levels of service and comfort provided across different stores.

Table of Contents

1. INTRODUCTION

Small commercial buildings are significant energy users. Commercial buildings under 10,000 square feet account for 19% of all commercial buildings' square footage, and these small commercial buildings consume 28% of all energy used in the commercial sector (Energy Information Administration 1986). Many small commercial buildings appear to be relatively energy inefficient, and offer considerable opportunities for cost-effective energy efficiency improvements (Farhar and Fitzpatrick 1989). Some barriers to efficiency, therefore, are organizational or behavioral rather than technical or financial. In this report we use on-site interviews with small commercial building occupants to document the behavioral and institutional barriers to energy efficiency. The interviews uncover several important issues, including a lack of accurate, useful information on energy use. We then devise experimental graphical feedback of energy consumption and evaluate it as a method of rectifying the information barrier to energy efficiency.

Previous research in the residential sector (Socolow 1978) has demonstrated the value of looking at a few buildings in depth in order to better understand energy use and conservation potential. Here we use the case study approach to enhance our understanding of energy use and behavior in small commercial buildings. Our case study shopping center, which we will call The Jersey Mall, is located in central New Jersey, approximately 60 mi (100 km) from New York City. The mall was built in 1953, and includes 220,000 ft^2 of conditioned space. The Mall is actually six distinct buildings surrounding a central open-air courtyard. The construction type is simple concrete-block walls, with flat roofs and unfinished basements used for storage. All but one of the buildings are single-story.

There are 52 businesses at the mall. Three of the businesses are large anchor stores (a 20,000 ft^2 supermarket, a 26,000 ft^2 supermarket, and a 60,000 ft^2 department store), and the remaining 49 businesses cover a range of areas, including banks, a health club, restaurants, video rentals, and a dentist (see Table 1). About 35% of the businesses are members of chains, with an on-site manager. Energy-using equipment at the Mall includes space conditioning (heating, cooling, ventilation), lighting, and process loads (refrigeration, cooking, etc.). The majority of businesses have individual HVAC systems, although a few businesses share equipment due to changes in layout which followed equipment installation. Space heating units are mostly natural-gas fueled forced air systems, although the large department store has an oil-burning furnace and several small stores have supplemental electric heat. All 52 businesses are served by electric space cooling systems. Both lighting and process equipment varies by business. Restaurants and the laundromat use natural gas for cooking, drying, and water heating; and several businesses (supermarkets, restaurants) use electricity for freezing and refrigeration.

Table 1. Businesses at the Jersey Mall.

SIC Groups	Description	Number	Total Square Feet	Examples
52,53,55-57,59	Retail trade	24	122,310	Drug store, hardware store
54	Retail food sales	4	53,500	Supermarket, bakery
58	Restaurant	6	11,100	Coffee shop
60-67	Finance, insurance, real estate	4	5310	Bank, loan agency
70-84	Services	14	23,400	Health club, barber, dentist

2. EXPLORATORY INTERVIEWS

Behavioral and institutional factors affecting energy use at the Jersey Mall are discussed using interviews with two levels of managers: the manager of the mall itself, and managers of the individual businesses.

2A. Mall Management Interviews

A series of interviews were conducted with the manager of the Jersey Mall, who represents the mall owner. These interviews provided an understanding of how responsibility for energy and energy-using equipment is shared between mall management and tenant businesses. Here we describe both the method by which equipment choice decisions are made and the system for sharing energy costs.

Equipment choice

In a privately owned residence, the homeowner pays the energy bills and makes any decisions concerning retrofits and behavioral changes affecting energy use. In small commercial buildings, many actors affect energy use: the property owner, the property manager, the business owner, the business manager, the employees, and the HVAC contractors.

The owner of the mall is represented by an on-site manager, known as the Mall manager. The Mall manager has many responsibilities, from hiring grounds maintenance crews to negotiating leases. Much of her time is spent dealing with the businesses' day-to-day problems and with arranging promotional activities. She is also the main link between the mall owner (in this case, a property management company) and the businesses. Most of the businesses pay a monthly fee for a maintenance contract covering the HVAC equipment, and if a business has a problem with the equipment they call the mall manager, who then calls the HVAC contractor. The HVAC contractor is hired by the Mall manager to maintain and repair the HVAC systems at the Mall. The businesses at the Mall are a mix of chain stores with off-site ownership (35%) and owner-occupied stores (65%). In the chain stores, the in-store manager is a salaried employee, and in most cases is given specific responsibilities which do not include energy management. Any decisions concerning changes in these stores are made at the main headquarters. In short, equipment decisions are made by multiple actors.

Energy Costs

Every business has its own electricity meter, which is read directly by the utility. Tenant businesses are billed directly by the utility, and the Mall management has no direct role. However, eight businesses (17%) share at least part of their HVAC systems with other tenant businesses. For these eight businesses the Mall management pays the actual electricity bill for the HVAC system, and bills these businesses a flat fee for HVAC electricity. This fee is not directly tied to consumption. This arrangement came about due to changes in store layout and location after the original construction of the mall, resulting in a discrepancy between store boundaries and metered areas.

The electricity rate schedule faced by those billed directly for consumption has two components--a consumption charge and a demand charge. The consumption rate is approximately 6.0¢/kWh, and the demand rate is approximately $10/peak kW-month. On average, 43% of the electricity bill for businesses at the Jersey Mall is due to the demand charge. Large customers can make use of a time-of-day rate, which has three time periods: On-Peak (Monday-Friday 8am-10pm), Intermediate (Saturday 8am-10pm), and Off-Peak (nights and Sundays). The selection of either the simple demand or time-of-day rate schedule is up to the user, but the utility recommends the time-of-day rate only for those with a monthly demand greater than 150 kW. Three of the 52 businesses at the Jersey Mall have a monthly demand greater than 150 kW, and two of them have chosen to be put on time-of-day-rates.

Natural gas is used for space heating by all but two businesses. Natural gas is also used for various process loads--the restaurants use natural gas for cooking, the laundromat uses gas for water heating and clothes drying, and the health club uses gas for water heating. The Jersey Mall was originally built with one main gas line, which served all businesses at the Mall. In 1984, sub-meters were installed on seven businesses thought by the Mall manager to consume the most natural gas. These were four restaurants, the health club, the laundromat, and a supermarket. These seven sub-meters are read monthly by the Mall management, and these seven businesses are billed for their actual gas consumption by the Mall management. The remaining businesses, however, are billed a flat monthly fee for gas use. This fee is based on the square footage of the business, and has no direct link to actual consumption. The actual charge per square foot varies, and is part of the lease agreement signed by the business and the management. Once per year, the management adds (or subtracts) a correction factor to the monthly gas charge to cover any discrepancy between billed gas charges and actual gas consumption for the previous year.

In summary, incentives for energy use and equipment operation are shared by a number of individuals. All businesses are responsible for any equipment inside their store, including lights and any store-specific equipment. The Mall management is responsible for most of the HVAC equipment, and works with a contractor when making HVAC equipment purchase decisions. All businesses receive an electric bill directly from the local utility, and for most this bill includes the actual electricity consumption of their HVAC equipment. Most businesses pay a flat fee based on square feet for natural gas consumption, but those businesses with process requirements for natural gas pay for their actual consumption.

2B. Tenant Business Interviews

On-site interviews were conducted with small businesses at the Jersey Mall from November 1987 through March 1988. These interviews were exploratory in nature, and were intended to uncover energy-related problems and issues as seen by the businesses. Initially all 52 businesses at the Mall were sent a letter, stating that energy use at the Mall was being studied by Princeton University and requesting that the owner or manager of the business meet with a researcher for a brief interview. The businesses were then called to set up a time for the interview. Interviews were actually conducted with 40 (77%) of the businesses at the Mall.[1]

The interviews were conducted with the owner or manager of each business, and typically lasted 15-20 minutes. The style of the interviews was, in part, ethnographic.[2] An ethnographic interview can be seen as a guided conversation, which allows the interviewee to influence the agenda of the interview. The interview also used some fixed questions, covering heating and cooling system control, perceptions of energy costs and bill-paying procedures, and attitudes toward improved energy information and automated control. The interview took place at the business, and in most cases involved the manager and one interviewer, who took notes throughout the interview. If the store was quiet, other employees sometimes joined in the conversation. If there were many customers, the manager often interrupted the interview to help customers. In the initial telephone conversation to set up the interview, the interviewees were often hesitant to participate and

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[1]Twelve businesses were excluded because they did not want to participate or because we were unable to contact the owner or manager.

[2]For other applications of ethnographic methods to energy behavior research, see Kempton and Montgomery (1982), Wilk and Wilhite (1982), and DeCicco and Kempton (1987). A full description of the technique can be found in Spradley (1979).

said that they did not really know much about energy. However, we often opened the interview with a question such as, 'Does the heating system work well?', which made it clear that we were not testing their technical knowledge. This helped establish an atmosphere in which the interviewee felt free to share his or her beliefs and understandings of energy use, and reduced the pressure to tell the energy experts (us) what they thought we wanted to hear.

The interviews did not include an audit of the physical plant or an evaluation of the equipment. In some cases it might have been interesting to verify, for example, whether a report of broken equipment was due to malfunction or misunderstanding. However this would have been difficult to do during working hours, and therefore was not attempted.

Interview results are presented by topic. For each topic, we have summarized business responses in a qualitative manner. Numerical data are added where appropriate; however, the strength of the ethnographic interview is not in the collection of numerical results but in its ability to uncover interviewee's thoughts and perceptions, which in many cases were not anticipated at the beginning of the research.

<u>HVAC System</u>

Very few managers demonstrated awareness of or concern with energy use of their heating or cooling system. They showed an interest in the system only when it intruded on their business by breaking down or being difficult to control. For example, when asked what kind of fuel the heating system used, only 60% of gas-heated businesses were aware that their heating system used gas, 40% were not. Similarly, respondents were not interested in the space cooling system unless it affected their day-to-day activities.

The major interaction of the occupant with the HVAC system is through the thermostat. We were therefore especially interested in how the businesses used and perceived their thermostats. The most surprising finding was the lack of working clock thermostats. We had expected that businesses would be an ideal setting for clock thermostats, as businesses have regular hours of operation. However, we did not find even one working clock thermostat in the 40 businesses interviewed. Three stores mentioned that they used to have clock thermostats, but that they had been removed. Reasons given for removal included unreliability, inaccuracy, and difficulty in setting the on/off times. Two stores actually had clock thermostats which the managers operated as manual thermostats. Managers in both these stores claimed that the clock thermostats were not operating correctly. Further questioning revealed that the managers were given no information on how to use the thermostats, and therefore found it easier to operate them manually. Several managers reported bad experiences with clock thermostats. Said one, "I have a clock thermostat at home--the damn thing doesn't work. It says 80 when it's 68."

