
Prototype Dining Hall Energy Efficiency Study

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June 1988

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Housing and Services Directorate
U.S. Air Force Engineering and Service Center
Tyndall Air Force Base, Florida
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Pacific Northwest Laboratory
Richland, Washington 99352

SUMMARY

The energy consumption of food service facilities is among the highest of any commercial building type, owing to the special requirements for food preparation, sanitation, and ventilation. Consequently, the U.S. Air Force Engineering and Services Center contracted with Pacific Northwest Laboratory to collect and analyze end-use energy consumption data for a prototypical dining hall and make specific recommendations on cost-effective energy conservation options. This information will be used to establish or update criteria for dining hall designs and retrofits as appropriate.

The study involved the following discrete steps:

1. A dining hall was selected to serve as a prototype for this study, based upon its typicality and ease of measurement.
2. A measurement plan was developed to sub-meter major energy end-uses, interior temperatures, and climate factors.
3. Sensors and data logging equipment were installed and calibrated.
4. Data quality was verified, and hourly interval data were collected for a 1-year period.
5. Characteristics data were compiled to initialize an energy use simulation model.
6. A simulation model was calibrated, making use of the energy consumption measurements.
7. A climate analysis was conducted to cluster 46 U.S. weather stations into four climate types for the simplified analysis method.
8. A list of energy conservation opportunities was developed and specified for new or retrofit construction based on the prototype.
9. The simulation model was used to estimate the energy savings associated with each measure in each climate type.

10. A simple procedure was developed to calculate the savings-to-investment ratios based upon locally derived fuel costs, escalation rates, and measure costs.

This analysis reveals that the prototype dining hall energy usage is similar to that of other full service restaurants that have been previously studied. The dining hall was estimated to consume approximately 480,000 Btu/ft²/yr as compared to a range of 390,000 to 730,000 for the other restaurants studied. Between one-third and one-half of dining hall energy is used for heating, ventilation, and air conditioning, depending upon the severity of the climate and the interior conditions to be maintained. Approximately one-quarter of the energy consumed is for food preparation, and the remaining energy is for refrigeration, sanitation, and lighting.

Two types of energy conservation opportunities are described: load reduction measures, and system efficiency improvements. Because the energy savings and cost-effectiveness of these measures is largely affected by weather, a total of 46 different weather stations were used to develop four climate domains for a simplified analysis method. In each of these domains, 22 load reduction opportunities are assessed, as well as 8 system efficiency improvements.

Application of all the measures found to be cost effective for the prototype dining facility using average national fuel prices and escalation rates, would result in energy savings of from 20% to 35% of the base case energy use, depending upon the severity of the climate. The total cost of these measures would range from \$75,000 to \$125,000 per facility.

In light of the dependency of the performance of energy conservation measures on climate, and the dependency of cost-effectiveness on local fuel prices, it is necessary to conduct conservation assessments using site specific information. For this reason, a set of worksheets have been prepared to guide a simplified analysis that is tailored to a particular climate type and set of OOE regional fuel prices. For even greater accuracy, the ASEAM 2.1 simulation model utilized for this study can be modified and run with

local weather summaries. The report documents the development and calibration of this tool for the prototype dining hall to pave the way for future applications.

ACRONYMS

AFESC	U.S. Air Force Engineering and Services Center
ASEAM 2.1	A Simplified Energy Analysis Method, Version 2.1
ASHRAE	American Society of Heating, Refrigerating, and Air Conditioning Engineers
ASTM	American Society for Testing and Materials
COP	coefficient of performance
DOE	U.S. Department of Energy
EPRI	Electric Power Research Institute
FC	fuel costs
FEMP	Federal Energy Management Program
H&V	heating and ventilating unit
HVAC	heating, ventilation, and air conditioning
IES	Illuminating Engineering Society of North America
MBtu	million British thermal units
NPV	net-present-value
NRA	National Restaurant Association
PNL	Pacific Northwest Laboratory
SIR	savings-to-investment ratio
UPW	uniform present worth factors
USAF	U.S. Air Force
VAV	variable air volume

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1.0 INTRODUCTION

The energy consumption of food service facilities is among the highest of any commercial building type, owing to the special requirements for food preparation, sanitation, and ventilation. Consequently, the U.S. Air Force Engineering and Services Center (AFESC) contracted with Pacific Northwest Laboratory (PNL) (a) to collect and analyze end-use energy consumption data for a prototypical dining hall and make specific recommendations on cost-effective energy conservation options. This information will be used to establish or update criteria for dining hall designs and retrofits as appropriate.

The determination of cost-effective energy conservation measures for a specific facility is confounded by many considerations, including: 1) mission requirements (i.e., number of meals served and hours of operation) that vary from site to site, 2) the highly variable condition of existing facilities and equipment, 3) the dependence of mechanical equipment sizing upon the design conditions, 4) the impact of climate conditions and fuel sources on energy conservation measure effectiveness, 5) the significant variation of costs and escalation rates of energy from one region to another, and 6) the unknown and difficult to quantify and verify in situ performance of many conservation measures.

To provide useful and technically correct guidance to optimize building designs or retrofit projects, it is necessary to account for these conditions in the analysis or to make simplifying assumptions. Both approaches were used in this study. Simplifying assumptions were made by inferring that the characteristics data and non-heating, ventilation, and air conditioning (HVAC) energy use measurements at the prototype dining hall were representative of all dining halls. Sensitivity analyses were carried out to indicate the affects of climate on energy savings. Based upon these analyses, and on

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reference information on fuel costs and escalation rates, a simple procedure to estimate the cost-effectiveness of generic energy conservation measures was developed.

Alternatively, the energy use model developed and calibrated by this study can be used to generate customized savings estimates and savings-to-investment ratios for particular cases. The model operates on a personal computer and can easily be initialized with the base case file developed by this study. This file can then be modified as necessary to simulate the anticipated conditions at a particular site. Then the identified energy conservation opportunities can be simulated to generate savings estimates and savings-to-investment ratios which are appropriate for the particular case. For this reason an appendix is provided to detail the base case model inputs and the calibration process.

The report is organized into six sections and two appendixes. Section 2 describes the prototype dining hall selected for study and the measurement plan that was developed to submeter major energy end-uses, interior temperatures, and climate factors. The results of the end-use electrical consumption measurements are summarized and presented graphically.

Section 3 describes the ASEAM 2.1 (A Simplified Energy Analysis Method, Version 2.1) simulation model employed to estimate the steam heating requirements and the energy savings of selected conservation opportunities. The estimated energy use of the prototype dining hall is compared with seven other restaurants studied by the National Restaurant Association (NRA) as a reasonableness check. The prototype facility is modeled in each of 46 weather locations to indicate the sensitivity of heating, cooling, and total energy consumption to climate conditions and to develop climate domains for the simplified analysis method.

Sections 4 and 5 discuss the conservation measures applicable to the prototype dining hall, as well as other measures that should be considered when retrofitting an existing facility or building a new one. For each energy end use, the consumption estimates are reviewed and general guidance is offered regarding appropriate analysis methods and data sources for conservation

assessment.

Section 6 describes a simple method to determine energy conservation measure cost effectiveness. Forms have been developed for each of four climate types to summarize the energy savings analysis and to guide the cost-effectiveness evaluation. An example is provided to detail the application of the simple method for a specific case study.

Section 7 provides a summary of conclusions and recommendations regarding cost-effective energy conservation measures. These findings are based upon the use of the simplified analysis method using average fuel prices and escalation rates to calculate savings-to-investment ratios for the full suite of conservation measures itemized. While the findings are not definitive, they do provide a valuable indication of the measures which are very cost-effective or sensitive to climatic affects.

Two technical appendices have been prepared. Appendix A describes the ASEAM modelling and calibration process. The ASEAM base case model inputs are provided in Appendix B.

2.0 THE PROTOTYPE DINING HALL

This section provides a brief description of the prototype dining hall characteristics and energy data. More detailed information is provided in the technical appendixes. These data were developed from the Patterson Dining Hall at the Dover Air Force Base in Delaware. This facility was selected by the AFESC to be typical of mid-1950 construction practice.

2.1 HOURS OF OPERATION AND ACTIVITY LEVELS

The dining hall serves breakfast, lunch, dinner, and a late night (midnight) meal. Two serving lines are operated according to the schedule identified in Table 2.1. During reserve officer training encampments in the summer, a second serving line is operated from 0630 to 0745 hours. During exercises and alerts, the schedule is altered to that shown in Table 2.2.

Table 2.1. Patterson Dining Hall Regular Hours of Operation

Daily Serving Hours - Workdays

<u>Meal</u>	<u>Serving Hours</u>	<u>Serving Lines</u>
Breakfast	0600-0830	1
Lunch	1100-1300	2
Dinner	1600-1900	2
Late	2245-0045	1

Daily Serving Hours - Weekends and Holidays

<u>Meal</u>	<u>Serving Hours</u>	<u>Serving Lines</u>
Brunch	0600-1300	1
Dinner	1530-1800	2
Late	2245-0045	1

Table 2.2. Patterson Dining Hall Exercise and Alert Hours of Operation

<u>Meal</u>	<u>East Line</u>	<u>West Line</u>
Breakfast	0400-0830	0530-0930
Lunch	0930-1330	1030-1430
Dinner	1430-1930	1530-2030
Late	2030-0300	2130-0400

Figure 2.1 depicts the number of meals served during each month of the monitoring period. The highest frequency of food service occurred in August 1986 with a total of 58,357 meals, or approximately 1880 meals per day. The lowest food service frequency was in December 1986 with a total of 43,675 meals, or approximately 1400 meals per day. The annual average number of meals per month and day is 50,174 and 1650, respectively. Thus, monthly meal counts vary by as much as 15% from the average.

The facility manager indicated that peak food preparation activities typically occur from 0600 to 1030 hours and 1230 to 1530 hours daily. Cleanup activities are concentrated during the periods 0830 to 1030, 1300 to 1430, and 1900 to 2030 hours. Peak baking hours are from 2200 to 0630 daily.

2.2 CONSTRUCTION FEATURES

This section briefly describes the building floor plan, elevations, and mechanical equipment. More detailed information used to develop and calibrate the simulation model is provided in Appendix A.

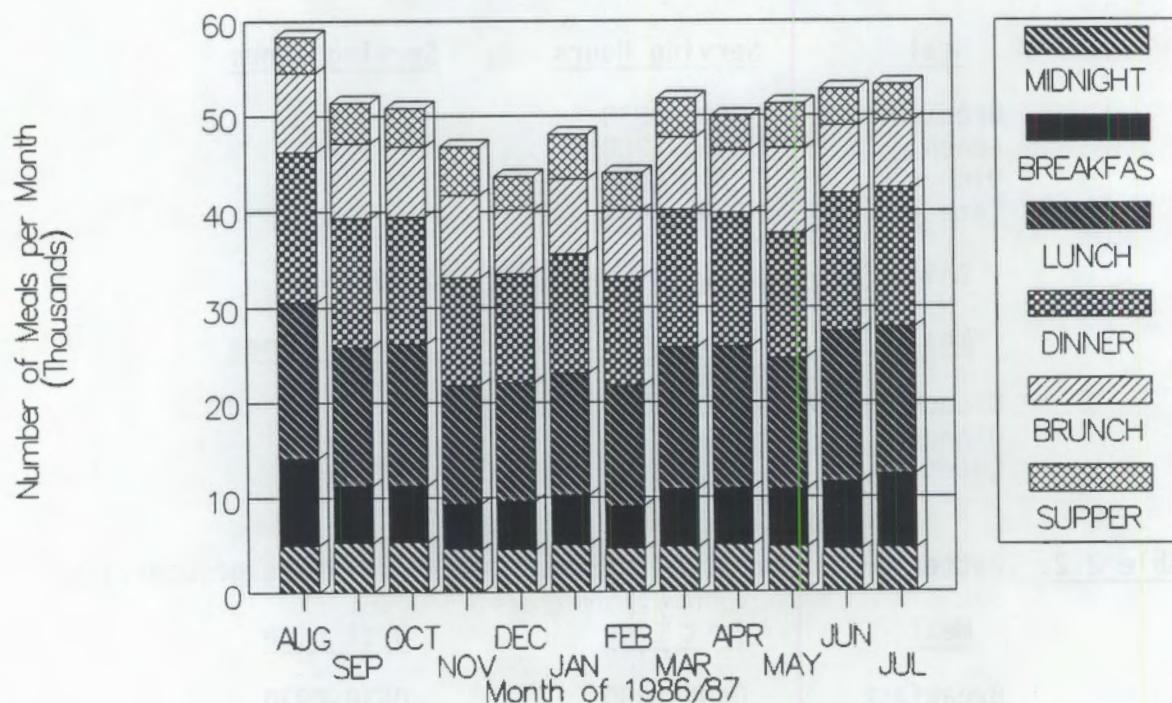


FIGURE 2.1. Monthly Total Meal Count

2.2.1 Floor Plan

The dining hall floor plan is depicted in Figure 2.2. There are two dining areas of approximately 4000 ft² each. The east dining area includes a snack line, while the west dining area is used principally for meal service. Entry to these areas is through vestibules facing the east and west. Two small bathrooms are located at the front of the building for customer use.

The two dining areas are separated by a 840-ft² dishwashing area. A Hobart CPW117 dishmachine is enclosed, as well as a conveyor to move dishes from the scrapping area.

The kitchen lies to the north of these three areas and is approximately 2650 ft². Four lines of food preparation equipment are placed underneath exhaust hoods in the center. The west wall includes separate rooms for vegetable preparation, pot washing, and baking.

Dry good and refrigerated storage areas, as well as a small office, lie to the east of the kitchen. These areas total approximately 1350 ft².

The northeast section of the building provides employee bathrooms and locker rooms. The northwest section includes an office for contractor use. A covered loading dock is located between these areas. To the west of the office area, an unconditioned mechanical room houses the electrical switchgear, heat exchangers, and associated mechanical equipment.

2.2.2 Envelope Features

The walls are constructed of 8-in. concrete masonry units and 4-in. face brick. These layers are divided by a 2-in. air space. Figure 2.2 indicates the location of 8-ft-high windows with a 1-ft-high section at the base, which can be opened. The total glass area is 827 ft², or 12% of the total wall area. In addition to the two vestibule entries, there are glass emergency exit doors at the rear of the east and west dining areas, and two sets of metal doors leading to the loading dock.

