The Project on Restaurant Energy Performance—End-Use Monitoring and Analysis

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THE PROJECT ON RESTAURANT ENERGY
PERFORMANCE--END-USE MONITORING
AND ANALYSIS

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May 1985

A Multiyear Collaborative Effort of
The Pennsylvania State University
The National Restaurant Association
Pacific Northwest Laboratory

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(a) Affiliated with Pennsylvania State University.

PREFACE

The rapid increase in the costs of energy supplies over the past decade has placed increased emphasis on the efficient use of energy in commercial buildings. Studies conducted by the U.S. Department of Energy (DOE) and others have revealed that significant amounts of energy can be conserved in a cost-effective manner through proper selection and application of conservation principles.

Metered energy consumption data by end use and time of day are typically unavailable for commercial buildings. There is little direct evidence of the relative effect that climate, building structure, operation, and occupancy have upon energy use in commercial buildings, and almost no measured information reveals the interaction of these factors. Architectural design and design tools are consequently based chiefly upon direct application of the laws of physics and component-based algorithms in computerized simulations of building operation. These simulations in turn are generally validated only against monthly utility billings. Actual end-use energy consumption data must be collected to understand how commercial buildings really use energy if the design and operation of these buildings for cost-effective energy consumption is ever to become the rule, rather than the exception.

This document provides a description of a project undertaken as part of the Commercial Building Energy Use and Design Program, a multiyear research program sponsored by the U.S. Department of Energy, Architectural and Engineering Systems Branch, Building Systems Division. The program is managed by Pacific Northwest Laboratory (PNL), operated for DOE by Battelle Memorial Institute. Under this project PNL and its contractors collect and analyze metered energy performance data from a series of commercial buildings to develop a reliable and publicly available data base for the buildings community.

The Project on Restaurant Energy Performance (PREP) was originally proposed by the National Restaurant Association (NRA) and designed by The Pennsylvania State University (PSU). Pacific Northwest Laboratory refined the technical approach and adjusted the project scope to match the funds available

from DOE and the in-kind contributions from the project participants. The Institutional Engineering Advisory Services of PSU's College of Engineering managed the day-to-day operation of the project, with oversight from NRA and PNL.

ACKNOWLEDGMENTS

This project represents significant contributions from the following groups: the National Restaurant Association, The Pennsylvania State University, and the Pacific Northwest Laboratory. The collaborative efforts of individuals in these institutions have provided the synergy necessary to achieve the project goals within a limited budget and schedule.

The conscientious efforts of the late Dr. Andrew P. Poledor, Director of Technical Services at the National Restaurant Association, proved invaluable to efficiently coordinate and focus project activities. Robert Palmer, NRA Associate General Counsel, whose involvement with the project stems back to the preliminary contract negotiations, has capably brought this project to its completion. Lance Charriere, P.E., Kent Howard, and Teri Richman were instrumental in establishing support for this project. Early in the project a technical advisory group consisting of members of the Multi-Unit Architects, Engineers, and Construction Officers (MAECO) was assembled to assist in project design and execution. Frequent meetings and discussions with these individuals were arranged at their own expense to review project progress and resolve problems. The primary participants were Bruce Tatusko and Douglas Smith, P.E., of Host International, Robert Keagy of Steak & Ale, Leonard Riffel of Pizza Hut, Carroll Johnson, P.E., of Friendly Restaurants, Donald Trittin of Burger King, and Jack Sly of Marriott Corporation. The technical insights provided by Bryce Norwood, P.E., of Friendly Restaurants, Chairman of the MAECO/PREP Advisory Committee, were invaluable and deserving of special note.

The Pennsylvania State University proficiently executed the project with careful attention to the project requirements established by NRA and PNL. Charles Claar, P.E., Director of Institutional Engineering Advisory Services, was the project's principal investigator. Other key PSU staff participating in the project included Thomas Collins, Kimberly Fornicola, Harold Hegarty, Edward Hull, Edward Klevans, and Samuel Swanson. Pennsylvania State undergraduate engineering students contributing to the project were John Balogh, JoAnn Lenze, Frank Martinez, and Lenka Nemec.

The Public Service Electric and Gas Company of New Jersey, the Philadelphia Gas Works, and Washington Gas are to be commended for contributing installed meters to monitor end-use natural gas consumption. Without this contribution we would have been unable to accurately disaggregate end-use consumption for three of the monitored sites.

At PNL Raymond Reilly, Manager of the Buildings Program; Thomas Foley; and Jack Tawil established and maintained project direction and funding. Finally, the technical contributions of James Heidell, Leslie Olsen, and Jody Kohlman in the processing and analysis of project data are recognized.

Many thanks to all,

Richard P. Mazzucchi
Senior Research Engineer
Energy Systems Department
Pacific Northwest Laboratory

EXECUTIVE SUMMARY

Although energy bills for restaurants throughout the United States exceed 5 billion dollars annually, very little has been documented with respect to when and how restaurants use energy, or how such use can be reduced cost-effectively. This report summarizes the results of a multiyear collaborative research effort of the National Restaurant Association (NRA), The Pennsylvania State University (PSU), and the Pacific Northwest Laboratory (PNL), designed to collect information on end-use energy consumption. Described here are the project objectives and methods, data sources, and preliminary findings.

The overall objective of this effort is to reveal the quantities and profiles of energy consumption of typical food service operations by time of day and end use. This information, when examined in conjunction with building characteristics, allows detailed study of energy use cause and effect and energy conservation potential. To provide the needed empirical basis, seven representative monitoring sites were selected, a computerized data acquisition network was designed and implemented, and detailed energy performance was compiled for a 1 year period (July 1983 through June 1984).

Each of the seven facilities monitored was carefully selected by the NRA to represent the seven most common restaurant types and to provide information on a wide variety of commonly used restaurant equipment. The seven categories are

- fast food limited menu (FFLM)
- fast food expanded menu (FFEM)
- cafeteria (CAFE)
- pizza (PIZA)
- coffee shop (COFE)
- full service limited menu (FSLM)
- full service expanded menu (FSEM).

Each participating restaurant submitted as-built construction plans, conducted an air balance to assure that the building HVAC system was operating as designed, provided monthly meal or customer counts, and agreed to coordinate any modifications to the facility during the measurement period.

A measurement plan was developed for each site to isolate energy consumption for heating, ventilation, and cooling (HVAC) equipment; food preparation; sanitation; lighting; and refrigeration. Interior temperature adjacent to thermostats was measured, as well as external solar flux, temperature, wind speed, and direction. For three sites hot water consumption volume was also monitored. Data on water supply temperatures were collected from nearby secondary sources. Onsite microcomputers recorded and transmitted data from the monitored sites to the processing facility at PSU on a daily basis. Data quality was verified or appropriate corrective action was determined promptly. Over 87% of available 15 minute interval data was verified, and missing values could be reliably determined by difference and interpolation from monthly manual meter readings.

Restaurants were found to be very intensive users of energy, due largely to the frequent use of food preparation equipment and the high ventilation requirements. Figure S.1 presents the average end-use consumption shares for the seven metered facilities. Over one-third of energy was consumed for food preparation; slightly less than one-third was used for HVAC; and the remainder was used for sanitation, lighting, and refrigeration. Figure S.2 displays how the end-use consumption shares varied from site to site during the monitoring period. Figure S.3 depicts the comparative energy use levels per square foot for each of the monitored facilities by energy end-use category. The restaurants in Figures S.2 and S.3 are listed in order of decreasing energy consumption on an MBtu/sq ft basis.

The monthly total energy use for each of the monitored facilities is shown for each month of the measurement period in Figure S.4. The monthly variation in energy use was primarily due to HVAC energy needs, since consumption for other needs was relatively stable throughout the year. The exception was facilities with large seasonal changes in food service activity, where variations in food preparation and sanitation energy were significant. A robust relationship of monthly HVAC energy to average exterior temperature was documented, permitting reliable prediction of HVAC energy needs.

Some general observations can be made with respect to energy conservation opportunities. The need for regular maintenance of restaurant equipment and

FIGURE S.1. Average End-Use Consumption Shares for Seven Metered Facilities

FIGURE S.2. Comparative Levels by Energy End-Use Category for Seven Metered Facilities

FIGURE S.3. Comparative Energy Levels by End-Use Category for Seven Metered Facilities

FIGURE S.4. Monthly Total Energy Use Per Square Foot for Each of the Monitored Facilities

the establishment of operational guidelines are of vital importance. In several cases equipment was found to be improperly sized, maintained, or controlled, which resulted in inefficient energy use. Corrections of these problems would not affect the quality of the food service delivered. Frequently equipment was energized when no immediate need was evidenced. Restaurant staff need to be educated as to the consequences of such practices and motivated to take corrective action. A "modular" approach to equipment selection is recommended, by which several units of smaller capacity are specified rather than one large unit, allowing energy loads to be more closely matched to activity levels.

The data set also permits the evaluation of more sophisticated energy conservation measures such as heat recovery, energy management control systems, air conditioning precoolers, heat-pump water heaters, and efficient lighting systems. Many of these technologies offer great promise for cost-effective energy savings, and detailed analysis of the assembled data set can provide the insights necessary to design, market, and operate such equipment effectively. Although these conservation techniques may require significant capital investment, it is probable that properly installed systems can provide for a rapid recovery of invested capital and many years of energy savings benefit. Further data analysis should be conducted to test these hypotheses.

Project activities were monitored by a technical advisory committee involved in the project's design, execution, and reporting. This report includes summaries of the committee's observations of the validity and usefulness of the acquired data, as well as insights gained through this research project. The identification of promising energy conservation strategies and practices should be of special value to restaurant operators and designers. The project records have been carefully archived and documented at PNL so that they may be useful to a wide variety of analysts. This report includes appendixes summarizing the data collected, the formats of machine-readable records, and a user's guide for data manipulation. The project participants assembled this data set, hoping that interested parties would make use of it to design and operate more energy efficient restaurants.

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1.0 INTRODUCTION

This report provides a comprehensive review of the objectives, methods, and results of a multiyear program to measure and analyze the energy performance of seven carefully selected restaurants. The program, entitled Project on Restaurant Energy Performance (PREP), involved the coordinated efforts of the National Restaurant Association (NRA), The Pennsylvania State University (PSU), the Pacific Northwest Laboratory (PNL), and the participating restaurant organizations.

1.1 PROJECT PURPOSE

The purpose of this research effort was to reveal the quantities and profiles of energy consumption of typical food service operations by time of day and end use. The impetus for collecting empirical data from operational sites resulted from the lack of consensus among energy users and regulators regarding actual levels of end-use energy consumption in restaurants. During the course of the program this issue became less significant than understanding energy use cause-and-effect relationships and identifying energy conservation potentials for new and existing food service facilities. Fortunately, the research program was constructed to respond to each of these objectives.

1.2 REPORT CONTENTS

This report begins with a discussion of the project activities and methods in which the specific elements of the research program and the techniques to conduct the research are described. Chapter 2 also includes information on project planning and execution, site selection, and the data collection plan. The emphasis then shifts with Chapter 3 to the description of the facilities selected for monitoring, which includes a summary of architectural and thermal features, building equipment, restaurant menu and clientele, and operational practices.

Chapter 4 summarizes the data collected from each of the seven sites and discusses the data capture rate and data quality. A variety of tabular and graphical data summaries is provided to indicate monthly end-use consumption levels, typical weekly energy use patterns, and typical daily energy use profiles. Also summarized are appropriate determinant data such as meal and customer counts, exterior temperatures, and building microclimates.

Chapter 5 is a discussion of the data analysis conducted to date, including comparisons of the energy use levels among the monitored facilities and normalization of the data to a number of energy use indexes. Such parameters as energy use per square foot, per customer, and per degree-day are presented and discussed. Some regression tests of energy use cause and effect are evaluated, such as the relationship between HVAC energy use and exterior temperature.

Opportunities for cost-effective energy conservation are discussed in Chapter 6. Also discussed are operation and maintenance techniques, building construction modifications, selection of restaurant equipment, and energy management concepts which can increase efficient use of energy in restaurants. These remarks are based upon a review of the data collected by this project and the experiences of the technical advisory committee with energy conservation measures.

The report concludes with Chapter 7, which presents findings and recommendations. This discussion reviews the project results, highlights problem areas and their resolution, and makes recommendations for further study.

Two appendixes are included to facilitate use of the project data by analysts not involved in the original experiment design. Appendix I presents the measurement plans, data quality reports, record and summary of data acquisition problems, monthly listing and summary of energy use by end-use categories, and graphs associated with each of the monitored facilities. Appendix II is a user's guide with instructions for analysts interested in accessing and processing machine-readable data records compiled by this project.

2.0 PROJECT ACTIVITIES AND METHODS

This section of the report describes the various components of PREP and the techniques applied in its conduct. The project planning process and measures to assure the accuracy and value of the project are discussed first. Next the process used to select facilities for monitoring activity is described. This is followed by a discussion of the data collection plans and procedures and the scope of data processing and analysis efforts to date.

2.1 PROJECT PLANNING AND EXECUTION

The seed for this research project was planted in early 1979, when NRA took exception to mandatory building energy performance standards proposed by the U.S. Department of Energy. The NRA's concern was that regulation of allowable energy consumption levels for new buildings on a per-square-foot basis has limited validity for restaurants, due to the dominant impact of process energy requirements. These concerns were centered upon the general lack of measured building energy performance at the end-use level, measurements which many consider an essential ingredient in the development and evaluation of defensible building energy use targets. At the time there existed no empirical evidence with respect to how much of restaurant energy consumption was due to comfort needs versus process needs.

In response to NRA's concerns, DOE asked them to design a research program to measure the energy use of typical restaurants. The NRA worked closely with PSU to develop a proposal for DOE consideration. The DOE instructed PNL to review the proposal for technical sufficiency and to manage the research program. Pacific Northwest Laboratory recommended that climatic data be collected at all sites, that telecommunications be used to retrieve data, and that information on activity levels at each site be provided. This set of requirements necessitated a reduction in the number of facilities to be studied in order to match the project budget.

Anxious to undertake the program, PNL, PSU, and NRA established a technical advisory committee to plan and oversee the project. Members for the committee were drawn from NRA headquarters and a special NRA group called the

Multi-Unit Architects, Engineers, and Construction Officers (MAECO). The National Restaurant Association contracted for the services of the Institutional Engineering Advisory Services of the College of Engineering at PSU to execute the research program.

One condition of participation in the monitoring program was regular attendance at project progress meetings. These meetings were invaluable in the recognition and resolution of project problems. They also provided an opportunity for participants to discuss related energy issues and improve the overall understanding of restaurant energy use. The success of this program is largely attributable to the conscientious involvement of all the participants in its design, execution, and reporting.

2.2 SITE SELECTION

Budgetary considerations limited the number of monitoring sites to seven to provide the level of detail desired by PNL. Consequently, the first challenge for the advisory committee was to define seven restaurant categories to most comprehensively cover the variety of restaurant operations. The categories defined and restaurants selected to represent these categories are:

- Coffee shop (COFE) - Friendly Restaurants
- Fast food limited menu (FFLM) - Burger King
- Fast food expanded menu (FFEM) - Roy Rogers
- Pizza (PIZA) - Pizza Hut
- Full service limited menu (FSLM) - Steak & Ale
- Full service expanded menu (FSEM) - Charley's Place
- Cafeteria (CAFE) - Morrison's

The next challenge was to identify suitable facilities willing to comply with participation ground rules established by PNL and the project participants.

The facilities for monitoring were selected to satisfy the following criteria: 1) be a freestanding building constructed after 1973; 2) have the capability for both heating and cooling; 3) contain process equipment representative of that particular type of restaurant; 4) be representative of that particular type of restaurant with respect to meal count, total food sales, and

hours of operation; 5) have the ability to be successfully instrumented; and 6) be selected to include all major types of equipment specific to that particular type of restaurant.

In addition, sites were clustered in the northeastern U.S. to reduce travel costs and other logistical complexities. This offered the ability to more directly compare performance among the restaurants, since climatic variability was limited.

Participants were required to provide as-built construction plans, conduct air balances and properly adjust HVAC settings, provide meal or customer counts, coordinate any modifications to the facility during the measurement period, and assign an individual to regularly attend project progress meetings. Fortunately, most participants were sufficiently interested in learning about their organization's energy use, so these provisions were acceptable even though they incurred significant costs.

2.3 DATA COLLECTION

Criteria for restaurant selection included ease of installation of measuring equipment, access to equipment to be measured, adequate room for all instrumentation and data acquisition equipment, and anticipated cooperation on the part of the restaurant management.

Each facility participating in the project provided as-built drawings that included site plans to provide data on site orientation, site utilities, building construction materials, and amount of glass. Prior to the start of archivable data collection each restaurant performed an air balance and critical maintenance work necessary to place the building in a condition that most approximated that which existed at the time the building was built and opened.

A connected load survey was conducted at each of these facilities to determine the ratings of food preparation, sanitation, refrigeration, and HVAC equipment as well as indoor and outdoor lighting. This information included quantities and types of equipment and connected loads of only the largest equipment.

Site-specific measurement plans were developed based upon the information collected above. These plans specify the type and location of sensors and the formulas to calculate end-use energy consumption quantities. The material which follows describes the measurement plan preparation process, the sensors deployed, and the data retrieval system.

Each restaurant was equipped with 16 to 33 meters measuring electricity, gas, or water use. In addition, each restaurant was equipped with an outdoor weather station to measure wind direction, wind speed, solar radiation, and outdoor dry bulb temperature. A thermistor was installed adjacent to each indoor thermostat to measure indoor dry bulb temperature.

2.3.1 Measurement Plan Preparation

A customized instrumentation or measurement plan was available for each restaurant. The primary purpose of the study and thus the design of the instrumentation plan was to divide the data received into five end-use categories:

- food preparation--energy for slicing, mixing, warming, cooking, presenting, and otherwise preparing food
- sanitation--energy for service water heating, dishwashing, laundry, and other cleaning requirements
- refrigeration--energy for cold storage to include refrigeration, walk-in coolers, freezers, and ice machines
- lighting--energy for interior and exterior illumination
- heating, ventilating, and air conditioning--energy for space conditioning and ventilation requirements.

The instrumentation plan was designed keeping in mind two subsets of end-use categories: process energy and comfort energy. Thus it is possible to divide the energy use into the process and comfort categories at each facility.

As a general rule, large individual loads such as HVAC equipment, grills, fryers, ice machines, compressors, ranges, broilers, hot water heaters, booster heaters, and dishwashers were metered. In addition, entire panelboard loads

were frequently measured. Since the individual loads were most often sub-metered off entire panelboard loads, the energy use by end-use category was determined with customized formulas for each restaurant. For example, a panelboard which is predominantly lighting was metered; the submetering on that panel measured the consumption of the grill and the fryer. By adding the energy consumed by the individually measured points and subtracting this sum from the entire panel load, the results were allocated to the lighting end-use category.

Where equipment falling into more than one end-use category was present on the same circuit, it was necessary to calculate end-use loads by approximation based upon a one-time measurement and assumed use schedule. This was required in only a few instances and the relative magnitude of the approximated loads was small. Therefore, the instrumentation plans accurately reflected energy consumption by end-use category.

At each restaurant an outdoor weather station was installed that included an anemometer to measure wind speed and direction, a pyronometer to measure the horizontal global solar radiation, and a thermistor to measure outdoor dry bulb temperature. The top of the mast was approximately 30 ft above ground and close to the side of the building subjected to prevailing winds.

On several occasions during the data collection phase of the project it became apparent that the instrumentation plans did not properly reflect energy use and needed to be changed. Reasons for the discrepancy included modifications to the building or equipment, alterations in electrical service, and inaccurate designations of circuit labels. When such changes occurred, the instrumentation plans and data processing software were revised.

2.3.2 Sensors

The following paragraphs describe the sensors that were used to collect data for this project.

- Electric meters--All the electric meters used in this project are utility type watt-hour meters manufactured by Westinghouse and equipped with pulse initiators that generate 9 digital pulses for each 25 revolutions of the meter disk. Types of meters used were

single-phase two-wire, single-phase three-wire, and three-phase four-wire. Approximately half of the meters were an in-line type rated at 100 or 200 amp, while the balance were instrument-rated meters that require the installation of current transformers around the wires for the equipment or panels measured. This equipment was purchased by competitive bidding. Except for occasional problems when the pulse initiator became misaligned at the gear train, the meters functioned reliably. Manual meter readings proved to be a valuable check on the computerized data acquisition system and a reference to interpolate missing data values.

- Gas meters--Fifteen gas meters were furnished and installed free of charge by local gas companies at the three restaurants using natural gas. Each meter was equipped with a pulse initiator; it was connected to the gas flow dial such that each revolution of the gas flow dial determined the amount of cubic feet of gas measured and generated a digital pulse. Except for one instance in which a gas meter malfunctioned for a short period, all meters functioned properly for the entire length of the project.
- Water meters--Three water meters were installed on the inlet to the hot water heaters at three different restaurants. These water meters, purchased from Rockwell, were sized to accommodate the estimated flow and were equipped with pulse initiators. Each 2, 5 or 10 gallons of water used was equivalent to a digital pulse. No water meters failed during the project.
- Wind speed and direction sensors--This equipment (Model W200-SD) was purchased from the Weathermeasure Corporation. Calibration tests on this equipment were conducted by the Meteorology Department at PSU. There were no failures of the wind speed and wind direction sensors during the entire length of the project.
- Solar sensor--A pyronometer (Model LI-200B) manufactured by Li-Cor measured solar insolation. A spare pyronometer was purchased and then installed when one pyronometer failed prior to the start of data archiving.

- Temperature sensors--All temperature sensors used in this project were thermistors furnished by the Yellow Springs Company and designed to measure dry bulb temperature. There were no thermistor failures during the data collection phase of this project. It should be noted that to measure outdoor temperature the thermistor was installed inside a polyvinyl chloride (PVC) plastic tube of approximately 2 in. diameter which in turn was concentrically installed inside a 3 in. diameter PVC plastic tube; the interiors of both tubes were painted with flat black paint and the exteriors of both tubes were covered with reflective tape to protect the thermistor from direct solar radiation.

2.3.3 Data Acquisition System

The basic data acquisition system was a Cromemco System II microcomputer equipped with two disk drives, 64 K of RAM, microclimate amplifiers, a digital data acquisition board, a combination analog-to-digital convertor and clock board, and a modem board. In the middle of July the disk drives were disabled and data acquisition was accomplished by the installation of an EPROM (Erasable Programmable Read Only Memory) and use of the RAM. The change from disk drives to EPROMs was necessitated by extensive disk drive failures due to airborne particulates that are found in almost all restaurant environments. The Cromemco was selected after investigation of several different computer data acquisition systems. The primary selection criterion was the fact that the Cromemco is designed for use in an industrial atmosphere. The equipment that was added to the basic Cromemco system to facilitate data collection is described below. Both digital and analog boards were designed by PSU.