Of the businesses asked, thirty-eight percent reported that they do not turn the heat down at night. Two types of reasons were given for not doing so. Twenty-one percent just did not bother, either because they did not think it was worth it or because they never touch the thermostat (one tenant replied "As long as it's working I'm not going to touch it"). The remaining 17% did not set back because they believed their equipment or merchandise would be damaged by changes in temperature.

Lights

Newer businesses and those with more business experience stressed the importance of 'good' lighting as a way of attracting business. The meaning of 'good' was not clear, but it was some combination of attractive lighting fixtures and sufficient lighting levels without glare. Many of the newer businesses used spot-type incandescent lamps to emphasize certain merchandise. No business, however, mentioned that the energy costs of additional spot lighting (both for lighting and for additional cooling load) are quite high.

Further information about lighting was obtained with a night walk-through of the mall, in which it was observed that 90% of the businesses kept at least one light on at night. When managers were asked why they left lights on at night, they reported that it was done for security and to increase the visibility of the store. Based on observations made during the interviews, about 75% of the stores had one or more burned-out lamps in their fluorescent fixtures. When asked about lamp replacement, managers were surprised to hear that high-efficiency fluorescent lamps exist. Managers classified lights into fluorescent and incandescent, and when describing fluorescents they usually gave only the length (as in 'those are four foot bulbs'), and did not mention wattage or lumen output. One interviewee reported that the 'long, bright bulbs' (fluorescent lamps) were bigger energy users than the 'little bulbs' (incandescent lamps).

Other Energy-Intensive Equipment

Many businesses require specialized energy-using equipment. All businesses involved in food had refrigeration equipment, as expected, and the restaurants all had cooking equipment. Some of the retail shops also had special needs. The flower shop, for example, had refrigerated cases for the storage of cut flowers, and the electronics store had several color televisions that ran all day. Many of the retail stores and service businesses had small refrigerators for employee use. These refrigerators were not mentioned by the managers when we asked about significant energy users, however, and we found them only by walking around and peering into corners. More visible and noisy devices, such as radios and dentist's drills, were typically mentioned when we asked if there were any devices using significant amounts of energy.

Information and Control

Recent technological advances involving microelectronics and computer-based equipment control have created new opportunities for applications of automated building control to small commercial buildings. Energy management systems (EMS), which until recently were cost-effective only in large industrial and commercial buildings, are now being used in smaller and less energy-intensive settings.[3] These systems can control multiple end-uses, and can also provide limited information on energy use to building occupants and operators. One goal of our interviews was to measure the perceived need for these automated systems in small commercial buildings. These systems were originally designed for use by a trained building operator, and were oriented more to building automation than to improved occupant information. We hoped that, through our interviews, we could explore the potential of improved information and control systems in small commercial buildings. In the interviews, we discussed three technologies--a continuous display meter (which would give a continual readout of cents per day for electricity, for example), a clock thermostat, and an end-use breakdown ($ for lights, $ for cooling, etc.). We would describe the technology and ask for the respondent's reactions to it. The continuous display meter was unanimously unpopular. It was described as "petty", "unnecessary", and "I already have enough to worry about". A comment heard throughout the interviews was often repeated here, "I can't do anything about [energy costs]".

Reactions to the clock thermostat were also generally negative. Those who did set the heat back at night said it was no bother to do so. Said one, "It wouldn't be worth the bother--it takes only seconds to adjust [the existing thermostat]." Those who did not set it back at night usually gave a reason for not changing their behavior, as discussed above. However, two managers mentioned that they did not turn it down at night because it was too cold in

[3]For a discussion of EMS in small commercial buildings, see EPRI (1986), also North Carolina Alternative Energy Corporation (1987).

the morning, and they agreed that a clock thermostat would help solve that problem by turning the heat on before they arrive. This suggests an opportunity for marketing of clock thermostats.

A breakdown by end-use was presented as, "What if you had a form which showed how much you spent on electricity for lights, air conditioning, and other areas. Would that be useful or informative?" This got mixed reactions. The standard reply, "I can't do anything about it," was often given here. Many people felt that simply knowing, for example, what the lights cost was useless because they would still have to be on. Others seemed somewhat intrigued by the idea. Some asked how that could be done, and one manager said that a breakdown would be useful so he "would know where the waste is...[but only if] something can be done about it."

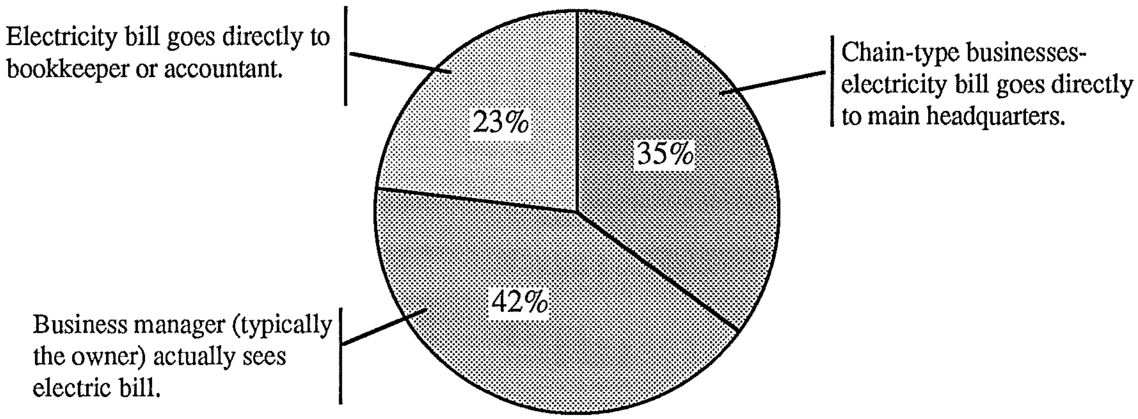
Energy costs and energy bills

Prior to the interviews, we expected that energy costs would be treated like any business cost, and would receive attention in rough proportion to the size of the bill. We also expected small businesses to use some approximate method, such as simple payback, when analyzing conservation investments. We were wrong on both counts. The truth is quite a bit more complicated, and involves both the mixed incentives discussed above and the lack of information available to businesses concerning energy use.

Approximately 35% of the stores are members of chains (Figure 1). These stores are usually operated by a salaried manager, and in all but one of these stores all bills, including rent and utility bills, are sent directly to the main headquarters. The store managers have no direct information about their energy use. These salaried managers usually said that the main headquarters monitored their bills and would notify them if a bill was much higher or lower than usual. However, only one manager could recall ever being notified about an electric bill, and this was due to a mistake made by main headquarters in reading the bill.

Sixty-five percent of the stores are owner-occupied. These owner-occupied stores all receive electric utility bills, yet many of them reported that they do not pay any attention to the bill. It generally goes directly to the bookkeeper or accountant. Only 42% of the stores reported that they actually looked at the bill. We asked one owner to show us his electric bill. When we remarked that it gave no information other than the amount due, he remarked that the 'other stuff', meaning the bill inserts and the section of the bill providing consumption information, was thrown away when the bill was received.

Figure 1. Breakdown of businesses by bill-paying procedure. Only 42% actually see the electricity bill (based on self-reports of behavior).



Very few tenant businesses understood that in the Jersey Mall their gas bill was not directly affected by their consumption, but that their electricity bill was. This misunderstanding, coupled with poor knowledge about which appliances use gas and which use electricity, led us to conclude that the mixed incentives for equipment maintenance and for gas and electricity consumption are only part of the story. For example, tenant businesses reported parallel thermostat behavior for cooling and heating, even though heating is not directly charged and cooling (for most tenant businesses) is. We asked one tenant why she set her heat back at night, if there was no financial reward for doing so. She replied, "waste offends me." Similar attitudes have been documented in master-metered multi-family housing, both for air conditioning (Kempton *et al.* 1989) and for space heating (DeCicco and Kempton 1987).

Finally, of the approximately twenty tenant businesses asked, not one knew that they were charged for electricity demand (kW) as well as consumption (kWh). We asked this question in a variety of ways. At first we asked about 'demand charges', but this resulted in a puzzled look. We then asked if their bill was different than the bill they got at home. A few tenant businesses knew that something was vaguely different about their bill, but not one of those asked knew how it differed.

2C. Analysis of Interview Results

The exploratory interviews were quite fascinating, and uncovered a wealth of previously undiscovered issues. The single most striking finding was the poor quality of energy-related information available to the businesses. Here we summarize the information problem in several distinct areas--energy-using equipment, energy billing, and energy efficiency.

Energy-using Equipment

Small commercial energy users are uninformed about their HVAC equipment--40% of those with natural gas heating systems did not know their system used gas. Clock thermostats are not popular, as they are seen as complicated and difficult to control.

When asked which appliances used a lot of energy, many respondents mentioned appliances that were visible or noisy--such as dentist's drills and radios. Less visible or controllable appliances, such as refrigerators or air conditioners, were often ignored. This is consistent with research in the residential sector showing that consumers estimate an appliance's energy use partly by perceptual salience (Kempton *et al.* 1985).

Energy Billing

Demand charges average 43% of their electricity costs, yet in our interviews not one of the approximately 20 small businesses asked knew that they were billed for demand. Previous research in the residential sector has shown that users often do not know the price of a kilowatt-hour (Kempton and Montgomery 1982), but in this case users do not even know how they are charged for electricity.

Ninety-six percent of the businesses are not individually metered for natural gas consumption, and therefore are given no feedback on their natural gas consumption, receive no penalty for inefficient use, and no reward for efficiency. As mentioned above, 58% of the businesses do not pay attention to the electric bill. Thus for these 58%, the managers making electricity consumption decisions have little information on how much electricity they use or how much they are paying for that electricity.

Energy Efficiency

Two premises of energy efficiency--that building occupant behavior will affect building energy use, and that an efficiency improvement does not require a decrease in comfort or amenity--are generally accepted by energy analysts. Unfortunately belief in these premises is not shared by small businesses in our case study.

Previous studies (Socolow 1978) have shown that the behavior of the occupant in a residence has a significant effect on the energy use of the building. This finding surprised many energy researchers, and we wanted to know how small commercial business managers and owners view the link between what they do and how much energy they use. We therefore asked small business people if they thought energy use was fixed or could be changed. Most made comments like, "There's nothing I can do about it." Small business people in our case study have a strong belief that energy use, and therefore energy costs, cannot be controlled.