The roof is of built-up construction over a 1-1/2-in. metal deck. This deck is supported by steel joists. Acoustical tile is suspended approximately

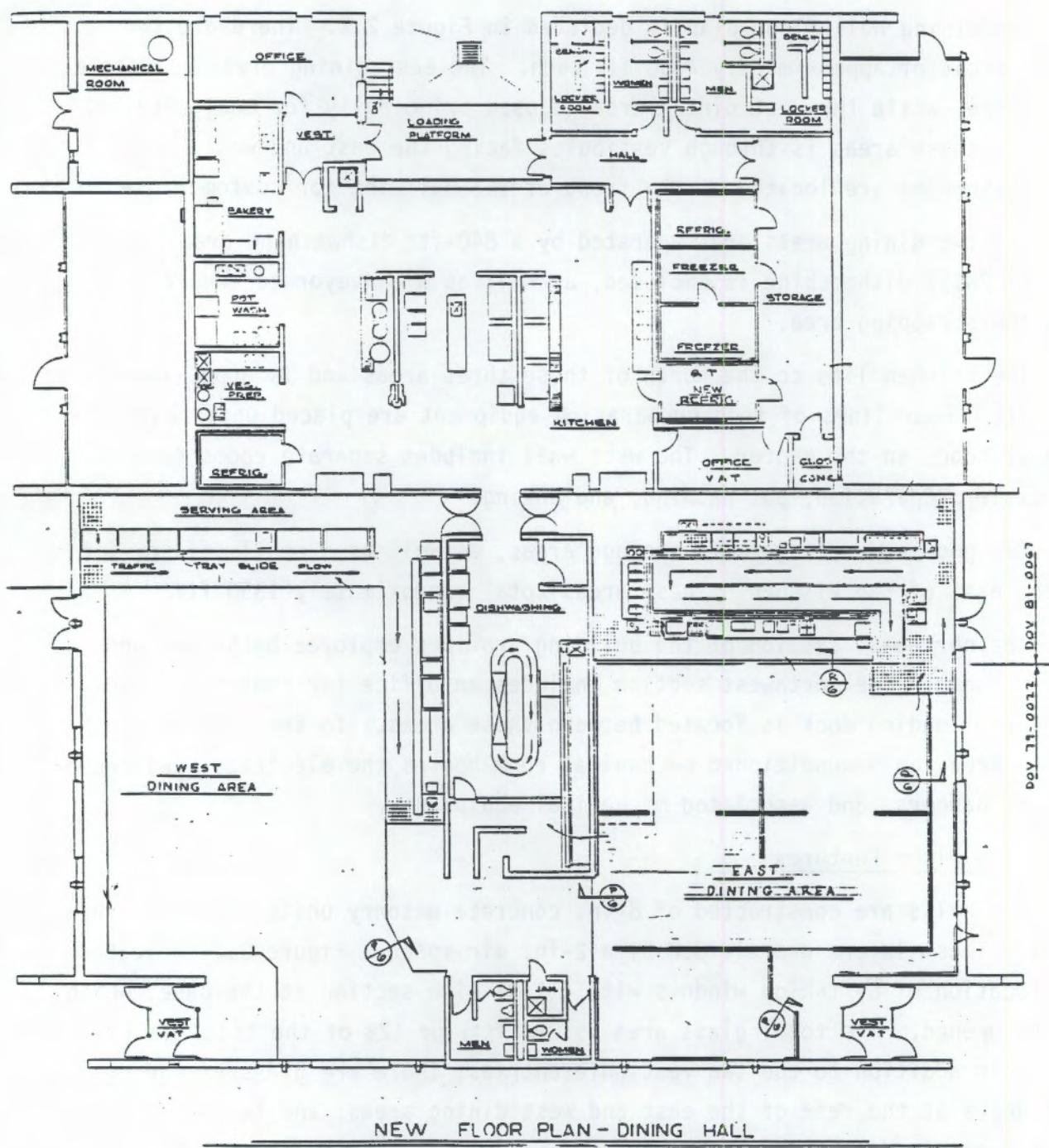


FIGURE 2.2. Dining Hall Floor Plan

3-ft below the roof. Ducting for the heating and cooling systems is located in this space.

The foundation is a 4-in. concrete slab poured over a vapor barrier. One inch of rigid insulation is installed around the perimeter to a depth of 2-ft.

2.2.3 System Features

The dining hall is served by four HVAC systems: two large vapor compression air conditioners, one large heating and ventilating unit serving the kitchen, and several hot water heating coils and convectors for the vestibules, bathrooms, and storage areas. Heating is provided by a hot water loop that is energized by a steam-to-hot water heat exchanger. This steam is provided by a coal-fired central heating plant serving the entire base.

The interior lighting is fluorescent with the exception of the east dining area, which has decorative incandescent fixtures. Exterior lighting is both incandescent and mercury vapor.

Food preparation and refrigeration equipment is located in the two serving lines and in the kitchen. Details regarding the type and capacities of this equipment are provided in Appendix A.

2.3 PROTOTYPE ENERGY CONSUMPTION MEASUREMENTS

The prototype dining hall was instrumented during the period from August 1986 through July 1987 to determine end-use energy consumption levels. Hourly interval data for over 100 sensors were collected and verified, to calibrate the simulation model and to provide valuable insights of daily energy consumption profiles. This section briefly describes the measurement plan and summarizes the measurements.

2.3.1 Measurement Plan

Three 56-channel data loggers were installed. Two loggers, designated A and B, were devoted to the submetering of electrical consumption. The third logger collected temperature data to measure the HVAC system performance and interior comfort levels. Current transformers were placed around individual electric circuits and connected to electronic wattmeters. These wattmeters accumulated true power consumed for each phase of electrical service on an

hourly basis. These values were stored in the logger memory and communicated to PNL on a weekly basis over telephone lines.

In Logger A, all three phases of the building total mains were monitored, as well as all three phases of the electrical panel mains, each air conditioning unit, hot water circulation pumps, indoor lighting, small food preparation devices, disposals, the pot washer, food storage in the snack line, steam kettles, and exhaust fans. The interior temperature of the cashier's office and the kitchen are also monitored by Logger A.

Logger B monitored all three phases of the panel mains, as well as all three phases of the exhaust fans, refrigeration units, receptacles, steam equipment, fryers, grills, the heat and vent unit, ovens, food storage, dishmachine, snack line, and griddles.

Logger C measured the temperature of the hot water supplied to and returned from each piece of terminal equipment. This includes the air conditioning units, the heating ventilating unit, unit heaters, and the vestibule convectors. The temperature of the air supplied to and from these terminal devices was also monitored, as well as the space temperatures in the office, kitchen, and dining areas. Finally, the exterior temperature and global horizontal solar flux was monitored. All these data were collected as hourly averages for periods during the heating and cooling seasons.

2.3.2 Data Verification

The data verification plan was designed to evaluate the accuracy of the installation and metered data. The data were examined in two manners: visual and energy use sum-check. These examinations used both 15-min interval and hourly interval data.

In the initial step, the first 5 days of data were subjected to a detailed visual inspection. This inspection identified obvious installation and documentation errors such as reversed current transformers or improper scaling factors.

The second step subjected the data to an energy balance using the First Law of thermodynamics. The balance requires that the electrical energy

entering each service panel be equal to the electrical energy delivered to each of the circuits or devices served from the panel. This procedure verified that all the active circuits in the building were monitored correctly by the data acquisition system.

The verification process was completed three times randomly throughout the monitoring period. The initial verification found no installation errors. The second verification found an operational amplifier failure on one channel of Logger B that was subsequently repaired. The third verification revealed several building modifications that continued through the end of the project.

After the initial verification, several Lotus 1-2-3(a) templates were developed to summarize and display the measurements. Each month, spreadsheets were examined to ensure data quality. The next section describes and summarizes these spreadsheets.

2.3.3 Electrical Measurement Summary

Display and discussion of all the end-use energy consumption measurements would entail the preparation of thousands of pages of graphics and text. This section endeavors to provide useful summaries of the data and display selected windows of the hourly measurements. However, all the available hourly consumption data were used to develop inputs for the simulation model employed to estimate energy savings potentials.

The end-use shares of electricity are depicted in Figure 2.3. The total is disaggregated into the following end uses: 1) interior lighting, 2) freezers and refrigeration equipment, 3) food preparation equipment, 4) sanitation (dishmachines and garbage disposals), 5) HVAC equipment, and 6) baking equipment. As indicated in Figure 2.3., one-third of the electrical use is for HVAC equipment, even though space and water heating energy is provided by district steam. Food preparation and baking comprise another one-third of the electrical use, and lighting, refrigeration, and sanitation constitute the remaining one-third.

(a) Lotus 1-2-3 is a registered trademark of the Lotus Development Corporation, 55 Cambridge Parkway, Cambridge, MA 02142.

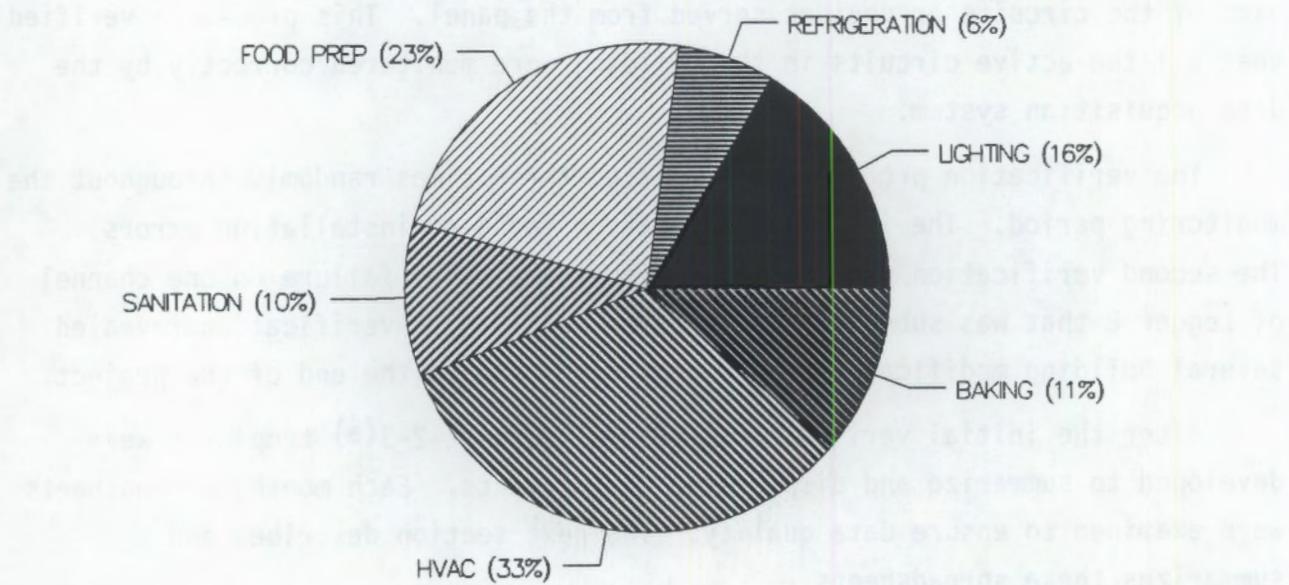


FIGURE 2.3. Electrical End-Use Shares for Prototype Dining Hall, 1986-1987

Electrical consumption totals for each month of the monitoring period are depicted in Figure 2.4. As indicated, the lighting levels are stable throughout the year, refrigeration loads are highest during summer months, food preparation energy is lowest in the winter, sanitation energy is quite variable, and electrical requirements of the HVAC system are pronounced in the summer months to satisfy the space cooling loads.

Figure 2.5 portrays the electricity consumed for interior lighting for each day in January 1987. As shown, the lighting energy for the kitchen, meal room (west dining area), and the snack line (east dining area) is nearly constant from day to day, although hours of operation do vary for weekdays and weekends.

Figure 2.6 displays the electricity consumed by the major types of food preparation equipment for each day of January 1987. In contrast to the lighting, these loads vary dramatically from day to day, in response to the particular menu and levels of food service. The steam jet cookers are the largest energy consumers, followed by the tilt grills and ovens.