- Microclimate equipment amplifiers--The analog signals derived from the microclimate sensors were too low to be recognized by the data acquisition equipment; therefore, it was necessary to design amplifiers to boost the signals from these devices. The Electronic Design Services Group, part of the Electrical Engineering Department at PSU, designed the amplifiers for this project to boost the signals for all the microclimate data to the 0 to 5 volt range. The amplifiers were tested and calibrated, as previously noted. Early in the project

data collection phase it was discovered that this equipment was subject to transients induced by lightning. Consequently a major modification was made to all the amplifiers to limit their output voltage.

- Analog-to-digital (A/D) convertor and clock board--To handle the microclimate information, which was in analog form, the computer was equipped with a 16 channel A/D convertor. In all cases the board was designed to receive analog information in the 0 to 5.1 volt range. As an integral part of this board a clock was installed with a backup battery to keep track of time, since measurements were taken every 15 minutes. The analog boards were plagued with A/D convertor failures early in the project, primarily due to transient voltages greater than 5.1 volts entering the computer through the microclimate amplifiers and destroying the A/D convertor. When the amplifiers were modified to prohibit output greater than 5.1 volts, the A/D convertor problems virtually disappeared.
- Digital board--This board was designed to handle data acquisition from a maximum of 40 digital channels. The board viewed every digital channel once every 40 microseconds. When a change in state was noted from the previous reading, the digital board recognized that change as a contact closure or a pulse from the meters. Each digital channel was equipped with a counter, which counted each pulse or count. Every 15 minutes of every day the counter wrote the number of counts to the memory and the counter was zeroed. The data acquisition cycle then continued.
- Modem board--Each computer was equipped with a modem board for telecommunications and a microcoupler to interface the computer with the telecommunications systems. Equipment was manufactured by Hayes and operated at a rate of 300 baud. Early in the project it was thought that there were many modem board failures. Hayes checked the boards and found them to be good. Further investigation indicated that what was considered a modem board failure was actually a computer shutdown

due to transient conditions probably caused by lightning. Therefore, with few exceptions the telecommunications link through the modems worked well.

2.3.4 Other Information

Each restaurant participating in the project furnished meal counts or the number of transactions. Subsequently information was required to enable transactions to be related to customer count by applying multipliers. The information was furnished by the applicable restaurants and based on their system-wide experience. In addition, each restaurant furnished water, gas, and electric bills for the entire length of the project. This assisted in verifying that computer-acquired data were correct. Each restaurant also documented major maintenance work conducted during the data collection phase. It should be noted that each restaurant practiced its usual maintenance procedures and did not take any extraordinary actions precipitated by their participation in this project.

Supply water temperature data were obtained for each month of data collection from the companies serving each restaurant, as shown in Appendix I. As a check, weather data collected from this project were compared with weather data for Pennsylvania and Virginia, which were obtained from NOAA (National Oceanic and Atmospheric Administration).

2.4 DATA PROCESSING AND ANALYSIS

This portion of the report describes the data validation process, routine data summaries, and the type of analysis conducted.

2.4.1 Data Validation

Each restaurant was telephoned daily to obtain the previous day's data. A restaurant day was defined as 4:00 a.m. to 4:00 a.m. the following day. Information received at PSU was in the form of number of counts, pulses, or contact closures per 15 minute period. In-house software then translated the data from pulses to kilowatt hours (kWh), cubic feet (CF), or gallons per 15 minute period. A daily computer printout was prepared showing for each meter point

the consumption for every 15 minute period. Also, a summary of the energy use or water consumption for the day was determined.

Each day's data were reviewed to determine if the information was accurate. In most cases this first check was done by comparing daily consumption per meter point versus previous manual meter readings, which were made once a month in concert with any minor maintenance work that had to be done at that time. If the computer-obtained information did not agree with manual meter readings, the apparent problem was analyzed further. If it was determined that there was a major problem with a key piece of equipment, someone was dispatched to make the necessary repairs.

Computer software for PREP was designed to enable determination of energy use for each point for a given length of time. During field visits for meter readings and minor maintenance, this information was compared with the energy use determined by the manual meter readings to ascertain that each point was functioning properly at the time of PSU visits.

To check the validity and accuracy of microclimate information, temperature readings were compared with NOAA weather data for each area. Additionally, weather data for restaurants close to one another were compared with respect to wind direction, wind speed, outdoor dry bulb temperature, and solar insolation. Temperature points were calibrated with a digital thermometer accurate to within one-half degree Fahrenheit.

This system of checks and balances facilitated a determination of whether or not a point had functioned properly for each day at each restaurant.

Channel data were only considered adequate if they had been collected for at least 22 hours of a day. When it was determined that a point or points had malfunctioned or were inoperative, energy use for that day was manually inserted. In Appendix I, the variance analyses for each restaurant indicate by point number and date those occasions when manual data were input. The information was input in the aggregate for each day as opposed to every 15 minute period. Magnitudes of consumption/use are based on manual meter readings for the appropriate periods.

2.4.2 Routine Reports

Each month PSU provided to NRA, PNL, and each participating restaurant a summary that indicated the data capture rate for each restaurant and the overall data capture rate for that month. Also outlined were major problems that were observed and/or corrected. The monthly report also included for each restaurant the meter point numbers and dates for which manual data were entered, as well as a variance analysis of why manual data had to be entered for those points and/or days.

For each site, the following data summaries were prepared on a monthly basis:

- daily meter point totals
- daily summary energy use by end-use category
- monthly listing and daily energy use by category
- monthly summary of energy use by category.

The contents of these reports are shown and described in Appendix II.

2.4.3 Regression Analysis

During the project several regression analyses of end-use categories were made. Heating degree-days and cooling degree-days were converted to the average temperature for a day or month. Applying this information to HVAC energy use and performing a regression analysis revealed that there were excellent correlations between HVAC and average daily temperature. Regression analyses were also done for food preparation per customer, refrigeration use versus average outdoor temperature, sanitation energy use versus inlet water temperature, and several other factors. Results of these analyses are discussed in Chapter 5, Data Analysis.

3.0 DESCRIPTION OF METERED FACILITIES

This section of the report provides summaries of the monitored facilities. This information is useful in analyzing the data and in gaining insight into energy use cause and effect. The restaurants are listed by geographical locations from north to south.

First the fuels and equipment at each site and comparative energy use levels are discussed. This discussion is followed by descriptions of the menu and equipment use. Then hours of operation are discussed and observations are made regarding the use of equipment during the restaurant day.

Appendix I contains a construction summary, a building equipment by end-use category listing, and a floor plan for every restaurant.

In the following description and comparison of restaurants, the facilities are compared on the basis of total site MBtus. It must be recognized that this comparison does not account for the conversion efficiencies for natural gas and electricity.

3.1 FRIENDLY RESTAURANTS

Friendly Restaurants, designated a coffee shop for this project, is a family type restaurant which specializes in ice cream desserts. The facility is located about 5 miles east of downtown Lancaster, Pennsylvania on Route 30, a major east-west highway in southeastern Pennsylvania. The facility is in the heart of the Pennsylvania Dutch/Amish region, a major tourist attraction; therefore, its customer count is very seasonal: low in the winter and high in the summer.

Among all the restaurants participating in this project, Friendly Restaurants is the second lowest consumer of HVAC and total energy and has the lowest energy use per square foot. This facility also has experienced the coldest average temperature and has the lowest average temperature for the water it purchases.

3.1.1 Building Description

The 4210 sq ft building rests on a 4-inch thick concrete slab and is built with brick walls with 1-inch-thick rigid insulation. The roof is insulated with 6-inch-thick batt insulation over a common wood truss. The facility has 262 sq ft of double pane clear glass, four exterior doors (107 sq ft), and one walkup service counter.

This all-electric facility has three hot water heaters, each rated at 5 kW, that provide water for domestic purposes and to a booster heater on the high temperature dishwasher. All refrigeration equipment is located in the attic of this facility and is water cooled. Kitchen lighting is fluorescent and the dining room lighting is incandescent. Outdoor lighting is incandescent, fluorescent, and high intensity discharge (HID). This facility uses two heat pumps for heating and cooling and resistance heat as the backup or supplemental heat for the winter. A makeup air unit is provided that operates only during the summer.

3.1.2 Menu and Equipment Use Descriptions

This family type restaurant has a fixed menu and serves all three meals. Most of the food served is delivered to the facility prepackaged and frozen. Therefore, little food preparation is required; only cooking energy is necessary. Eggs, bread, coffee, juices, breakfast meats, and pancakes are available for breakfast. The lunch and dinner menus are the same: they consist of sandwiches with french fries, salads, and soups. A few dinner platters are available. Soft drinks, coffee, tea, and milkshakes are also offered. This facility specializes in ice cream, selling some over the counter, mostly in the form of cones. Desserts at this facility are one of its specialties and they typically include ice cream.

This facility consumes the second lowest amount of energy for food preparation, primarily due to the small kitchen/cooking area and the efficient design and specification of kitchen equipment.

3.1.3 Hours of Operation

Closed Thanksgiving and Christmas

Open Summer (June through Labor Day)

Sunday through Thursday 0700 - 2400

Friday and Saturday 0700 - 0100

Winter (Labor Day through May)

Sunday through Thursday 0700 - 2300

Friday and Saturday 0700 - 2400

This restaurant's busiest day is Saturday, closely followed by Sunday. The "slowest" days are Tuesday and Wednesday. Like the cafeteria monitored in this project, Friendly's experiences a high seasonal variation because it is located in a tourist area.

The major pieces of cooking equipment are the fryers, which are operated from about 0600 to 2400. Major energy consumption occurs over the lunch and dinner hours, but is slightly higher at dinner. The grill operates from about 0600 to 2400 also; its energy consumption is evenly distributed over the three meal periods. Toasters and a soup warmer are connected to the same circuit, which operates from 0615 to 2200. Their heaviest use occurs during morning hours. Another metering point is a circuit for the coffeemaker and soup warmer. This circuit operates all day, with its heaviest loads at breakfast and during evening snack times.

A high temperature dishwasher usually operates from 0900 to 0100, as required. The dishwasher booster heater tracks the use of the dishwasher. The hot water heaters for this facility are turned off by time clock for the 4 hours per day that the restaurant is closed. When the hot water heaters are on their electrical load is constant.

The water cooled compressors for this restaurant are located in the attic and experience a rather constant load. The ice machine operates continuously and makes ice as required.

Outdoor lighting for this facility is connected to a time clock, which turns on the lights at dusk and turns them off at closing. There is apparently some manual override capability, since lights are sometimes turned on during

the day. Indoor lighting is on continuously at this facility, primarily because the cleaning is done after closing.

This restaurant is equipped with a makeup air unit which operates only during the cooling season. Exhaust fans are turned on for the grill and the fryer when cooking begins and are turned off when cooking is stopped. HVAC equipment consists of two heat pumps with resistance heat backup. This equipment is sensitive to outdoor temperature and marginally sensitive to customer load. Preventive maintenance of the HVAC equipment is done periodically by an outside contractor. Other maintenance is usually done as needed.

3.2 BURGER KING

Burger King is a fast food limited menu restaurant located in the Oxford Circle section of Philadelphia. This facility uses the third highest food preparation energy among the seven facilities. This high energy consumption is primarily due to the use of a gas-fired chain broiler and gas-fired fryers. This facility also consumes the largest amount of energy per sq ft of floor space.

3.2.1 Building Description

This 3093 sq ft restaurant is constructed of brick and architectural glass. The walls are insulated with 3-1/2-inch-thick fiberglass. The windows are non-opening double pane glazings (445 sq ft total) with metal frames. Built on a concrete slab with 2-inch-thick styrofoam perimeter insulation, the structure is roofed by a built-up roof over metal decking insulated with 2-inch-thick rigid insulation. The facility has four entry doors (97 sq ft total), three for customers and one for employees and deliveries. The restaurant has a drive-through window.

Burger King restaurant uses natural gas for broiling and frying; the balance of the food preparation equipment is operated by electricity. The water heater uses natural gas; no automatic dishwashing is done at this facility. All the refrigeration equipment is electrically operated with compressors mounted on the roof. Indoor lighting is a combination of fluorescent and incandescent. Outdoors both incandescent and high intensity discharge (HID)

light sources are used. The HVAC equipment is electrically operated with five rooftop units, three of which are dedicated to the dining area and two to the kitchen.

3.2.2 Menu and Equipment Use Descriptions

Burger King specializes in a variety of hamburger menu items and a few other specialty sandwiches. French fries and a small salad bar are also provided. Coffee, hot and cold tea, milkshakes and soft drinks are available. Desserts are also on the menu. The breakfast menu for this facility is a croissant sandwich available in several different combinations of eggs, sausage, and ham fillings. Deep fried hash browns are also offered until 1000.

Food preparation energy is relatively high for this facility because the chain broiler used for burger cooking and roll heating operates the entire time that the facility is open, except during the start-up and clean-up phases. The broiler is energy intensive and exhausts an enormous amount of hot air. The fryers are also energy intensive, especially when compared to electric fryers used at other facilities in this study.

3.2.3 Hours of Operation

Closed Thanksgiving, Christmas and Easter

Open Sunday through Thursday 0700 - 2300

Friday and Saturday 0700 - 2400

The customer count is highest on Fridays and Saturdays and lowest on Sundays and Mondays. Almost all the equipment except lighting and HVAC is turned on at opening and left on until closing. The broiler is turned on at about 1000 and left running all day until closing, while the fryer runs from about 0630 to 2200. The milkshake machine is turned on at about 0800 and runs at about the same load until closing. The broiler fan is turned on at 0930 and also runs constantly until closing.

The hot water heater is used primarily during clean-up. Its peak use is about an hour immediately after breakfast is finished being served. After closing the restaurant there is again high use of hot water for clean-up.

The cooler and freezer use little energy during closed hours, since there is no traffic into that equipment. During normal operating hours the cooler and freezer load is about twice that which is experienced during the time the facility is closed.

The lighting equipment is manually controlled. In general, all indoor lighting is turned on when the facility is opened early in the morning and, with the exception of safety and security lights, all indoor lighting is turned off when the last employee leaves the restaurant. Outdoor lighting is turned on at dusk and is generally left on until dawn.

Energy consumption for space heating and cooling corresponds to the outdoor temperature. The manager selects the HVAC units to be operated and makes any manual adjustments of thermostat settings in response to customer comments.

Evaluation of the 15 minute energy use data does not indicate a strong correlation between customer load and energy consumption for this restaurant.

This facility's maintenance plan includes preventive maintenance by store personnel as well as periodic checks by contractors, especially on the HVAC equipment. A good deal of the maintenance is corrective.

3.3 ROY ROGERS

Roy Rogers is a fast food extended menu restaurant located in Willingboro, New Jersey, approximately 1-1/2 miles east of the Delaware River, which separates New Jersey from Pennsylvania. Willingboro is located along Route 130, a major north-south highway in southwestern New Jersey.

This restaurant consumes the least amount of site energy for sanitation and ranks at or below the middle in all other energy use categories. Roy Rogers is the second smallest building of the seven considered in this project.

3.3.1 Building Description

This 2758 sq ft facility is constructed of brick, concrete block, and architectural glazing. The walls are not insulated and the roof has

2-inch-thick rigid insulation over wood trusses. The building has two customer entry doors and one delivery door (77 sq ft) in the rear. The facility has 400 sq ft of insulated glazing.

This restaurant uses both natural gas and electricity as energy sources. About 50% of the energy used for food preparation is gas. The major pieces of gas cooking equipment are the grill and fryer, and the major pieces of electrical cooking equipment are chicken fryers and a slow-cook oven for the beef. The facility does not have a dishwasher. Domestic water is heated by natural gas. All refrigeration is electric and is primarily provided by rooftop-mounted compressors; the ice machine is an indoor air-cooled compressor. The outdoor lighting at Roy Rogers is HID and incandescent, the indoor lighting in the kitchen area is fluorescent, and the lighting in the dining room is incandescent. In March 1984, the interior of the facility was renovated and the lighting load was reduced. This facility is heated and cooled by two rooftop-mounted units, one for the dining room and one for the kitchen. Heating is by natural gas, cooling by electricity.

3.3.2 Menu and Equipment Use Descriptions

Roy Rogers serves an identical lunch and dinner menu. The menu includes a selection of hamburgers, roast beef sandwiches, fried chicken, and french fries. Soft drinks, milkshakes, coffee, and tea are available, plus a limited selection of desserts. Fresh chicken and roast beef are delivered to the facility and are prepared and cooked there. The balance of the food is delivered frozen and is cooked at the restaurant.

About half of the energy used for food preparation is electric and the other half is natural gas. This facility is not particularly energy intensive with respect to food preparation.

3.3.3 Hours of Operation

Closed Thanksgiving and Christmas

Open Summer (June through Labor Day)

Sunday through Thursday 1000 - 2400

Friday and Saturday 1000 - 0100

Winter (Labor Day through May)
Sunday through Thursday 1000 - 2300
Friday and Saturday 1000 - 2400

The busiest day is Friday and the second busiest is Saturday. The slowest days are Sunday and Monday.

According to the analysis of the 15 minute data, the gas cooking equipment is turned on at about 1000 and runs at a nearly constant load until closing. The beef panel, which energizes the beef slicer, warming well, and small equipment, is turned on at 1000 and turned off at closing. A panel located near the serving line has connected to it a small group of food service equipment. This equipment is turned on at about 0800 and left on, running at a nearly constant load until closing. The slow-cook oven which is used to prepare the roast beef has a high, short period of use around 0730 and then is run for very short periods to maintain oven temperature and to cook the beef very slowly.

The gas hot water heater is used intensively immediately prior to opening, shortly after the lunch hour, and for short periods after the dinner hour. The most extensive use of gas to heat water occurs after closing, when restaurant personnel are cleaning the facility.

The icemaker operates as required. The walk-in cooler and freezer generally experiences higher use during the hours the restaurant is open.

The kitchen lighting is turned on when the first restaurant employee arrives; the dining room lighting is not turned on until about 1/2 hour before the restaurant opens. The dining room lighting is left on until cleaning is complete and then with the exception of night and security lights, all indoor lighting is turned off when the last person leaves the facility. Parking lot lights are turned on at dusk and turned off sometime between closing and when the last employee leaves. A group of outdoor lights is turned on at dusk and left on until dawn, primarily for security purposes.

The HVAC equipment is very responsive to outdoor temperature and operates as needed to maintain temperature set points at the facility; however, both

HVAC units are manually set back at night and turned up in the morning by management personnel. Exhaust fans are turned on shortly before opening and turned off immediately after closing.

Like the other fast food restaurant in this study, analysis of the 15 minute energy utilization records reveals little correlation between energy use and the number of customers served.

Preventive maintenance at Roy Rogers is essentially done by in-house personnel, with primary attention focused on HVAC equipment. Wherever possible, corrective maintenance is also done by a centralized in-house maintenance department. Very little maintenance is done by store personnel. "In-house" in this context means that a number of Roy Rogers restaurants near this unit are using the same maintenance personnel for any work that is needed.

3.4 PIZZA HUT

Pizza Hut is a pizza restaurant catering to families. This facility is located in the Bensalem township in Bucks County, about 3 miles north of the Philadelphia city line. Since the facility is located on Pennsylvania Route 232 and is approximately 1 mile west of Interstate 195, it receives a lot of business.

Of all the restaurants participating in this project, Pizza Hut consumes the least amount of site energy for food preparation, lighting, and HVAC, and consequently the least amount of total energy. It is also the smallest building of the seven. Outdoor temperatures experienced here were the second lowest among those of the project's other restaurants.

3.4.1 Building Description

This 2275 sq ft facility is built on a 4-inch-thick concrete slab. The brick walls are insulated with 4-inch-thick fiberglass. The roof is also insulated with 4-inch-thick fiberglass over a common roof truss. The facility has two customer entrance doors and one delivery/employee door (75 sq ft) in the kitchen. The building has 285 sq ft of insulated glass.

The entire facility is operated with electricity. The variety of food preparation equipment in this facility is limited. Most of the energy is

consumed by operation of the pizza oven. One water heater is used to supply hot water for domestic purposes and to supply a dishwasher booster heater. The refrigeration equipment for this facility is rooftop mounted. During the data archiving phase of the project a walk-in cooler which includes some dry storage was added to the rear of this facility. The exterior lighting is fluorescent and incandescent, the kitchen lighting is fluorescent, and the dining room lighting is incandescent. A single HVAC unit is used to both heat and cool this facility.

3.4.2 Menu and Equipment Use Descriptions

Pizza Hut primarily serves pizza. The identical lunch and dinner menus include a few pasta dishes and sandwich selections. Pizza dough is made from scratch, proofed, and retarded. No desserts are served and the standard non-alcoholic beverages and beer are available.

The single deck conveyor pizza oven consumes approximately 28 percent of the total energy used; food preparation requires about 31 percent of the total energy use. It is apparent that appropriate use and control of the pizza oven will result in more effective use of energy.

3.4.3 Hours of Operation

Closed Thanksgiving and Christmas

Open Summer (June through Labor Day)

Sunday 1200 - 2300

Monday through Thursday 1100 - 2300

Friday and Saturday 1100 - 0100

Winter (Labor Day through May)

Sunday 1200 - 2300

Monday through Thursday 1100 - 2300

Friday and Saturday 1100 - 2400

The busiest day at Pizza Hut is Friday and the second busiest day is Saturday; the slowest day is Monday and the second slowest day is Tuesday.

The pizza oven is turned on about 1015 and is turned off at closing. One of the metering points is for food preparation equipment, which includes a

group of small cooking appliances that are used from about 1100 until closing. These appliances seem to consume more energy during dinner than during lunch. The drink machine produces a rather constant load during the time that the restaurant is open and a slightly reduced load when the facility is closed.

The dishwasher is used almost every morning for a very short period of time, is then used in mid-afternoon to clean the lunch dishes, and is last used quite heavily from about 2000 to shortly before closing. Both the water heater and the booster heater, which is attached to the dishwasher, have energy consumption patterns almost identical to that of the dishwasher.

Both the ice machine and the metering point which measures the energy consumption of free-standing coolers and freezers experience constant loads throughout the entire day. The walk-in cooler experiences higher energy consumption during operating hours, when employees are entering and leaving the cooler, and slightly decreased use during the period the restaurant is closed.

Most of the indoor lighting is turned on when employees first arrive at the restaurant; this lighting is left on until the facility is closed and the last employee leaves. A group of outdoor lights installed in the soffit is normally left on during all open hours. The outdoor sign is on from dusk until closing.

The HVAC equipment for this restaurant consists of one unit for both heating and cooling. Consumption patterns vary directly with outdoor temperature and to some extent with customer load. This facility experiences a higher customer load for dinner than it does for lunch, and the 15 minute record information shows that more energy is consumed during dinner and the early part of the evening than at any other time of the day.

Maintenance for Pizza Hut is primarily corrective and is done by an employee of Pizza Hut in charge of maintenance for many stores in the Philadelphia area.

3.5 STEAK & ALE

Steak & Ale is a full service limited menu restaurant located in Alexandria, Virginia, at the intersection of Interstate 395 and Seminary Road,

about 5 miles south of downtown Washington, D.C. The facility has a bar and several small dining rooms. The bar trade is not nearly as large during "happy hour" and evening hours as that reported for the other full service restaurant.