Any suggestions we made concerning reduced energy use were interpreted as requiring a corresponding reduction in comfort. For example, when we asked what could be done to reduce energy use, many respondents said that they could turn down the heat or turn off the lights, but that a cold, underlit store would discourage their customers. This is consistent with findings described by Kempton *et al.* (1985), in which residential energy users saw energy conservation primarily as behavioral curtailment rather than better management or more efficient equipment.

2D. Summary and Implications for Future Program Design

Based on our interviews, we believe that the small commercial sector presents some distinctive, yet surmountable, barriers to the implementation of energy efficiency. In this section we suggest some directions for future programs that address these barriers. The subsequent section selects one of these directions for further research.

Recognize and Exploit Non-Financial Determinants of Behavior

It is often assumed that energy efficiency investments are determined by trading off dollars spent for dollars gained. This economically rational model of behavior, however, is not well supported by our interviews. Other factors, including perceived comfort effects, convenience, appearance, general dislike of waste, and lack of interest arose as important factors influencing energy-related behavior. This is consistent with findings reported by Komor and Wiggins (1988a, 1988b) in the residential sector, and by Hobson *et al.* (1988), and EPRI (1987) in the commercial sector. Energy efficiency programs must recognize that dollars are not sole determinants of behavior, and that other factors, though less well-defined, must be addressed when attempting to influence behavior.

These factors can be used to encourage energy conservation. For example, many of our interviewees stressed the importance of maintaining an attractive, comfortable store, and conservation actions were seen as reducing comfort and/or attractiveness. However, some conservation actions can increase comfort. Weatherstripping can reduce drafts, leaving doors open rather than running the air conditioner can attract customers, and retrofitting lights can both reduce lighting energy and enhance store appearance. Promotion of these non-financial benefits of conservation could increase the probability of the energy conserving actions being taken.

Target Decision-Makers

The goal of most energy efficiency programs is to increase energy efficiency by changing behavior. The target behaviors can be divided into two types--energy-using equipment selection and utilization. Equipment selection decisions are not made by small business managers, but by contractors. Therefore programs to encourage efficient equipment choice should be targeted not at small business people but at equipment contractors. Equipment utilization decisions are made by small business people, and therefore programs to encourage efficient use of existing equipment should be targeted at small business people.

Intervene at Time of Retrofits and Remodels

Small business people we interviewed showed little interest in replacing energy-using equipment merely to save energy. HVAC equipment is replaced only when it fails, and lighting fixtures are redone only when the store changes hands or when the store is remodeled. This is consistent with findings by Wilk and Wilhite (1985), who found that residential weatherization was most often installed right after moving in. Therefore opportunities to promote efficiency should be highly visible at the time retrofits and remodels are being planned. Planned remodeling sites might be identified by building permit applications (usually publicly available) or by requests for new utility service or name changes on existing accounts.

Improve User Information

We have documented the poor quality of energy-related information supplied to small commercial users. Improving this information, however, requires matching the information to the needs and interests of the recipients. Given small commercial users' relative lack of interest in energy, a complicated and difficult presentation of energy-related information will most likely be ignored. Research in the residential sector has shown that a simple report summarizing past consumption can increase user interest in energy consumption (Layne *et al.* 1988). We expected that this feedback technique could easily be extended to the small commercial sector. Of the several problem areas in the small commercial sector, we chose one--feedback for improving energy information--as a manageable issue for further experimental research. We designed several graphical energy reports and tested them on users, as described in the following section of this report.

3. FIELD TESTS OF GRAPHICAL FEEDBACK

In this section we present results from a second round of in-depth interviews with eight energy decision-makers in four Jersey Mall businesses. These second interviews were intended to evaluate one promising method of addressing the energy information problem--the use of graphical feedback.

There are several ways that graphical feedback could address problems described in the previous section. As our interviews revealed, small businesses often feel that energy costs are fixed and independent of their behavior. If a graph of hourly electricity consumption showed, for example, that energy use was higher on the night they left the lights on, this would more clearly relate energy use to their behavior. The belief that reduced energy use leads to discomfort might be disproven if it could be shown, using an inter-store comparison, that a neighboring store uses less energy even though that store is well-lit and comfortable. A monthly graph distinguishing demand and consumption charges may help users recognize and understand demand charges. As we discuss further in the conclusions, several delivery mechanisms are possible. Graphical feedback could be provided as part of an energy audit, it could be mailed to customers responding to a bill stuffer, or it could be automatically mailed to all commercial customers.

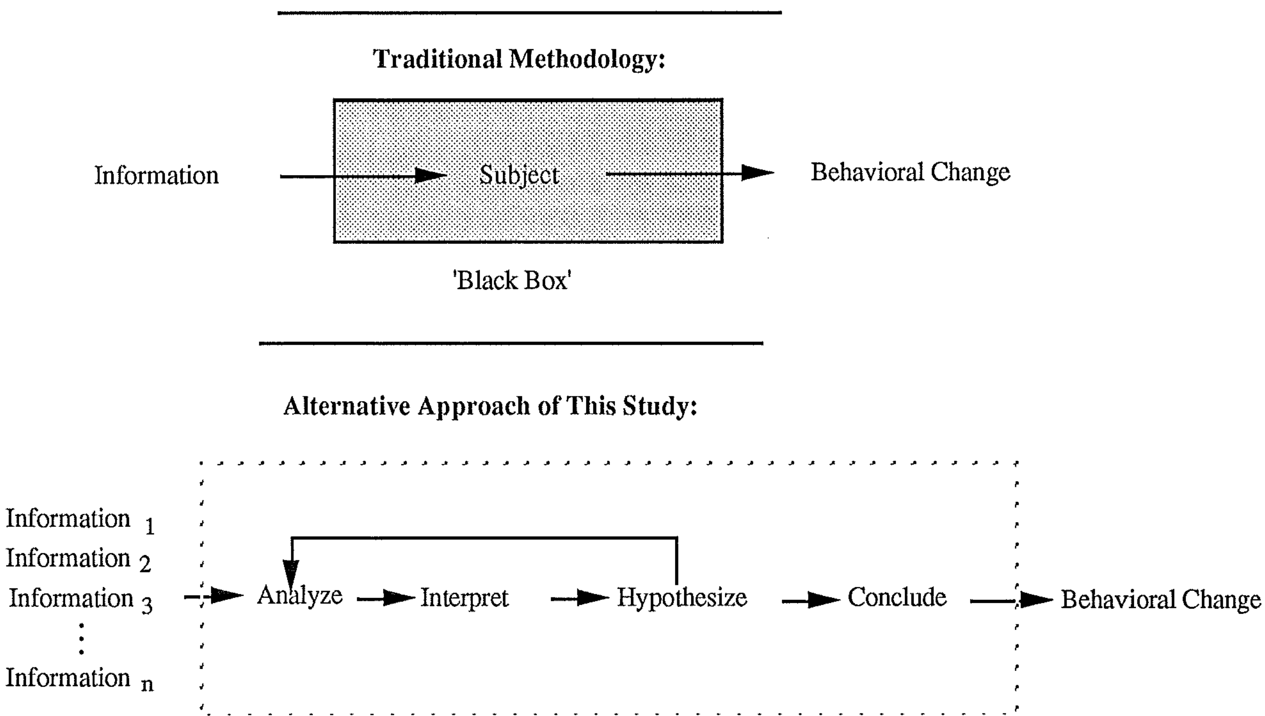
Some of the barriers to energy efficiency in these buildings, such as diffusion of responsibility, are not information or perceptual issues, and will not be solved by graphical feedback. However, feedback has the potential to improve user information and is a necessary component of an overall energy efficiency program.

3A. Introduction

Classical microeconomic theory requires 'perfect information' for efficient market operation. Consumers can make perfectly rational consumption decisions only if they have a perfect understanding of the costs and benefits of their actions. This requirement of perfect information is a useful theoretical concept, but is hard to find in the real world. The lack of accurate, useful information is well documented in the field of energy use (Stern and Aronson 1984). Consumers know very little about energy use and energy costs, and must make energy-related decisions on the basis of inaccurate and sparse information concerning costs and benefits. This is especially true in the small commercial sector, as we have shown in our exploratory interviews with tenant businesses at the Jersey Mall.

One method to address this information problem is through the use of feedback. Many studies have provided energy users with information on their past consumption, and measured the effects of this feedback on consumption (e.g., Seligman *et al.* 1978; Katzev and Johnson 1987, p.54-67). As we will discuss shortly, results have been mixed. Although these studies use different technologies and formats for presenting information, they use a common experimental methodology--the independent variable is the information, and the dependent variable is change in energy use. Fewer studies have looked closely at the intermediate process in which information is presented, analyzed, interpreted, and acted on (see Figure 2). Thus, there has been little discussion of why a specific information format was used or how individuals conceptually relate the information to their own behavior.

Figure 2. Traditional and alternative approaches to studying the effects of energy feedback.



The goal of our field tests was to further understanding of the relationship between energy information, energy-using behavior, and energy use. Specific questions addressed in this section include:

-How can inter-store comparisons provide an indicator of energy use?
-Which time periods of feedback facilitate which inferences?
-What graphic forms do users find informative and easy to read?
-What energy units are preferred by users?
-How can the concept of energy demand (kW) be communicated through feedback?

This research addresses these questions through the use of in-depth interviews with energy users. An information packet with several different types of energy-related information is presented to energy users, who are then interviewed to obtain data on their perceptions and interpretations of each type of information. The focus is not on the effects of information on behavior *per se*, but on the way energy users perceive, analyze, and interpret energy-related information as presented in the packet. Considerable attention is paid to comparing different forms of feedback, including the time period of energy information shown and the units used.

3B. Existing Research

Both graphic design and energy feedback have been studied extensively by researchers in various fields. We briefly review this research, focusing on implications for the design and analysis of energy graphics.

Graphics/Display Literature Review

Research in graphics and display formats is of two types--computer graphics and graphic design guidebooks. Computer graphics research has emphasized the use of experiments, in which subjects are exposed to information in various formats and their responses are measured. Guidebooks are generally written by experienced graphic designers who use their professional experience to suggest methods of effective graphic design.