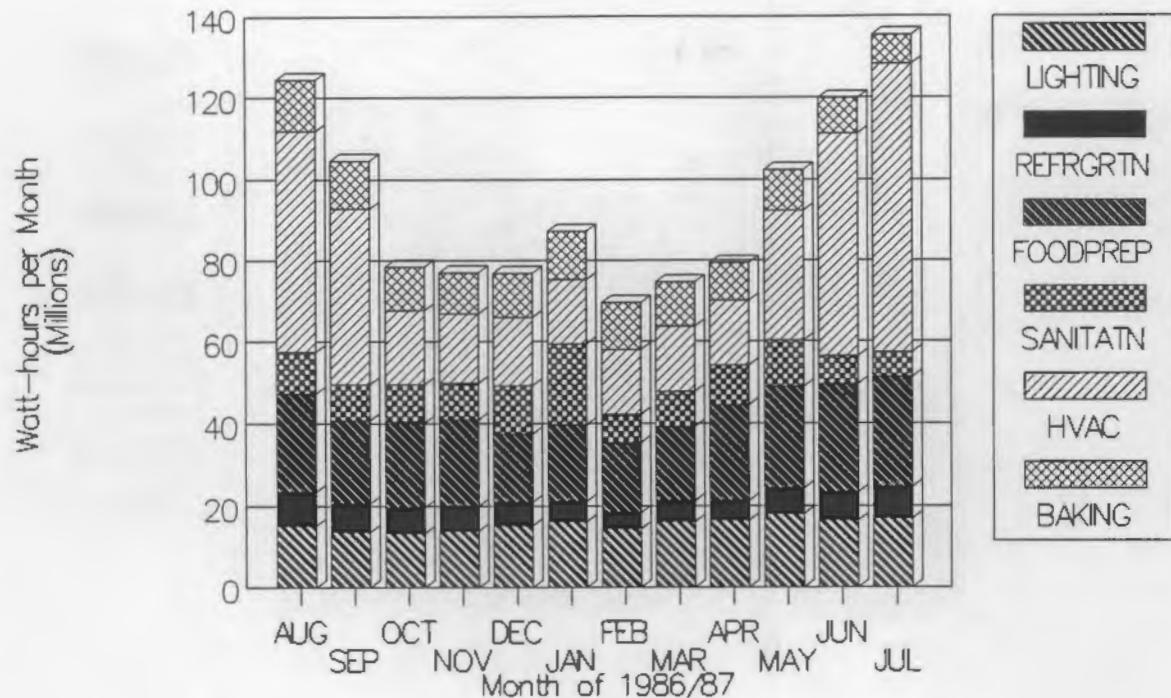


FIGURE 2.4. Monthly End-Use Electrical Consumption

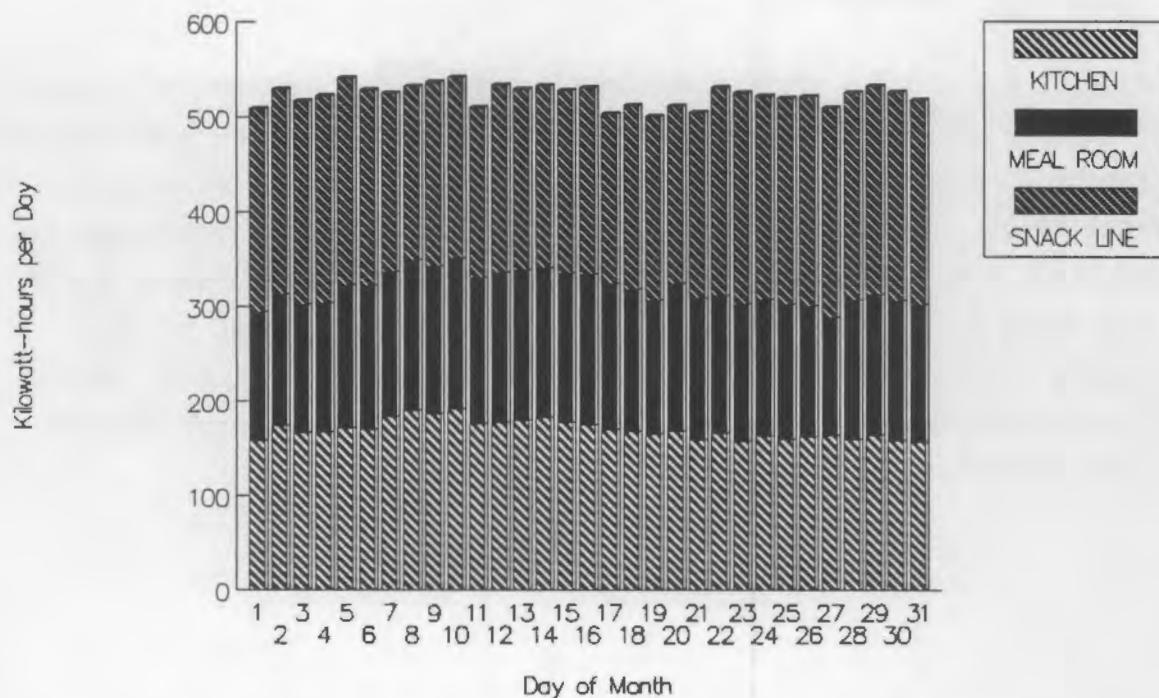


FIGURE 2.5. Electricity Consumption by Interior Lighting Components, January 1987

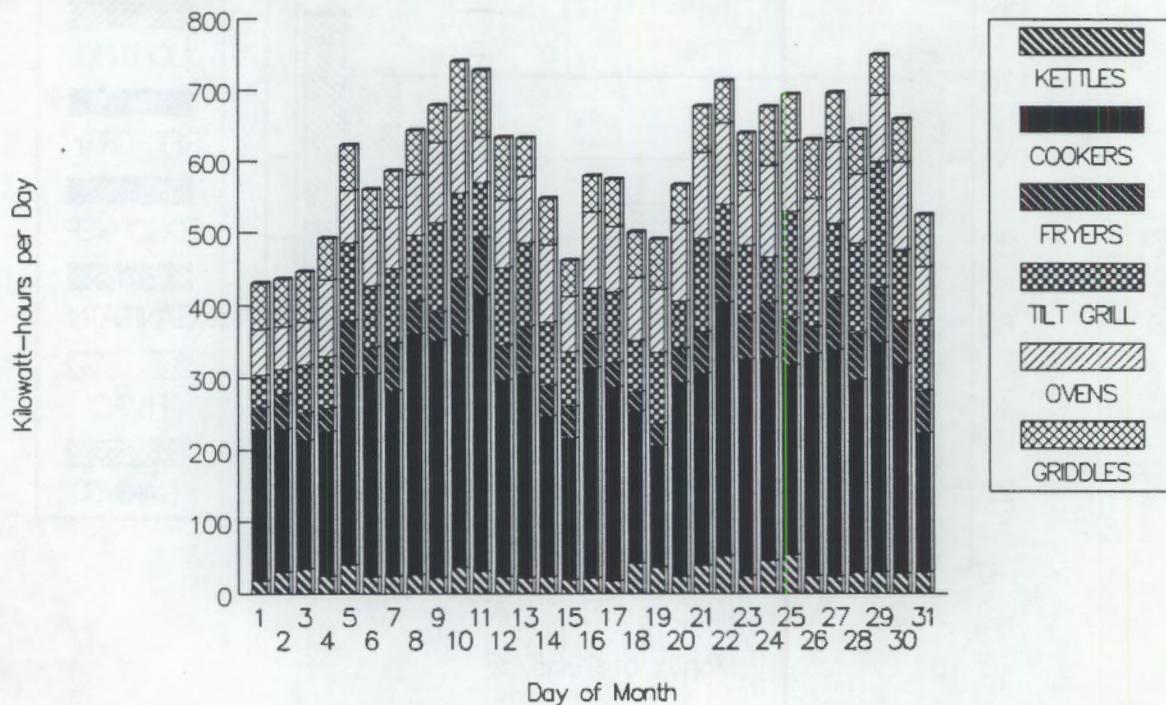


FIGURE 2.6. Electricity Consumption by Food Preparation Components, January 1987

Figures 2.7 and 2.8 profile the hourly end-use consumption for an average day in January and July 1987. These profiles indicate that the HVAC electrical requirements are relatively flat during a particular day, but at dramatically different levels in the winter and summer. The lighting energy consumption is greatest during the hours of 0800 to 1900 and then drops to about 80% of the peak value during the early morning hours. Energy required for food preparation is greatest prior to meal service, while the sanitation and refrigeration loads are greatest following these periods. Energy used for baking is highest around midnight and noontime.

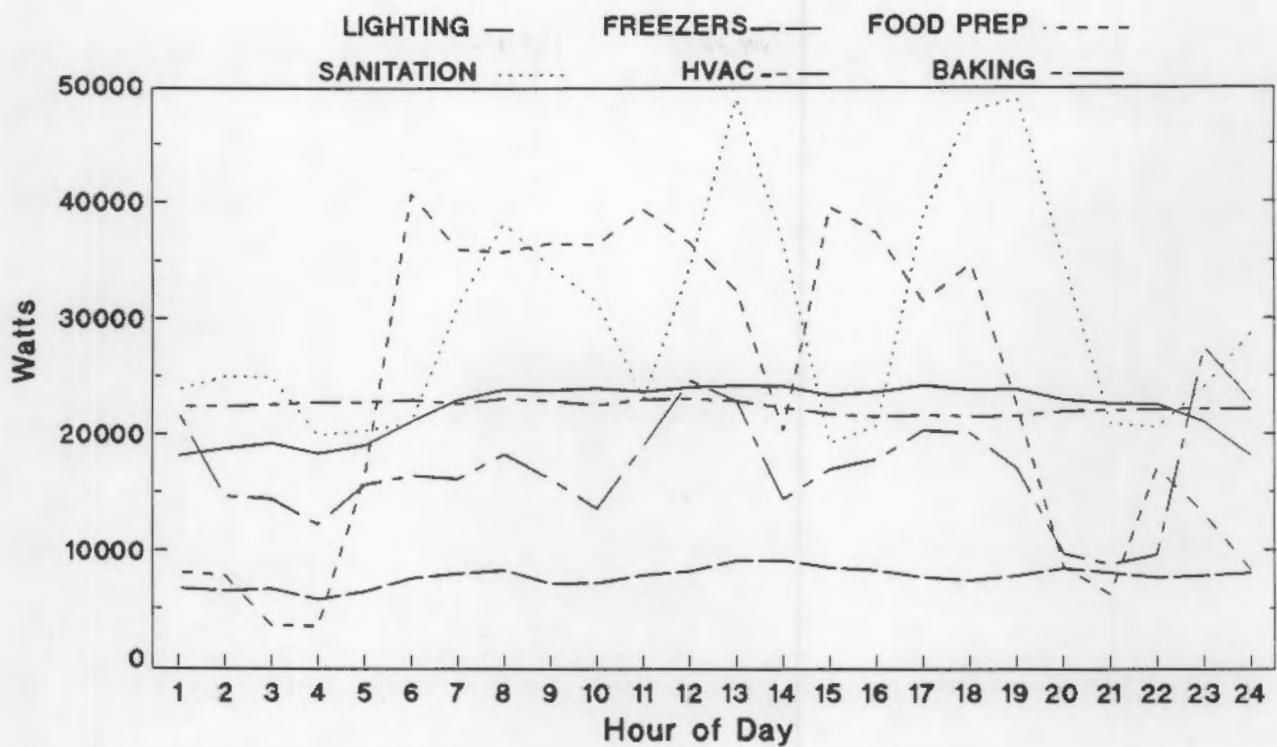


FIGURE 2.7. January Average Day End-Use Profiles

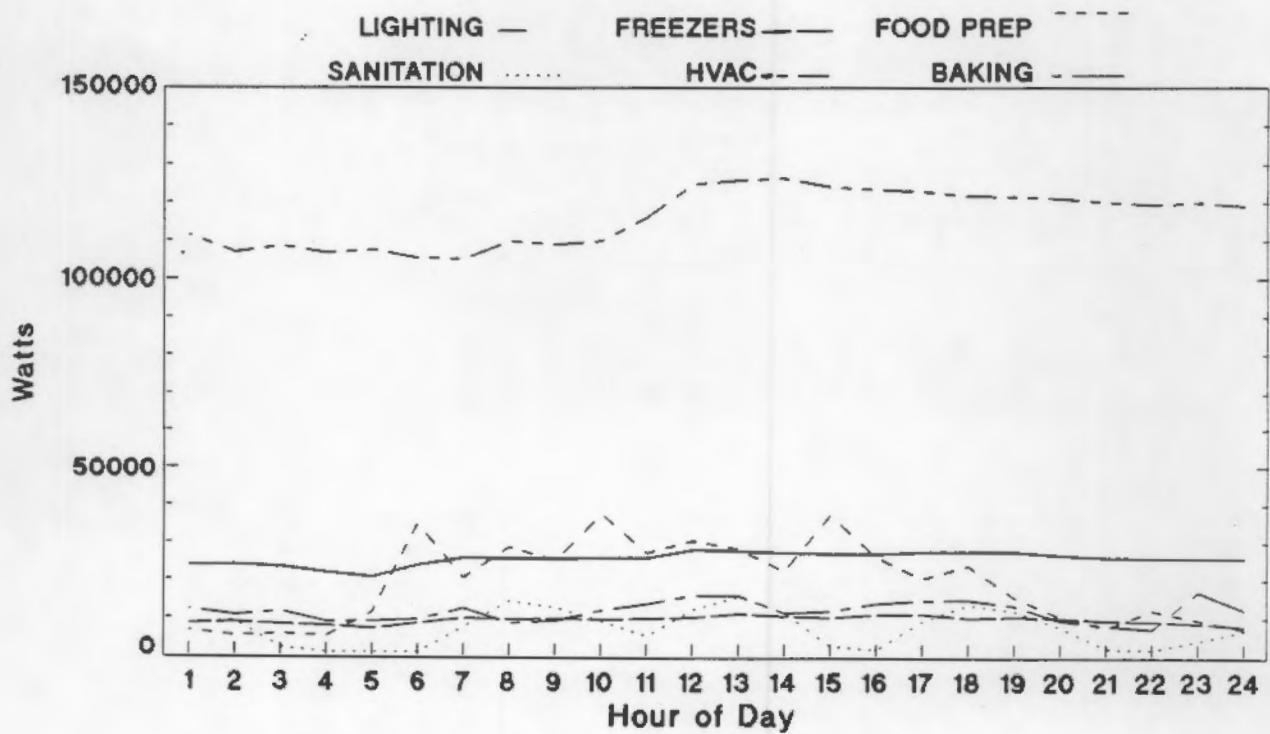


FIGURE 2.8. July Average Day End-Use Profiles

3.0 PROTOTYPE SIMULATION MODEL AND ANALYSIS PROCESS

This section describes the analytical methods employed to develop estimates of baseline total energy consumption and conservation measure performance for USAF dining halls. The results achieved by using this model for the prototype dining hall are presented and compared with measurements from other previously studied restaurants.

3.1 THE ENERGY USE SIMULATION MODEL

The ASEAM-2.1 (A Simplified Energy Analysis Method, Version 2.1) energy simulation model was selected to estimate energy conservation potentials and to extrapolate dining hall performance to various climate regimes (ACEC Research & Management Foundation 1987). This model is a modified bin method program for calculating the energy consumption of residential and commercial buildings. The method employs weather summaries that are commonly available for USAF facilities. These data indicate the number of hours during each month that temperatures lie within specific "bins." Using the data, the model estimates the heat transferred through the building shell and the ventilation system.

Once these loads are calculated, they are added to the internal gains from lights and equipment for each thermal zone. The capacity of the space heating and cooling systems for each zone is then determined, and energy requirements are calculated by considering the interior temperatures to be maintained. Finally, the performance of central plant equipment is modeled to determine the overall energy requirements of the building.

This tool was developed for the U.S. Department of Energy (DOE) and is being routinely applied to federal buildings by the Federal Energy Management Program (FEMP). The ASEAM-2.1 model was selected for the dining hall analysis because it is in the public domain, operates on personal computers, and uses algorithms recognized by the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE). The model is supported by the American Consulting Engineers Council Research and Management Foundation.

Inputs for the model were developed from the detailed end-use energy consumption measurements and the as-built construction documents. A special program was written to develop diversity factors that are required by the model to indicate the frequency with which non-HVAC equipment is energized. These factors are usually input as "best guesses"; however, for this project they were developed from the hourly end-use consumption data.

To estimate HVAC energy use for a particular location, the model uses bin temperature data. The model provides typical weather for 46 locations. However, such data exist for hundreds of other locations and can be manually entered for specific years of interest. Because this study entailed the development of recommendations for cost-effective conservation measures, PNL researchers decided to use the model-provided weather data, which are considered typical of weather conditions for each of these locations.

For this study, the model was calibrated to the available metered data. Specifically, inputs for interior lighting and non-HVAC equipment use were derived from the end-use energy measurements. Consequently, the monthly estimates of energy consumed for these end-uses was within 5% of the measured values. The next step involved comparison of the estimated and measured energy requirement for fans and air-conditioning. This process revealed that the cooling energy calculated by the model is approximately half of that metered. It appears that either the actual coefficients of performance of the air-conditioning systems are significantly lower than the design specification, or the economizers are not operating properly. Some sensitivity analyses conducted to understand this discrepancy, as well as other details relating to the model calibration, are described in Appendix A.