This facility is the second largest consumer of both refrigeration and lighting energy and the third largest consumer of HVAC and total energy. In addition, it is the third largest building and it experienced the second highest average outdoor dry bulb temperatures during the period that temperatures were recorded for this study.

3.5.1 Building Description

This 6775 sq ft all-electric facility is constructed on a 6-inch thick concrete slab. Its walls are brick and concrete, and its roof is comprised of two construction types: one has 3-1/2-inch-thick lightweight insulated concrete over a metal deck and the other has 6-inch-thick batt insulation over 2-inch by 6-inch rafters. The building has several doors: a customer vestibule entry, a delivery door in the kitchen, and several emergency exit doors (142 sq ft total). Windows cover an area of 326 sq ft.

The facility has two water heaters which furnish hot water to a tank heater for a high temperature dishwasher and for other domestic purposes. A separate dishwasher booster heater is also used. The refrigeration compression equipment is rooftop mounted. Outdoor lighting for this facility is both incandescent and fluorescent, with some HID lighting. Indoor lighting in the dining areas and bar area is exclusively incandescent, and the kitchen and storage area lighting is fluorescent. The facility is electrically cooled and heated with electric resistance heating using three rooftop mounted units. A broiler and a kitchen makeup air unit are operated independently of the exhaust system.

3.5.2 Menu and Equipment Use Descriptions

The lunch menu at Steak & Ale offers sandwiches and entrees served with baked potatoes. The dinner menu is primarily entrees served with vegetables or baked potatoes. Both meals are dominated by beef, but fish and chicken are available and a salad bar is included with most lunches and dinners. A full range of alcoholic and nonalcoholic beverages is served.

Food preparation energy use, which ranks in the mid-range, is primarily due to the fact that the all-electric kitchen equipment seems to be turned on early in the business day and left on during the entire day; thus energy consumption for food preparation bears little relationship to customer count.

3.5.3 Hours of Operation

Closed Christmas

	Dining	Bar
Monday through Friday	1130 - 1400 (Lunch)	--
Monday through Thursday	1700 - 2200 (Dinner)	1130 - 0100
Friday	1700 - 2300 (Dinner)	1130 - 0200
Saturday	1700 - 2300 (Dinner)	1700 - 0200
Sunday	1200 - 2200 (Dinner)	1200 - 2400

The busiest day of the week for Steak & Ale is Friday and the second busiest day is Wednesday. The slowest days are Sunday and Monday.

A group of small appliances for food preparation is used during lunch and dinner. Energy consumption during dinner is generally heavier. Another group of small appliances for food preparation is utilized almost exclusively from 1700 to 2200, although it is used for food preparation prior to lunch. The ovens at this facility are turned on about 0900 and used rather consistently until about 1330. They are then utilized at a rather constant rate from about 1615 to 2030. Oven energy consumption during dinner is generally heavier. The ranges are turned on at about 0800 and are generally turned off at about 2200. More energy for food preparation is consumed over the dinner hour. The broilers at Steak & Ale are turned on at about 1000 and turned off at about 2400. In general they are used most during dinner.

The dishwasher is used during lunch and dinner and immediately following these serving times. A booster heater, which supplies the dishwasher, is used in a manner identical to that of the dishwasher. The dishwasher tank heater operates only when the dishwasher operates. Two water heaters supply hot water to the booster heater and domestic hot water for the restaurant. These heaters

generally utilize significant amounts of energy from about 0930 to 0100, with a little heavier use at dinner and during the period of final clean-up after closing.

The ice machines at Steak & Ale run virtually at full load when the outdoor temperature is high, when heavily loaded, or when the ice requirements are above normal. During those periods when the outdoor temperature is not very high, the ice machine runs at full power only during the hours that the facility is open. The cooler and freezer for this facility run with a constant load throughout the entire day.

The outdoor lighting for Steak & Ale signs is turned on at dusk and turned off when the employees leave the facility after closing. There is some security outdoor lighting as well. The indoor lighting is generally turned on when employees first arrive and left on until employees leave after closing. Some lights are turned off in dining areas after dinner is served, when only the bar is open.

The exhaust fans in this facility are turned on when the employees arrive and are left on until closing. The HVAC equipment in this facility is manually operated and controlled. Thermostats on the heating equipment are set back at night, and the HVAC equipment is turned on as required when employees arrive in the morning or when the first meals are served. This facility is equipped with broiler and kitchen makeup air units, which are used as needed by operating personnel. In newer installations the makeup air units are automatically controlled by the exhaust fans.

In summary, the data indicate that higher energy consumption occurs during and immediately following dinner, which is also "happy hour" in the bar, because more customers are served then.

Routine preventive maintenance of the HVAC equipment is performed by outside contractors. The balance of the maintenance at this site is corrective in nature and is done by an outside contractor.

3.6 CHARLEY'S PLACE

Charley's Place is an extended menu full service restaurant located in Springfield, Virginia, approximately 1 mile south of the intersection of Interstate 95 and Interstate 495 (the Washington Beltway). The restaurant is approximately 10 miles south of downtown Washington, D.C. Originally constructed by the Marriott Corporation, Charley's Place was purchased from them by Host International. Its interior was remodeled by Host and it was reopened in early 1982. The facility has three dining areas and a large bar. The bar has large "happy hour" and late evening crowds.

This facility is second largest in terms of gross square footage, consumes the most energy for refrigeration and lighting, and is the second highest HVAC user among all the restaurants participating in the project. It is also the second largest consumer of food preparation and sanitation energy as well as the second largest consumer of total energy.

3.6.1 Building Description

The 9485 sq ft ground-level facility has a 2067 sq ft unheated basement storage area. The basement is built on a 6-inch-thick concrete slab with 12-inch-thick concrete block walls. The main level has three wall types; the predominant type is insulated with 4-inch-thick batt insulation. The roof is built up over a steel deck with 2-inch-thick rigid insulation. The facility has three exterior doors (105 sq ft total) and approximately 246 sq ft of 1-inch-thick insulated glass.

Most of the food preparation equipment uses natural gas. Several pieces of cooking equipment and all food preparation appliances use electricity. This facility has a low temperature dishwasher and uses natural gas to heat its water. One water heater is used to supply hot water for both domestic and dishwashing use. This facility has the largest amount of floor space and equipment space dedicated to refrigeration. Most of the compression equipment is rooftop mounted. The ice machines are both air cooled and water cooled. The dining room and bar lighting is exclusively incandescent, the kitchen and dishwashing area lighting is fluorescent, and all outdoor lighting is either

incandescent or HID. The building is heated with five heating units operated by natural gas and cooled with five electrically operated, rooftop mounted air conditioners.

3.6.2 Menu and Equipment Use Descriptions

A fairly extensive standard menu is available. Both lunch and dinner menus are quite varied: seafood, beef, pork, and pasta dishes are offered and at each meal there are two to four chef's specials that are not a part of the regular printed menu. The dessert menu for this facility is large and varied.

This facility uses the second largest amount of energy for food preparation, probably because almost all the food is prepared from scratch. This high energy use is also due to the large number of gas operated cooling appliances.

3.6.3 Hours of Operation

Closed Thanksgiving and Christmas

	Dining	Bar
Monday through Friday	1130 - 1430 (Lunch) 1730 - 2200 (Dinner)	1130 - 0200
Saturday and Sunday	1730 - 2100 (Dinner)	1130 - 0200

This restaurant's busiest day is Friday and its second busiest day is Wednesday. Customer load is influenced by "happy hour" on both days. The "slowest" days at this facility are Sunday and Monday.

This facility uses both gas and electricity for cooking. Food preparation energy use, on a site MBtu basis, is predominantly by cooking equipment: a range, a grill, and a convection oven use gas. The equipment is operated most heavily between 1000 and 2300, with more energy consumed during dinner. A gas operated steamer operates from about 0900 to 2400. Its heaviest use occurs in the morning hours prior to lunch. A group of small electrical cooking appliances is connected to an instrumented panel. This equipment operates from 1015 to 2300, with heavier energy use during dinner.

The dishwasher in this facility is a low temperature type used most often after lunch and dinner. The water heater energy use pattern is essentially identical to that of the dishwasher, with more energy being consumed after

dinner. This facility is equipped with a gas dryer for laundry. The dryer is used most often in the morning shortly after the facility is opened and immediately after lunch and dinner.

The refrigeration equipment at Charley's Place appears to operate at a fairly constant load throughout the 24 hour period. Any variations appear to be periodic. The magnitude of the energy use is related to outdoor temperature. This facility is equipped with two ice machines, one that is water cooled and one that is air cooled. One meter measured both pieces of equipment. Energy use for this equipment is essentially constant throughout the day; however, there is heavier use during the dinner-"happy hour" period.

The lighting for this facility, which is mostly incandescent, is turned on when employees first arrive in the morning and is turned off when employees leave at night. The outdoor lighting is operated by a time clock so that it turns on at dusk and turns off when the employees leave at night.

The energy used by the HVAC equipment is essentially driven by the outdoor temperature and to some extent by customer load. Analysis of the 15 minute data reveals that some HVAC units are manually set back at night when personnel remember to do so.

A review of the 15 minute data for Charley's Place indicates that most of the energy is consumed during and immediately following the dinner-"happy hour" period, when the customer count is highest.

Maintenance for this facility is primarily corrective. However, the HVAC equipment is maintained by an outside contractor on a preventive maintenance schedule. It should be noted that the electric steamer, metered in this project, was frequently broken.

3.7 MORRISON'S

Morrison's is a cafeteria located in Williamsburg, Virginia on Route 60, approximately 1-1/2 miles west of the restored colonial village of Williamsburg. Since Williamsburg is a tourist area, this facility has a high seasonal

load, with low customer counts in the winter and high customer counts in the tourist season. Breakfast service is seasonal (April through October); lunch and dinner are served year-round.

This facility is the largest consumer of total energy among the seven restaurants tested, consuming the highest amount of energy for food preparation and sanitation, while consuming the second highest amount for HVAC. This facility is the largest in terms of gross square footage, and it experienced the highest average outdoor temperature and also the highest average inlet water temperature during the period in which data were collected.

3.7.1 Building Description

This 10,152 sq ft facility is constructed of brick and concrete block. The walls and roof are not insulated. The building rests on a 4-inch-thick concrete slab. The facility has 392 sq ft of double pane glass and 3 entry doors (215 sq ft total).

Electricity is the only energy source for Morrison's. Mechanical equipment includes several large hot water heaters and a steam boiler. The steam is used for dishwashing and for steam tables on the cafeteria serving line; the hot water is used for domestic purposes and high temperature dishwashing. Refrigeration compression equipment, including the ice machine compressors, are rooftop mounted. Lighting for the dining room and the cafeteria serving line is incandescent. The kitchen and work area lighting is fluorescent and the outdoor lighting is incandescent, fluorescent, and HID. The building is heated and cooled through rooftop mounted units with economizers.

3.7.2 Menu and Equipment Use Descriptions

Morrison's is a cafeteria that serves entrees with side dishes, salads, breads, desserts, and nonalcoholic beverages. The entree and side dish menu varies daily, but the dessert and salad menu stays essentially the same. Entrees include seafood and beef. Side dishes include potatoes, vegetables, and some pastas. Many kinds of salads are available. Desserts served include pies, cakes, fruits, and puddings.

This facility is the largest consumer of food preparation energy of the restaurants studied, due to the following factors:

- It has the largest customer count.
- The necessity of keeping food warm in the cafeteria serving line requires a steam table; thus a considerable amount of energy is used to simply maintain food temperatures.
- There is a bakery in this facility as well as three large ranges, a number of fryers, and other large pieces of cooking equipment.

3.7.3 Hours of Operation

Summer (March 15 through November 4)

Every day 0700 - 1000 (Breakfast)

1130 - 2100 (Lunch and Dinner)

Winter (November 5 through March 14)

Every day 1130 to 2000 (Lunch and Dinner)

The bake ovens in this facility are turned on at about 0600. The heaviest energy consumption occurs between 1000 and 1130 and between 1500 and 1700. The load on the bake ovens in the early morning varies. This variation is probably related to the day's menu. The portable grills are only operated from 0615 to 1000, when breakfast is served. Fryers are used primarily from 1015 to 1330 and from 1600 to 2030, with the greatest use during dinner. Grills are on from about 0530 to 2230 with a varying load; however, higher use usually occurs around breakfast. Although the other food preparation equipment was not metered separately, it is apparent from the above information that the heaviest use of food preparation equipment occurs either immediately before or during the periods that meals are served.

There are two water heaters in this facility. Water heater 1 is usually on from 0600 to 2300 at rather heavy loads. There is a noticeable load increase for this hot water heater after lunch and dinner. Water heater 2 is used to supplement the hot water requirements and only comes on when water heater 1 cannot carry the load. The steam boiler generally operates at high loads from about 0530 to 2130. This facility is equipped with a laundry where the washer is run on demand from about 0800 to 2330; the dryer runs from about 0600 to 2200.

Most of the refrigeration equipment in this facility has a rather constant load throughout a 24 hour period. However, the coolers, which are entered more frequently in the morning, consume more energy then than in the balance of the day.

The majority of lighting at Morrison's is on from 0530 to about 2230. The kitchen lighting is turned off a little later, when clean-up is completed for the evening. There are a few outdoor lights for ornamental and security purposes; most of the outdoor lighting is supplied and billed separately by the local power company.

The HVAC equipment for this facility is equipped with an economizer that can be controlled manually by restaurant managers or automatically by equipment that will shut off the HVAC equipment at night. Consumption is dependent primarily on outdoor temperature and to some extent, customer load. Total energy consumption, which is highest during and immediately following dinner, is also somewhat dependent on customer count.

This facility has a preventative maintenance contract with an outside HVAC contractor. Other maintenance is corrective.

4.0 DATA SUMMARY

This chapter describes the data collected over the course of the project. The chapter begins with a discussion of the data capture rate, which is followed by a summary of the acquired data for each facility on a monthly basis and an average hourly basis for the winter and summer seasons. Finally the monthly data presentation formats are described. Actual data from the seven monitored sites are presented in Appendix I.

4.1 DATA CAPTURE RATE/QUALITY

The data capture rate (DCR) is the percentage of possible archivable data received and verified by PSU. When a meter point, whether it is for energy consumption or climatic condition, was determined to be operating correctly for a given day, the day was called a good point day (GPD). The ratio of good point days to total point days (TPD) is the data capture rate. The DCR for analog, digital, and both types of data was calculated monthly for each facility and was totaled.

For a day of data collection to be declared good, at least 22 of 24 hours of data had to have been received and verified. There were very few cases that did not fit into the "good" category; therefore, in almost all cases the DCR reflects complete days of data. Although the assessment of whether data were good was precise, especially with respect to the digital data, there was still the need for use of good judgment.

It should be noted that to achieve a high DCR, it was necessary to conduct both routine (monthly) maintenance visits and corrective maintenance visits when failures were noted at PSU. The amount of maintenance required was considerably more than that expected by PSU and PNL.

The following summary of the data capture rate is based on 84 restaurant-months. During the course of the project there were 11 restaurant-months when the DCR was 100%; approximately 50% of the months have DCRs above 90%. Eleven times during the monitoring period the monthly DCR fell below 70%. It should be noted that it was not unusual to have at least one power interruption or transient per month at each facility. The longest consecutive number of days

(221) of daily data collection and transmission to PSU occurred at Burger King from the end of October to the beginning of June.

Table 4.1 shows the monthly and average DCR for each facility and the monthly weighted average DCR. The DCR for all the restaurants for the duration of the project was 87.8%.

Approximately 9% of the data were lost at the restaurants; the losses were due to power failures, power transients, and the failure of several different types of microcomputer boards located onsite. The largest contributors to problems associated with data received at PSU that were subsequently declared unusable were capacitor and A/D convertor failures on the remote unit computers. Table 4.2 provides a compilation of the causes of data loss over the course of this project.

4.2 SUMMARY OF ACQUIRED DATA

The information acquired from PREP is useful for a wide variety of investigations. The summaries provided in this chapter have been selected to provide the reader with an overall understanding of end-use consumption patterns in the facilities examined. Consumption patterns for intervals of less than 1 month are not presented here; however, they will form the basis of other technical reports.

Both natural gas and electricity are used in three of the seven sites. In order to permit comparisons of overall energy consumption patterns and levels among sites, the energy contents of the fuels are converted to British thermal units (Btu) using site conversion factors of 1020 or 1030 Btu/CF (depending on the utility) for natural gas and 3413 Btu/kWh for electricity. These factors do not account for the relative efficiencies of delivering energy to the site, which are reflected in energy prices, or the efficiency of end-use equipment. Consumption of individual fuels for the end uses is documented in Appendix I and the data archived.

The results are discussed using generic restaurant category titles; however, it should be recognized that the information is based upon data from one site for each category, and peculiarities associated with individual structures

TABLE 4.1. Data Capture Rate Summary

Restaurant	7/83	8/83	9/83	10/83	11/83	12/83	1/84	2/84	3/84	4/84	5/84	6/84	Avg.
Burger King	90.5	70.6	62.1	57.2	99.1	94.9	96.5	93.1	100.0	98.4	94.2	61.2	84.8
Charley's Place	81.0	92.6	89.9	94.6	95.0	96.8	95.6	99.3	100.0	80.0	99.3	93.3	93.1
Friendly's	63.0	61.3	100.0	100.0	96.7	96.8	96.8	96.6	93.5	96.7	90.3	96.7	90.7
Morrison's	79.7	84.8	93.3	89.6	100.0	90.5	96.2	86.1	91.6	99.1	93.5	100.0	92.0
Pizza Hut	53.1	19.0	90.0	89.5	81.0	80.6	70.1	43.0	70.1	90.7	96.8	83.3	72.3
Roy Rogers	76.1	85.1	72.8	93.6	63.3	96.5	98.6	81.7	100.0	96.4	75.9	66.0	83.9
Steak & Ale	63.4	84.5	96.7	83.9	82.3	100.0	97.1	92.3	100.0	80.0	100.0	100.0	90.0
Weighted avg. - all facilities	74.0	75.4	86.9	87.1	89.6	94.4	93.8	86.7	94.5	91.1	93.4	87.1	87.8

TABLE 4.2. Lost Data Summary

<u>Problem</u>	<u>No. Days</u>	<u>Total No. Lost Point Days</u>	<u>Total Point Days, %</u>
Power failure	80	2,546	3.3
Unknown	124	1,348	1.7
Modem board problem	50	1,244	1.6
Clock board failure	43	864	1.1
Failed capacitor	836	836	1.1
Temperature amp failure	110	360	0.5
Change to EPROM (Disk drive problem)	10	346	0.4
Overheated computer	14	322	0.4
Human error	34	300	0.4
ROM problems	9	250	0.3
Computer repairs	10	236	0.2
A/D convertor failure	23	170	0.2
Climate equipment failure	28	167	0.2
Telephone line failure	5	150	0.2
CPU failure	5	150	0.2
Pulse initiator failure	135	<u>135</u>	<u>0.2</u>
Total		9,424	12.0

can alter energy use patterns significantly. This review of the results focuses upon the differences in energy use among the facilities to explore the determinants of restaurant energy consumption.

Table 4.3 provides by restaurant a summary of the monthly levels of energy end-use consumption. Also included is the percent of total energy attributed to each end use. The customer count, average outdoor temperature and inlet water temperatures are noted as well. Finally, for the three sites where gallons of hot water was measured, monthly consumption levels are shown.

As expected, restaurants were found to be very intensive users of energy, due to the high level of process activity and ventilation. Figure 4.1 presents by restaurant the average monthly energy consumption for the period July 1983 through June 1984. Use ranges from approximately 100,000 MBtu to slightly over

TABLE 4.3. Monthly Levels of Energy Consumption by End Use for Each Restaurant Type

FRIENDLY'S (COFE)

Month	Food Prep		Sanitation		Refrigeration		Lighting		HVAC		Total	
	MBtu	%	MBtu	%	MBtu	%	MBtu	%	MBtu	%	MBtu	MBtu/ft ²
JUL	62580	38	24370	15	6611	4	18200	11	52838	32	164599	39
AUG	64439	39	23733	14	6718	4	18777	11	50756	31	164423	39
SEP	50839	40	24907	20	5918	5	19237	15	26109	21	127010	30
OCT	41398	38	28317	26	4791	4	24547	22	11127	10	110180	26
NOV	37143	33	26074	23	3899	3	24217	21	21915	19	113248	27
DEC	33823	23	26657	18	3294	2	24088	16	59877	41	147739	35
JAN	29751	18	27254	16	3496	2	24489	15	83024	49	168014	40
FEB	29269	22	29405	23	3397	3	23909	18	44382	34	130362	31
MAR	31645	21	37937	25	3845	3	25366	17	51311	34	150104	36
APR	32476	28	37909	33	5276	5	23939	21	15173	13	114773	27
MAY	33642	29	38394	33	5356	5	23075	20	16053	14	116520	28
JUN	34048	25	36484	26	5889	4	23089	17	38417	28	137927	33
AVG	40088	29	30120	22	4874	4	22744	17	39249	29	137075	33

Total Minus HVAC,		Customer		Outdoor		Hot Water Use,		Inlet Water	
MBtu		Count		Temp., °F		gal		Temp., °F	
111761		40487		72		31430		81	
113667		39825		72		30790		82	
100901		26944		61		26612		73	
99053		24187		51		26752		55	
91333		19489		42		23990		43	
87862		17211		26		20565		36	
84990		14312		22		22194		36	
85980		16998		34		29688		40	
98793		19813		30		37936		41	
99600		24316		43		47376		46	
100467		24463		54		52644		52	
99510		27883		65		56396		66	
97826		24661		48		33864		54	

TABLE 4.3. (contd)

BURGER KING (FFLM)

Month	Food Prep		Sanitation		Refrigeration		Lighting		HVAC		Total	
	MBtu	%	MBtu	%	MBtu	%	MBtu	%	MBtu	%	MBtu	MBtu/ft ²
JUL	85106	46	13988	8	8934	5	34133	18	42834	23	184995	60
AUG	84028	45	11355	6	9099	5	35954	19	46118	25	186554	60
SEP	82734	50	12263	7	8065	5	34739	21	28437	17	166238	54
OCT	88528	52	17580	10	7924	5	36308	21	20413	12	170753	55
NOV	79753	45	16966	10	8476	5	35747	20	36003	20	176945	57
DEC	82636	36	19453	8	7265	3	38745	17	84095	36	232194	75
JAN	81232	31	20602	8	6750	3	38643	15	12706	43	259933	84
FEB	79864	42	20092	11	6597	4	36603	19	44874	24	188030	61
MAR	83307	40	20571	10	7047	3	36677	18	58895	29	206497	67
APR	80528	51	19129	12	7370	5	35238	22	14541	9	156806	51
MAY	86873	53	18569	11	8208	5	36218	22	13767	8	163635	53
JUN	86006	48	15293	9	8514	5	34251	19	33885	19	177949	57
AVG	83383	44	17155	9	7854	4	36105	19	44714	24	189211	61