The recent price decreases in computers and computer-based display technologies has led to increasing use of computer graphics to present data and information. There has also been a corresponding increase in research on the impacts and effectiveness of computer-based graphical methods.[4] Due to the diversity of academic disciplines involved in graphics research, the methods, definitions, and research goals vary considerably. DeSanctis (1984), in a review of the use of computer-generated graphics research concludes, "There are many empirical studies on the effectiveness of various graph types, yet practical guidelines on graph selection cannot be formulated because of conflicting results and lack

[4]The term computer graphics is used here to include graphics produced by a computer and printed on paper, like that used in our research, as well as real-time displays on monitors.

of systematic effort in the research." Despite these limitations, the existing literature provides a starting point for our research. Important findings include the need to keep graphs simple and to consider differing interpretations of graphics across individuals.

Energy Feedback Literature Review

The literature on energy feedback is quite similar to the research on graphic design in that, although plentiful, it has provided little understanding of how energy feedback is used and interpreted. Although many studies have measured the effects of feedback on energy use, few have looked closely at how feedback information is analyzed and interpreted.

A recent review of the feedback literature found 11 studies reporting feedback which resulted in reduced energy use, and 8 studies reporting no effects of feedback on energy use (Katzev and Johnson 1987). These studies use various formats to provide feedback, including continuous display monitors, written notes, and methods for individuals to monitor their own energy use. The feedback is given on an instantaneous, daily, weekly, or monthly basis. The diversity of approaches and methods used makes it difficult to reach an overall conclusion on the effectiveness of feedback as a conservation strategy.

Layne *et al.* (1988; also Kempton and Layne 1988) studied the consumer's processes of analyzing and interpreting energy data. They used ethnographic interviewing methods to evaluate energy feedback in the form of a Home Energy Report providing raw monthly billing data and weather-corrected annual energy consumption data to households. Like the current study, they evaluated several forms of information and used interviews to elicit processes of interpretations and analysis. The pilot information form used a single yearly index, but they found that users wanted first a table of the actual monthly data. Energy users in their study found the concept of weather-adjusted annual consumption difficult to understand, so improved layout and interpretive text were used to help lead consumers to accurate inferences. Some respondents used the experimental report to evaluate past retrofit actions. The authors point out an important difference between short- and long-term feedback. The short-term feedback used predominantly in other studies, such as continuous or daily, is appropriate for influencing short-term energy-using behavior (turning off lights, setting back thermostats, etc.). Longer term feedback (such as monthly bills or an annual report) is more appropriate for evaluating retrofits or conservation investments.

As in the review of the graphics literature, the energy feedback literature (with the exception of Layne *et al.* 1988) is limited in its applicability to this study by its treatment of the user as a black box, with the emphasis on change in energy consumption as a dependent variable. The variation in the time interval used in the feedback (real-time, daily, monthly, etc.) suggests this variable deserves further research attention. Recent advances in energy metering technology have made the collection of short-term (i.e., less than monthly) data relatively easy.[5] However the applicability of shorter-term data to small business managers is not yet clear. This question is explored in this research.

3C. Methods

The field tests of graphical feedback discussed here are intended to improve understanding of the relationship between energy information, energy-using behavior, and energy consumption. This relationship is investigated through extensive interviews with energy users, as part of a larger study also including detailed metering of energy use in small commercial businesses. An information packet, presenting feedback in several formats for different time periods, was prepared and given to energy users. Ethnographic interviewing methods, along with the use of some fixed questions, were then used to draw out the participants' perceptions and interpretations of the energy information. This section describes the subjects, the information packet, and the experimental procedure.

Four businesses at the Jersey Mall--a large (60,000 ft^2) retail department store, a health club, a retail furniture store, and a stationery supply store--were selected for participation in the study. These four businesses reflect the variety of business types found at the Jersey Mall. At the large department store, a preliminary interview with the store manager identified four individuals as responsible for energy use and energy-using equipment at the store--the manager, the owner, and two building contractors. At the three smaller businesses, preliminary interviews identified the owner/manager as the primary decision-maker. The furniture store was in the process of being sold, and both the old and new owner/managers were involved in energy-related decisions. Therefore a total of eight individuals in four businesses were targeted for interviews.

Pulse-generating kilowatt-hour meters were installed and calibrated at the four stores to collect short-term electricity consumption data continuously. A data acquisition system

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[5]For example, the Metscan Company (Honeoye Falls, NY) sells a residential gas meter which can be programmed to automatically provide consumption data via phone lines for any time period .

collected and stored the data on disk. For long-term comparison, monthly consumption data for two years were obtained from the electric utility serving the four businesses.

The information packet is designed to meet several criteria--to show a range of time periods, make use of several different formats, separate demand from consumption information, and be as clear and informative as possible. Differences in energy-using equipment among the four participating businesses required minor modifications in the forms. The specific form used in the department store is shown in Figures 3-6. The form includes:

-An annual summary of energy use, and a comparison with other businesses
-A plot of monthly electricity consumption for the most recent twenty months
-A plot of daily electricity consumption for a recent month
-A two-dimensional plot of hourly electricity consumption for a recent week
-A three-dimensional plot of hourly electricity consumption for several months

The annual section has two parts--a pie chart providing a breakdown of energy costs into weather-sensitive and non-weather sensitive consumption, and a comparison of the building's energy use with neighboring businesses (see Figure 3). The pie chart provides a breakout of energy consumption for heating, cooling, and other. The PRISM method (Fels 1986) is used to distinguish weather-sensitive from base-level consumption. The monthly section provides a simple bar chart of monthly electricity costs for 20 months, and distinguishes demand (kW) from consumption (kWh) charges (see Figure 4). The daily section uses a bar chart to provide feedback on daily electricity use for a recent month, with scales for both $ and kWh units (see Figure 5). The hourly section uses two formats--an area graph and a 3-dimensional graph--to provide feedback on hourly electricity consumption (see Figures 6A and 6B).

Each person interviewed was presented with the information packet for his or her business. Each page was presented individually, and the person was encouraged to vocalize his or her interpretations and responses. The interviews were intentionally open-ended to allow for unanticipated responses. Each interview lasted approximately 45 minutes.

3D. Results

The interview results are summarized in three areas--user conceptions and understandings of units, including kW, kWh, and dollars; user understandings of variables influencing energy use, including his or her own behavior, equipment operation, and exogenous

Figure 3. Annual summary of energy use and comparison with other businesses.

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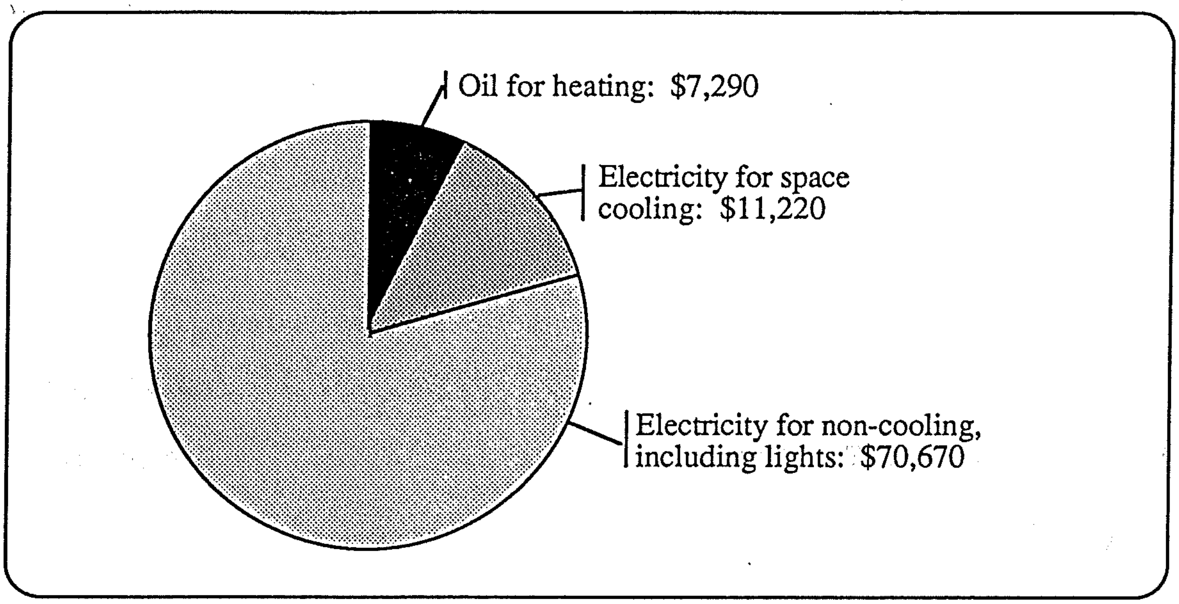
ENERGY REPORT FOR: **DEPARTMENT STORE**

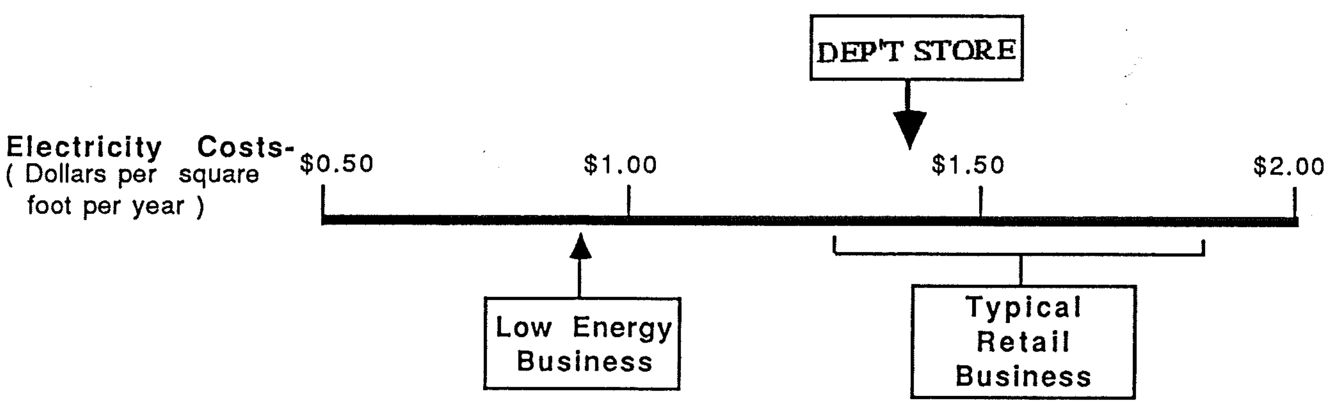
Part 1: Summary of Electricity Use

Total Energy Costs (Sept. 1987-August 1988): $89,180



Explanations: Oil deliveries, not consumption, are shown. 'Electricity for space cooling' is estimated as the increase in electricity use and demand during hot weather months. The remainder is considered 'non-cooling'. Consumption is not weather-adjusted.

HOW DO YOU COMPARE?