Once the model was calibrated to the electrical energy consumption measurements, it was run to estimate the heating energy requirements. Although this quantity was not directly measured, various heating system temperature measurements were used to ensure that the quantities of heat estimated to be provided by the system were reasonable. A heat balance was completed using a set of one-time flow measurements and 3 weeks' worth of temperature data to benchmark the heating system performance.

Because the volume of hot water consumption was not measured, it was necessary to use data from other full service restaurants to estimate the energy requirements for this end-use. An average value of 50,000 gallons per month was assumed and adjusted according to the ratio of the measured monthly sanitation energy to the average monthly sanitation energy. This assumes that hot water use is proportional to the dishmachine usage. Next, the inlet water temperatures were estimated from mean monthly outdoor temperature data. Finally, the energy requirement for water heating was calculated assuming a 130°F supply temperature.

The results of the space heating and water heating energy estimates are depicted in Figure 3.1 for each month of the monitoring period. These estimates assume a 70% efficiency for the steam and hot water production. The quantities are added to the measured electrical consumption and depicted in Figure 3.2, which shows the monthly electrical baseload (total less space cooling), space cooling, space heating, and water heating. Variations in the baseload are attributable primarily to levels of food service. Figure 3.3 indicates the annual average consumption shares for each of nine energy end uses.

3.2 COMPARISON OF THE PROTOTYPE DINING HALL ENERGY USE WITH OTHER RESTAURANTS

Several adjustments were made to the calibrated model, to estimate the energy use of the prototype dining hall as designed. This was done to compare the energy intensity of USAF dining halls with other restaurants previously metered (Claar, Mazzucchi, and Heidell 1985) for the National Restaurant Association (NRA). The energy consumption estimates derived above were divided by the conditioned square footage and converted to thousands of British thermal units for comparison.

This comparison of energy use is presented in Table 3.1 and depicted in Figures 3.4. and 3.5. These restaurants are located in the climate type as the prototype dining hall, so the intensities for heating and cooling should be comparable. Two of the facilities are heated with natural gas; the rest are electrically heated. The gas-heated buildings are most comparable to the dining hall because of the assumed 70% conversion efficiency.

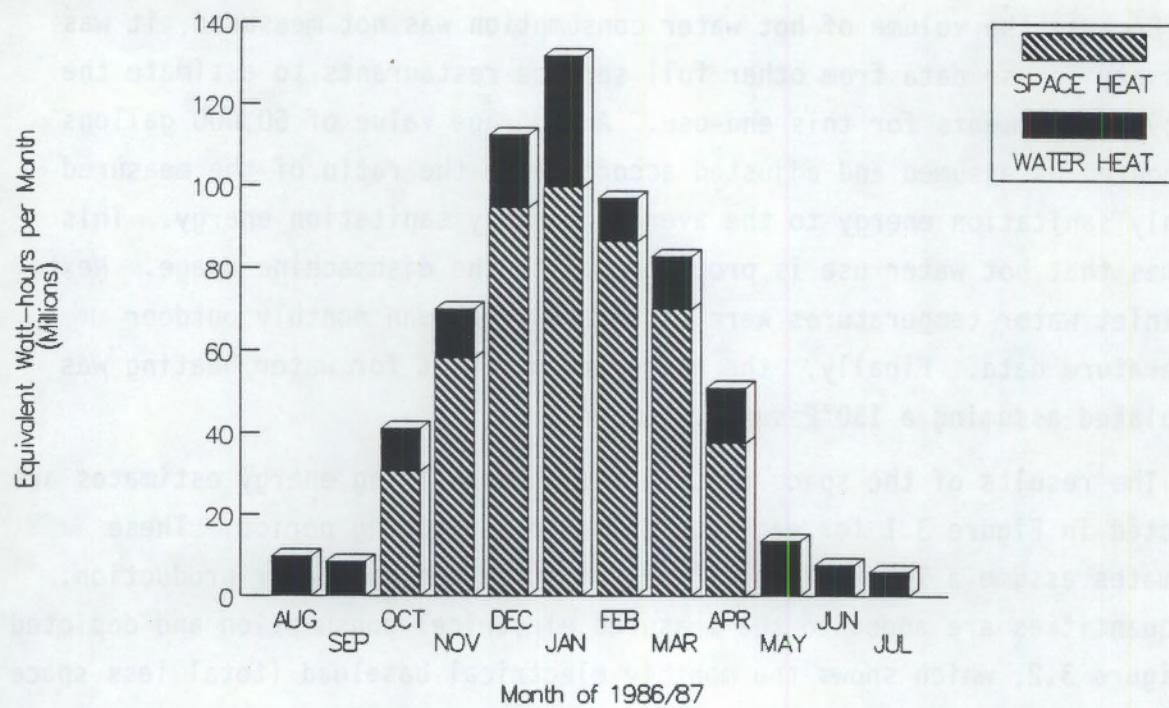


FIGURE 3.1. Estimated Energy Consumption for Steam Production

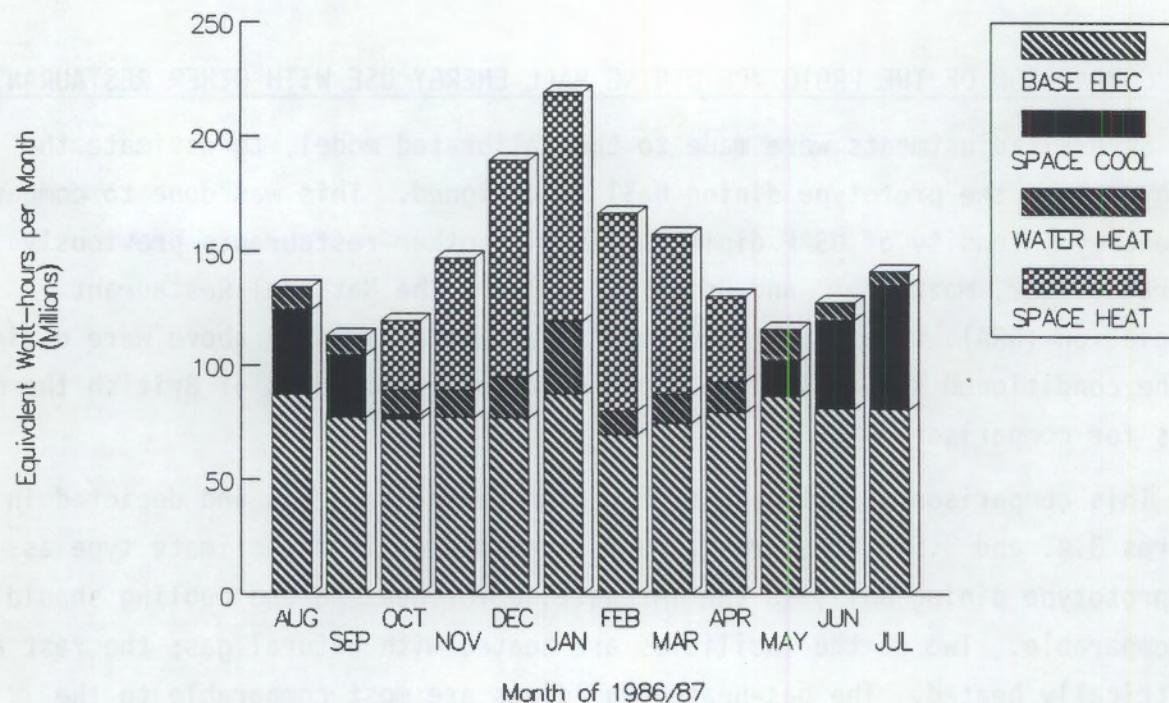


FIGURE 3.2. Estimated Total Monthly Energy Consumption

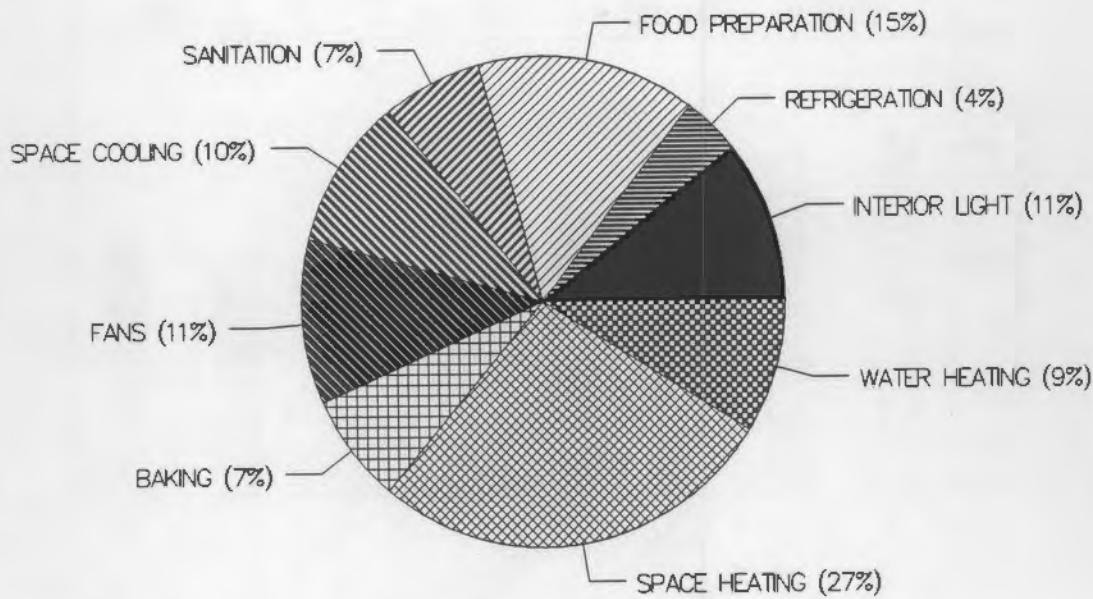


FIGURE 3.3. Estimated Energy Consumption Shares by End Use

TABLE 3.1. Comparison of USAF Dining Hall End-Use Energy Intensities

FOOD SERVICE TYPE	SQUARE FOOTAGE	ENERGY INTENSITY (Thousand Btu per Square Foot per Year)					
		FD.PRP	SANIT	REF	LTG	HVAC	TOT
FAST FOOD LIMITED	3100	322.77	66.41	30.40	139.76	171.00	730.34
FAST FOOD EXPANDED	2750	216.17	42.13	33.27	68.05	263.27	622.87
CAFETERIA	10150	242.74	177.64	20.08	43.85	128.40	612.72
FULL SERVICE EXPANDED	9500	178.48	132.03	37.20	61.84	139.64	549.18
PIZZA	2275	159.00	93.80	46.79	65.30	150.50	515.38
FULL SERVICE LIMITED	6770	99.55	84.72	41.56	73.96	107.71	407.50
COFFEE SHOP	4210	114.27	85.85	13.89	64.83	111.87	390.71
USAF DINING HALL	12000	108.94	77.51	20.68	52.97	220.75	480.86

From the comparison shown in Figure 3.4, it can be seen that the dining hall energy use per square foot is similar to that of the other full service facilities, ranging from 400 to 500 Btu x 10³/ft²/yr. Energy consumption for the dining hall HVAC is higher than the other restaurants on a percentage basis because of the extended hours of operation and the apparent inefficiency of the air conditioning systems. Nonetheless, the opportunities for energy

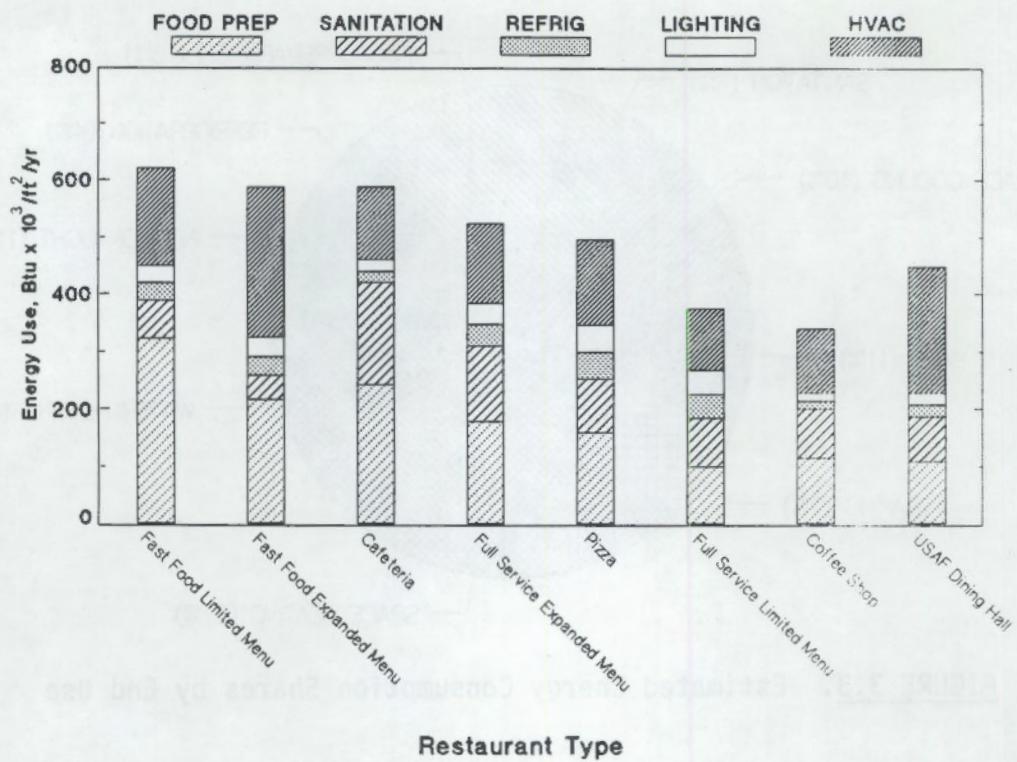


FIGURE 3.4. Comparison of Restaurant Energy Use Intensities by End Use

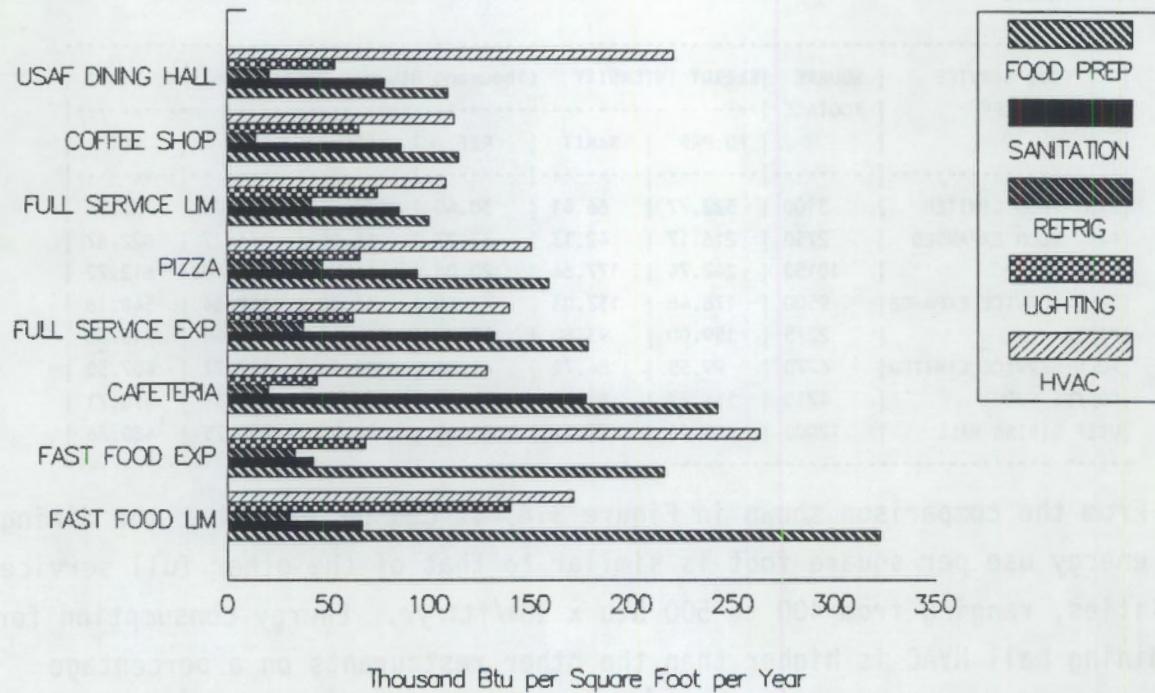


FIGURE 3.5. Comparative Restaurant Energy Use Intensities by Individual End Use

conservation would appear to be similar to those indicated by the previous work.