Total Minus HVAC,		Customer		Outdoor		Hot Water Use,		Inlet Water	
MBtu		Count		Temp., °F		gal		Temp., °F	
142161		30286		79		12430		82	
140436		26291		77		9310		83	
137801		26156		66		10244		78	
150340		28638		53		14106		65	
140942		24079		46		12940		51	
148099		26757		34		13560		40	
147227		24330		29		12710		32	
143156		26357		40		12178		40	
147602		25281		37		12994		45	
142265		27203		50		12232		50	
149868		29203		60		13034		62	
144064		28985		72		11287		73	
144497		26964		54		12252		58	

TABLE 4.3. (contd)

ROY ROGERS (FFEM)

Month	Food Prep		Sanitation		Refrigeration		Lighting		HVAC		Total	
	MBtu	%	MBtu	%	MBtu	%	MBtu	%	MBtu	%	MBtu	MBtu/ft ²
JUL	54199	39	8336	6	10261	7	17692	13	47456	34	137944	50
AUG	53814	39	7926	6	10279	8	19081	14	45470	33	136570	50
SEP	42613	39	8148	7	8937	8	19211	17	31144	28	110053	40
OCT	49410	46	9346	9	9194	9	17843	17	21559	20	107352	39
NOV	44825	35	11031	9	7348	6	15241	12	49608	39	128053	47
DEC	46662	24	10987	6	6616	3	15092	8	113081	59	192438	70
JAN	46261	21	12393	6	5308	2	13133	6	138730	64	215825	78
FEB	41755	27	11099	7	5116	3	9989	6	88482	57	156441	57
MAR	46792	26	9554	5	5271	3	13148	7	107906	59	182671	66
APR	52745	44	9675	8	5896	5	14084	12	37768	31	120168	44
MAY	56811	56	9277	9	7798	8	15065	15	11897	12	100848	37
JUN	58569	47	8077	6	9459	8	17543	14	30880	25	124528	45
AVG	49538	35	9654	7	7624	5	15594	11	60332	42	142741	52

Total Minus HVAC,		Customer		Outdoor		Inlet Water	
MBtu		Count		Temp., °F		Temp., °F	
90488		12902		77		58	
91100		12401		74		58	
78909		10483		66		57	
85793		11445		53		56	
78445		9990		45		55	
79357		10723		32		54	
77095		10377		27		53	
67959		9328		38		53	
74765		9762		35		54	
82400		10099		48		55	
88951		12838		54		56	
93648		13260		69		57	
82409		11134		52		56	

TABLE 4.3. (contd)

PIZZA HUT (PIZA)

Month	Food Prep		Sanitation		Refrigeration		Lighting		HVAC		Total	
	MBtu	%	MBtu	%	MBtu	%	MBtu	%	MBtu	%	MBtu	MBtu/ft ²
JUL	34876	30	17837	15	10278	9	12160	10	42885	36	118036	52
AUG	33755	30	17023	15	10149	9	12019	11	40737	36	113683	50
SEP	31379	31	16110	16	9191	9	11602	12	32445	32	100727	44
OCT	31741	36	16438	19	8462	10	11877	13	19907	23	88425	39
NOV	27614	41	15648	23	5175	8	11064	16	8388	12	67889	30
DEC	29067	31	17510	19	5035	5	12327	13	30532	32	94471	42
JAN	27866	23	21622	18	9382	8	12892	11	47989	40	119751	53
FEB	26996	32	14971	18	9501	11	12038	14	19693	24	83199	37
MAR	30618	30	18529	18	8952	9	12935	13	32301	31	103335	45
APR	29311	33	25667	29	9546	11	12933	14	12007	13	89464	39
MAY	30312	33	17418	19	10451	11	13709	15	20403	22	92293	41
JUN	28177	28	14620	14	10320	10	12986	13	35105	35	101208	44
AVG	30143	31	17783	18	8870	9	12379	13	28533	29	97707	43

Total Minus HVAC,		Customer		Outdoor		Inlet Water	
MBtu		Count		Temp., °F		Temp., °F	
75151		18639		76		82	
72946		18596		75		83	
68282		19353		65		78	
68518		17650		52		65	
59501		15878		44		51	
63939		14099		31		40	
71762		12805		27		32	
63506		12890		38		40	
71034		15257		34		45	
77457		14549		47		50	
71890		14610		56		62	
66103		12519		69		73	
69174		15570		51		58	

TABLE 4.3. (contd)

STEAK & ALE (FSLM)

Month	Food Prep		Sanitation		Refrigeration		Lighting		HVAC		Total	
	MBtu	%	MBtu	%	MBtu	%	MBtu	%	MBtu	%	MBtu	MBtu/ft ²
JUL	54474	25	40547	19	26052	12	38468	18	55215	26	214756	32
AUG	51346	24	37772	18	27071	13	38992	19	55290	26	210471	31
SEP	51664	28	35751	19	23933	13	38260	21	35580	19	185188	27
OCT	53350	30	37173	21	22656	13	38508	22	26676	15	178363	26
NOV	57445	26	48017	22	20462	9	41899	19	51935	24	219758	32
DEC	59426	20	55576	18	21267	7	47545	16	120215	40	304029	45
JAN	59395	19	58134	18	20680	6	48166	15	132734	42	319109	47
FEB	58261	23	58983	23	20263	8	44449	18	70902	28	252858	37
MAR	60883	22	60204	22	21886	8	45216	17	83709	31	271898	40
APR	58767	29	57969	28	23869	12	40492	20	23984	12	205081	30
MAY	57580	29	46469	23	26741	13	40910	20	29390	15	201090	30
JUN	51367	26	36930	19	26483	14	37776	19	43594	22	196150	29
AVG	56163	24	47794	21	23447	10	41723	18	60769	26	229896	34
Total Minus HVAC, Customer Outdoor Hot Water Use, Inlet Water												
MBtu Count Temp., °F gal Temp., °F												
159541 8377 78 45638 74												
155181 8575 76 45852 76												
149608 8795 68 43199 75												
151687 8398 56 47820 66												
167823 7643 47 39820 55												
183814 8326 34 46400 45												
186375 7785 31 50600 38												
181956 8116 45 53660 43												
188189 9051 39 54600 45												
181097 9265 52 55515 52												
171700 9264 61 46820 62												
152556 8773 74 42420 66												
169127 8531 55 47695 58												

TABLE 4.3. (contd)

CHARLEY'S PLACE (FSEM)

Month	Food Prep		Sanitation		Refrigeration		Lighting		HVAC		Total	
	MBtu	%	MBtu	%	MBtu	%	MBtu	%	MBtu	%	MBtu	MBtu/ft ²
JUL	130193	31	58304	14	33498	8	49201	12	142570	34	413766	44
AUG	137023	32	65905	15	34886	8	48889	11	146111	34	432814	46
SEP	133994	34	76092	19	31330	8	47781	12	106318	27	395515	42
OCT	140664	36	102445	26	28687	7	50088	13	73092	19	394976	42
NOV	145153	36	118655	30	26695	7	47983	12	62360	16	400846	42
DEC	149156	29	137711	27	27160	5	48816	10	147872	29	510715	54
JAN	150621	28	141077	26	27945	5	50031	9	167086	31	536760	57
FEB	143492	33	123019	28	25960	6	46786	11	101562	23	440819	46
MAR	151985	32	136949	29	27499	6	51738	11	107532	23	475703	50
APR	138973	36	119398	31	28653	7	48604	13	53185	14	388813	41
MAY	142324	35	93550	23	30254	8	49527	12	86076	21	401731	42
JUN	131966	31	81145	19	30828	7	48010	11	132772	31	424721	45
AVG	141295	32	104521	24	29450	7	48955	11	110545	25	434765	46

Total Minus HVAC,		Customer		Outdoor		Inlet Water	
MBtu	Count	Temp., °F	Temp., °F	Temp., °F			
271196	27146	78	74				
286703	28281	78	76				
289197	26275	66	75				
321884	29128	52	66				
338486	29645	42	55				
362843	29729	31	45				
369674	27002	29	38				
339257	11488	40	43				
368171	29815	38	45				
335628	26415	50	52				
315655	28615	59	62				
291949	28781	70	66				
324220	26860	53	58				

TABLE 4.3. (contd)

MORRISON'S (CAFE)

Month	Food Prep		Sanitation		Refrigeration		Lighting		HVAC		Total	
	MBtu	%	MBtu	%	MBtu	%	MBtu	%	MBtu	%	MBtu	MBtu/ft ²
JUL	229349	40	154993	27	20112	4	39083	7	124749	22	568286	56
AUG	232717	41	150978	27	23262	4	39134	7	123337	22	569428	56
SEP	224305	42	158319	30	18915	4	38067	7	88662	17	528268	52
OCT	228282	44	160538	31	18460	4	39720	8	71216	14	518216	51
NOV	182852	41	137210	30	16087	4	35646	8	79482	18	451277	44
DEC	170539	35	124418	25	12992	3	34695	7	149459	30	492103	48
JAN	146361	29	113950	23	12722	3	31953	6	192431	39	497417	49
FEB	152299	37	118161	28	13691	3	30727	7	101945	24	416823	41
MAR	201565	39	165824	32	14285	3	34152	7	107252	21	523078	52
APR	241479	43	195671	35	16591	3	39143	7	69148	12	562032	55
MAY	238077	43	176570	32	17643	3	42869	8	75315	14	550474	54
JUN	215999	40	146435	27	19049	4	39931	7	120276	22	541690	53
AVG	205319	40	150256	29	16984	3	37093	7	108606	21	518258	51

Total Minus HVAC,		Customer		Outdoor		Inlet Water	
MBtu	Count	Temp., °F	Temp., °F				
443537	57180	76	84				
446091	54904	77	82				
439606	45238	69	77				
447000	55641	59	67				
371795	34919	51	57				
342644	26538	41	45				
304986	17047	35	42				
314878	20358	43	47				
415826	33503	40	51				
492884	51836	50	59				
475159	57362	61	70				
421414	51552	71	75				
409652	42173	56	63

FIGURE 4.1. Average Monthly Energy End-Use Totals by Restaurant Type, MBtu

500,000 MBtu for the cafeteria. The end-use categories are labeled as follows: FP--food preparation; SAN--sanitation; REF--refrigeration; L--lighting; and HVAC--heating, ventilation, and air conditioning.

Figure 4.2 presents the average monthly energy use on an MBtu per square foot basis. The fast food restaurants are the highest users of energy on a per square foot basis, due to the relatively large ventilation requirement and the use of less efficient gas equipment. The cafeteria follows closely because of the large sanitation requirement (for dishwashing) and the large food preparation requirements. The full menu dinner house and the pizza restaurant are moderate consumers of energy on a per square foot basis. The limited menu dinner house is one of the least intensive users, since it has the lowest levels of food preparation energy and a relatively high square foot to customer count ratio. The coffee shop is the lowest energy user per square foot because of an efficient HVAC system and other operational practices.

Figures 4.3 to 4.16 depict the energy consumption values for each facility. These figures include a plot of end-use and total energy use consumption by month and a pie chart showing percent end-use energy consumption on an annual basis. A review of these plots reveals several energy use patterns.

FIGURE 4.2. Average Monthly Energy End-Use Totals by Restaurant Type, MBtu/sq ft

First, the profile of total energy use throughout the year is similar to the HVAC energy consumption pattern, being shifted higher by a relatively constant baseload associated with other end uses. The only exception appears to be the cafeteria, where sanitation and food preparation energy are high and closely related to customer count. Customer counts during the winter months are less than half those of the summer months.

4.3 AVERAGE HOURLY SUMMARIES

The collection of data at 15 minute intervals provides insights into the operating schedules for the facilities and indicates the end uses which are seasonally dependent and/or which drive building energy use. Due to the overwhelming amount of data at this level of detail, the data have been reduced to average hourly end-use energy consumption for the heating and cooling seasons. The hourly averages are calculated from the 15 minute data over a 1 week period. Typically a week in August is used to represent the cooling season and a week in January is used to represent the heating season. The selection of representative weeks is based upon time periods with both a high data capture rate and typical consumption based upon an inspection of the end-use energy

FIGURE 4.3. Yearly Energy Use for Coffee Shop

FIGURE 4.4. Monthly Energy Use for Coffee Shop

consumption profiles aggregated to the daily level. These data are depicted in Figures 4.17 through 4.30. Hour 0 corresponds to midnight.

The hourly end-use profiles for each restaurant show many similarities. Refrigeration energy consumption is relatively constant throughout the day. Food preparation energy use tends to be characterized by a large base load which is turned on early in the day with peaks before the lunch and dinner periods. The heating energy use usually dominates winter energy use and most facilities do not set back their thermostats after closing. However,

FIGURE 4.5. Yearly Energy Use for Fast Food Limited Menu Facility

FIGURE 4.6. Monthly Energy Use for Fast Food Limited Menu Facility

facilities with night setback have a significant reduction in energy use during winter nights. The large amounts of heating energy required during winter days suggest that waste heat from the food preparation equipment or refrigeration compressors could be used to reduce heating energy consumption. Specific descriptions of the hourly profiles follow.

Friendly Restaurant (Figures 4.17 and 4.18), the coffee shop, differs from the other restaurants since its food preparation energy use is seasonal. It is significantly higher during the summer, although the restaurant is only open

FIGURE 4.7. Yearly Energy Use for Fast Food Expanded Menu Facility

FIGURE 4.8. Monthly Energy Use for Fast Food Expanded Menu Facility

one hour longer per day than in winter. Refrigeration is relatively constant over the day and season. HVAC is the dominant energy use in both summer and winter.

Burger King (Figures 4.19 and 4.20), the fast food limited menu facility, has the same operating hours year round. Consequently, the hourly profiles for food preparation, sanitation, lighting, and refrigeration do not differ significantly between summer and winter. The food preparation energy consumption

FIGURE 4.9. Yearly Energy Use for Pizza Facility

FIGURE 4.10. Monthly Energy Use for Pizza Facility

remains high during all of the open hours, indicating that there is no scheduling of the major energy consuming equipment such as the chain broilers. HVAC energy consumption is the predominant end use during the winter and it does not decrease significantly during the day in response to the internal loads and microclimate. During summer the cooling energy requirements are responsive to the time of day: the cooling energy use increases during the morning, peaks at around 1:00 p.m. and then slowly drops during the afternoon. Sanitation energy use peaks at night after the restaurant closes.

FIGURE 4.11. Yearly Energy Use for Full Service Limited Menu Facility

FIGURE 4.12. Monthly Energy Use for Full Service Limited Menu Facility

Roy Rogers (Figures 4.21 and 4.22), the fast food expanded menu facility, has a significantly different hourly profile for HVAC energy use than the fast food limited menu facility. Winter heating energy changes dramatically during the course of a day, indicating the savings from night adjustment of the thermostat. Heating energy use decreases dramatically after the restaurant closes at midnight and then increases in the morning and peaks shortly after the facility opens. In the summer the cooling energy also changes with the hour of the day. Peak cooling energy consumption occurs in the mid-afternoon.

FIGURE 4.13. Yearly Energy Use for Full Service Expanded Menu Facility

FIGURE 4.14. Monthly Energy Use for Full Service Expanded Menu Facility

Refrigeration energy is relatively constant regardless of the season or time of day. Sanitation, food preparation, and lighting energy do not show much seasonal variation. Sanitation increases only slightly in the winter. This increase is probably due to lower inlet water temperatures. However, it is dampened by the small amount of hot water use. The local peaks in food preparation energy consumption correspond to the three meals of the day, with the peak food preparation energy use occurring before lunch.

FIGURE 4.15. Yearly Energy Use for Cafeteria

FIGURE 4.16. Monthly Energy Use for Cafeteria

Pizza Hut (Figures 4.23 and 4.24), like most of the other restaurants, has a large base load for food preparation. The majority of the base load is due to the pizza ovens, which are turned on in the morning a few hours before the restaurant opens. The peak food preparation load occurs during the evening hours. This hourly profile is not seasonally dependent. Like the other restaurants, the refrigeration energy use is the smallest end use and is relatively constant year round. Lighting energy use increases during the opening

Δ = Fd Prp
 $*$ = Sanit
 $\square$ = Ref
 $\diamond$ = Ltg
 $+$ = HVAC

FIGURE 4.17. Winter Hourly Profile for Friendly's (COFE)

Δ = Fd Prp
 $*$ = Sanit
 $\square$ = Ref
 $\diamond$ = Ltg
 $+$ = HVAC

FIGURE 4.18. Summer Hourly Profile for Friendly's (COFE)

Δ = Fd Prp
 $*$ = Sanit
 $\square$ = Ref
 $\diamond$ = Ltg
 $+$ = HVAC

FIGURE 4.19. Winter Hourly Profile for Burger King (FFLM)

Δ = Fd Prp
 $*$ = Sanit
 $\square$ = Ref
 $\diamond$ = Ltg
 $+$ = HVAC

FIGURE 4.20. Summer Hourly Profile for Burger King (FFLM)

Δ = Fd Prp
 $*$ = Sanit
 $\square$ = Ref
 $\diamond$ = Ltg
 $+$ = HVAC

FIGURE 4.21. Winter Hourly Profile for Roy Rogers (FFEM)

Δ = Fd Prp
 $*$ = Sanit
 $\square$ = Ref
 $\diamond$ = Ltg
 $+$ = HVAC

FIGURE 4.22. Summer Hourly Profile for Roy Rogers (FFEM)

Δ = Fd Prp
 $*$ = Sanit
 $\square$ = Ref
 $\diamond$ = Ltg
 $+$ = HWAC

FIGURE 4.23. Winter Hourly Profile for Pizza Hut (PIZA)

Δ = Fd Prp
 $*$ = Sanit
 $\square$ = Ref
 $\diamond$ = Ltg
 $+$ = HVAC

FIGURE 4.24. Summer Hourly Profile for Pizza Hut (PIZA)

FIGURE 4.25. Winter Hourly Profile for Steak & Ale (FSLM)

Δ = Fd Prp
 $*$ = Sanit
 $\square$ = Ref
 $\diamond$ = Ltg
 $+$ = HVAC

FIGURE 4.26. Summer Hourly Profile for Steak & Ale (FSLM)

Δ = Fd Prp
 * = Sanit
 $\square$ = Ref
 $\diamond$ = Ltg
 + = HVAC

FIGURE 4.27. Winter Hourly Profile for Charley's (FSEM)

Δ = Fd Prp
 $*$ = Sanit
 $\square$ = Ref
 $\diamond$ = Ltg
 $+$ = HVAC

FIGURE 4.28. Summer Hourly Profile for Charley's (FSEM)

Δ = Fd Prp
 $*$ = Sanit
 $\square$ = Ref
 $\diamond$ = Ltg
 $+$ = HVAC

FIGURE 4.29. Winter Hourly Profile for Morrison's (CAFE)

Δ = Fd Prp
 $*$ = Sanit
 $\square$ = Ref
 $\diamond$ = Ltg
 $+$ = HVAC

FIGURE 4.30. Summer Hourly Profile for Morrison's (CAFE)

hours but remains constant throughout the day. Sanitation energy oscillates frequently during the day. The heating energy is distinctive due to both its small amount and its oscillation. In the summer the cooling energy use is significant and remains relatively constant from noon until midnight.

Steak & Ale (Figures 4.25 and 4.26), the full service limited menu facility, shows the greatest variation in hourly energy use of all the restaurants metered. Sanitation energy use has the same profile in the summer and winter, although the consumption is much higher in the winter, due to lower inlet water temperatures to the water heaters. Peak sanitation energy consumption occurs in the evening at 2000 to 2200, with a smaller peak in the late morning and early afternoon. Food preparation is not seasonally dependent and is characterized by a large base load which starts in the morning and is highest prior to serving dinner, with a smaller peak before lunch. Heating represents a dominant energy use in winter. However, the heating energy decreases after closing due to the setback of the thermostat. In the summer cooling energy is a major, but not the dominant, energy use in the afternoons and evenings. The lighting profile indicates that lighting use is turned on as needed. Lighting energy use increases over the morning, stays relatively constant during the afternoon and then increases in the evening.

Refrigeration energy use for Charley's Place (Figure 4.27 and 4.28), the full service expanded menu facility, is relatively constant regardless of the hour of day or season. The lighting energy does not show seasonal variation and is relatively constant during the hours that the restaurant is open for meal preparation and business (8:00 a.m. until 2:00 a.m.). Food preparation shows about the same average hourly profile and magnitude of energy use in summer and winter. Sanitation energy, however, decreased dramatically in summer. This is probably due to the higher input water temperatures to the hot water heaters. The peaks in sanitation energy use follow the peaks in food preparation energy use. HVAC energy use is dependent upon the season and hour of the day.

The winter and summer average hourly profiles for Morrison's (Figure 4.29 and 4.30), the cafeteria, indicate that refrigeration and lighting energy use is relatively constant and represents a small part of the energy load during

restaurant operating hours. The food preparation and sanitation energy consumption profiles indicate a difference in winter and summer operating hours, with the peak energy consumption during the summer occurring earlier in the day when breakfast is served.

4.4 MONTHLY END-USE CONSUMPTION

Appendix I provides two pages of data summaries per month for each facility. The first page is a monthly listing of daily energy use by category, a simple matrix of all the energy categories and total energy as well as customer count, heating and cooling degree-days, and water consumption where applicable by day of the month. The amount of gas and electricity consumed for each of the categories is shown for each day as well as the total MBtu. There is also a monthly total of the gas, electricity, and MBtu by end-use category and the other criteria enumerated above. The second page for each restaurant is a monthly summary. It shows energy use in MBtu for each end-use category and total energy and it also lists the total MBtu consumed by each category in percent of total energy use. In addition, for each energy end-use category the MBtu/heating degree-day, MBtu/cooling degree-day, MBtu/customer count and MBtu/square foot are also shown.

5.0 DATA ANALYSIS

This chapter describes the analysis of PREP data conducted to date. It should be recognized that the purpose of this project was to collect empirical performance data for representative facilities, not to conduct detailed data analyses. It is hoped that in the future, empirical and theoretical modeling approaches for these data can be developed and evaluated, and energy conservation and load management strategies can be assessed.

The chapter begins with a discussion of the comparative performance of the monitored sites. This includes normalization of the total and end-use data to a variety of indexes such as floor area, customer count, and temperature. The next section describes a set of regression tests used to identify statistically significant energy use cause-and-effect relationships. The analyses presented are limited to single determinant investigations. For example, we investigated the relationship of sanitation energy to water supply temperature, but we did not evaluate its relationship to the combination of customer count and water supply temperature. Once again, these explorations are the result of a limited level of effort, since the project funding did not provide for extensive data analysis and evaluation.

5.1 NORMALIZED PERFORMANCE OF FACILITIES

In a project of this scope many factors can be used to make normalizing comparisons. Only those deemed reasonable and logical are presented. Unless otherwise noted, the MBtu value is the average per month for each restaurant. Figure 5.1 depicts the average monthly energy use by end-use category for each of the seven facilities.

5.1.1 Normalization of Total Energy Use

The following normalization of total energy use was evaluated:

1. Average monthly MBtu/sq ft (Figure 5.2) - The range of values varies from 33 to 61, with a mean of 45.7. These data indicate that MBtu/sq ft may not be a good method of comparing or determining

FIGURE 5.1. Average Monthly Energy Use by End-Use Category, MBtu

FIGURE 5.2. Average Monthly Energy Use by End-Use Category, MBtu/sq ft

restaurant energy use. On the basis of this analysis Burger King, Roy Rogers, and Morrison's were the most intensive consumers of energy per square foot.