Explanations: 'Typical retail business' is based on a small sample of businesses at the Shopping Center, and excludes grocery stores and restaurants. Range shown is one standard deviation. 'Low energy business' is an average value for the lowest 10% of businesses in the sample.

Figure 4. Monthly energy consumption.

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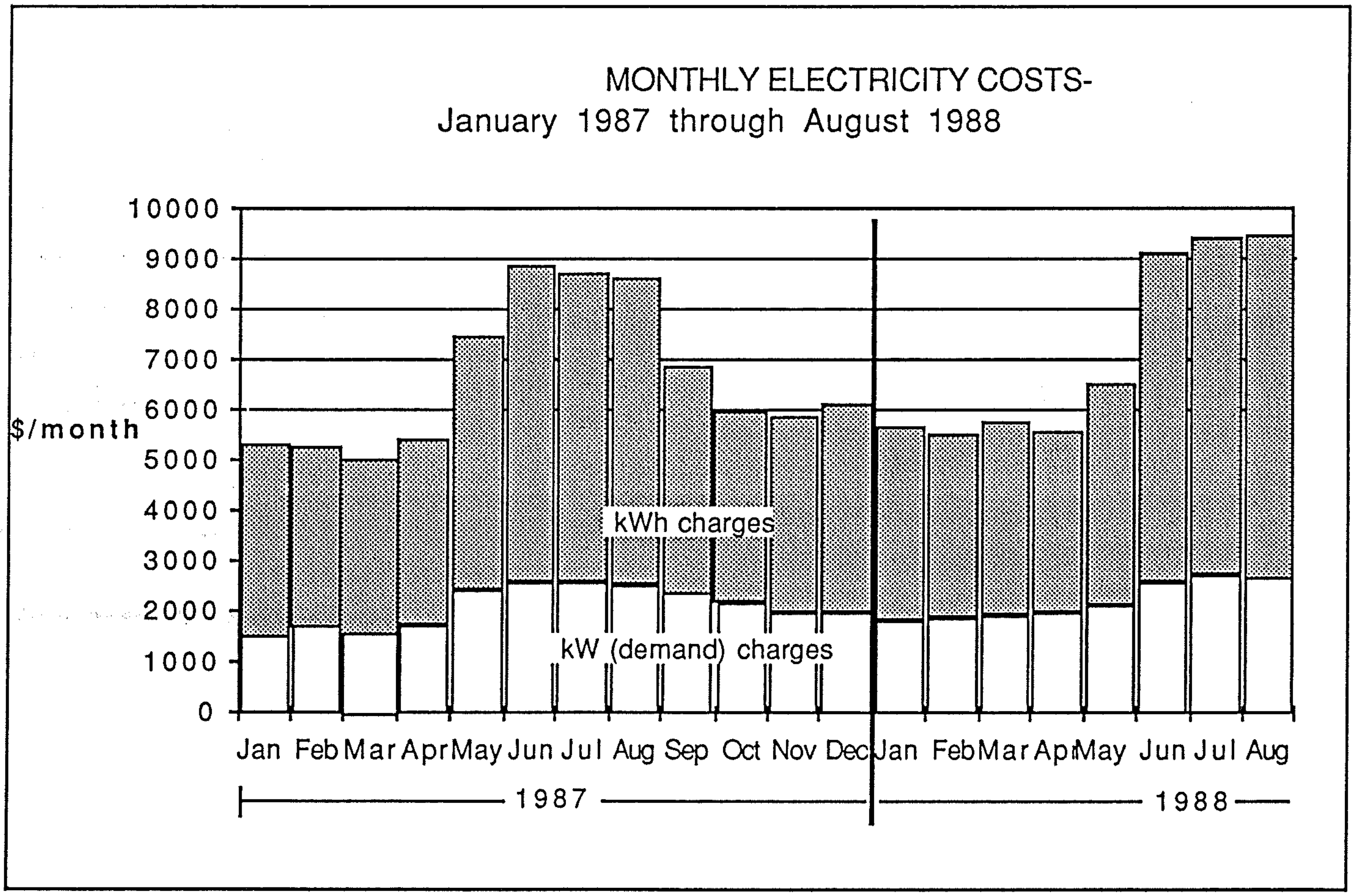
ENERGY REPORT FOR: **DEPARTMENT STORE**

PART 2: Monthly Electricity Use



Months are from approximately 10th of month shown through 10th of following month. Data not weather-adjusted.

Annual Summary for 1987	
kWh	$53,500
kW (demand)	$25,000
Total	$78,500

Figure 5. Daily energy consumption.

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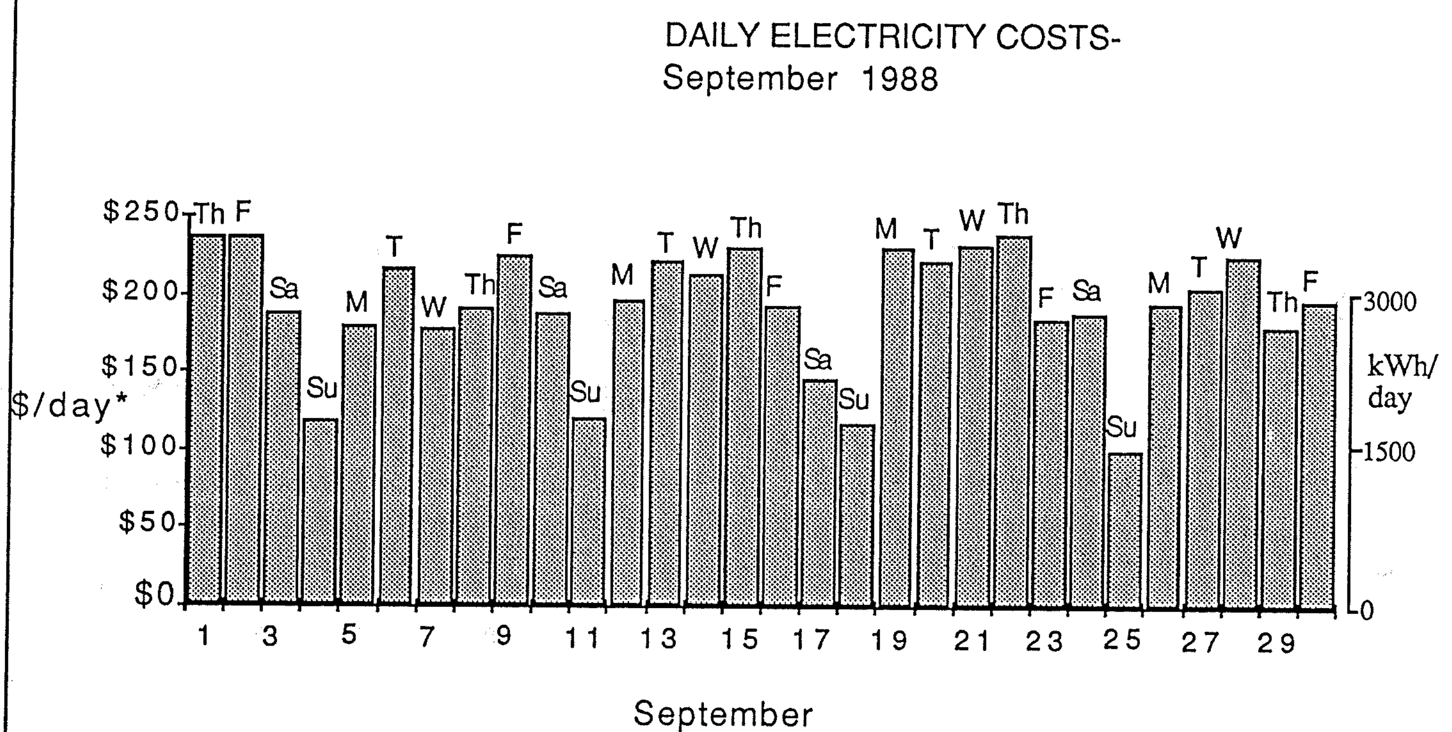
ENERGY REPORT FOR: **DEPARTMENT STORE**

PART 3: Daily Electricity Costs for Recent Month



*Excluding demand charges

Figure 6A. Hourly energy consumption.

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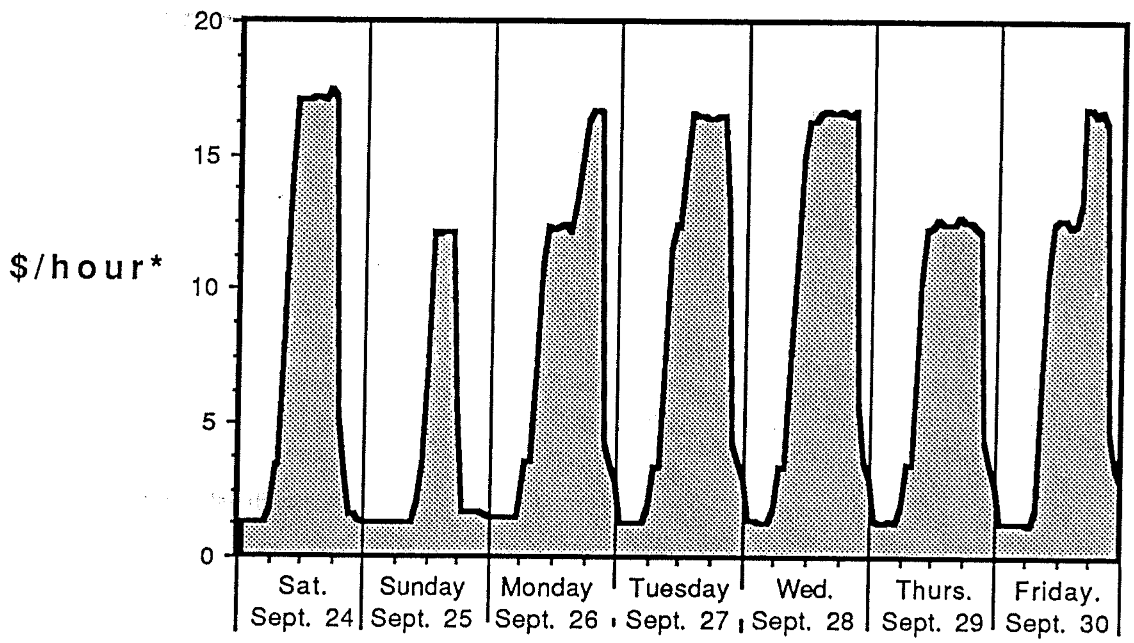
Princeton University