3.3 ANALYSIS OF WEATHER EFFECTS ON ENERGY CONSUMPTION

Having calibrated the model to the available measured data, and achieving a satisfactory comparison of the prototype energy use estimates with other metered facilities, the model was ready for the conduct of sensitivity analysis. This section describes the results of a thorough examination of how weather affects energy use in the prototype dining hall.

The base case model was run using weather data from all 46 weather locations provided with the ASEAM model. The results of this analysis are summarized in Table 3.2 and Figure 3.6. These data show that approximately 70% of dining hall energy use is not related to weather. Energy for space heating constitutes 32% of total energy consumption in Bismark, North Dakota, while space cooling constitutes up to 16% of total requirements in Miami, Florida. Space heating and cooling requirements for all other locations are smaller on a percentage basis. Consequently, while HVAC energy does vary dramatically by location, its significance is reduced in light of the predominant levels of process energy requirements.

Four climate domains were established to incorporate this weather sensitivity into the simple analysis method. These climate domains were selected based upon the estimated energy requirements for space heating and space cooling for the 46 available weather locations. The domains can be characterized as follows:

- cold - high heating, low cooling
- cool - high heating, moderate cooling
- warm - moderate heating, high cooling
- hot - low heating, high cooling.

Figure 3.7 displays these data by positioning the index number for each weather location, as identified in Table 3.2., according to the annual heating and cooling energy consumption estimates. Within each of these domains a weather location in the center of the cluster was selected to conduct the energy conservation assessments.

TABLE 3.2. Summary of Consumption for 46 U.S. Cities

LOCATION STATE	LOCATION CITY	LOCATION INDEX	CLIMATE TYPE	HEAT MBTU/YR	COOL MBTU/YR	OTHER MBTU/YR	TOTAL MBTU/YR
ALABAMA	BIRMINGHAM	1	WARM	680	509	2845	4034
ARKANSAS	LITTLE ROCK	2	WARM	778	550	2858	4186
ARIZONA	PHOENIX	3	HOT	396	707	2847	3951
CALIFORNIA	LOS ANGELES	4	WARM	393	471	2834	3699
COLORADO	DENVER	5	COOL	1458	286	2879	4623
FLORIDA	MIAMI	6	HOT	109	804	2798	3710
FLORIDA	TALLAHASSEE	7	HOT	413	631	2830	3874
FLORIDA	TAMPA	8*	HOT	240	716	2820	3776
GEORGIA	ATLANTA	9*	WARM	705	482	2838	4025
IOWA	DES MOINES	10	COOL	1546	339	2872	4757
IDAHO	BOISE	11	COOL	1380	284	2877	4541
ILLINOIS	CHICAGO	12	COOL	1451	312	2863	4625
INDIANA	INDIANAPOLIS	13	COOL	1324	351	2862	4537
KANSAS	DODGE CITY	14	COOL	1249	396	2872	4516
LOUISIANA	LAKE CHARLES	15	HOT	415	648	2829	3892
MASSACHUSETTES	BOSTON	16	COOL	1309	294	2866	4469
MAINE	PORTLAND	17	COLD	1735	235	2878	4848
MICHIGAN	DETROIT	18	COOL	1533	287	2867	4687
MINNESOTA	MINNEAPOLIS	19	COLD	1940	280	2878	5097
MISSOURI	KANSAS CITY	20	COOL	1150	436	2866	4452
MISSOURI	ST. LOUIS	21	COOL	1149	402	2862	4413
MONTANA	GREAT FALLS	22*	COLD	1879	218	2877	4973
NEBRASKA	OMAHA	23	COOL	1452	360	2870	4681
NORTH CAROLINA	RALEIGH	24	WARM	853	446	2847	4146
NORTH DAKOTA	BISMARCK	25	COLD	2215	253	2891	5359
NEW MEXICO	ALBUQUERQUE	26	COOL	1037	395	2867	4298
NEVADA	LAS VEGAS	27	WARM	640	548	2861	4049
NEW YORK	NEW YORK	28	COOL	1139	344	2861	4344
OHIO	CLEVELAND	29	COOL	1426	293	2862	4582
OHIO	DAYTON	30*	COOL	1317	336	2865	4517
OKLAHOMA	OKLAHOMA CITY	31	WARM	924	487	2861	4272
OREGON	MEDFORD	32	COOL	1244	294	2882	4420
OREGON	PORTLAND	33	COOL	1081	267	2872	4220
PENNSYLVANIA	PITTSBURG	34	COOL	1410	286	2865	4562
SOUTH CAROLINA	CHARLESTON	35	WARM	539	579	2835	3953
TENNESSEE	NASHVILLE	36	WARM	879	458	2852	4188
TEXAS	AMARILLO	37	COOL	1049	420	2864	4333
TEXAS	BROWNSVILLE	38	HOT	198	778	2813	3789
TEXAS	DALLAS	39	WARM	587	589	2844	4020
TEXAS	EL PASO	40	WARM	627	524	2846	3997
TEXAS	SAN ANTONIO	41	HOT	434	641	2838	3913
UTAH	SALT LAKE CITY	42	COOL	1371	311	2879	4561
WASHINGTON	DC	43	COOL	996	400	2852	4248
WASHINGTON	SEATTLE	44	COOL	1194	195	2860	4249
WISCONSIN	MADISON	45	COLD	1832	276	2877	4985
WYOMING	CHEYENNE	46	COLD	1746	215	2882	4843

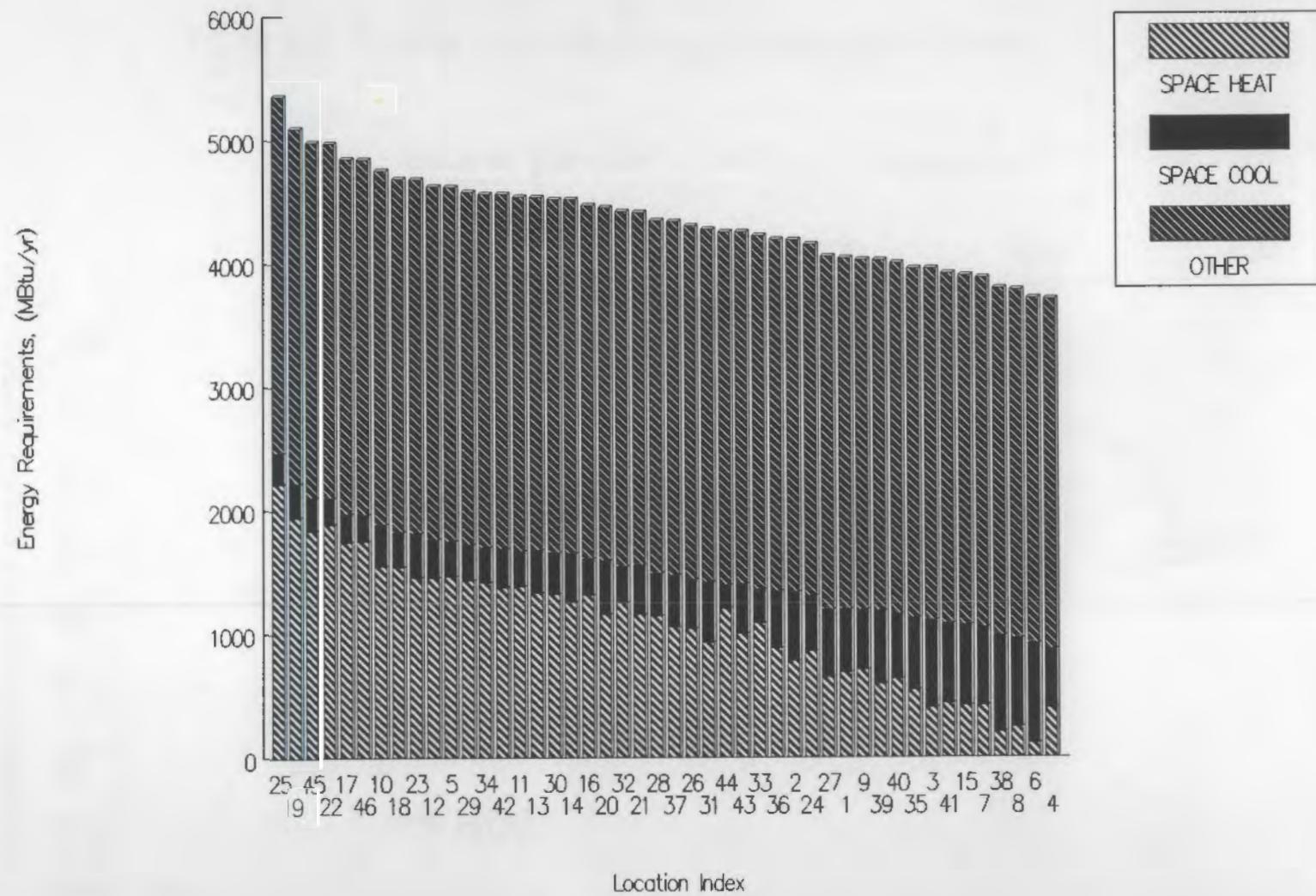


FIGURE 3.6. Impact of Climate Variation on End-Use Energy Consumption

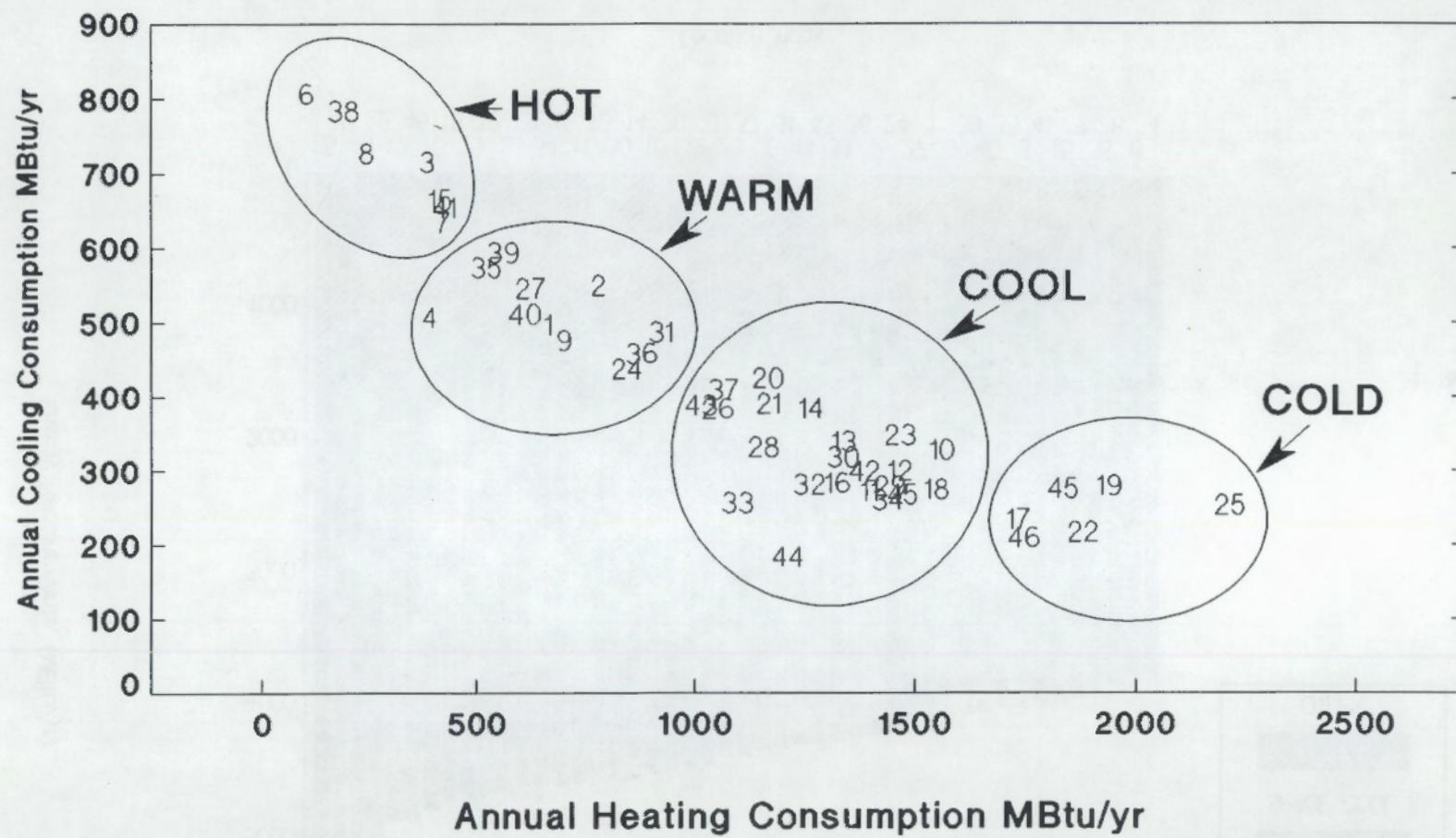


FIGURE 3.7. Climate Areas for the Simplified Analysis Method

The weather file selected to represent each climate domain and the locations falling within each domain are listed in Table 3.2 in the Climate Type column. An asterisk is placed by those sites selected to represent each of the four climate types for purposes of the simplified analysis method.