2. Total MBtu/customer (Figure 5.3) - The mean monthly value for the seven restaurants is 10.1 MBtu/customer and the range is 5.7 to 17.9. This range is much wider than the previous category, showing that MBtu/customer may less accurately explain restaurant performance than MBtu/ft². Using this criterion Charley's Place and Steak & Ale were the most intensive users of energy.
3. Total MBtu/°F (average temperature) (Figure 5.4) - This normalizing factor is closely related to heating degree-days as an evaluation technique. The range of values is 1.9 to 9.3 with a mean value of 4.7 MBtu/°F. There is a wide variation in energy use because of the predominant share of process energy needs. Morrison's consumed the most energy according to this normalizing factor.

The above tests demonstrate that none of these methods appears to be a good way to normalize total energy consumption across the entire restaurant industry. Based on the above normalizing factors, each restaurant type is a most intensive energy consumer, with the exception of Friendly Restaurants and Pizza Hut. This is a strong indication that these factors are not good normalizing techniques when considered individually.

FIGURE 5.3. Total Energy Use by End-Use Category, MBtu/customer

FIGURE 5.4. Total Energy Use by End-Use Category, MBtu/average temperature

5.1.2 Normalization of End-Use Energy Consumption

Several normalizations were made of end-use consumption levels. The following tests were selected based upon a prior judgment of significance:

1. Food preparation MBtu/customer (Figure 5.5) - On the basis of this normalizing factor Charley's Place, Steak & Ale, and Morrison's are the largest users. Their customer counts are third highest, lowest, and highest, respectively. Their high consumption is due in part to their relatively large number of menu items. In the case of Steak & Ale it is also apparent that the kitchen equipment was operated without regard for energy conservation.
2. Sanitation MBtu/°F average inlet water temperature (Figure 5.6) - Earlier in this document it is reported that inlet water temperature strongly influences sanitation energy use. Morrison's, Charley's Place, and Steak & Ale were the largest consumers of sanitation energy on the basis of this analysis. Since these restaurants have dishwashers, high customer counts, bars, and large amounts of dinnerware and glassware, it is not surprising that they consume so much

FIGURE 5.5. Total Energy Use for Food Preparation, MBtu/customer

FIGURE 5.6. Total Energy Use for Sanitation, MBtu/average water temperature

more than the other restaurants. This analysis demonstrates no basis for comparison studies among all types of restaurants.

3. Refrigeration MBtu/°F average temperature (Figure 5.7) - This analysis shows that full service restaurants and the cafeteria consume

FIGURE 5.7. Total Energy Use for Refrigeration, MBtu/average temperature

more energy per degree of average temperature than the others. Since the compression equipment is located outdoors (except in the case of Friendly Restaurants), this relationship is worth investigating. The full service restaurants and the cafeteria are probably high users because of the bar trade and the very high customer count, respectively.

4. Lighting MBtu/sq ft (Figure 5.8) - The bar chart for this factor shows that except for the fast food limited menu restaurant, normalized energy consumption in this category is similar. This would indicate that lighting energy use can be more closely controlled throughout the entire spectrum of the restaurant industry. This is more true for lighting than for any other single end-use category and is irrespective of the light source type since the largest consumer, Burger King, uses a predominance of fluorescent lights.
5. HVAC MBtu/°F average temperature (Figure 5.9) - Use in this category ranges from 0.56 to 2.08 with a mean of 1.2. This analysis demonstrates that this normalizing factor may not be a good measure for comparing energy use among restaurants.

FIGURE 5.8. Total Energy Use for Lighting, MBtu/sq ft

FIGURE 5.9. Total Energy Use for HVAC, MBtu/average temperature

Table 5.1 shows the range of end-use energy as a percentage of total energy used. There is a wide variance in these ranges for each end-use category, and the average for each restaurant is close to the mean for all facilities in each end-use category. These data indicate that a single set of

TABLE 5.1. Percent End-Use Category Analysis

<u>End Use</u>	<u>Range Average/mo</u>	<u>Non-Coincident Range Use/mo</u>	<u>Average All Restaurants</u>
Food preparation	24 - 44	18 - 53	34.8
Sanitation	7 - 29	6 - 35	17.8
Refrigeration	3 - 10	2 - 14	5.8
Lighting	7 - 19	6 - 22	13.5
HVAC	21 - 42	8 - 64	28.0

energy use criteria cannot be established for all segments of the restaurant industry. However, project data do indicate several energy use distinctions among restaurant types that should be explored and exploited.

5.2 REGRESSIONS OF ENERGY USE CAUSE AND EFFECT

This section provides statistical analyses of five different relationships listed and discussed below (Tables 5.2 through 5.6). Linear and polynomial regressions are tested for each relationship. The regressions are based upon the monthly summary data; thus there are 12 observations in each regression.

TABLE 5.2. Food Preparation Energy Use as a Function of Customer Count

<u>Restaurant Type</u>	<u>Food Preparation,^(a) MBtu =</u>	<u>R²</u>	<u>t Test</u>	
			<u>Dependent</u>	<u>Constant</u>
COFE	1.01*C + 1307464	0.89	9.09	4.53
FFLM	0.952*C + 54635	0.55	3.49	6.61
FFEM	1.94*C + 10578	0.75	5.47	1.48 ^(b)
PIZA	0.845*C + 16977	0.70	4.84	6.17
FSLM	-0.594*C + 63831	0.02	-0.407 ^(b)	3.38
FSEM	2.28*C + 77101	0.47	1.47 ^(b)	1.77 ^(b)
CAFE	2.19*C + 113079	0.93	11.38	13.20

(a) C = Customer count.

(b) Not statistically different than 0 at the 95% confidence interval.

TABLE 5.3. Sanitation Energy Use as a Function of Inlet Water Temperature (°F)^(a)

Restaurant Type	Sanitation, ^(b) MBtu =	R ²	t Test	
			Dependent	Constant
COFE	-115.09*W + 36363	0.11 ^(c,d,e)	-1.14 ^(f)	6.34
FFLM	-166.21*W + 26864	0.85 ^(g)	-7.31	19.40
FFEM	-731.16*W + 50233	0.81 ^(g)	-6.61	8.18
PIZA	-60.54*W + 21319	0.12 ^(c,h)	-1.18 ^(f)	6.81
FSLM	-681.43*W + 87374	0.87 ^(c,e)	-8.12	17.49
FSEM	-2057.80*W + 224044	0.91	-10.33	18.90
CAFE	765.83*W + 10208	0.22 ^(c,d)	1.69 ^(f)	3.49

(a) Obtained from local water company.

(b) W = inlet water temperature (°F).

(c) Electric.

(d) Affected by relief valve stuck in open position for last 4 months of data collection.

(e) May be influenced by high seasonal customer count.

(f) Not statistically different than 0 at the 95% confidence interval.

(g) Natural gas.

(h) Maintenance problems with booster and hot water heaters.

TABLE 5.4. Refrigeration Energy Use as a Function of Outdoor Temperature (°F)

Restaurant Type	Refrigeration, ^(a) MBtu =	R ²	t Test	
			Dependent	Constant
COFE	144.02*T + 3510	0.92 ^(b)	10.99	5.36
FFLM	43.04*T + 5547	0.78	5.90	13.56
FFEM	106.54*T + 2137	0.84	7.24	2.69
PIZA	56.06*T + 6002	0.27 ^(c)	1.92	3.82
FSLM	137.65*T + 15864	0.75	5.54	11.15
FSEM	145.53*T + 21772	0.84	7.14	19.31
CAFE	206.71*T + 5391	0.92	10.41	4.69

(a) T = Outdoor dry-bulb temperature (°F).

(b) Compression equipment is water cooled and located indoors.

(c) Refrigeration added to facility in January 1984.

TABLE 5.5. HVAC Energy Use as a Function of Outdoor Temperature (°F)

Restaurant Type	HVAC, (a) MBtu =	R ²	† Test			
			Temp. Squared	Temp.	Constant	F Test
COFE	82.40*T2 - 8316.41*T + 225143	0.97	16.03	-16.73	20.61	-146.83
FFLM	100.13*T2 - 11926*T + 369211	0.95	10.95	-11.82	14.27	-90.29
FFEM	113.74*T2 - 13778*T + 438202	0.96	9.98	-11.40	14.76	-119.19
PIZA	48.26*T2 - 4883*T + 138994	0.83	6.49	-6.23	7.29	-22.39
FSLM	118.94*T2 - 14622*T + 475731	0.97	12.16	-13.43	16.75	-141.56
FSEM	143.37*T2 - 15364*T + 482338	0.84	6.84	-6.71	8.33	-23.61
CAFE	198.32*T2 - 23166*T + 744039	0.83	6.32	-6.48	7.70	-21.90

(a) T = Outdoor dry-bulb temperature (°F).

TABLE 5.6. Total Energy Use as a Function of Monthly Average Outdoor Temperature (°F)

Restaurant Type	Total, (a) MBtu =	R ²	† Test			
			Temp. Squared	Temp.	Constant	F Test
COFE	85.59*T2 - 8238*T + 314542	0.93	11.24	-11.18	19.43	-63.23
FFLM	99.36*T2 - 11951*T + 517410	0.94	9.74	-10.62	17.92	-77.64
FFEM	115.00*T2 - 13563*T + 505821	0.98	13.96	-15.52	23.56	-184.01
PIZA	52.90*T2 - 5275*T + 214799	0.73	4.60	-4.38	7.29	-12.00
FSLM	125.95*T2 - 16155*T + 706352	0.96	8.50	-9.79	16.41	-103.85
FSEM	146.88*T2 - 17639*T + 915795	0.89	6.40	-7.04	14.45	-35.71
CAFE	43.30*T2 - 2904*T + 536212	0.42	0.58 ^(b)	-0.34 ^(b)	2.32	-3.23 ^(b)

(a) T = Outdoor dry-bulb temperature (°F).

(b) Not statistically different than 0 at the 95% confidence interval.

The regressions with the coefficients of determination are shown for each relationship. Other relationships were tested but not shown since the correlation coefficients were poor.

5.2.1 Food Preparation MBtu and Customer Count (Table 5.2)

The high R² values for four of the restaurants indicate that the data fit the relationships well. Based upon the t test at the 95% confidence interval, all the independent variables are statistically significant except for Charley's Place and Steak & Ale. The poor relationships for the full service restaurants may result from the fact that food service equipment was left on throughout the entire day and may also result to some extent from the bar

trade. Also worthy of mention is that both Friendly Restaurants and Morrison's, the coffee house and cafeteria, have large seasonal tourist trades and very high coefficients of determination for this relationship.

5.2.2 Sanitation MBtu and Inlet Water Temperature (Table 5.3)

The test of sanitation energy use versus customer count yielded no useful information. However, when tested against inlet water temperature, four of the units had statistically significant correlation coefficients. All units except Morrison's had negative coefficients, which simply indicates that as water temperature goes down sanitation energy use increases. The low correlation coefficients of determination for Friendly's and Pizza Hut indicate problems with domestic hot water heating systems, as noted earlier.

5.2.3 Refrigeration MBtu and Outdoor Temperature (Table 5.4)

All units have statistically significant coefficients for the relationship of refrigeration versus outdoor temperature. However, the data for Pizza Hut indicate a poor curve fit, based upon the R^2 value. Friendly Restaurants has compression equipment that is water cooled and installed in an insulated, unheated attic; therefore, to some degree the refrigeration energy use must be related to outdoor temperature as well as inlet water temperature. At Pizza Hut new refrigeration equipment was added to the facility midway through the project. This additional equipment added load and thus energy use and probably caused the relatively poor relationship to outdoor temperature.

5.2.4 HVAC MBtu and Outdoor Temperature (Table 5.5)

All units had excellent correlation coefficients for this second order regression. HVAC MBtu energy was also tested against monthly heating degree-days, which yielded no meaningful results.

5.2.5 Total MBtu and Outdoor Temperature (Table 5.6)

Statistically significant coefficients were obtained for the relationship of total energy consumption versus temperature in all facilities except Morrison's. These results show that outdoor air temperature, and not customer count, building size, or volume, appears to be the best predictor of total energy use. It should also be noted that the constant term, which in part

represents the base load, varies significantly from one restaurant to another, thus indicating that outside temperature by itself will not predict energy consumption in any given facility. At this time there is no good explanation for the Morrison's relationship, except that it uses 69% of its energy for food preparation and for sanitation and its customer count varies by a factor of 3 from month to month.

5.2.6 Regression Graphs

The results of the following regression tests are provided in Appendix I:

- Food preparation MBtu versus monthly customer count
- Sanitation MBtu versus monthly inlet water temperature
- Refrigeration MBtu versus monthly average temperature
- HVAC MBtu versus monthly average temperature.

6.0 CONSERVATION OPPORTUNITIES

After analyzing the PREP data, engineers from the seven participating restaurant companies recommended specific actions to reduce energy consumption and expense. These recommendations, based on findings of the study, comprise this chapter of the report.

Certain threads, such as the need for regular maintenance and the importance of the human element in cutting energy use, run throughout these summaries. Furthermore, though particular recommendations, consumption values, and savings estimates may vary among different restaurant types, most of this expert advice is adaptable to a wide range of food service facilities and is applicable to independent operators as well as to large chains.

Sections 6.1 through 6.5 summarize general energy use and conservation considerations in each of the study's five major areas (food preparation; sanitation; refrigeration; lighting; and heating, ventilation, and air conditioning), as well as the material presented in Sections 6.6 through 6.12. Sections 6.6 through 6.12 present recommendations specific to each restaurant type. These sections have many common elements, since each restaurant engineer prepared a summary for his facility. The intent of these sections is to provide a general blueprint for industry action in reducing energy costs. After reading Sections 6.1 through 6.5, many readers may wish to focus their attention on the facility of special interest.

6.1 FOOD PREPARATION

Over one-quarter of food service energy consumption is devoted to food preparation. Following are recommendations that, if followed, will reduce energy consumption for food preparation.

- The best conservation advice here, as in other areas, is to keep equipment clean, maintained, and turned off when not in use. Energy management systems, which range in sophistication from simple time clocks to microcomputers, can effect sizable savings here, but so can employee effort.

- Posting and adhering to specific startup and shutdown times for equipment to save energy while at the same time allowing adequate equipment warmup time. Implementing this suggestion will not affect product quality or customer service. Participants in PREP found that equipment was frequently turned on or left on when not needed, with little or no attention paid to scheduling equipment operation. Shorter warmup periods and more shutdowns during slow periods are called for in many food service establishments.
- Some food production equipment consumes energy in direct relation to the amount of food it produces. This type of equipment (for example, a deep fat fryer) is to some extent self-regulating; that is, it will use less energy when not in operation and expend more when necessary. New technology in the area of gas-fired infrared fryers may bring greater efficiency in this area.
- Other equipment, such as heat lamps or conveyer toasters, expend a constant amount of energy regardless of the amount of food being processed. Here again, special attention paid to turning off this type of equipment when it is not needed will save money.
- Ranges, grills, and even ovens radiate excess heat energy. While this may help heat the establishment in winter, though generally not in the most efficient manner, it will add to the air-conditioning burden at other times and thus needs to be tightly regulated. The idea here is to use the smallest piece of equipment necessary to do the job. Using a smaller grill or a few burners or shutting down a second oven when one is adequate will result in savings.

6.2 SANITATION

An average one-fifth of restaurant energy consumption is used for sanitation, primarily by the dishwasher, which is a restaurant's greatest consumer of hot water. Below are suggestions for action to reduce energy consumption in this area.

- Conversion of high-temperature dishwashers to low-temperature chemical sanitizers can result in savings, principally due to elimination of the machine's booster heater. This requires more thorough scraping of dishes before sanitizing and increased machine maintenance; the sanitizer may also discolor "soft" metals such as pewter and aluminum. Nevertheless, the potential savings are substantial.
- Short of conversion, other simple techniques can be used to cut the expense of generating hot water: insulating the hot water tank, for example, or running only full racks of dishes in the machine.
- More sophisticated techniques that can be used include heat recovery systems, which capture heat from the refrigeration equipment and use it to preheat water entering the water heater, and hot water heat pumps, which take excess kitchen heat and use it to generate hot water, providing an air conditioning benefit as well.
- Energy management systems can be used to turn off the water circulating pump and hot water heater draft fans during closed hours.

6.3 REFRIGERATION

Refrigeration accounts for less than 10 percent of food service energy use. Actions that can be taken to decrease the energy consumed by refrigeration are described below.

- Periodic maintenance on refrigeration equipment should include ensuring tightness of door gaskets and closures, cleanliness of evaporator and condensing coil, and adequate freon levels.
- For walk-in refrigeration units, products should be stored in such a way that they do not impede air flow within the unit and do not block the fan intake. Loading periods can be scheduled to reduce the number of times the door is opened, and self-closing doors should be considered if doors are habitually left open. Employees can be trained to quickly locate items within the unit to minimize open-door "shopping."

- Vinyl strip curtains on walk-in refrigeration units are substantial energy savers, able to reduce compressor run times by up to 30 percent. Unfortunately, employees frequently protest and even undermine the use of these curtains. Stronger management action to secure employee acceptance may be appropriate in many establishments.
- Ice machines should have one large "head" for ice production rather than several smaller stacked heads. Coils should be kept clean on air-cooled machines; valves should be checked periodically on water-cooled machines to avoid losing condensing water, a common problem that can waste up to 100,000 gallons/month. Air-cooled equipment uses more electricity but also reduces the waste water problems experienced by water-cooled equipment.
- When possible, frozen foods should be thawed slowly in the refrigerator, rather than quickly in an oven. Though this will require planning ahead, it will make more efficient use of cooking and refrigeration equipment.
- Passive double-walled heat exchangers can be used to extract "free" heat from freon leaving the compressor and use that heat to preheat water for the water-heating system, resulting in a double benefit--increased efficiency of refrigeration equipment and a reduction of required water-heating energy.
- Remote compressor packages, which use only one set of condenser fans, may be useful in many operations.
- Locating condensing units in environmentally controlled enclosures or in areas with cooler ambient temperatures will reduce energy consumption.

6.4 LIGHTING

Control of lighting can lead to a reduction of the current 15 percent average restaurant energy use for that category. Recommendations for control strategies follow.

- Energy savings can be achieved through simply turning off lights. While restaurant staff are capable of doing this, restaurant management can employ various types of equipment such as time clocks and photo cells for outdoor lighting and twist timers and motion sensors for indoor lighting. Use of this equipment assures that lights are shut off after operating hours or in interior areas that are not being used.
- Indoors, the emphasis is on more efficient fluorescent lamps and ballasts; for example, replacing four 40 watt lamps with 34 watt lamps, replacing R or PAR floodlights with lower watt ER floodlights, replacing incandescent bulbs with lower watt screw-in fluorescent units, and replacing flood lamps with ellipsoidal reflectors. However, any changes in lighting level and lamp type should not be at the expense of reducing the quality element of lighting.
- Outdoors, sodium vapor lamps can take the place of incandescent lamps to lower energy costs and frequently to provide more pleasant or dramatic lighting.

6.5 HEATING, VENTILATION, AND AIR CONDITIONING (HVAC)

Space conditioning is a major variable in energy consumption, accounting for over one-quarter to one-half of a restaurant's energy use. Seasonal changes in heating and cooling needs cause the greatest swings in energy use. Food service operators cannot control the weather, but they can cut energy costs even in this unpredictable area.

- Starting with basic maintenance, filters should be checked, fan belts should be tightened, vents should be cleaned, and thermostat calibration should be checked and should be tamperproof.
- Outside air infiltration should be reduced as much as possible. Ventilation loads and air exchange should be reduced to the lowest possible levels permitted by local codes. Windows should be caulked, utility through-the-wall connections sealed, and vestibules or revolving doors installed at busy entrances.

- Structures should be adapted to climate. In colder areas, windows should be double glazed, and walls and ceilings should be well insulated, with roofing systems of at least R-24 to R-30 and wall systems of at least R-12 to R-19. Warm weather operations should make use of reflective glass, awnings, shades, or other devices that reduce solar heat gains.
- Procedures should be established for times when the establishment is closed. All exhaust fans, the makeup air unit and auxiliary heaters should be shut off.
- Several types of HVAC equipment may be helpful:
 - Economizers, or automatic motorized dampers, can be used on air-conditioning units. When outside temperature and humidity are low, the dampers open and let outside air in. This "free cooling" reduces air conditioning load and is especially adaptable to situations where crowds of customers create a cooling demand in non-cooling seasons. These devices cost approximately \$750 to \$850 and can be retrofitted to existing air conditioning systems. While they do require extra maintenance because dampers can leak, resulting in higher water energy consumption, they can substantially reduce air conditioning energy consumption.
 - Evaporative precoolers also attach to air conditioning units and pre-cool the air passing by the air conditioning condenser coils. The coils are able to give off more heat, thereby increasing the cooling capacity of the air conditioning unit and decreasing compressor run times. Evaporative precoolers cost approximately \$700 and have an average payback period of 2 years.
 - Energy management systems are primarily used in HVAC control. A system's time-of-day function will turn equipment on and off according to a predetermined schedule, while the optimum start/stop function controls the start-up time of HVAC equipment to allow the building to reach its operating temperature at the appropriate time.

6.6 CONSERVATION OPPORTUNITIES ASSESSMENT: COFFEE SHOP^(a)

6.6.1 Overview

Coffee shop facilities are among the lowest energy consumers in the restaurant industry. The coffee shop participant in this study was the second lowest consumer on a gross energy basis and the lowest consumer on a per square foot or per customer basis. Energy intensive menu items in coffee shops are not prepared in advance and held but rather are prepared on an as-ordered basis, so cooking equipment idles between uses. Careful attention must be paid to scheduling of equipment use times as well as business volume demands throughout the day. Seasonal variations in customer count and food preparation energy must also be recognized. Due to the nature of coffee shops and the manner of product presentation, sanitation energy for dishwashing and HVAC energy for customer comfort are also significant energy use areas. During the course of this study Friendly's consumed 502,800 kWh at a cost of \$37,300.

In the following sections, energy use and conservation opportunities by category will be explored.

6.6.2 Energy Use by Category

The energy use of this all-electric coffee shop was among the lowest of the restaurant concepts monitored, due in large part to the manner in which the foods are prepared and the ability to turn off equipment not needed in slow customer periods. Food preparation energy for this particular coffee shop relates primarily to the actual energy needed to cook the food; only minor amounts of energy are needed to keep cooked foods warm for short periods.

HVAC energy was certainly the most dominant determinant of overall energy use throughout the monitoring period. Figure 6.1 shows that the HVAC energy line and the total energy line are virtually parallel. In spring and fall the HVAC energy use was low because there was little need for mechanical cooling or heating. The total energy line also dips lower in these seasons. It should be

(a) Prepared by Bryce A. Norwood, P.E., Director of Design and Engineering, Friendly Restaurants.

FIGURE 6.1. Monthly Energy Use for Coffee Shop

noted that this unit experienced the lowest outside temperatures for the longest time of any of the monitored facilities.