ENERGY REPORT FOR: DEPARTMENT STORE

PART 4: Hourly Electricity Costs

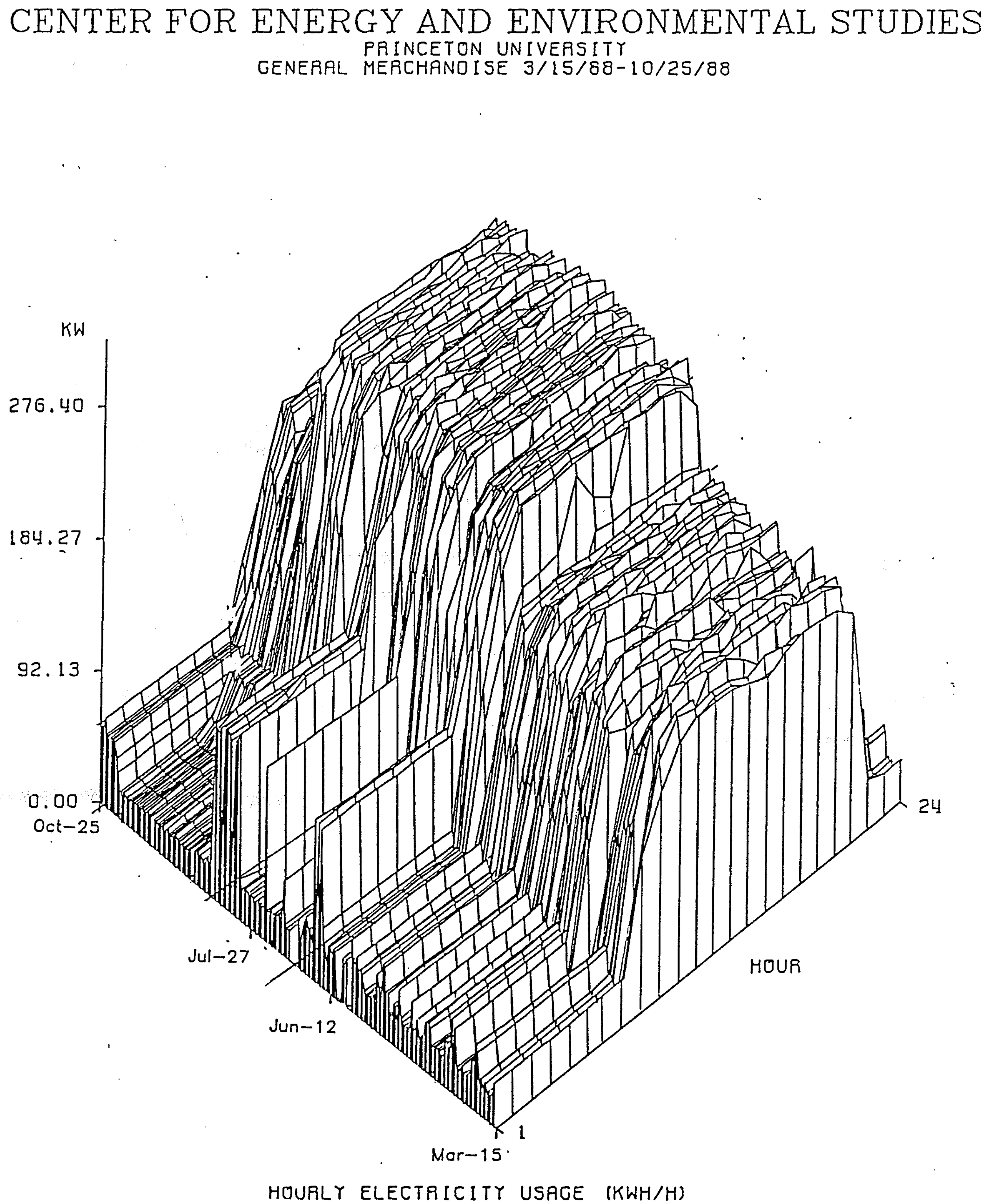
HOURLY ELECTRICITY COSTS- September 24-30, 1988



Average Daily Temperature (F):	68°	65°	68°	65°	68°	68°	65°

*Excluding demand charges

Figure 6B. Hourly energy consumption using a three-dimensional representation.



variables such as weather; and user preferences for format and time period of feedback data.

Units

The information packet used three basic units related to energy use--kWh, kW, and dollars. The monthly plot divided energy costs into two components--kW charges and kWh charges. In addition, the daily plot showed daily energy consumption in both kWh and dollars. User comments and interpretations provided some insight into how individuals perceive and interpret energy units.

Our initial interviews at the Jersey Mall uncovered a lack of understanding related to demand charges. This finding was strengthened by our field tests of graphic feedback. When the eight users were shown the monthly plot with the kW charges, only one demonstrated any understanding of what this charge was due to. One participant (an HVAC contractor for the department store) commented, "KW demand..What's this kW demand?" The store manager said, "I don't understand demand--or how it affects costs. The average consumer cannot understand demand." One HVAC contractor demonstrated a partial understanding of demand charges, "This kW charge is probably a surcharge for equipment starting and stopping, and going over their demand limit." As suggested by the earlier interviews, these results indicate that users do not clearly understand demand charges. Furthermore, the comments by HVAC contractors indicate that energy-using equipment in these small commercial stores is selected and installed without regard for electric demand.

Users were asked their preferences for dollars versus kWh. Dollars were in general preferred, but energy units were also seen as of some value. The furniture store owner commented, "Dollars per day makes sense. Kilowatts...I don't know a kilowatt from a...well...whatever" (she was actually looking at a plot labeled kWh). She also compared her monthly energy costs to her bill at home-"July (energy charges) are about four times what I pay at home." Similarly, the stationery store owner said, "Money makes more sense than the other figures. Most people do not know how to translate that [points to kWh scale] into something they can compare." The owner of the department store, who was considering several energy-related retrofits, said both units were useful-"We do financial budgeting in dollars, so dollars are better for the monthly and annual figures. However, from a project standpoint, we deal with kWh--the goal should be in kWh." A contractor indicated a preference for dollars so he could compare the costs of efficiency improvements to the capital costs of new equipment. These results suggest that energy units of dollars provide a useful way to compare energy to other business costs, but that there is some recognition that kWh can also be useful. This is consistent with Layne *et al.* (1988), who use both units in their Home Energy Report for the residential sector.

One component of the annual section of the information packet gave energy use in units of dollars/ft^2. Users found this informative, but recognized that it could be misleading. Said one, "I don't know if you can compare us with the smaller stores." Similar comments included, "These low energy businesses--are they very cold or very dark? Maybe they're not open as long as we are", and "This comparison is based on businesses in the area. But what if the whole neighborhood is high?" Several users said that the comparison should be relative to similar businesses--'If this graph showed Fitness Centers--that would be interesting."

The use of prior beliefs as a cognitive reference point in comprehending the information was revealed by user comments on the end-use breakdown provided by the pie chart. Comments such as, "I spend a lot on lights...I expected that," and "That seems pretty low for just the chiller" suggest that an initial use of the energy feedback is to see how it compares with prior beliefs. Information that was strongly inconsistent with prior beliefs was viewed with suspicion--"Why isn't it constant?...This is totally ridiculous," commented one user when viewing daily consumption showing large day-to-day variations in energy use. A user with minimal prior conceptions of the details of her energy use found the information difficult to comprehend--"I'm not getting much out of the (pie chart). I don't know anything about any of this stuff."

End uses were also compared--"Lights are the largest cost center," leading to conclusions on which end-uses were deserving of further attention--"I guess more efficient lights would have the biggest impact," and "The primary focus should be on...lighting." However, a contractor noted the need for some form of normalization--"...doesn't tell me whether or not the lights are efficient. The oil for heating-it's not against anything."

<u>Influencing Variables</u>

One intention of this study was to see how users tie graphic information to the real world--that is, the connections made between the energy feedback data and their own behavior, as well as the connections between the data and other factors affecting energy use. These connections differed for the monthly, daily, and hourly graphs.

The monthly data were linked to the presence of air conditioning, as indicated by comments such as, "It's obvious that the cooling season makes it go up," and "The air conditioning causes a peak in May to September." Interestingly, users were uncomfortable when they did not see a summer increase in energy costs--"July and August electricity use is medium--I would expect it to be high. I wonder what happened," responded one user.

The daily plot was tied to business hours and to weather. Business hours were often mentioned first--"I guess these low days--we must be closed." "We aren't open as much on Sunday, and you can see that." Also mentioned in conjunction with variations in daily consumption was weather--"This Friday is higher than that Friday...must be weather." "There's also a variation week-to-week..it is probably weather influenced."

The hourly plot was closely connected to energy-using behavior. One respondent pointed to a low-consumption period and said, "Maybe somebody forgot to turn the chiller on, or maybe it wasn't working." She also tied the hourly data to her own work schedule, "It never reaches the peak on Thursday. I'm off Thursdays-what are they doing when I'm not here?" An owner/manager asked, "Why does it fluctuate so much? I never touch the thermostat...it must be the lights." A contractor pointed to an hourly fluctuation and noted, "Somebody screwed up here..things are staying on. What's this peak on Monday? Must be air conditioning."

The time period shown and the corresponding causal variables identified by users are summarized below in Table 2.

Table 2. Feedback time periods and corresponding variables.

Time Period	**User Explanations for Variations in Energy Use**
Monthly	Presence of air conditioning
Daily	Business Hours, Weather
Hourly	Behavior

Preferences--Time and Format

The forms used several different formats to present energy information for four time periods (annual, monthly, daily, and hourly). Following the presentation of all forms, respondents were asked, 'If you could keep only one of these forms, which one would it be and why?' The results suggest that energy information is valued in the context of the specific responsibilities and interests of the user. A contractor preferred the monthly plot because, "...it reflects the kW demand, which I could do something about." A store manager, by contrast, preferred the daily plot because it provided information on equipment operation, which was her responsibility. The store owner preferred the monthly plot, as he "...could use it to verify the calculations of contractors." Another store owner also expressed a preference for monthly data as, "Most of my bills and expenses are monthly."

Preferences for types of graphs were also revealed in the interviews. In spite of its increased use in the research community (for example, see Christensen 1984, Haberl and Vajda 1988, Reiter 1986), the three-dimensional plot was universally disliked by the untrained participants in this study: "The way it's charted, I can't see what's going on. I don't think it's a good representation." "It's pretty confusing. I'd need a lesson to figure this one out." "Who designed this? I have no idea what's going on." Both the bar and pie charts were understood by most users, and no clear preference between these two formats was revealed.