4.0 ENERGY CONSERVATION MEASURES FOR DINING HALLS

This section describes the energy conservation opportunities applicable to USAF dining halls and approaches to analyze their cost-effectiveness. The performance of many measures can be assessed in a generic fashion, while others are so site-specific that a case-by-case analysis is required. The section begins with an overview discussion of the types of conservation opportunities and analysis methods. The specific conservation opportunities covered by the simple analysis method are then described.

Conservation opportunities are organized by energy end-use category. Within each category, the magnitude and variability of energy consumption is first discussed to place the detailed measure descriptions that follow in context.

4.1 Food Preparation

Energy use by food preparation equipment was responsible for 34% of the electrical consumption of the prototype dining hall. Eleven percent was devoted to the baking ovens and equipment, and 23% to the mix of kettles, steam cookers, fryers, tilt grills, ovens, and griddles.

The best conservation advice here is to keep the equipment clean, maintained, and turned off when not in use. Energy management systems, which range in sophistication from simple time clocks to microcomputers, can affect sizable savings here, but so can employee effort. The metered data, however, indicated few instances of equipment being left on.

Posting and adhering to specific equipment start up procedures can produce considerable savings. In some cases, equipment is turned on well in advance of actual need, resulting not only in direct energy waste, but also in additional air conditioning loads as the space is heated.

Opportunities exist for savings by careful selection of food preparation equipment. New technologies, proper equipment sizing and placement, and efficiency features of food preparation equipment should be considered carefully before procurement. Examples of new technologies include microwave ovens, convection ovens, and infrared fryers. These technologies may affect

the appearance and quality of certain food types; consequently, they should be tested before routine acquisition.

Specification of several small pieces of equipment is generally more efficient than one large unit. This is because the capacity of equipment applied to a particular operation can be better matched to the actual requirement. In addition, this practice reduces reliance on a given device so that, in the event of equipment failure, the other units can be more heavily used until a repair is affected. The placement of equipment can affect overall efficiency by facilitating the removal of excess heat through exhaust hoods.

Certain features of food preparation devices can contribute to energy efficiency. Unfortunately, standardized test procedures for food preparation equipment efficiency are not currently available so it is difficult to verify vendor claims of energy savings. Standards and test procedures are currently being explored by the Electric Power Research Institute (EPRI), American Society for Testing and Materials (ASTM), and DOE, so verification of claimed energy savings should be possible in the future. However, some features can be judged intuitively, such as increased insulation on ovens, efficient motors for mixers, and covers for cookers and fryers.

The simple analysis procedure quantifies the value of energy savings from a 10% improvement in food preparation equipment efficiency, as well as a 10% reduction in food preparation equipment energy use during the unoccupied period. These reductions relate to use of more efficient food preparation equipment and better control of food preparation equipment, respectively. Savings are induced in two ways: directly through reduction of food preparation equipment energy consumption, and indirectly through reductions in space cooling requirements if the equipment is located in an air conditioned space. If adopted, these measures may increase space heating requirements because of the reduction in internal gains. The simple analysis method accounts for all of these effects, which vary from one climate domain to another.

4.2 Sanitation

Approximately 20% of the prototype energy consumption stems from sanitation requirements for water heating, dishwashing, and garbage disposals. The lion's share of this energy is to support the dishwashing function, where approximately half of the energy is required to provide 130°F water to the dishmachine, and half is used by the dishmachine and its dedicated booster heater.

Conversion of high-temperature dishwashers to low-temperature chemical sanitizers can result in savings, principally due to the elimination of the booster heater. This requires more thorough scraping of dishes before sanitizing and increased machine maintenance and chemical costs. The sanitizer may also discolor soft metals, such as pewter and aluminum. Nonetheless, the energy savings can be very substantial, on the order of 25 to 50% depending upon equipment type and use.

The other major area for sanitation energy savings is improving the energy efficiency of the domestic hot water system. Several technologies can be considered here, including insulation of hot water tanks and pipes, scheduling of the water heater and hot water circulation pump, waste heat recovery, and use of heat pump water heaters. The hot water tank and pipes in the prototype facility are insulated. If the pipes or tank are not insulated, savings on the order of 10% of water heating requirements can result.

Scheduling of the water heater and pump does not appear to be particularly effective for USAF dining halls due to the extended hours of operation and the need for hot water even in the early morning to support the baking function. Recovery of heat from refrigeration condensers is often practical, particularly if the compressors are close to the water supply. This technology is not recommended for retrofit applications, however, because of the need to install special condensers and heat exchangers customized to the existing equipment. This technology should be considered for new building applications, however.

The most promising method to reduce water heating requirements is the use of heat pump water heaters, particularly if water is now heated

electrically. The heat pump effectively moves the heat of warm air into water, with a coefficient of performance of 2.0 to 3.0. This means that electrical consumption of water heaters can be reduced by 50 to 65%. The performance is greatest when the water heater is situated in a warm area, such as the baking room. As an added benefit, the heat pump cools the air from which the heat is removed, acting the same as an air conditioner.

Another approach to reduce water heating requirements is to use point-of-use water heaters. These devices are located adjacent to the hot water fixtures and provide hot water on demand. In the case of the prototype dining hall, these water heaters are appropriate for the bathrooms. In this way, the energy required by the hot water circulation pump, as well as the heat loss of the pipes, can be conserved. For buildings yet to be constructed, additional savings can result by obviating the need for hot water pipes to these areas.

The simple analysis method includes one sanitation conservation measure related to retrofit of a heat pump water heater. This device is assumed to reduce the domestic heating requirement by 50%. The additional benefit of cooling for the kitchen is not quantified, as it is assumed that the heater is installed in an area that is not mechanically cooled. Nonetheless, the chefs will benefit by having a more comfortable workplace.

4.3 Refrigeration

The energy required for freezing and refrigeration is approximately 6% of the prototype dining hall electrical consumption. Although this is a small share, numerous energy conservation opportunities exist.

Periodic maintenance on refrigeration equipment should include ensuring tightness of door gaskets and closures, cleanliness of evaporator and condensing coils, and adequate freon levels.

For walk-in refrigeration units, products should not impede the air flow within the unit and around the fan. Loading periods can be scheduled to reduce the number of times the door is opened, and self-closing doors can be effective if they 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 can significantly reduce energy requirements by reducing compressor run-times by up to 30%. The effectiveness of these curtains is sometimes negated by employees who tie them back to provide easier access. With proper training management oversight, this should not be a problem.

Ice machines can be considerable energy consumers; however, in the prototype dining hall, only small machines are used. It is seldom cost-effective to replace machines solely for energy efficiency, but if a new machine is needed, consideration should be given to efficiency features. Single-head production machines are usually more efficient than smaller stacked heads. Coils should be kept clean on air-cooled machines, and valves should be checked on water-cooled machines to avoid losing condensing water, a common problem that can waste up to 100,000 gallons per month. While water-cooled equipment is more energy-efficient, the value of water and costs of disposal may offset these energy savings.

Passive double-walled heat exchangers can be used to cool refrigeration condensers and preheat domestic hot water. The feasibility and cost-effectiveness of this strategy in retrofit applications is very site-specific, and may void equipment warranties. The water heating load is sufficiently large to effectively use this "free-heat" most of the time.

Careful location of equipment compressors and condensers can significantly affect energy requirements. These components should be located in cool, shaded areas when possible. However, they should not be placed in mechanically cooled areas, as they will impose an additional burden on the space cooling equipment.

The simple analysis method includes two conservation measures related to refrigeration. First, a 10% reduction in refrigeration capacity is modeled to correspond to the saving resulting from installation of strip curtains on the walk-in coolers and freezer. Second, a 25% reduction of refrigeration system energy use is modeled to correspond to the improved efficiency of using water-cooled condensers for the walk-in units. As mentioned above, this feature can be combined with a heat recovery system to preheat domestic hot water. Additional reductions may be cost-effective for new buildings, as the

incremental costs of many of the above-mentioned conservation measures can be quite low. Furthermore, for slightly higher capital costs, more efficient compressors and condensers can be obtained.

4.4 Lighting

Lighting for the prototype dining hall consumes 16% of the electricity. Approximately 150 kWh/day are consumed in the kitchen area and 150 kWh/day in the west dining area by the fluorescent fixtures. The east dining area, with its decorative incandescent fixtures, consumes approximately 200 kWh/day.

Energy conservation opportunities for this end use can occur in three ways: 1) specifying more efficient lamps and fixtures, 2) reducing hours of operation, and 3) reducing lighting levels. Caution must be exercised here to ensure that lighting quantities and qualities are sufficient for the particular task requirements. New efficient technologies should be tested and evaluated in actual application prior to routine procurement.

The savings from use of more efficient lamps is revealed by the difference in lighting between the east and west dining areas. These areas are of similar size and use. However, the east dining area uses about 33% more energy for its incandescent lamps than do the fluorescent lamps in the west area. Energy-efficient fluorescent lamps now available require only 34 W for the equivalent lighting output of a 40-W lamp. Complete retrofit of such lamps can result in a 15% energy reduction. Replacing incandescent bulbs with screw-in fluorescent units, and replacing R or PAR floodlights with ER or ellipsoidal reflector floodlights, can be very cost-effective. Another efficiency improvement can be obtained by replacing the ballasts associated with fluorescent fixtures. New electronic ballasts are available that can reduce the energy consumption of a fluorescent fixture by 18 to 25%. These ballasts can also improve the quality of light by increasing the "flicker rate" so as to be unnoticeable. A third method to increase lighting efficiency is to use more efficient fixtures to focus and direct the light to the working surfaces. Use of parabolic reflectors and efficient lenses can reduce the number of fixtures required to illuminate a space. While this may be cost effective for

new designs, the capital costs of fixture replacements for energy savings alone are likely to be prohibitive.

The second method to reduce lighting energy requirements is through better scheduling. The hourly measurements as depicted in Figures 2.7 and 2.8 reveal that lighting during the early morning hours drops to only about 80% of the peak values. This is surprising, because no one is using the dining areas that constitute approximately two-thirds of the consumption for lighting during the early morning hours. Better lighting layouts and zone-controlled switches can facilitate better modulation of lighting energy to zone lighting requirements, if staff are trained to use the switches. Motion detectors are available to automatically extinguish lights when zones are unoccupied and these can be very cost effective if personnel habitually leave lights on. Considerable savings can also be achieved by effective use of daylight with fixtures which dim in response to available natural light. Although this strategy works best when incorporated into the initial design of the building to ensure effective natural light distribution, it can also be cost-effective for perimeter areas adjacent to windows for retrofit applications.

The third method to reduce lighting energy requirements is to reduce lighting levels. Many areas may be overlit in consideration of the task requirements and the escalating costs of electricity over the past decade. Care must be exercised to ensure that the lighting levels are maintained for safety; IES publishes guidelines for minimum safe lighting levels for particular tasks (IES 1981). In most dining establishments, considerable savings can be obtained through effective positioning of fixtures to achieve good atmosphere and contrast. If there are areas which are used for various activities, it may be desirable to use dimmers or multiple switches to permit lighting levels to be matched to the actual demands. One popular strategy is to separately wire and switch the middle tube of three tube fluorescent fixtures to provide three levels of light associated with the center tube, the two outside tubes, and finally all three tubes. Although such rewiring may be difficult to retrofit, the incremental costs for new designs are much smaller. This strategy would appear to be ideal for the dining hall, as lighting at night and in the early morning could be reduced by approximately

two-thirds for security purposes. Separate fixtures for the baking area could be kept on to ensure adequate lighting for this early-morning task.

4.5 Heating, Ventilating, and Air Conditioning

Heating, ventilating, and air conditioning accounted for approximately 33% of the prototype dining hall electrical consumption and over 80% of the steam energy consumption. Because these demands are dependent on climate, a sensitivity analysis was carried out. This analysis revealed that consumption for HVAC can constitute from 25 to 50% of dining hall energy requirements. As such, it is an area with considerable conservation potential and a wide variety of conservation opportunities. These three end uses are discussed together because the performance of each component is linked to the others.

Conservation opportunities can be classified into three areas:

- 1) modifications to the building shell, 2) use of more efficient HVAC equipment, and 3) incorporation of effective control strategies. Each of these areas is discussed below, to indicate how the heating, ventilation, and cooling end uses can be affected.

The thermal integrity of the building shell (roofs, walls, windows, doors, and floors) can be improved by reducing the thermal conductance (U-value). Such reductions will decrease space heating energy requirements and affect space cooling requirements. If the shell has low thermal integrity and internal heat gains are small, then space cooling requirements will decrease with thermal integrity improvements. However, if the shell has high thermal integrity and the internal gains are high, thermal integrity improvements may increase space cooling requirements. This is because the internal gains are "bottled-up" within the shell and more mechanical cooling will be needed to remove them as conductance through the shell is reduced.

Consequently, the optimal levels of shell thermal integrity are a complex function of space heating and cooling system efficiencies, internal gains, ventilation levels, and building microclimate. The ASEAM model does take each of these factors into account, so it can be very useful for site-specific optimization. For the simplified analysis method, the model is run for 11 different thermal integrity energy conservation measures. These are the

addition of R-11, R-19, and R-30 wall insulation; R-11, R-19, R-30, R-38, and R-49 roof insulation; and double, triple, and tinted window glazing. Review of the results confirms that diminishing returns set in as thermal integrity is improved; i.e., doubling the insulation values results in less than double the energy savings. The costs and savings of these measures have been calculated on an incremental basis so as to determine the optimal levels of thermal integrity for each climate and prototype configuration.

The capital costs of most thermal integrity improvements are substantially higher for retrofits than for new construction. For example, the cost of additional wall insulation for a building yet to be constructed is predominantly the cost of the materials, whereas for a retrofit it may be necessary to refinish the exterior or interior walls once the insulation is installed. In many cases the costs are prohibitive, or physical problems cannot be overcome.