Food preparation was the second largest factor in total energy use. This factor varied from a low of 18% to a high of 35% in response to varying customer traffic, partly due to its location in a popular tourist area. The methods of food preparation discussed earlier are reflected in these variations.

The relatively large amount of sanitation energy reflects the method of food presentation employed by this restaurant. The dishes and silverware used in serving the foods must be sterilized in a dishwasher for reuse. There are two items which must be considered in evaluating sanitation energy use for this facility: first, this unit experienced the greatest variation in incoming cold water temperature, from a low of 36°F to a high of 81°F; second, this unit experienced an undetected failure of a relief valve on the hot water system, which caused the final months to show high sanitation energy use. This failure highlights the need for regular equipment maintenance.

6.6.3 Energy Conservation Opportunities

6.6.3.1 Food Preparation

Three major factors determine how much excess energy is actually consumed by food preparation equipment:

1. the equipment controls
2. the sizing of equipment
3. the operating time schedule.

Equipment Controls. Equipment controls should be such that energy use is at least somewhat proportional to the amount of food being prepared. Any thermostatically controlled equipment would fall into this category. A deep fat fryer is a good example: when more products are cooked, energy input increases; when fewer products are cooked, energy use decreases.

The least desirable type of equipment controls allows energy to be continuously expended at a constant level regardless of whether or not any food is being cooked. Heat lamps and conveyor toasters are good examples of this type of equipment. Whenever they are turned on they run at full power.

Equipment Sizing. Much of the energy consumed by cooking equipment is released into the kitchen area as heat. While this energy may reduce building heating costs in winter, it increases air conditioning costs in summer and is wasted in terms of food preparation. For example, a 6-ft-long grill wastes twice as much energy as a 3-ft-long grill of the same width and temperature. Thus one way to reduce energy consumption is to install/use the smallest piece of equipment available that will handle the cooking load.

In many restaurants the peak cooking load(s) occur for a few hours a day during meal times, and are 2 to 3 times the average load. In these cases it is energy-wise to install, for example, two to three small grills rather than one large grill. Thus, one of the grills can be on all day, and the other(s) turned on only during peak times.

Operating Time Schedules. Probably the easiest way to reduce the energy used in food preparation is to reduce the length of time that equipment is on.

For example, while a bun warmer might be needed during peak hours, the edge of an already-in-service grill could be used to warm buns the rest of the day.

The savings achieved by turning off any one piece of equipment for a few hours a day may be small, but the total savings of such a practice with many pieces of equipment can be significant.

6.6.3.2 Sanitation

There are three ways to reduce the amount of energy consumed for sanitation purposes:

1. reduce the temperature of the hot water used
2. reduce the amount of hot water needed
3. heat the water more efficiently.

Reduce Temperatures. Hot water temperatures, except for those uses of hot water mandated by law, can be reduced from the usual 140°F to as low as 105°F, this saves energy use and dollars by lowering standby losses.

Reduce Amount Needed. In most restaurants the dishwasher is by far the largest hot water user. The person running the dishwasher should be trained to run only full racks through because the dishwasher uses the same amount of hot water whether or not the rack is full.

Improve Efficiency. Many changes can be made to increase water-heating efficiency. One low cost method is simply to insulate the hot water heater. Another method is to preheat the incoming cold water using "free" energy: either solar energy or waste heat recovered from refrigeration/air conditioning equipment. The third method of increasing water-heating efficiency is to increase the operating efficiency of the heater itself. This might mean installing a new, high efficiency burner on a gas or oil heater, or installing a heat pump water heater.

6.6.3.3 Refrigeration

The amount of energy used for refrigeration is affected heavily by

1. the type of refrigerant condenser used (air cooled versus water cooled)

2. the quality of the refrigerated rooms
3. the menu mix: in general, the more products a restaurant sells that require refrigeration, the more energy is used to run refrigeration equipment. This is especially true if the restaurant uses frozen meats or serves frozen products such as ice cream, because it takes more energy to maintain products at 0°F than it does to maintain them at 35°F.

Refrigeration-Condenser Type. The coffee shop monitored in this project uses water-cooled refrigeration condensing units. The energy used by this type of refrigeration equipment is heavily dependent on the temperature of the building's water supply. A more modern practice would be to use air-cooled condensing units in an environmentally controlled enclosure mounted either on the roof or in some non-air-conditioned space inside the building.

An essential part of reducing the energy consumed for refrigeration is proper maintenance of refrigeration equipment. Water-cooled compressor valves should be inspected regularly for wear. Air-cooled refrigeration condensers should be inspected at least twice a year and any debris or dust buildup cleaned off with a vacuum cleaner or soft brush. The level of freon should be checked at the sight glass, if available, on all refrigeration systems. A refrigeration system that is low on freon can use up to twice as much energy as a properly charged system. Another excellent energy conservation technique is to install a passive double-walled exchanger to extract heat from the hot freon gas leaving the compressor for use in heating water for sanitation and food preparation.

Quality of the Refrigerated Space. Typically the largest load in a refrigerated space is the warm air that enters when the door is open. Stocking the refrigerator should be done at one or more scheduled time(s) during the day. Self-closing doors with properly adjusted hinges and latches can eliminate the possibility that doors will be left open accidentally. Plastic strips can also reduce warm air infiltration. Finally, door gaskets should be intact and ensure a good seal.

6.6.3.4 Lighting

Energy consumption can be reduced by using more efficient bulbs, although care must be taken to maintain a pleasant and comfortable atmosphere. Some possibilities are replacing 4 ft 40 watt fluorescents lamps with 34 watt lamps; replacing R or PAR floodlights with lower watt ER floodlights; and replacing incandescent bulbs with lower watt, screw-in, fluorescent replacement units.

The amount of energy used for exterior site and identity lighting is a function of restaurant operating hours and the time of year. Both high-pressure sodium and fluorescent lamps are more efficient than incandescent lamps, although for certain signs and other identity lights the less efficient incandescent may be desired for its color or intensity.

6.6.3.5 Heating, Ventilation, and Air Conditioning (HVAC)

The energy consumed by heating, ventilation, and air conditioning equipment is determined primarily by five factors:

1. outside air temperature and humidity
2. building structure
3. building operation
4. HVAC equipment efficiency
5. inside temperature and humidity.

Outside Conditions. In many parts of the country the average outside temperature and humidity vary significantly from season to season. As a result, the energy consumed for HVAC purposes also varies greatly, depending on the time of year. The seasonal variation in HVAC energy use is generally much greater than the variation in any of the other categories. A graph reflecting HVAC energy use by month would have essentially the same shape as one reflecting total energy use, since the other end uses tend to be relatively constant.

Building Structure. The building structure of a restaurant should be appropriate to the climate in which it is located. In cold climates this would mean installing double-glazed windows and insulation in the walls and above the ceiling. In hot, sunny climates this would mean reducing solar heat gains by using reflective glass, awnings, or window shades.

In all climates an effort should be made to reduce outside air infiltration. In order to minimize infiltration, the amount of makeup air supplied must equal or exceed the amount of exhaust air so that proper air pressure is maintained inside the building. Other measures which help reduce infiltration include caulking around windows and doors; sealing the building openings where electrical lines, piping or duct work enter; and installing a vestibule at the most frequently used doors.

Building Operation. The previous section emphasized that in order to minimize infiltration, the amount of makeup air brought in should equal or exceed the amount of air exhausted. There are several ways to minimize the amount of energy used to heat or cool this makeup air. The easiest is to reduce the amount of air exhausted to the minimum required by code and comfort. The amount of makeup air brought in can then be reduced accordingly. A second possibility is to bring in the makeup air close to the exhaust fan and in such a way that it can be untempered, or only partially tempered, without reducing comfort. How much untempered air can be realistically brought in depends on the equipment design and the climate.

HVAC energy use can also be reduced considerably by scheduling HVAC equipment. Whenever the restaurant is closed, all exhaust fans, make-up air units, and auxiliary heaters (e.g., vestibule heaters) should be shut off. All outside air dampers should be closed and the thermostats set back in winter or set up in summer. Installing a time clock(s) is an inexpensive way to automatically accomplish these goals, although manual control can be used instead.

Equipment Efficiency. Important items to check include the following:

- Filters: Dirty filters reduce the air flow through the system, making the furnace/air conditioner run longer while providing less heating/cooling.
- Belts: When a fan belt becomes loose or breaks, the motor still runs, but the air flow is reduced or nonexistent. Thus the energy used is almost totally wasted.

- Cleanliness: If the return air or outside air inlets are dirty or clogged with debris, the air flow through the HVAC system is reduced, potentially increasing drafts due to infiltration. If the heat exchangers are dirty, the system is not able to transfer heat as effectively. Both conditions will make the system run longer, while providing less heat/cooling and dehumidification.
- Condensate Drains: If the condensate drain is plugged, the air conditioner cannot control humidity properly. Uncomfortable conditions and possible "sweating" floors will result.
- Maintenance on economizers: stuck dampers waste large amounts of energy.

6.7 CONSERVATION OPPORTUNITIES ASSESSMENT: FAST FOOD LIMITED MENU FACILITY^(a)

6.7.1 Overview

6.7.1.1 Operation and Maintenance

One of the main conclusions of this study is the need for a controlled maintenance program. Regular training of operations personnel to accomplish maintenance training is part of Burger King's new energy program. In this program there is a set of standard maintenance procedures for equipment, as well as training of personnel to turn equipment on and off at the proper time to conserve energy. In restaurants with energy management panels, Burger King has stressed to operating personnel not to place equipment on "override" except in an extreme emergency. On the new panels the override switch has a preset timer to automatically turn equipment back on in proper sequence at a predetermined time. This procedure has saved considerable amounts of energy.

6.7.1.2 Building Construction

The study indicates that Burger King should be designing restaurants with an emphasis on a tight envelope to eliminate openings which leak air and cause heat chimneys. Burger King is now looking for new insulation and roofing

(a) Prepared by Donald Trittin, Manager, Engineering Standards, Burger King Corporation.

material that will have an "R" factor of at least 24, and for walls of at least R-12. In addition, double glazing in colder climates and reflective glass where the glass faces the sun in warmer climates is being considered.

6.7.1.3 Equipment

This research also shows the need for specifying and selecting the best energy saving equipment available. Using multiple air conditioning units or two or more stage units is one way to accomplish this. Burger King is now testing fryers rated from 89,000 to 120,000 Btu compared to the 145,000 Btu units used at the test site. The broiler used at this site is rated at 96,000 Btu; older 200,000 Btu models are still in use in some restaurants. This new broiler represents a savings of over 50%. Lower energy equipment is available on most food preparation equipment, as well as on air conditioning units and water heaters.

Use of compensating hoods reduces the amount of tempered air being exhausted from the restaurant. Also, hood systems designed for specific equipment reduce the amount of tempered air being exhausted. Compensating hood systems should be designed to use untempered air.

6.7.1.4 Energy Management

Automated energy management is almost a must in new restaurants, in order to eliminate the human element in turning on and off HVAC systems and interior and exterior lighting, including signs. To maintain a slight positive pressure at all times, the fryer and broiler hoods and the air conditioner fans are turned on and off through the energy management system.

During the year of this study this test site used 368,900 kWh of electricity and 9,800 CF of natural gas, costing \$26,700 and \$7,200, respectively.

6.7.2 Energy Use by End-Use Category

6.7.2.1 Food Preparation

According to PREP, Burger King's largest energy consumption (44% of the total) is for food preparation. This is due to the heat equipment (the broiler and fryers) which are used for food preparation. It is therefore important to have an energy management system in the restaurant to control the operating

time of the cooking equipment and the ventilation systems that must operate while cooking equipment is in use.

6.7.2.2 Sanitation

Burger King restaurants do not have dishwashers; therefore, energy consumption for sanitation is only 9%, lower than at a full service restaurant. Most of the sanitation energy is used for heating approximately 400 gallons of water per day.

6.7.2.3 Refrigeration

The metered restaurant used less than 5% of its total energy for refrigeration. This low value is the result of restaurant design; the walk-in cooler and freezer has less traffic than other refrigeration systems. Small portable freezers are used in the food preparation area. The resulting decrease in traffic in the walk-in freezers yields energy savings.

6.7.2.4 Lighting

Burger King restaurants use approximately 20% of their total energy for lighting, which is possibly 25% more than most restaurants. This is due to both the type of lighting used and Burger King's policy to have a well-lit restaurant at all times. There is room for improvement, however; a new study should be conducted on the lighting levels to find ways to reduce energy consumption. In restaurants with energy management panels, the amount of energy being used by interior and exterior lighting, including that for the signs and the parking lot, is automatically controlled.

6.7.2.5 Heating, Ventilation, and Air Conditioning (HVAC)

Burger King was surprised at the results of the PREP study, which revealed low energy consumption by the HVAC system. With an energy management system, the Burger King studied here could reduce its power consumption by as much as 10% by having automatic night setback and by setting inside temperature relative to outside temperature.

6.8 CONSERVATION OPPORTUNITIES ASSESSMENT: FAST FOOD EXPANDED MENU FACILITY^(a)

6.8.1 Overview

This fast food expanded menu restaurant serves fried chicken, roast beef sandwiches, and hamburgers. Salad and special condiment bars are available. All items except french fries are received "fresh" and the menu mix of the operations requires extensive preparation.

Of the seven restaurants monitored, Roy Roger's was the second highest energy user on a per square foot basis. However, it was the third lowest overall user of energy. For the year of the study the electric use was 221,200 kWh and cost \$19,100, and natural gas use was 9,400 CF and cost about \$6,600.

6.8.2 Energy Performance Review

Energy consumption of the major use categories is shown in Figure 6.2. Heating, ventilation, and air conditioning was the dominant category, averaging 42.3% of total monthly consumption. Food preparation (34.7%) was the second highest category, followed by lighting (10.7%), sanitation (6.8%), and refrigeration (5.3%). The variation in energy use by category is shown in Figure 6.3.

Heating and cooling energy use closely tracked the average outside temperature, because of the ventilation (exhaust) requirement of approximately 8 air changes/hour. Food preparation energy use ranged from 21 to 56% of the average monthly total. The study showed a significant correlation between customer counts and food preparation energy consumption. Based on a Btu per square foot relationship, lighting consumption was the third highest of the group, due to heavy use of incandescent lighting in the dining area. Sanitation energy requirements are the lowest in the group of seven restaurants, primarily because no dishwashing is involved. As in the other restaurants, the energy required to heat hot water varied inversely with the outside air and groundwater temperatures.

(a) Prepared by Jack Sly, Director of Energy Management, Marriott Restaurant and Theme Park Operations, Marriott Corporation.

FIGURE 6.2. Yearly Energy Use for Fast Food Expanded Menu Facility

FIGURE 6.3. Monthly Energy Use for Fast Food Expanded Menu Facility

Refrigeration condensers for this restaurant are air cooled. The total average monthly energy use of these units closely tracked outside air temperatures, ranging from a low of 2% in January to a high of 9% in October.

This project shows that significant opportunities exist for energy savings. Through applications of the conservation opportunities discussed in the next section, cutting energy use by 20 to 30% is possible. As a result, savings of \$6,000 to \$12,000 per year can be obtained for investments of \$15,000 to \$25,000.

6.8.3 Conservation Opportunities

6.8.3.1 Food Preparation

Over one-third of energy consumption for fast food expanded menu restaurants is devoted to food preparation. The best conservation method is to keep cooking equipment properly maintained and to turn off equipment not in use. The repair and replacement of timers and the calibration of thermostats are important. Turning on heat lamps, bun toasters, and grills 1 hour or more before they are needed is wasteful and costly. If one french fryer will handle the volume, two should not be run.

Equipment on/off schedules should be established and operators trained to follow these schedules. They should also be trained in the care, calibration, and handling of cooking equipment. The less abuse the equipment receives, the more efficient it will remain.

When replacing equipment, purchasing energy efficient models should be considered. Today, manufacturers are producing separate product lines of high efficiency ovens, fryers, and kettles. When purchasing new equipment, correct sizing is important. Oversized equipment is less efficient. An operator should consider buying two small units instead of one large one. One benefit of this approach is that a backup unit is available if one unit fails.

The use of sophisticated energy management systems (EMS) to control cooking equipment is not recommended. Most cooking equipment is self-regulating; in other words, cooking is controlled by thermostats. Automatic timers may be installed on exhaust fans and heat lamps, but the overambitious application of energy management systems on cooking equipment may lead to operator exasperation. It is better to apply EMS systems in other areas.

6.8.3.2 Sanitation

Sanitation required 7% of total energy use in the expanded menu fast food restaurant. Between 600 and 700 gallons of 140°F water were used per day. Several effective methods for reducing consumption are available.

The hot water heater should be inspected annually. Heating elements and tanks should be cleaned and drained to remove accumulated scale and sludge.

Standing pilot lights in gas-fired equipment may be replaced by electronic ignitions. Gas burners should be adjusted for maximum operating efficiency. Controls should be set for 140°F and calibrated to that temperature. Hot water lines should be insulated wherever possible; and where practical, water flow restrictions should be installed on hot water faucets and pre-scrub hoses.

If a hot water heater is replaced, an energy efficient model should be purchased. These cost only slightly more than a standard heater, and operating efficiency is improved significantly. In some situations heat pump water heaters may be practical. These provide supplemental cooling for the kitchen and make hot water at the same time. They are less expensive to operate than all-electric resistance hot water heaters.

If sufficient refrigeration capacity is available, a minimum of 5 horsepower condenser heat can be recovered and used to preheat domestic hot water. A typical system costs \$4,500 and can pay for itself in 2 years or less. Typical sources of condenser waste heat are ice machines, walk-in freezers and coolers, reach-in refrigerators, and air conditioners. Heat recovery systems are very desirable--where water cooled condensing units are used, they reduce the amount of waste water and additional sewage charges.

6.8.3.3 Refrigeration

Refrigeration systems in fast food restaurants use 6 to 8% of the total energy. Theoretically, refrigeration systems only operate when cooling is required. In actual practice, though, doors get left open, the temperature drops, and condenser/evaporator coils become dirty. Operators should be trained to shut refrigerator doors and maintenance personnel should be instructed to clean coils.

Sound refrigeration design dictates that condensers should be properly sized and located in a space with favorable temperatures. This means that they should not be placed in indoor areas where temperatures exceed 90°F. Remember, as ambient temperatures increase, refrigeration capacity decreases. One solution is to combine the refrigeration system with a condenser heat recovery system.

In new construction, installing remote packaged condensing systems is cost effective. These units can be designed with enlarged condensing coils and multiplexed compressor assemblies. By remoting the condensing systems, kitchen air conditioning loads are reduced, maintenance serviceability is improved, and refrigeration operating costs are cut.

6.8.3.4 Lighting

Lighting comprises approximately 11% of the energy in a fast food expanded menu restaurant. This percentage may be reduced by turning lights off when not in use. This can be done manually, through mechanical time clocks, or with an energy management system.

The restaurant can be relamped with a more efficient light source. ER type lamps can replace floodlamps and reduce wattage by up to 30%. Color corrected screw-in fluorescent lamps can replace incandescent lamps in some fixtures and reduce lighting wattage loads by up to 80%.

Outside lighting can be improved and energy costs reduced by changing from fluorescent or metal halide lamps to high pressure sodium lamps. Some types of 150 watt floodlamps can be replaced with 90 watt bulbs.

Lighting is an area where savings can always be found. Representatives from lamp manufacturers can advise the most effective ways to reduce lighting costs.

6.8.3.5 Heating, Ventilation, and Air Conditioning (HVAC)

HVAC energy can account for 25 to 50% of the restaurant's energy. Seasonal changes in heating and cooling requirements cause the greatest fluctuations. The first step in reducing HVAC energy consumption begins with preventive maintenance. Coils must be cleaned, belts tightened, and ductwork sealed and connected.

Exhaust ventilation loads should be reduced to the essential code minimums. Ductwork should be properly sized to maintain adequate air flow for grease extraction at reduced air flow.

Makeup air quantities should be provided in an amount equal to 80% of exhaust air requirements and should be introduced into or near exhaust hoods.

Makeup air should be tempered, heat only, unless the restaurant is located in a highly humid region. There is no reason to heat the makeup air for a building to 110°F or 120°F or to cool it to 55°F. Kitchens do not need to be cooled to 70°F.

Structures should be adapted to the environment in which they are erected. In cold areas, windows should be double-glazed and walls and ceilings well insulated. Warm weather operations should make use of reflective glass, awning, shades, or other devices that reduce solar heat gains.

Where appropriate, economizers should be installed on HVAC equipment to provide free cooling for the building. Most restaurants have a balance point around 55°F. In other words, cooling is needed above 55°F due to interior heat loads. A wide temperature range of outside air is available for cooling. This is the function of economizer controls.

Evaporator precoolers attached to air conditioning condensing units should be considered for hot, dry climates. These devices cool the air going through the condenser, reducing compressor run time, maintenance costs, and operating costs.

Motor controllers available for retrofit to belt-driven exhaust fans and blower motors can produce up to 30% savings in motor operating costs. These controllers reduce motor voltage/amp requirements and improve the motor power factor.

The air balance of the restaurant significantly affects its energy consumption. When the inside of the building has a higher air pressure than the outside, infiltration, or the flow of hot or cold air into the building, is reduced. Therefore, the exhaust and makeup air requirements of the restaurant must be correctly engineered in the initial building design and then maintained during its operation. For each cubic foot of air exhausted from the building, another cubic foot must enter. This makeup air should not come through the doors or windows.

6.8.3.6 Energy Management Systems (EMS)

An energy management system provides automated control of lighting, exhaust fans, hot water heater(s), and HVAC systems. Experience has shown that

energy savings of 15% or greater may be obtained with an EMS. A simple EMS can cost as little as \$6,000, and a more sophisticated system can cost near \$20,000.

An overview of basic EMS strategies for a typical fast food restaurant entails the following:

1. Time-of-day control of
 - a. outside lighting/sign lighting
 - b. exhaust/makeup air fans
 - c. HVAC units
 - d. space heaters
 - e. dining room lights
2. Economizer cycle: The use of outside air for cooling
3. Remote thermostat location: The location of a sensor in the controlled space--set point controls should be mounted where employees and patrons cannot tamper with them
4. Night setback of space temperatures
5. Load shed/duty cycle function: The controlled cycling of selected equipment to limit peak electrical loads and kWh use.

6.8.3.7 Conclusion

Most fast food restaurants can significantly reduce their energy bills by 20 to 30%. The first step is to ensure that the building and its equipment are properly maintained. A planned maintenance program can cut energy use by 10 to 15%. Money is wasted if a sophisticated energy management system is installed and is not maintained.

When a planned maintenance program is in place, an energy audit of the facility must be made. The audit should uncover the opportunities, costs, and benefits of achieving an additional 15 to 20% reduction in energy consumption.

6.9 CONSERVATION OPPORTUNITIES ASSESSMENT: PIZZA FACILITY^(a)

6.9.1 Overview

The restaurant monitored in this test consumed the least amount of energy for food preparation, lighting, and HVAC as well as total energy when compared to the other test restaurants. For the year, this all-electric facility consumed 343,500 kWh at a cost of \$31,500.