Users were asked what specifically they might do differently because of the information. Several comments suggest that the data would be used either to forecast or to evaluate the effects of conservation--"This (monthly) graph is good...especially if we make a change in something and want to see the effect." "If I could see (consumption) to the minute, I could tell if they're turning lights on too early." The information also served to build interest in energy conservation. "This is good information--what can I do to make this a low-energy business?", asked one owner of a new store at the end of the interview. He was making several retrofit decisions at the time, and his willingness to consider energy use in these decisions supports our point made earlier concerning the need to intervene at the time retrofits and remodels are being planned.

3E. Summary of Field Test Results

The results obtained in the field test are summarized below:

1. Energy feedback is first compared to one's prior beliefs. If the two are very inconsistent, then the new information may initially not be believed.

2. kW demand charges are poorly understood, and demand is not influenced by these charges.

3. Dollars are in general the preferred units, but kWh are also seen as valuable.

4. The need for normalization to compare energy use across stores is recognized, however normalizing by floor area alone is seen as misleading.

5. Different time periods of feedback are conceptually linked to different causal variables. Hourly data are linked to equipment operation, daily data to operating schedules and weather, and monthly data to heating/cooling seasons.

6. The time period of interest to a user is that most closely matching his or her responsibilities.

7. Three-dimensional plots are not appropriate for average small business managers.

4. IMPLICATIONS AND CONCLUSIONS

The results of our interviews and field tests have implications in two distinct areas--the design of programs to implement energy efficiency in small commercial buildings, and the direction for future research on energy use in these buildings.

4A. Policy/Program Design

Our exploratory interviews uncovered a severe lack of energy-related information for managers in small commercial buildings. For example, 40% of users did not know their heating system used gas. Appliance energy use was often estimated by noise and visibility. None of those asked was aware of demand charges. Users see energy use as unchangeable, and conservation as requiring discomfort and sacrifice.

We have suggested four directions for future programs to address these issues. These are to recognize and exploit non-financial determinants of behavior, to target decision-makers, to intervene at time of retrofits and remodels, and to improve user information. We have then experimentally evaluated the effects of improved information using graphical feedback techniques.

It was found that feedback is much more effective when matched to the user's area of responsibility. Contractors and others making equipment selection decisions and evaluations can benefit most from annual or monthly data. Building operators and those responsible for equipment management find more value in shorter-term data, which can be used to evaluate specific equipment control decisions. Both dollars and energy units should be used in providing energy feedback--dollars are more readily understood, and energy units provide a method of controlling for rate changes. Users recognize the need to normalize consumption when comparing different businesses, but they see normalizing by floor area as insufficient to allow credible inter-store comparisons of consumption. Users correctly see inter-store variations in hours of operation and amenity levels as making these comparisons difficult. Comparison of a business with others with the same SIC code would be a logical first step in producing a credible inter-store comparison.

We are not arguing that merely supplying information will be sufficient to induce energy efficiency improvements. The issues discussed earlier, including a diffusion of responsibility for energy use and users' concern with non-financial factors, also act as barriers to energy efficiency. Nevertheless, the provision of carefully designed targeted information is a necessary component of an overall program to encourage cost-effective energy efficiency improvements.

4B. Future Research

The results presented here, although based on a small sample, do provide important working hypotheses and sharpen the questions for future work. Users' poor understanding of demand charges, and the inability of our graphical feedback to improve this understanding, raise the question of why demand charges exist at all. If a demand charge is intended only to charge users for the generating capacity they are using, then it is not necessary for users to understand it. However, the economic argument for the existence of a demand charge is to, "(encourage) existing customers to spread their loads over a longer period in order to minimize their demand charges" (Bonbright 1961, p.311). Since demand charges do not currently seem to be recognized or understood by customers, this goal cannot be met.

Several questions related to the specifics of information design were raised. The relationship between time period of feedback given and perceived causal variables deserves further research. This relationship could be validated on a larger sample by attempting to match the time period of feedback to specific behavioral goals. The relationship between feedback on energy versus feedback on other business expenses is of interest. Do small businesses generally think of costs on a monthly basis? How can energy feedback be integrated into the overall business expense information environment?

The method through which such information is given to the user is of interest. Should it be part of an audit, or should it be sent to the user on an ongoing basis, as has been suggested for the residential sector (Kempton and Layne 1988)? If it is integrated into an energy audit, should the auditor take the feedback to the site, send it ahead of time, or use it as a follow-up for evaluation?

Finally, one could interpret the information and motivation problems uncovered here as meaning that any decisions to increase energy efficiency should not rely on the users. An energy service company, for example, could be hired by the mall management to retrofit all businesses in the mall, bypassing the small business managers entirely. This could solve several of the investment decision problems, but we do not advocate it as an exclusive answer for several reasons. First, the users will still operate the equipment, and in the absence of improved information will continue to operate it without regard to energy use.

Second, decisions on lights and business-specific equipment are made by the individual businesses, and these decisions cannot be made by energy service companies. Third, the businesses are paying energy costs in any case, and therefore have a right to know what they are paying for and what they could do to pay less.

ACKNOWLEDGEMENTS

The assistance of the owners, managers, and contractors at the Jersey Mall is greatly appreciated. Meg Fels, Richard Katzev, Les Norford, Cathy Reynolds, Mark Sieben, and Rob Socolow provided advice and/or valuable comments on this manuscript. This work was part of the New Jersey Energy Conservation Laboratory, which is supported by the seven New Jersey gas and electric utilities and the New Jersey State Department of Commerce, Energy, and Economic Development.

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Figure 3. Annual summary of energy use and comparison with other businesses.

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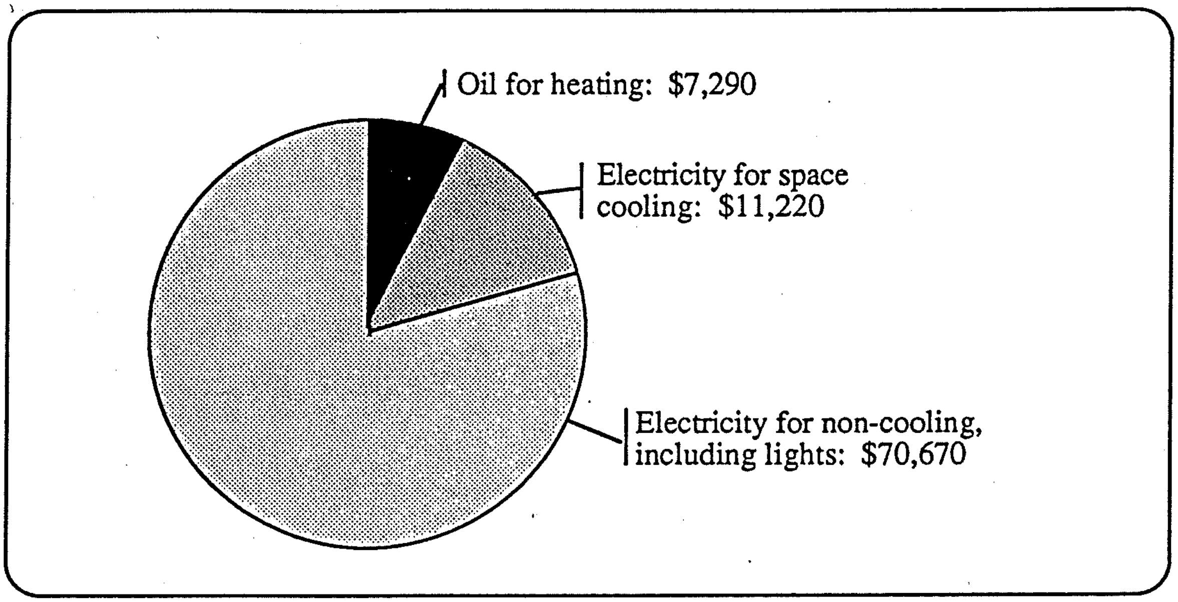
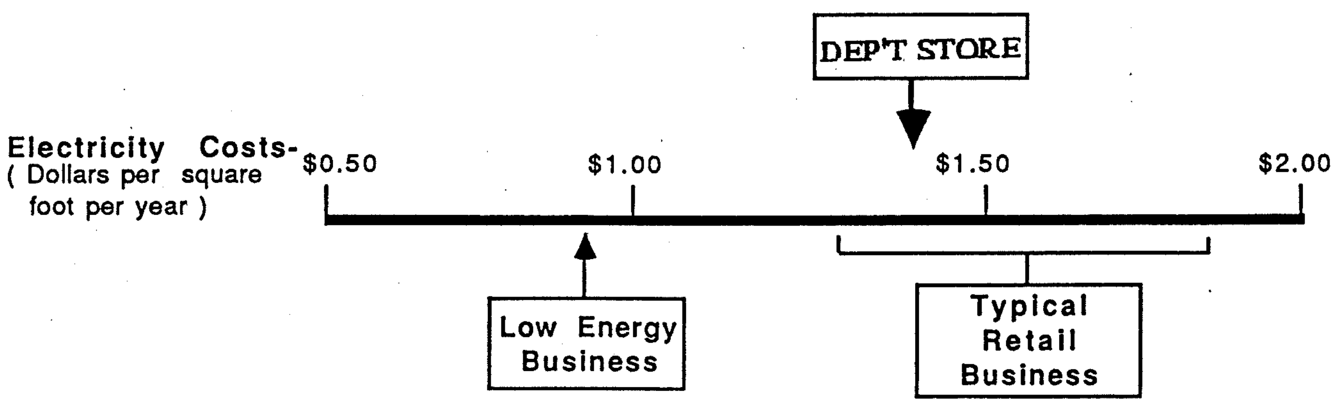


Explanations: Oil deliveries, not consumption, are shown. 'Electricity for space cooling' is estimated as the increase in electricity use and demand during hot weather months. The remainder is considered 'non-cooling'. Consumption is not weather-adjusted.

HOW DO YOU COMPARE?



Explanations: 'Typical retail business' is based on a small sample of businesses at the Shopping Center, and excludes grocery stores and restaurants. Range shown is one standard deviation. 'Low energy business' is an average value for the lowest 10% of businesses in the sample.

Figure 4. Monthly energy consumption.