Another type of shell improvement is the reduction of infiltration of outside air. In many buildings, air will leak through the wall joints, window frames, doors, and other penetrations. However in the case of the prototype dining hall, the building mechanical systems maintain a higher pressure indoors than outdoors, so at most times infiltration is minimal. With proper balancing, it would be expected that the kitchen would be negatively pressured relative to the dining areas, so that kitchen odors and heat are vented through exhaust fans rather than moving into the dining areas. In such a scenario, some infiltration to the kitchen from the outside would be expected, so attention to the "tightness" of the exterior walls would result in energy savings. However, because such measures are difficult to specify and measure, no attempt to quantify infiltration reductions has been made.

The second generic group of energy conservation measures associated with HVAC equipment is to increase the efficiency of specific components. These components include boilers, furnaces, chillers, fans, pumps, heat exchangers, pipes, ducts, and diffusers. The types and configuration of this equipment are dependent on the type of system, fuel sources, and building loads to be met. A detailed discussion of all the configurations and options for energy efficiency improvements of the HVAC system is beyond the scope of this report.

However, general areas for improvement are described below, and specific conservation measures applicable to the prototype characteristics are described in some detail.

The simple analysis method considers two HVAC system efficiency improvements. One is application of a more efficient chiller to satisfy the air conditioning needs. The coefficient of performance of this device was altered from a value of 1.9 determined by calibration of the base case model to a value of 2.5 that is more representative of modern efficient equipment. The other measure simulates the effect of using a variable air volume (VAV) HVAC system in place of the constant volume system in the prototype. Site-specific savings can be examined using the ASEAM model, once it is modified to reflect the actual system characteristics for the facility under study.

Unitary boilers or furnaces may be used to provide space heating and/or domestic water heating. If these devices are fossil-fueled, the combustion efficiencies should be tested periodically and the air/fuel ratios adjusted as appropriate. Efficiencies should be above 70% for well maintained equipment, resulting in less than 30% of the heat going up the flue or radiated within the mechanical room. Heat may be recovered from the flue using a heat exchanger to preheat domestic hot water or to preheat combustion air.

Chillers or packaged vapor-compression air-conditioning units are used to provide space cooling. The energy efficiency of these devices can be expressed as a coefficient of performance (COP). This coefficient is the ratio of the heat moved by the device over the energy input to the device. Hence, greater COPs correspond to more effective energy conversion and use. The equipment design has a large effect on the COP, as does the operation and maintenance of the equipment. Effective maintenance includes frequently lubricating bearings, replacing belts and filters, and ensuring that the freon charge is maintained and that controls are calibrated.

Another method to reduce space cooling energy requirements is to use economizers. These devices modulate the quantity of outside air introduced to the building according to outside temperature or enthalpy. If cooling is required and outside air temperatures are low, the economizer dampers open to

admit 100% outside air to provide "free" cooling. The dampers can also be controlled by an enthalpy sensor, which also considers the water content or humidity of the outside air. Although enthalpy economizers offer better efficiency, they are more expensive and difficult to calibrate and maintain.

Evaporative precoolers can also be attached to the air conditioning units to precool the air passing over the refrigeration condenser coils. The coils are able to give off more heat, thereby increasing the cooling capacity and reducing compressor run times. Evaporative precoolers cost approximately \$1000 and have payback periods of approximately 2 to 5 years depending upon climate and cooling load.

Two types of energy efficiency features for exhaust hoods should be considered--makeup air hoods and heat recovery hoods. The makeup air hoods provide outdoor air that moves across the underlying equipment and is subsequently exhausted. In this way, the need for heated or cooled air is reduced, thereby lowering the energy consumption for space heating and cooling. As the name implies, heat-recovery hoods transfer heat from the exhaust air to preheat the incoming air. Special provisions to remove grease accumulations from the heat exchanger coils must be incorporated to preclude fire risks or clogging of the exhaust ducts. In most applications, the makeup air hoods are more cost-effective and easier to maintain than the heat-recovery hoods.

The third area of HVAC conservation opportunities is equipment control. Set-back or "smart" thermostats, energy management control systems, and discriminator controls are examples of such opportunities. Set-back thermostats automatically reduce the thermostat settings during unoccupied periods to reduce heat losses through the building shell. Although these devices save energy, they can increase peak electrical demands when the building temperatures are increased. Hence, be sure to consider this effect if heating is provided electrically and demand charges are significant. More advanced "smart" thermostats are now available that determine the optimal time to turn the thermostat up to meet the interior temperature requirements. This time is dependent upon the outside and inside air temperatures, as well as the time that the building must be warmed up.

Discriminator controls are used by dual duct distribution systems to reset the deck temperatures for heating and cooling equipment. They sense the temperatures in each zone and determine the temperature of hot and cold ducts necessary to meet the loads of the hottest and coldest zones. Then, the heating and cooling coil temperatures are reset to meet this requirement. Energy savings result by minimizing the mixing of hot and cold air to provide temperature control for the intermediate zones.

Energy management control systems offer the features described above, as well as other features tailored to the specific equipment configurations. These systems typically measure numerous space conditions, consumption levels, equipment status, and building microclimate to automatically control the HVAC systems. Key concepts to keep in mind when evaluating these systems are simplicity and feedback diagnostics. In general, simple systems are more reliable and easier to maintain. More complex systems can offer greater energy efficiency; however, good feedback diagnostics are essential to ensure that the system is operating properly or to specify what maintenance may be required. Many complex applications do not operate properly because of unknown failures or complete overrides by maintenance staff not able to effect a correction or modification.

5.0 ENERGY SAVINGS SENSITIVITY ANALYSIS

This section discusses the analysis for many of the conservation opportunities described in Section 4. The effects of the energy conservation measures on both heating and electrical requirements are described in detail for the cool climate area. The impacts on total energy requirements, assuming an all electric dining hall, are then compared among the four climate types: hot, warm, cool, and cold. This will reveal how conservation measures affect heating and electrical requirements and how these, in turn, affect the performance of conservation measures in a given climate.

The energy conservation measures have been separated into load reduction measures and system efficiency improvements. Load reduction measures are those energy conservation opportunities that directly affect the heating, cooling, and non-HVAC electrical loads. System efficiency improvements are conservation measures associated with the equipment that is used to meet the loads of the building, such as the heating and air conditioning systems. These measures are distinguished for two reasons: 1) the efficiency of the heating and cooling systems can affect the overall savings of load reduction strategies, and 2) the size of the load can affect the savings of system efficiency improvements.

5.1 LOAD REDUCTION MEASURES

Twenty-two distinct load reduction conservation measures have been simulated for each of the four climate types. These measures fall into six categories: 1) window treatments, 2) roof insulation, 3) wall insulation, 4) lighting efficiency, 5) refrigeration efficiency, and 6) kitchen equipment efficiency. Figure 5.1 displays the change in the base case energy consumption induced in the heating and electrical requirements of the prototype dining hall for the load reduction measures.

5.1.1 Window Treatments

Three window treatments are considered:

- `wtriple` - triple glazing
- `wdouble` - double glazing
- `windcoeff` - tinting windows to reduce the shading coefficient to 0.5.

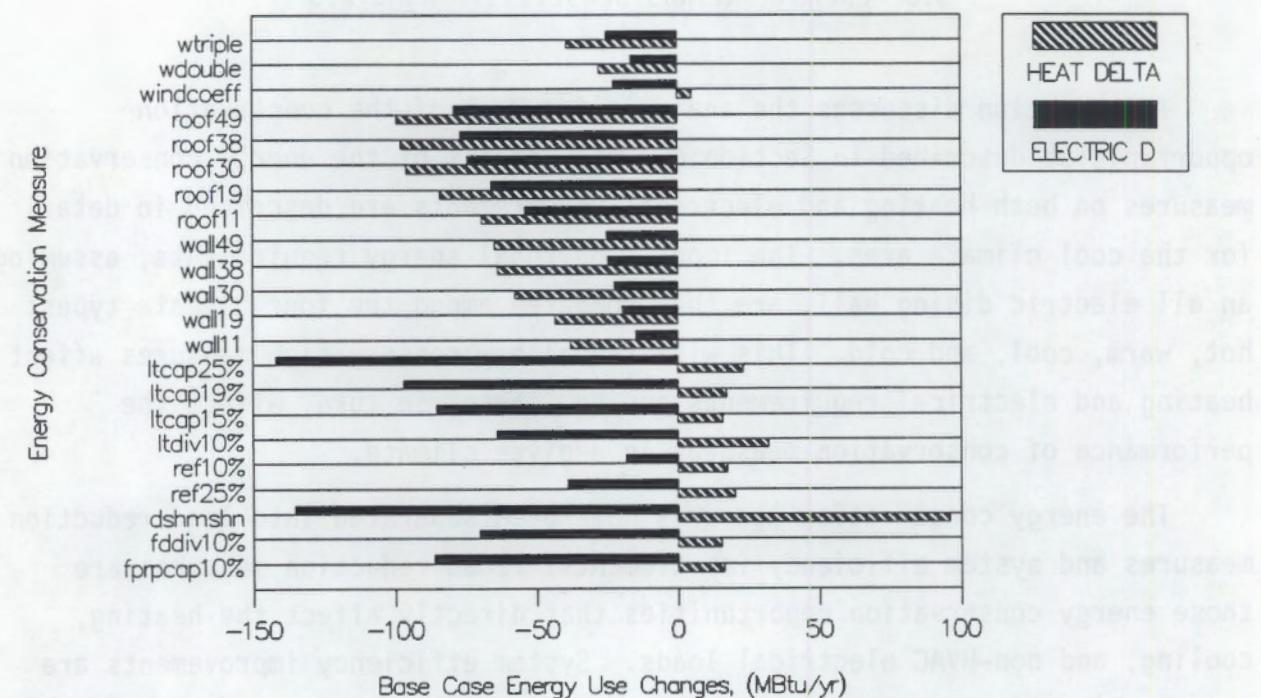


FIGURE 5.1. Energy Use Changes for USAF Dining Hall Load Reduction Measures

As shown in Figure 5.1, additional glazings reduce both heating and electrical air-conditioning requirements, while the tinting significantly reduces electrical requirements and slightly increases heating energy needs. These effects would be greater if the dining hall had more glazing. For new construction, glazing should be concentrated on the south and east facades, with appropriate overhangs and fins to minimize air conditioning loads and maximize useful solar gains.

5.1.2 Roof Insulation

The effect of five levels of roof insulation are indicated in Figure 5.1. These levels range from R-11 to R-49. Both heating and electrical requirements are reduced, and the diminishing returns of additional insulation are apparent by examining the incremental savings as the level is increased. The savings due to adding R-11 are fully 70% of the savings achieved by a more than four-fold increase to R-49 insulation. This has important consequences when the cost-effectiveness is evaluated.

5.1.3 Wall Insulation

Five levels of wall insulation are indicated in Figure 5.1, from adding R-11 to R-49. Energy savings are smaller than the comparable roof insulation effects, particularly for electrical demands. This is because the wall area is less than that of the roof, and the interior dishwashing area is not air-conditioned but heated. Heating needs for this interior area is reduced as roof insulation is added; however, adding wall insulation has no effect on this area.

5.1.4 Lighting Efficiency Improvements

The results of four lighting efficiency improvements are indicated in Figure 5.1. These are:

- ltcap25% - 25% capacity reduction (electronic ballasts and high efficiency fluorescent lamps)
- ltcap19% - 19% capacity reduction (use of parabolic reflectors)
- ltcap15% - 15% lighting reduction (high efficiency fluorescent lamps)
- ltdiv10% - reduction of lighting diversity by 10% (motion detectors to turn off lights during unoccupied periods).

These measures save significant amounts of electricity. However, they also significantly increase heating needs, because about 40% of the heat of the lights is useful to offset heating loads. This percentage is higher for the diversity reduction, because these savings occur predominantly during unoccupied periods when heating is more likely to be required.

5.1.5 Refrigeration Efficiency Improvements

Two levels of refrigeration efficiency improvements were simulated. These are:

- ref10% - reduction of refrigeration loads by 10% due the installation of strip curtains over the walk-in refrigerators
- ref25% - reduction of refrigeration loads by 25% from the use of water-cooled condensers.

These measures will increase heating loads only if the condensers are located inside the conditioned space. With external condensers, heating loads from the ref10% alternative will actually be reduced slightly due to the reduction of cold air entering the heated space.

5.1.6 Kitchen Equipment Efficiency Improvements

Three kitchen equipment efficiency improvement levels were simulated:

- dshmshn - use of a low-temperature dishmachine
- fddiv10% - reduction of food preparation equipment diversity factors by 10% by better operation and maintenance
- fprpcap10% - reduction of food preparation equipment capacity by a 10% improvement in appliance efficiency.

These measures provide large reductions in electrical demands and significantly increase heating demands. This is particularly true for the dishmachine, which is located in a highly ventilated area. Reduced waste heat from a low-temperature machine must be made up by the heating and ventilating unit to keep the dishwashing area warm.