The greatest opportunities for energy conservation are in HVAC, sanitation, and lighting. Conservation opportunities for food preparation are limited to better control of startup and shutdown times for the oven, which consumes the majority of this energy segment.

6.9.2 Energy Performance Review

The energy consumed in this facility was the lowest of the test restaurants. Although it was the smallest in terms of building area, it also experienced ambient temperatures that were second lowest. Figure 6.4 shows how each major end use category contributed to the total energy consumed. As in most of

FIGURE 6.4. Yearly Energy Use for Pizza Facility

(a) Prepared by John R. Paulus, Group Leader--Mechanical Engineering, Pizza Hut, Inc.

the test facilities, food preparation (30.9%) and HVAC (29.2%) were the highest users of energy, followed by sanitation (18.2%), lighting (12.7%), and refrigeration (9.1%). The total energy curve mirrors that of HVAC energy throughout the year, experiencing the same peaks and valleys. This correlates with the ambient temperature changes throughout the year. Although the extremes are not as great, the use curve for sanitation also follows closely that of total energy since the incoming water temperature changes follow the ambient air temperature changes. The curves for food preparation, refrigeration, and lighting are fairly constant through the year.

6.9.3 Conservation Opportunities

Following is a discussion of the opportunities available in each major end use category.

6.9.3.1 Food Preparation

As previously mentioned, food preparation used approximately one-third of the energy in this restaurant. Of this amount, the pizza oven accounted for 90%. For this reason, its startup and shutdown schedule should be strictly adhered to. There is no need to turn on the oven more than 1/2 hour before opening or leave it on after closing. Although this restaurant utilizes a single deck conveyor oven, many use double deck ovens. In those instances, it may be possible to leave off one deck completely if the expected sales volume for the day allows it.

6.9.3.2 Sanitation

The high temperature dishwasher, with its associated booster heater, accounted for the major portion (18%) of this energy use category. Approximately 50% of this energy was used by the booster heater. Installation of a low temperature dishwasher would greatly reduce the energy use but would require the purchase of process chemicals and would require more extensive pre-cleaning of the dishes and pans. Still, the overall savings could approach 10%.

A heat recovery device can be utilized to preheat domestic water using extracted condenser heat from walk-in coolers and air conditioners. These

units are not economically practical in Pizza Hut restaurants since hot water use is relatively low and space is limited for such a device.

6.9.3.3 Refrigeration

This energy category averaged 9% of the total consumed. Basic maintenance such as replacing door seals as needed, making sure doors latch tightly when closed, and cleaning condenser coils can help reduce consumption. Adding strip curtains to walk-in cooler/freezer doors can save a significant portion of the refrigeration use as well as extend equipment life. Strip curtains can pay for themselves in a short period of time if the operators make sure they are properly used. In addition, the use of remote condensing units will provide easier servicing and reduce air conditioning loads in the restaurant.

6.9.3.4 Lighting

Lighting consumed approximately 13% of this facility's total energy use. Basic principles such as turning out lights when they are not required can contribute to energy savings. This can be done manually or by the use of solar switches, timers, or energy management systems.

The proper selection of incandescent lamps such as the ER type can reduce wattage by up to 30%. In addition, changing out incandescent bulbs to low wattage fluorescent lighting can reduce energy use by 80% while reducing air conditioning loads. The selection of high pressure sodium lamps for outside use would not only reduce energy consumption, but would be an improved lighting source as well.

6.9.3.5 Heating, Ventilation, and Air Conditioning (HVAC)

The HVAC segment averaged approximately 30% of this facility's energy use. This facility was heated by resistance heat. The use of heat pumps in lieu of resistance heat would be more efficient. The use of high efficiency air conditioning units would save energy and should provide a sufficient payback on its initial investment.

The oven hood system in this restaurant brings in untempered makeup air through the hood. This system is more efficient than ones using tempered makeup air in the extreme winter and summer conditions experienced at this facility.

Night setback of the heating and locking out air conditioning during unoccupied hours saves energy and can be achieved manually or automatically with an energy management system.

Restaurant use of economizers, which bring in outside air for "free" cooling, has potential for saving energy. Due to the high concentration of people per unit floor area in a restaurant, cooling is required in months when air conditioning is not normally used.

6.9.3.6 Conclusions

The opportunity to save energy in this restaurant is quite apparent. Many items have been discussed which can save significant amounts of energy, but none of these savings can be sustained without proper training of personnel and without maintenance of equipment. Energy management systems, available in many different forms and price ranges, can be tailored to a variety of tasks. It is very important to select an energy management system which can provide a satisfactory payback without being overly complicated for a particular facility.

The information provided by this project can help establish an energy program which will save energy and millions of dollars in the years ahead.

6.10 CONSERVATION OPPORTUNITIES ASSESSMENT: FULL SERVICE LIMITED MENU FACILITY^(a)

6.10.1 Overview

The Steak & Ale Restaurant in Alexandria, Virginia is a full service dinner house with a limited menu. It serves both lunch and dinner 6 days a week throughout the year (it is not open for lunch on Sundays). The lounge area is used primarily by customers waiting for a dinner table.

(a) Prepared by Robert K. Keagy, Director of Energy and Maintenance, S&A Restaurant Corporation.

The restaurant is an all-electric unit with three rooftop air conditioning units, three water heaters, five exhaust fans, and two make-up air units. The major cooking equipment consists of a broiler, range, convection ovens, microwave ovens, and cheese melters. Refrigeration equipment consists of a walk-in freezer, a walk-in refrigerator, an ice machine, and several smaller units. Interior lighting in the dining areas is low wattage incandescent and is controlled by electronic dimmer switches. Kitchen lighting is supplied by fluorescent light fixtures. Exterior lighting is provided by 400 watt mercury vapor lamps and incandescent decorative fixtures. This unit also has a high temperature conveyor-type dishwasher. This facility paid \$54,800 for electricity and used 808,300 kWh during the test period.

6.10.2 Energy Performance Review

Analyzing energy consumption for this facility was quite a challenge. It was the third highest total energy consumer for the monitored restaurants (Figure 5.1). However, it was the second lowest energy consumer when dividing energy consumption by the building's square footage (Figure 5.2); but, when dividing energy consumption by customer count, this restaurant was again the third highest (Figure 5.3).

The shares of energy consumption for the major end-use categories are shown in Figure 6.5. Heating, ventilation, and air conditioning (HVAC) was highest at 26% of the total energy use during the year. This was followed very closely by food preparation at nearly 25%, sanitation at 21%, lighting at 18%, and refrigeration at 10.2%.

FIGURE 6.5. Yearly Energy Use for Full Service Limited Menu Facility

and refrigeration at 10%. Total energy consumption for this restaurant varies very closely with outdoor temperature (the total energy curve and the HVAC energy curve are nearly identical in shape). There appears to be no correlation, however, between energy consumption and customer count. Customer count does not vary enough (21% from lowest to highest monthly count) to cause a statistically significant variation in energy use. One interesting observation is that refrigeration energy consumption dropped in the winter months to one-half of the energy consumed during the summer months.

6.10.3 Conservation Opportunities

6.10.3.1 Food Preparation

Opportunities for energy conservation in this area are very limited. The type of cooling equipment used is dictated by menu items. For example, most Steak & Ale restaurants do not have deep fat fryers since they do not have fried foods on the menu. However, some of the restaurants do serve french fries and therefore are required to have fryers.

Energy-efficient equipment has been used where possible (e.g., microwave ovens and convection ovens rather than conventional ovens), more efficient heat lamps/heat strips have been installed, and energy-efficient prime rib "roast and hold" ovens are used.

The greatest potential for savings is in setting up realistic operating and maintenance schedules. The equipment must be properly maintained and calibrated. Also, specific schedules must be established for turning the equipment on and off. Historically, this facility has had neither a good maintenance program nor a good operating schedule. In fact, some equipment has even been modified to facilitate work at the cost of energy conservation. For example, the door on the bread-warmer oven has been removed to allow easier access to the hot bread. Also, much of the equipment is turned on early in the morning even though it may not be used for an hour or two. The equipment is usually left on between lunch and dinner even though it is not always needed.

At least a 10% reduction in energy consumption could be achieved through setting up proper maintenance and scheduling procedures. This represents an

average of 5,600 MBtu per month for a savings of over \$100 at a cost of \$0.07 per kWh. The cost to achieve these savings would be negligible.

6.10.3.2 Sanitation

One-fifth of the energy consumed in this restaurant is used to generate hot water. Most of this energy is used in the high temperature dishwasher. Hot water consumption is already very low in this restaurant, averaging 1,590 gallons per day. Similar units in our chain have used between 2,500 and 4,000 gallons per day; therefore, there is not much opportunity for reduced electrical consumption through reduced water consumption. However, we did find at the beginning of the study a bad valve on a dip well. The valve cost only \$35 to repair; if left unattended, it would have wasted 720 gallons of hot water per day, at a cost of approximately \$300 per month.

One way of conserving sanitation energy would be to convert the existing high temperature dishwasher to a low temperature sanitizer at a cost of about \$350. Additionally, chlorine sanitizer would cost about \$400 per year (\$33 per month). The savings would be realized through elimination of the 45 kW booster heater. This heater consumes an average of 1,740 kWh per month and adds 10 to 12 kW to the building's peak demand. At \$0.03 per kWh and \$9.58 per kW per month, this restaurant can save about \$158 per month. The payback period is a very attractive 3 months.

Problems arise, however, due to operations management's reluctance to use low temperature machines. Lower water temperatures require better scraping procedures and better dishwasher maintenance. Also, the sanitizer used in the low temperature machines may discolor soft metals such as pewter, aluminum, and cheaper grades of "stainless" steel. These problems are not insurmountable. Since this savings represents over 12% of the energy consumed for sanitation, I would highly recommend the conversion.

In new construction, the savings are even greater. A booster heater does not have to be supplied and the electrical service to the building can be reduced. This means a savings in electrical distribution panels, protective devices, wiring, and labor. The estimated savings is in the \$2,000 to \$2,500 range.

Since this restaurant heats water electrically, energy consumption could be reduced through the use of a hot water heat pump. This device can take the excess heat in the kitchen and use it to generate hot water. The byproduct of this process is the equivalent of several tons of air conditioning. For the amount of hot water used by the Steak & Ale, it could receive 3 tons of air conditioning benefit. The published coefficients of performance (COPs) of these devices range from 2.5 to 4.0; an electric water heater has a COP of 1.0. Therefore, we can heat water much more efficiently while receiving the air conditioning benefit. For this restaurant, which uses over 47,000 gallons of hot water per month and is charged an average of \$.07 per kWh (including demand charges), the annual savings would be about \$4,600. The air conditioning benefit would amount to an additional \$1,800 per year. A conventional water heating system would still be required for this system, since it could not be used during extremely cold weather, when heating is required in the kitchen. The cost to install this system would be about \$6,500, producing a payback in just under 1-1/2 years. This system is especially useful in the southern states, where air conditioning is required nearly the entire year.

As an alternative to the heat pump, a waste heat recovery system could be installed on the air conditioning and refrigeration equipment. Depending upon the system that is installed, 75 to 90% of the restaurant's basic hot water requirements could be met. This store uses an average of 9,625 kWh per month to heat incoming city water to 140°F. If a heat recovery system were installed to supply 80% of this requirement, the restaurant could save 7,700 kWh per month. At an average rate of \$0.07 per kWh, a yearly savings of over \$6,400 could be realized. Also, if the system were connected to a water-cooled ice machine, an additional yearly savings of about \$1,000 on the water/sewer bill could be achieved. Typical heat recovery systems could be installed for \$6,000 to \$7,500.

6.10.3.3 Refrigeration

One-tenth of the energy consumed in this building is for refrigeration. There are not many conservation opportunities in this area for the following

reasons: 1) it is a small amount of the total, 2) it is extremely vital to restaurant operation, 3) ample food supplies must be kept on hand, and 4) freshness must be maintained.

Proper maintenance is of primary importance for the efficient operation of refrigeration equipment. Both the evaporator and condensing coils must be kept clean, freon levels must be maintained, and worn door gaskets must be replaced. Door closers should be checked and adjusted regularly. Ice buildup on freezer evaporator coils should be removed and the cause eliminated. Evaporator coils in walk-in refrigerators should be checked for obstructions at the fan intake, and food should not be stored close to coils and fans to ensure proper air flow. Dented coil fins should be removed to improve heat transfer.

Reach-in refrigerators have special problems. Since most of them have condensing coils on top of the unit, usually in the kitchen, they must be cleaned monthly. Airborne grease in the environment will very quickly combine with dust in the air to form an insulating blanket on the coils. Many of these units also have defogger buttons. These buttons turn on heat strips around the door to eliminate moisture or ice buildup. The heat strips should only be used to remove the moisture or ice.

Ice machines must also be properly maintained. If they are air cooled, the coils need to be kept clean. If they are water cooled, valves should be checked to verify that condensing water is not being wasted (as much as 100,000 gallons per month). Freon levels should be checked, and in areas where hard water is a problem, the freezing section contact surfaces should be checked for lime buildup.

When buying new equipment, the most energy efficient that will meet the restaurant's capacity requirements should be purchased. Several manufacturers now offer remote compressor packages, which allow several refrigeration compressors to be installed on one frame and which condense the freon with one set of condenser fans rather than several individual condenser fans. This arrangement works efficiently, due to the constant refrigeration loads. Ice machines are usually more efficient when they have one large head to manufacture ice rather than having several smaller heads stacked on top of each other to obtain the same capacity. Finally, plastic strip curtains can be installed on doors

to walk-in units. Price varies with size and quality but usually is several hundred dollars; the curtains have paybacks of generally less than 1 year. They are disliked by operating personnel, who have to walk through them several times a day. Our experience with them has not been good; they are usually taken down or the strips are cut off before the end of the payback period.

6.10.3.4 Lighting

Lighting represents nearly one-fifth (18%) of our energy consumption but is an area that is particularly difficult for us to control. All lighting for Steaks & Ale restaurants is determined by the Design Department. To create the proper ambiance for the restaurant, this department determines both lighting levels and color.

Interior lighting is split between the dining and kitchen areas. The dining room lights are controlled by electronic dimmer switches, which allow several different lighting levels throughout the day and do not consume much energy. Kitchen lighting is supplied by fluorescent light fixtures. Energy efficient ballasts and bulbs can be installed to reduce consumption without a noticeable effect on lighting levels. In addition, several manufacturers have a product that can be retrofitted to existing fixtures to reduce consumption and allegedly increase the life of the ballast. This product is wired into the ballast circuit and reduces the voltage to the lamps. Lighting in areas that are not used very often, such as storage rooms or mechanical/electrical rooms, should be controlled by twist-timer switches. These switches will automatically turn off the lights after a period of time unless they are reset.

Outside lighting should be controlled by a photocell or by time clocks. If a time clock is presently being used, the on/off times should be reset periodically. Retrofitting existing incandescent light fixtures with some of the new "designer" fluorescent lamps should be considered. This can also be done on interior lighting if dimmer switches are not being used. Parking lot lights should be of the more efficient types, such as high or low pressure sodium lamps.

6.10.3.5 Heating, Ventilation, and Air Conditioning (HVAC)

Over one-fourth (26%) of this restaurant's energy consumption is used to maintain comfortable temperatures throughout the building. Next to sanitation, this area has the greatest potential for conservation. As with all equipment, a good preventive maintenance program is essential for efficient operation of the HVAC equipment. Thermostats must be properly calibrated and made tamper-proof by the use of metal covers, exhaust and makeup air must be balanced, and operating hours must be closely monitored.

This particular Steak & Ale restaurant has had problems with its two makeup air units, which are now over 10 years old. Their maintenance has been neglected in the past. Each has a 75 kW electric heater to preheat air as it is drawn into the kitchen. These heaters add a substantial load to the building's consumption and demand charges during the winter months. In new construction, we now install exhaust hoods with a makeup air system that introduces air directly into the hood. This "short circuited" air does not have to be heated or cooled, thereby greatly reducing the building's energy requirements.

Fresh air is brought into the dining areas through fresh air dampers on the rooftop air conditioning units. The amount of outside air is controlled by manually adjusted mechanical dampers. If automatic motorized dampers (economizers) were to be retrofitted to the air conditioning units, a reduction of 25% of the air conditioning energy could be realized. However, proper operation of the economizers depends upon an enthalpy controller, which measures the total heat content of the outside air. If the temperature and humidity of the air are low enough, then the fresh air dampers open up, allowing more outside air into the building. This cools the building without requiring the air conditioning compressors to run--it is essentially free cooling. Unfortunately, the economizer controls are somewhat delicate and can be difficult to maintain. Economizers can be retrofitted to existing units for about \$850 each. They can be ordered with new air conditioning units for about \$750 each.

Another product on the market that shows excellent potential for reducing air conditioning energy consumption is the evaporative precooler. This device precools the air passing by the air conditioning condenser coils. The coils

are able to reject more heat, thereby increasing the efficiency of the air conditioning unit. By improving the efficiency of the units, the cooling capacity is increased and the compressor run times are decreased. The precooling is accomplished by running water over a filter medium. The medium can be obtained in several thicknesses, depending upon the desired temperature drop. The pre-cooler costs about \$700 installed, one per air conditioning unit, and has about a 2 year payback period. Maintenance of the precooler is minimal; it does have a recirculating pump which needs to be replaced every few years.

The most popular item presently on the market is the energy management systems (EMS). These devices are capable of controlling many loads throughout the building, but are used primarily in restaurants to control HVAC equipment. These systems range in complexity from very simple time clocks to highly sophisticated microcomputers. Some of the most common functions are time of day, duty cycling, optimum start/stop, and demand limiting. Many have both digital and analog inputs and outputs and are therefore capable of monitoring temperatures, accumulating equipment run times, and recording consumption and peak demand loads. Energy management systems may present maintenance problems if not engineered and installed properly. Also, some restaurant management personnel have difficulty in turning over control of the building environment to a "black box."

Of the four basic functions of EMS, time of day and optimum start/stop have the most savings potential. Time of day turns the equipment on and off according to a predetermined schedule. Restaurant personnel could do the same thing except that they may forget and EMS does not. Optimum start/stop "optimizes" the startup time of the HVAC equipment so that the building reaches its operating temperature at precisely the most efficient time. It eliminates waste by preventing the equipment from turning on too early. Duty cycling is a questionable practice. There is much concern over the impact it has on HVAC equipment, and it is really only effective when there is some excess capacity in the air conditioning equipment. Typically our restaurants have an under-capacity problem and duty cycling would only compound the problem. Purchase

and installation of a typical 8 to 16 channel EMS for a restaurant would cost in the range of \$5,000 to \$12,000, and most manufacturers quote a payback period of under 2 years.

6.11 CONSERVATION OPPORTUNITIES ASSESSMENT:
FULL SERVICE EXPANDED MENU FACILITY^(a)

6.11.1 Overview

Full service expanded menu facilities such as this one are among the highest consumers of energy in the restaurant sector due to several factors. Typically, menu items are prepared from scratch, which requires a great deal of preparation energy, as well as refrigeration energy for raw products. The quantity of dishwashing is significant and laundry is done in-house. All public area lighting is incandescent to maintain a desired ambiance. A very busy cocktail lounge contributes to increased demand on HVAC, ice machine, and glass washing.

6.11.2 Energy Performance Review

The energy consumption for this facility was the second highest of the monitored restaurants. Its area is second largest, while in customer count, it placed third. As outlined above, the full-service format of the facility requires large energy expenditures for cooking, refrigeration, and the washing of full place settings of dishware. Dishwashing (sanitation) energy would total far more were it not for the installation of a low-temperature chemical-sanitizing dishwasher prior to this study.

The shares of energy consumption by major end-use categories are shown in Figure 6.6. Food preparation accounted for 32.5% of the year's total energy use, followed by HVAC at 25.4% and sanitation at 25%. Lighting and refrigeration totaled 11.3% and 6.8%, respectively. For the year, electricity costs totaled \$45,000, while gas cost \$19,500. The amount of electricity used was 679,100 kWh and the natural gas consumed was 28,400 CF. Gas is used for cooking, water heating, and drying laundry.

(a) Prepared by Bruce F. Tatusko, Director of Energy Management, Host International, Inc.

FIGURE 6.6. Yearly Energy Use for Full Service Expanded Menu Facility

The variation of energy use throughout the year is depicted in Figure 6.7. Food preparation, lighting, and refrigeration were fairly constant throughout the year, primarily due to fairly consistent customer counts. Sanitation energy showed a wide swing, from a low of 58 MBtu in July to a high of 141 MBtu in January. This is almost totally attributable to fluctuations in incoming city water temperatures, which ranged from 74°F in July to 38°F in January. Like sanitation, HVAC use tracks the uncontrollable variable of temperature, where lowest-use months were those in which average temperature was

FIGURE 6.7. Monthly Energy Use for Full Service Expanded Menu Facility

closest to 55°F. Outside temperatures above or below this mark increased HVAC use for cooling and heating, respectively.

6.11.3 Conservation Opportunities

6.11.3.1 Food Preparation

Food preparation is the largest category of energy use for this full service extended menu restaurant. It is also the least controllable in terms of automation of the processes, such as on/off times. Two suggestions for reducing food preparation energy use are given below.

- The area of greatest return is in employee training and discipline. Equipment should be clean, it should be turned on only when actually being used, and it should be the proper device for the cooking activity being performed. In many restaurants, improving employee discipline would result in great savings (20 to 25%) in the food energy budget. However, at this facility, the team is already well trained, so savings from additional training would not exceed 5 to 10%.

Savings: $5\% \times 16,950 \text{ CF/year (gas)} \times \$0.687/\text{CF} = \$582/\text{year}$

Investment: None

- Since the construction of this facility, new energy-efficient food production equipment has made its way into the marketplace. New equipment includes gas infrared fryers, electronically controlled convection ovens, better insulated conventional ovens, and electric ignitors on all gas burners. If considered as a system, all of this equipment would reduce consumption at this location by 10 to 15%, or by \$1,100 to \$1,700 per year. Therefore, to replace existing, working equipment would not be cost effective. In new construction, though, it would be highly recommended.

6.11.3.2 Sanitation

The largest single consumer of hot water, the dishwasher, is currently a low temperature, chemical-sanitizing model. It is equipped with a run-time limiting switch and is probably as efficient as possible. Suggestions for savings in sanitation energy are outlined below.

- Equip the laundry dryer with a device to recirculate hot exhaust air back into the combustion chamber, preheating the combustion air. Despite the humidification of the air, this method works and has been shown to reduce dryer gas consumption by 35%. This dryer's burners consume gas at a rate of 200 CF/day.

Savings: $2.0 \text{ CF/day} \times 0.35 \times 365 \text{ days} \times \$0.687/\text{CF} = \$176/\text{year}$

Investment: \$400

- Equip the dryer and the hot water heater with electric intermittent pilot ignitors to replace the standing pilot lights. The dryer pilot consumes about 40 cu ft/day, while the water heater uses about 60 cubic ft/day.

Savings: $1.00 \text{ CF/day} \times 365 \text{ days} \times \$0.687/\text{CF} = \$251/\text{year}$

Investment: \$450

- Install a heat recovery system to capture waste heat from the refrigeration systems and to preheat water entering the domestic water heater. The likely candidates for recovery are the five ice machine compressors, which run 18 to 20 hours/day, every day. The system would capture approximately 50% of the waste heat of the 8 tons of refrigeration.