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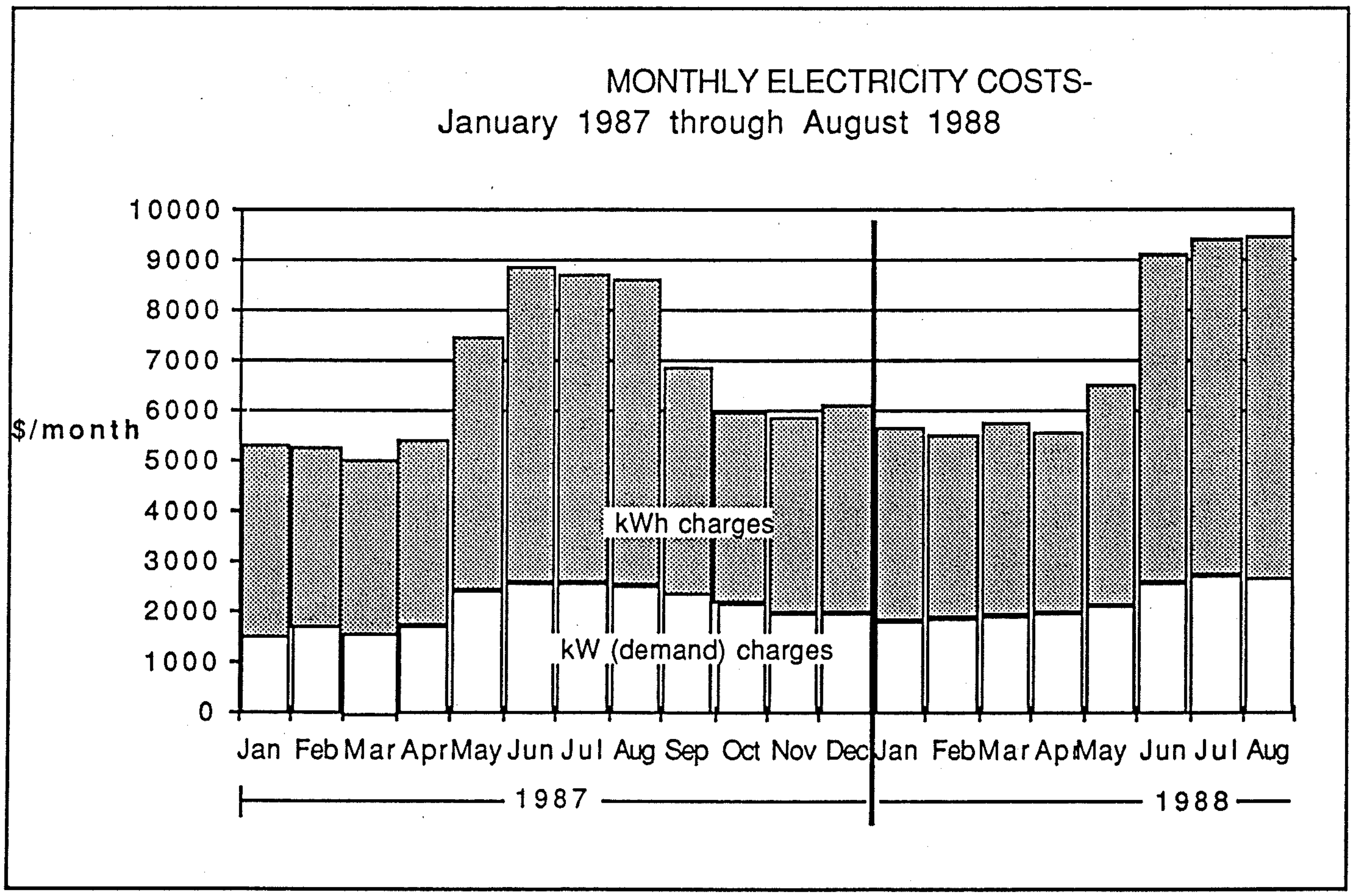
PART 2: Monthly Electricity Use



Months are from approximately 10th of month shown through 10th of following month. Data not weather-adjusted.

Annual Summary for 1987	
kWh	$53,500
kW (demand)	$25,000
Total	$78,500

Figure 5. Daily energy consumption.

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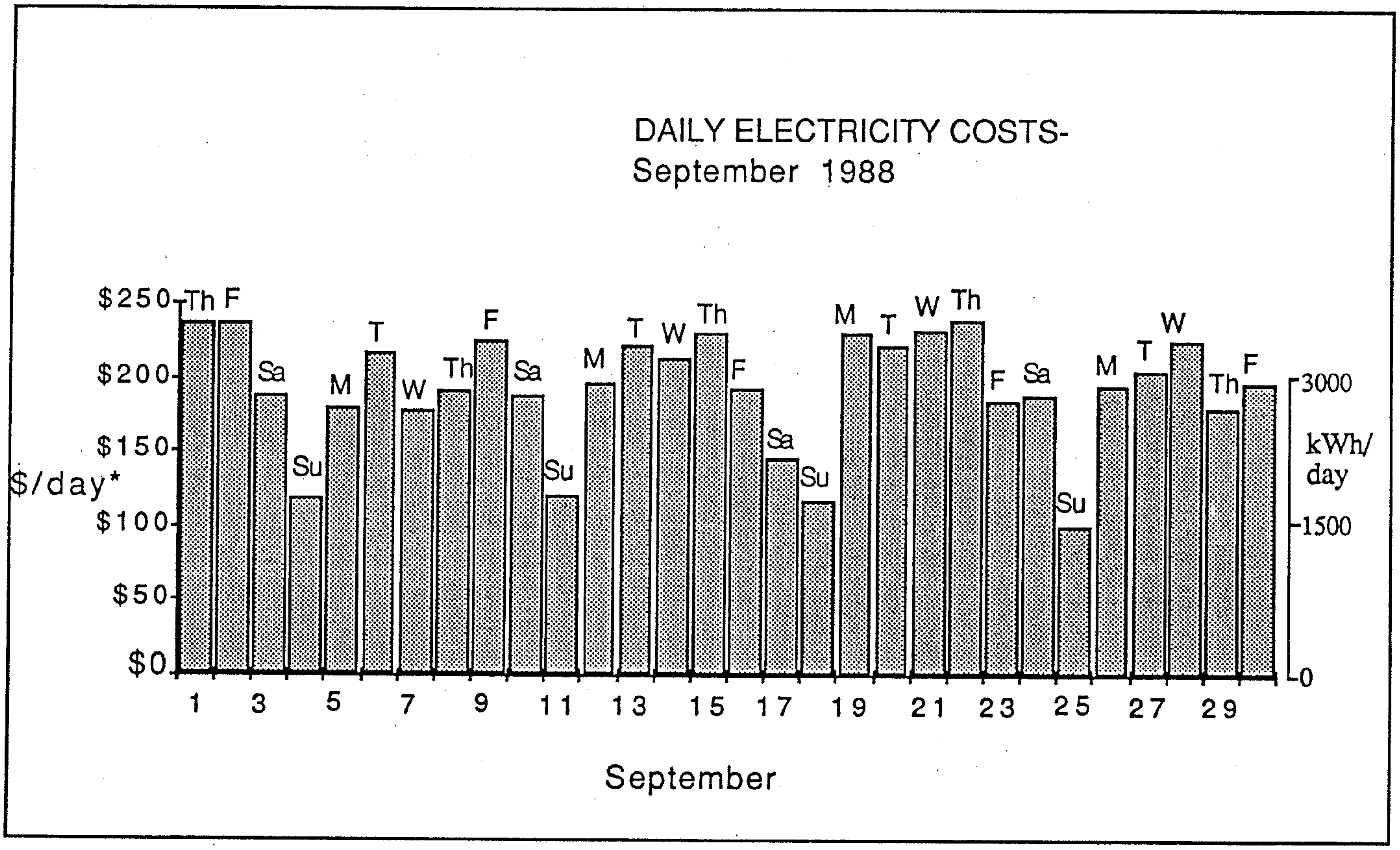
ENERGY REPORT FOR: **DEPARTMENT STORE**

PART 3: Daily Electricity Costs for Recent Month



*Excluding demand charges

Figure 6A. Hourly energy consumption.

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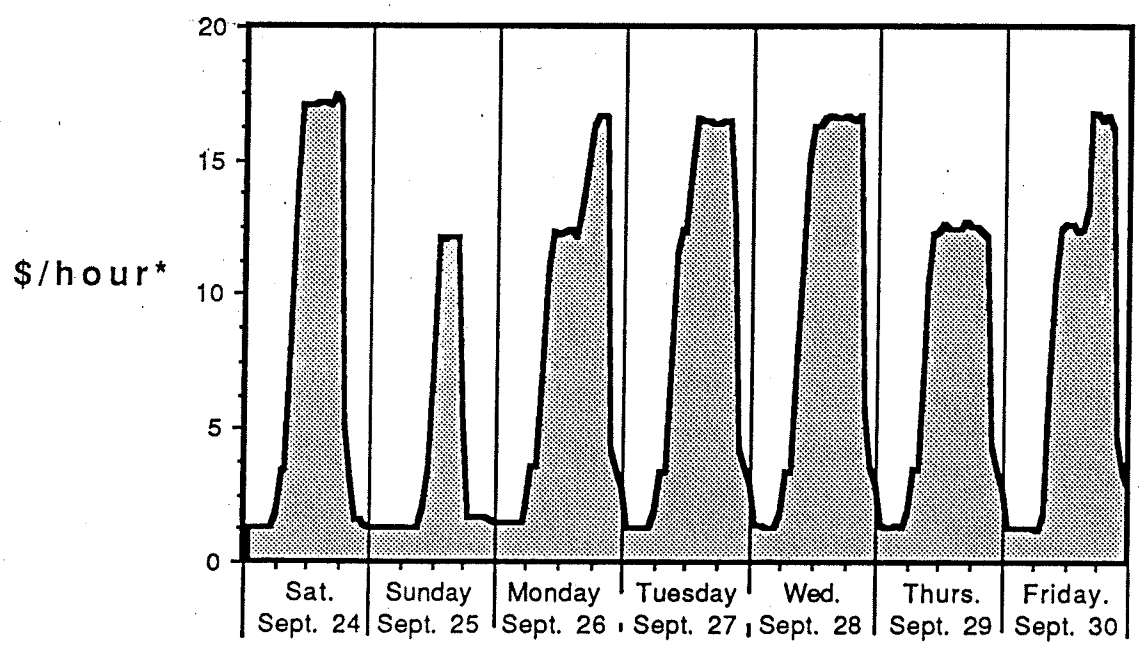
ENERGY REPORT FOR: DEPARTMENT STORE

PART 4: Hourly Electricity Costs

HOURLY ELECTRICITY COSTS-
September 24-30, 1988



Average Daily Temperature (F):	68°	65°	68°	65°	68°	68°	65°

*Excluding demand charges

Figure 6B. Hourly energy consumption using a three-dimensional representation.