Savings: $8 \text{ tons} \times 12,000 \text{ Btu/ton} \times 50\% \times 18 \text{ hr/day} \times 365 \text{ days}$
 $100,000 \text{ Btu/CF} = 3,154 \text{ CF/year}$
 $3,154 \text{ CF} \times \$0.687/\text{CF}/70\% \text{ boiler efficiency}$
 $= \$3,095/\text{year}$

Investment: \$8,000

- Install a timing device (an ordinary time clock or a control point of an EMS) to turn off the hot water circulating pump and boiler room exhaust fan during the restaurant's closed hours. This will save the electrical energy in the motors and also reduce gas use in the heater, since water will not be drawn out of the unit and cooled as it circulates around the building.

Savings: Motors-- $0.6 \text{ kW} \times 6 \text{ hr/day} \times 365 \text{ days} \times \$0.0663/\text{kWh} =$
 $\$87/\text{year}$

Heater--Meter readings show that between 3:30 a.m. and 8:00 a.m., the heater consumes about 216 CF of gas, of which 60 cu ft goes to the pilot (see bullet 2). Thus savings are $1.56 \text{ CF} \times 365 \text{ days} \times \$0.687/\text{CF} = \$391/\text{year}$

Total Savings: \$478/year

Investment: \$150

6.11.3.3 Refrigeration

Suggestions for reducing refrigeration energy use are provided below.

- Install vinyl strip curtains on the doorways of the walk-in coolers. These curtains prevent warm air from rushing into the coolers when the doors are opened, reducing compressor run times by up to 30% and extending the shelf life of food.

Savings: $3.7 \text{ kW} (2 \text{ compressors}) \times 30\% \times 18 \text{ hr/day} \times$
 $365 \text{ days} \times \$0.0663/\text{kWh} = \$484/\text{year}$

Investment: \$250 (two curtains)

- Maintenance of both walk-in and reach-in refrigeration equipment appears to be adequate. Employee discipline, however, should be improved. Doors should be opened as few times as possible and closed firmly. Food retrieval should be arranged so that "shopping" with the door open is minimized.

Savings: Following these common-sense guidelines would reduce consumption an additional 3 to 5%, at an annual savings of $3\% \times 103,500 \text{ kWh/year} \times \$0.0663/\text{kWh} = \$206$

Investment: None

6.11.3.4 Lighting

Suggestions for reducing lighting energy use are provided below.

- Replace existing 40 watt fluorescent lamps with 32 watt lamps. Replace the existing ballasts with high-power-factor, low wattage ballasts.

This facility has approximately 124 lamps and 62 ballasts. The combination of 2 lamps and 1 ballast consumes about 92 watts; the new combination would use only 65 watts/day where left on 18 hours/day.

Savings: $27 \text{ watts} \times 62 \text{ fixtures} \times 18 \text{ hr/day} \times 365 \text{ days} \times \$0.0663/\text{kWh} \times 0.001 \text{ kW/watt} = \$729/\text{year}$

Anticipated investment: \$1,488

- Replace existing 75 watt floodlamps, which are located in recessed "high hat" and track fixtures, with 50 watt ellipsoidal reflectors, which produce as much or more usable light and save 25 watts.

Savings: $25 \text{ watts} \times 122 \text{ lamps} \times 18 \text{ hr/day} \times 365 \text{ days} \times \$0.0663/\text{kWh} \times 0.001 \text{ kW/watt} = \$1,329/\text{year}$

Investment: \$366

- In the service bar, the boiler room, and the public restrooms, convert the incandescent lighting to fluorescent with appropriate fixtures and lamp colors. This would eliminate 2,265 watts of incandescent light, replacing it with six fluorescent fixtures totaling 470 watts.

Savings: $1,795 \text{ watts} \times 16 \text{ hr/day} \times 365 \text{ days} \times \$0.0663/\text{kWh} \times 0.001 \text{ kW/watt} = \$695/\text{year}$

Investment: \$600

- Add twist-timers and/or occupancy detectors (ultrasonic motion sensors) to storerooms, walk-in coolers and other little-used areas to automatically turn off lighting when no one is present. For example, lights in the walk-in refrigerators are typically on 18 to 24 hours per day, but these areas are only occupied 2 to 3 hours per day. The estimated load which can be controlled this way is 1,000 watts.

Savings: $1,000 \text{ watts} \times 10 \text{ hr/day (saved)} \times 365 \text{ days} \times \$0.0663/\text{kWh} \times 0.001 \text{ kW/watt} = \$242/\text{year}$

Investment: \$250

- Replace the exterior incandescent lighting, eleven 150 watt PAR lamps with four 70 watt high pressure sodium lamps and fixtures. This provides an aesthetically pleasing light on the wood exterior while reducing energy and bulb replacement costs.

Savings: $1,350 \text{ watts} \times 10 \text{ hr/day} \times 365 \text{ days} \times \$0.0663/\text{kWh} \times 0.001 \text{ kW/watt} = \$327/\text{year}$

Investment: \$800

6.11.3.5 Heating, Ventilation and Air Conditioning (HVAC)

The air conditioning units for the dining and bar areas are presently equipped with economizer systems, which are a proven energy saver. Proper maintenance of these systems is critical, since failures of sensitive control components would lead to increased energy consumption. Additional energy savings suggestions are provided below.

- Install a series of time clocks or an EMS to turn off HVAC systems, including exhaust fans, when they are not needed. Certain electrical cooking equipment might also be connected to assure that it too is off when not needed. Depending upon employees to consistently do this manually has been unsuccessful.

Savings: Conservatively estimated at 10% of the present actual total use of the HVAC units only.

Total use (gas and electric) = 13,265 therm/year^(a) (equivalent total) $10\% \times 13,265 \times \$1.32/\text{therm} = \$1751/\text{year}$

Investment: \$750 to \$2,000

(a) Therm represents the average cost of gas plus electricity.

6.12 CONSERVATION OPPORTUNITIES ASSESSMENT: CAFETERIA^(a)

6.12.1 Overview

One of the largest energy consumers in the restaurant industry is the cafeteria, due to its large customer counts, long serving periods, extensive menu, and accompanying sanitation requirements.

The cafeteria studied in this project consumes more energy than any other monitored facility. Food preparation consumes the largest amount of energy and refrigeration energy consumes the least. Morrison's is located in a favorite tourist area and thus has a high seasonal fluctuation in customer count. During the course of this study about 500,000 meals were served, over 143,000 more than any other unit in the project.

Major cooking equipment includes grills, ranges, and fryers. Hot water requirements for food preparation and sanitation are extremely high and are furnished by a steam boiler and two large hot water heaters. The HVAC equipment is equipped with an economizer, which accounts for the relatively low use of HVAC energy.

Maintenance of major energy-consuming equipment, other than that in the kitchen, is limited by budget constraints under which the value of energy costs are not recognized. This all-electric restaurant used 1,822,700 kWh at a cost of \$98,700 during the year of this research.

6.12.2 Energy Performance Review by End-Use Category

6.12.2.1 Food Preparation

This unit is the largest consumer of food preparation energy, while only the second highest with respect to percent of total use. Energy use closely tracks customer count on a linear basis: larger customer counts cause larger energy consumption. A bakery in this facility contributes to increased energy use but not significantly. The use of a steam table to keep the food hot is a major contributor to the large use of energy in this category.

(a) Prepared by Charles N. Claar, P.E., PREP Principal Investigator,
The Pennsylvania State University.

Most of the major food service equipment is used heavily over the lunch and dinner hours, and control of on/off times is haphazard. Specific information on energy consumption by individual equipment types is limited because there are a large number of food service equipment and a smaller number of metering points.

6.12.2.2 Sanitation

This facility is the largest consumer of sanitation energy in percent of total energy. Sanitation energy is consumed primarily by a large capacity high temperature dishwasher; a laundry for uniforms, napkins and other goods; and domestic hot water for cleaning and customer use.

Consumption for sanitation is influenced by customer count and especially by the temperature of the inlet water. The water temperature was higher for Morrison's than for any other facility. The boiler vents some steam to the mechanical room in which it is located and is "blown down" irregularly. For a major portion of this project the water treatment equipment did not function properly. It is suspected that heat transfer surfaces may be covered by scale and sediments, which cause large increases in energy use.

6.12.2.3 Refrigeration

Morrison's refrigeration energy consumption is 3% of its total energy use among the restaurants in this study, while the refrigeration usage is the third highest. For the cafeteria this end-use category consumes the least amount of energy. Consumption is of course highest during the summer months and lowest during the winter.

The amount of refrigeration equipment is not as large as that of the full service restaurant. This facility serves no alcoholic beverages and thus has no bar trade; bars require a higher refrigeration consumption.

6.12.2.4 Lighting

This unit uses the third highest amount of energy for lighting of the seven restaurants; however, as a percent of total energy consumption it ranks the lowest, with 7%.

The dining room lighting is entirely incandescent, primarily for ambiance. The fixtures are recessed except for several large colonial chandeliers. Kitchen, storage, and office lighting is fluorescent, usually with two tube, 4-ft-long fixtures. Outdoor lighting is used for signs and the soffit. Parking lot lighting is provided by the local utility, VEPCO, and is not part of the facility's electric service, nor is it metered by this project. Consequently, lighting energy use would be increased if the parking lot lighting were included in the energy use of the facility.

6.12.2.5 HVAC

Perhaps because this facility is located further south than any of the other restaurants, the average outdoor temperatures were the highest of the seven. This facility is the second highest user of HVAC energy, but surprisingly the lowest (21%) in percent of total consumption. There are several reasons for this: the relative large consumption of both food preparation and sanitation energy, the use of economizers with the HVAC units, and the use of an automatic system to regulate HVAC equipment. The automatic system can be overridden by restaurant managers as conditions warrant or in response to customer comments. The net result appears to be less energy consumption.

6.12.3 Conservation Opportunities

6.12.3.1 Food Preparation

The requirement to use a steam table in a cafeteria increases the energy use for food preparation, but it also emphasizes the importance of an excellent maintenance program and water treatment for the boiler.

A large food service facility such as this must be able to serve large groups of customers, sometimes on short notice. Therefore, there is a tendency to operate major pieces of cooking equipment during the entire time the facility is open for business. This can be quite costly and it is logical to assume that cafeterias could reduce food preparation energy costs by turning off equipment when it is not needed to cook food or for urgent standby purposes. Employees must be instructed in proper cooking equipment operating techniques, and management must identify when equipment can be shut down based on historical data, customer counts, weather, and time of day.

Purchasing properly sized equipment is crucial to limiting energy consumption and must be investigated. For instance, the bake ovens' connected electrical load seems to be too large for the baking load at this cafeteria.

6.12.3.2 Sanitation

One way to save sanitation energy consumption would be to increase hot water storage capacity, which would reduce the demand charges and the standby loss charges associated with operating two hot water heaters.

Low temperature dishwashing would be an excellent way for a cafeteria to reduce energy consumption. In addition, selecting the smallest possible dishwasher to do the job adequately should be investigated as a conservation strategy. Training personnel to properly operate the dishwasher with full racks is also important in reducing energy use.

In an operation of this size it is imperative, as noted in the previous section, that hot water tanks and their associated piping be free of scale and impediments to good heat transfer. It is also essential that a mandatory water treatment program be initiated at cafeterias and that proper procedures be instituted to maintain and monitor the treatment program. Improved tank insulation should be investigated onsite and in the manufacturing process.

Commercial laundries should be utilized where cost effective to reduce energy costs and consumption.

6.12.3.3 Refrigeration

The magnitude of refrigeration energy is relatively high with respect to the other restaurants, but is the lowest energy consumer for the cafeteria. Conservation opportunities are somewhat limited here. However, it is important to emphasize the necessity for adequate preventive maintenance of refrigeration equipment. Storeroom personnel should be instructed in properly storing refrigerated foods and in planning their work to limit access to refrigerated spaces.

6.12.3.4 Lighting

The dining room recessed fixtures would be good candidates for a conversion from incandescent to fluorescent lights. These color corrected lights

would have little effect on the cafeteria's "atmosphere" but could reduce lighting energy use by 50 to 75%. Little capital investment would be necessary since the fixtures need not be changed.

Where fluorescent lights are used, energy-saver tubes should be phased in gradually (as replacements) with little additional investment. Energy efficient ballasts should be used as replacements for failed fluorescent ballasts. Metal halide lights should be investigated as a possible way to reduce lighting load and costs in the kitchen and storage area.

A one-third reduction in lighting energy would save this facility about \$2,400 in energy costs, or 43,500 kWh.

6.12.3.5 HVAC

This facility has one customer entrance of two double doors and one employee entrance in the rear. The customer entrance has a large vestibule and the rear door has a door-operated air curtain. Thus infiltration by door openings is not a major problem. Earlier in this report it is noted that outdoor temperature significantly influences HVAC energy consumption.

An excellent way to reduce HVAC energy consumption would be to improve building shell insulation, window treatments, and construction techniques. Proper sizing of HVAC equipment, not thought to be a major problem here, is also essential to reduce consumption. Use of the economizer should be continued. The limited use of an HVAC management system should be continued and the system capability should be expanded to promote further reduction in HVAC energy consumption. Further, regular maintenance of HVAC equipment is necessary to assure continued effective use of the HVAC energy in this facility and all cafeterias.

7.0 FINDINGS AND RECOMMENDATIONS

This chapter provides an overview of results of the Project on Restaurant Energy Performance (PREP), a discussion of problem areas and resolutions, and recommendations for further study. This information should help future studies of this type by focusing research needs and documenting the problems encountered and how they were overcome.

7.1 PROJECT RESULTS REVIEW

This project succeeded in the accomplishment of its primary goal: to empirically document the end-use energy consumption of a variety of food service facilities. Over 200 sensors were deployed and queried daily using remote telecommunications. After 1 year of data collection extending from July 1, 1983 to June 30, 1984, over 87.8% of the available 15 minute records were collected. This represents more than 6.5 million data records archived in machine readable form.

Manual meter readings were made on over 20 occasions at each site during the measurement period. These readings provided a valuable check on the computerized files and permitted missing data to be reliably inserted by difference and interpolation. Consequently, the project participants are confident that the data records are accurate and complete.

The energy use records are available in machine readable form on a 15 minute step at the individual channel level. Section 4.0 contains a table of the monthly end-use consumption levels. Appendix I includes tables of daily end-use energy consumption levels for each monitored facility, and Appendix II includes a user's guide for processing machine readable data files.

In addition to energy use data, PREP has successfully compiled at seven locations microclimatic data, including exterior temperatures, horizontal global radiation, and wind speed and direction. Also, interior temperatures adjacent to HVAC thermostats were recorded at all sites, and the number of gallons of hot water used was measured at three sites. All this data is available in machine readable form at 15 minute intervals for the monitoring period.

Finally, the project collected information on the physical characteristics of the monitored sites including architectural and thermal features, equipment specifications, activity levels, maintenance practices, and notes on renovations or remodeling. Hence there are sufficient data to support a wide variety of analyses.

A limited amount of statistical analysis of the data suggests that the relationship of HVAC and refrigeration energy to exterior temperatures is quite robust, as is sanitation energy to supply water temperatures. For facilities experiencing significant changes in food service activity, good correlation of food preparation to customer count is evidenced. The limited analysis conducted to date has also revealed that each of the restaurants studied has unique energy consumption characteristics, and no simple normalizing techniques have been uncovered to predict total or end-use energy consumption.

Engineers from each of the participating restaurant corporations prepared a summary of the facility's performance and identified promising conservation opportunities. These summaries assess the applicability of practicable conservation technologies in each of the five end-use categories. Energy conservation potential of 10 to 25% of baseline energy use is estimated to be available with less than 2 year paybacks.

In summary, the data assembled provide a valuable empirical basis for detailed study of restaurant energy use and equipment performance, building energy use modeling, and utility load research.

7.2 PROBLEM AREAS AND RESOLUTIONS

The problems encountered have been divided into three categories: metering systems design and maintenance, installation related problems, and data collection problems.

7.2.1 System Design and Maintenance

The large amount of time and money to maintain the data acquisition systems and operational status in a satisfactory manner was unanticipated. Since inadequate funds were budgeted for maintenance, PSU had to expend its own funds

to keep the data acquisition systems operational, to perform maintenance, and to uphold a satisfactory data capture rate.

This project took many pieces of off-the-shelf equipment, such as a microcomputer, utility type meters, weather sensors, and communications equipment, and assembled them into a fully integrated operational system. However, the Pennsylvania State University (PSU) strongly believes that the installation, integration and operation of off-the-shelf equipment to create a data acquisition system is more than a simple refinement of existing technology: it is actually an advancement. This apparent misinterpretation of existing technology and its integration resulted in excessive maintenance costs, which seriously affected the funding and the data capture rate. It is suggested that in further studies of this type a much better assessment of maintenance costs be made by all parties.

7.2.2 Installation-Related Problems

The Cromenco microcomputer system used in this project was selected because it was designed for use in an industrial environment and because of assurances by the microcomputer supplier that good backup support for the software specialists would be provided. Unfortunately, project completion was delayed 2 to 3 months due to inadequate vendor support. In future projects prospective computer suppliers and/or manufacturers should be asked to indicate in writing the kind of backup support they will provide if their microcomputer is selected.

An electrical contractor hired to install the watt-hour meters at five of the seven restaurants was not provided with installation instructions for the meters. After the contractor had installed the electric meters it was determined that none of the instrumented rated watt-hour meters were properly installed. Project personnel then corrected wiring errors so that the installed meters worked properly. This resulted in at least a 1 month delay. PSU recommends that in other similar projects all outside contractors be given explicit instructions on how to install all equipment.

When the meters were properly installed it was determined that the data collected from the computer data acquisition systems were giving energy

readings greater than those of the onsite energy meters. A review of the pre-archiving phase indicate that the computer systems were operating properly. After discussing the problem with several computer experts at PSU, the data sensor scan was slowed down to accurately record real energy use. It was found that this change, initially adopted at Friendly Restaurants, was required to get adequate comparisons of onsite energy readings and computer readings. All computer systems were likewise modified.

At about the time the above problem was resolved, the installation of weather equipment at the seven restaurants was in the final stages. After this equipment was installed a number of analog to digital (A/D) convertor failures occurred in the microcomputer system. These failures were primarily due to weather sensor amplifiers permitting greater than 5.1 volts to pass through and into the A/D board. This problem was corrected by a redesign of the amplifier to limit the output voltage.

7.2.3 Post-Archiving Related Problems

The data archiving phase of this project was started July 1, 1983. Based upon data from 15 days into the data archiving phase and some previous experiences, it was determined that the reliability of data acquisition system was unacceptable. This was due primarily to a malfunction of the disk drives at each restaurant. It now appears that airborne particles were introduced into the computer, which affected the operation of the disk drives.

On July 20 and 21 all of the microcomputers were modified onsite to eliminate the disk drives for system control by installing an EPROM (Erasable Programmable Read Only Memory) and thereby switching the data storage to RAM. This change from disk drives to EPROMs resulted in a large increase in system reliability and substantial improvement in data capture rates.

During the early months of this project, the problem of computer readings being greater than the readings determined from onsite energy meters recurred. It was determined that some short duration spikes were induced on the digital channels; these could be eliminated by the installation of a 2.2 micro-fared capacitor. This step also improved the data capture rates.

During the course of the project the capacitors either opened or shorted at a rate considerably greater than that guaranteed/experienced by the capacitor manufacturer; thus we lost slightly over 500 point-days of data acquisition. PSU replaced the capacitors as soon as they were identified as a problem. In similar projects a more reliable grade of capacitor, although more expensive, should be installed if similar problems should arise.

The most complex problem--the one that led to the loss of the most data--was brought on by power transients. A transient is defined as a condition in which there is no loss of power; however, the voltage may dip to 70 to 80% of normal for 0+ to 10 Hertz and thus cause the computer to "hang up." Disturbance and outage records from the local utilities were reviewed; it should be noted that most power companies will only record outages that are greater than 1 minute.

This situation was identified most often when PSU was unable to establish a telephone connection with a computer located at any of the sites. In August 1983 the problem was thought to be a modem problem, and three additional modems to replace the modems at each of three facilities were acquired. The original modems were returned to the manufacturer, who determined that they were functioning properly. PSU still believed that modem problems were occurring. In September and October these failures decreased dramatically, coincidentally with the decrease in the number of thunderstorms that are prevalent in the East in July, August, and September. Modem failures as previously identified rarely occurred in November through March. In April, PSU once again experienced problems communicating with the restaurants. It was these events, which corresponded with the start of the thunderstorm season, that led PSU to conclude that electrical disturbances on electrical power systems during thunderstorms caused the computer to "hang up."

Also, during this study PSU was able to identify from power company records, conversations with unit managers, and from familiarity with weather conditions the exact times when power failures had caused a loss of data at restaurants. Some of these failures occurred during thunderstorms, while

others occurred randomly and were fairly typical of the daily operation of any utility electrical system. Early in 1984 PSU became aware of problems in power companies' electric reliability.

In June 1984 the data capture rate was seriously affected, again in PSU's opinion, by power company transients and power failures which might have been eliminated had surge protections and backup power supplies been installed. The analysis of lost data indicates that approximately 50% of the loss was due to power failures and/or power transients.

Based on these experiences, it is strongly recommended that computer data acquisition systems be equipped with transient surge protectors and a backup power supply or that microcomputers capable of handling power disturbances that last up to 1 minute be used for monitoring systems.

7.3 RECOMMENDATIONS FOR FURTHER STUDY

The results of this project suggested the following recommendations for further study.

- The most important work that can be done is additional data analysis. A considerable amount of information obtained from this project will probably never be analyzed unless funds are available from either the federal/state government or food service industry to further review, investigate, and study the existing data.

For example, this project's data can be used to determine the amount of demand diversification that occurs in restaurants, a quantity that is presently unknown. There is evidence to suggest that it is much greater than that permitted by the National Electrical Code (NEC) in the sizing of electric service entrances. If further study confirms this, then the restaurant industry could reduce the size of their electric service entrances and thus reduce construction capital expenditures.

- Almost equally important as the first point is that most of the restaurants in this project will make some operational and construction changes to their facilities as a result of participating in this

project to reduce their operating costs. It is recommended that funds be provided to monitor the effects of such changes on the total energy consumption and energy consumption patterns of these restaurants.

- Restaurants in other areas of the country should be studied to see if their energy consumption or energy consumption patterns differ significantly from those experienced in the PREP buildings. Only aggregate data may be necessary.
- The data should be used to calibrate and evaluate the capabilities of building energy use simulation models. These models can be based on theoretical or empirical data. Once verified, the models can be used to evaluate the cost effectiveness of practicable energy conservation measures and load management techniques.
- It is recommended that energy management systems (EMS) be investigated by independent restaurateurs and chain operators to reduce energy costs and energy consumption. Special emphasis should be placed on the EMS time-of-day capabilities, since scheduling of food preparation, sanitation, lighting, and HVAC equipment operation can have a very positive impact on energy costs.