5.2. SYSTEM ENERGY EFFICIENCY IMPROVEMENTS

The results of eight simulated improvements to system efficiency levels are indicated in Figure 5.2. These are:

- temp=55 - setback of heating season thermostat settings to 55°F during the unoccupied periods
- htpumphw - use of a heat pump water heater
- kitchcfm - 50% reduction of exhaust makeup air to the kitchen by using heat recovery or make-up air type exhaust hoods
- wsdp - use of a water source heat pump to provide space heating
- vav - use of a variable air volume heating and cooling system
- aahp - use of air-to-air heat pumps to provide space heating
- economizer - installation of an economizer cycle to reduce space cooling energy consumption

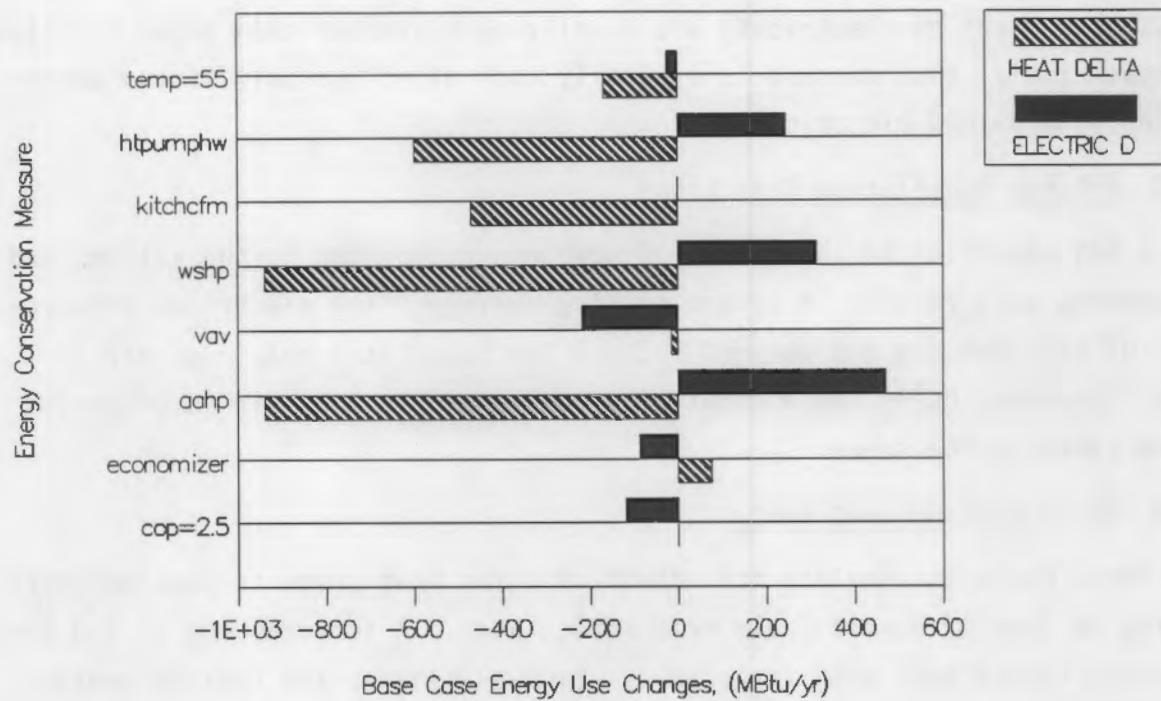


FIGURE 5.2. Annual Energy Use Changes for USAF Dining Hall for System Efficiency Improvements

- $\text{cop}=2.5$ - use of efficient air conditioning systems rather than the 1.9 COP unit in the prototype.

Each is discussed in the following paragraphs.

5.2.1 Set-Back Thermostats

The thermostat set-back strategy reduces both heating and air conditioning needs. The slight reduction in air conditioning requirements is caused by the effect of cooling off the building mass at night. This cooled mass will absorb some of the heat that would otherwise be removed by the air conditioning systems.

5.2.2 Hot Water Heat Pumps

Using an electric heat pump to provide for domestic hot water requirements reduces the demands for district heat, at the expense of significant increases in electrical requirements. Energy savings result from the fact that the

heat pump is over twice as efficient as the use of district heat. However, because the costs of electricity are usually much greater than those for steam or fossil fuels, this measure is typically cost-effective only if the water heating is provided electrically.

5.2.3 Kitchen Ventilation Reductions

A 50% reduction in the volume of makeup air provided to the kitchen and dishwashing area results in direct heating savings. The electrical requirements of the fans are not changed because the same total volume of air is moved. However, using these strategies, only half as much air is preheated before entering the space.

5.2.4 Space Heating Heat Pumps

These measures simulate the effect of using heat pumps to provide space heating in lieu of fossil fuels or district heat. A seasonal COP of 3.0 for the water source heat pump is assumed, which eliminates the heating energy requirements and increases electrical needs by 33% of this value. The air-to-air heat pump has an assumed seasonal COP of 2.0, increasing electrical needs by 50% of the base case heating requirements. In light of the differential heat and electric fuel costs, these measures are usually cost-effective only if the heating is provided electrically.

5.2.5 Variable Air Volume Heating and Cooling System

This energy conservation measure is applicable to new construction, where an alternative to the three system types in the prototype dining hall is installed. This system modulates the volume of heated and cooled air provided to the various dining hall zones in relation to the heating and cooling zone loads. In this way, fan energy requirements are significantly reduced. Heating increases slightly because of the reduced waste heat of the fans to offset space heating requirements.

5.2.6 Economizer Cycles

The use of an economizer to introduce outside air when it can be used to effectively cool the building reduces electrical needs due to the savings in air conditioning energy. If properly adjusted and maintained the measure

should not affect heating energy requirements. However, heating often increases somewhat due to equipment failures.

5.2.7 Improving the Air Conditioner COP

This measure simulates the savings obtained by increasing the seasonal COP of the air conditioner from 1.9 to 2.5. The value of 1.9 was obtained by calibrating the measurements from the prototype dining hall. The 2.5 value is more typical of performance to be expected, according to equipment manufacturers. This measure will decrease electrical requirements without affecting heating energy needs.

5.3 THE IMPACT OF CLIMATE TYPES ON ENERGY SAVINGS

This section describes how the interactions identified in Sections 5.1 and 5.2 affect the energy savings of the measures in various climate regimes. The performance of each energy conservation measure described above was estimated in each of four climate types. Tampa, Florida, was selected to represent hot climates; Atlanta, Georgia, warm climates; Dayton, Ohio, cool climates; and Great Falls, Montana, cold climates.

Figure 5.3 depicts the relative energy savings for each of 22 load reduction measures in each of the four climate regimes for an all-electric building. Because the efficiency of the heating system affects the performance of most conservation measures, the results would be somewhat different if fossil fuels or district heat were used. The relative energy use impacts are similar, and the simple analysis method accounts for this affect. This discussion is intended to give the reader an appreciation for the types of conservation measures most affected by climate change.

With the exception of the use of strip curtains on refrigerator doors in cold climates, all the measures result in energy savings. If the refrigeration condensers are located outdoors, even this measure will result in energy savings. On a percentage of savings basis, window tinting, refrigeration system improvements, and the use of low-temperature dishmachines is most affected by climate change. Insulation and lighting measures appear to be less sensitive to climate variation.

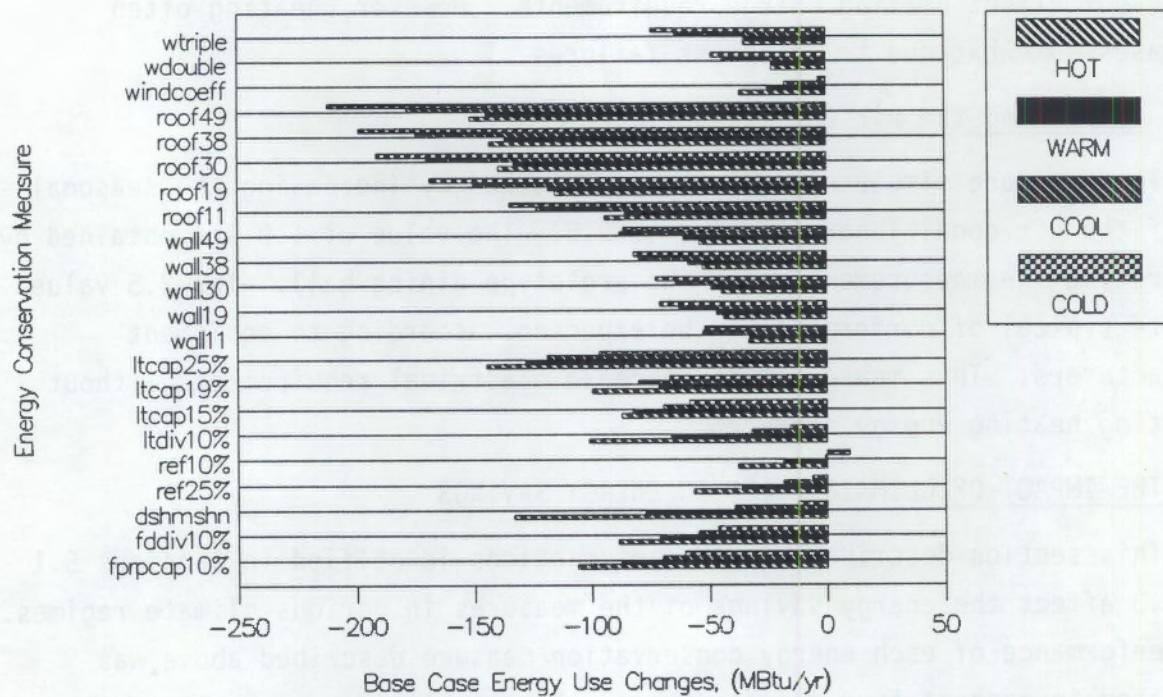


FIGURE 5.3. Impact of Load Reduction Measures on Total Energy Use in an All-Electric Building

It is interesting to note that the measures affecting the building envelope (walls, roofs, and windows) perform best in colder climates, while the measures affecting the efficiency of internal equipment perform best in the warmer climates. This stems primarily from the fact that the energy "wasted" by inefficient appliances is more effectively used to offset space heating in the coldest climates, resulting in lower net savings.

The impact of eight system efficiency improvements is depicted in Figure 5.4. The variable air volume system and economizer cooling are relatively insensitive to climate change, with the exception of the cool climate where the economizer savings are small. The other measures, with the exception of the more efficient air conditioners, perform significantly better in colder climates.

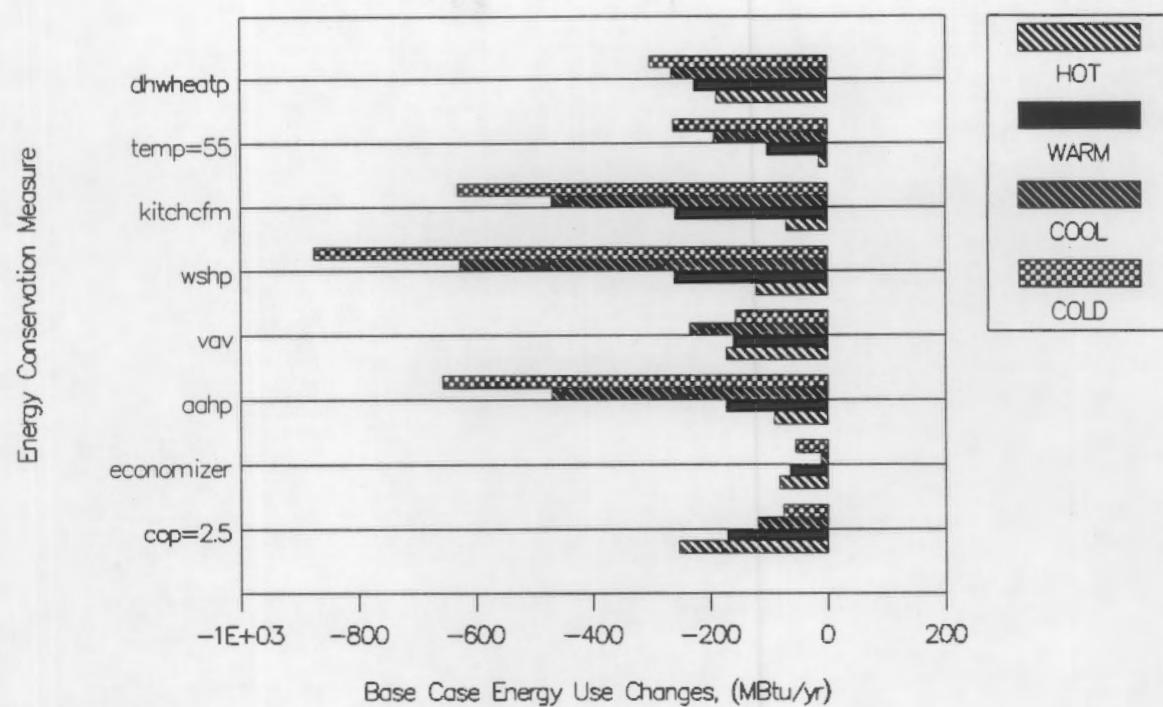


FIGURE 5.4. Impact of System Efficiency Improvement on Total Energy Use in an All-Electric Building

self, you will have to understand what you are trying to do and what you want to do with the model.

6.0 A SIMPLE METHOD TO DETERMINE ENERGY CONSERVATION MEASURE COST-EFFECTIVENESS

A principal goal of this study was to develop a simple method to determine the cost-effectiveness of energy conservation measures applicable to USAF dining halls. This effort was complicated by the dependency of energy savings on prototype configuration, climate, fuel costs, and escalation rates. To incorporate these sensitivities into the analysis, a set of tables was developed. Each table refers to a particular climate type and lists the energy savings estimates for specific conservation measures in the prototype dining hall.

This section describes the simple method for determining conservation measure cost-effectiveness and the assumptions upon which it is predicated. The method provides quick estimates of conservation measure cost-effectiveness and explicitly accounts for the major impacts of climate severity and energy costs. For more detailed and accurate estimates, the ASEAM 2.1 model should be calibrated to the specific building characteristics and conservation measure costs.

The first step of the method is to determine the appropriate climate type for the analysis. Table 3.2 and Figure 3.6 indicated the climate type for each of 46 weather locations. The site geographically closest to the building location generally should be selected. If several sites are close, it may be useful to compare typical weather-year data for the specific location with the weather summaries provided in the ASEAM documentation to select the best climate station. In most cases, however, these stations will be in the same climate type.

The ASEAM 2.1 model was run to provide estimates of the electrical and heat energy savings associated with each energy conservation measure in each of four climate types. Energy for heating is distinguished from nonheat electrical consumption, to incorporate both fossil and electrical energy costs into the energy savings calculation. If only electricity is used, then these savings can be combined before the economic analysis is performed.

The economic analysis is carried out using the appropriate form for the case under study. These forms include the results of the prototype energy analysis and spaces for entering an adjustment factor to account for the appropriate fuel conversion efficiency, fuel costs (FC), and uniform present worth factors (UPW). Multiplying the annual energy savings by the conversion efficiency and the fuel costs results in an estimate of the dollar value of energy savings in the first year. Multiplication of this value by the appropriate uniform present worth factor results in an estimate of the net-present-value (NPV) of these dollar savings over the expected life of the conservation measure. This calculation adjusts for the 7% discount rate (or time-value of money) mandated for federal investment relative to the escalation rate of fuel costs for each region of the country. Dividing the net-present-value of energy savings by the capital cost of the measure results in an estimate of the savings to investment ratio. According to the FEMP criterion, measures with a savings to investment greater than 1.0 are cost-effective.

If the cost/benefit ratios will be used to prioritize the opportunities, they should all be calculated using the same lifetime. Typically, 20 years is used as a lifetime for comparative purposes. Thus, for measures with useful lives of less than 20 years, such as efficient lights, the discounted replacement costs must be calculated. This procedure is discussed in detail in the Life Cycle Costing Manual for the Federal Energy Management Program (Ruegg 1987), and has been incorporated to develop the capital costs for the prototype conservation measures. This procedure is unnecessary if the intention is only to determine if a particular measure is cost-effective.

Worksheets to carry out the simplified energy analysis procedure for each climate type are presented in Tables 6.1 through 6.4. For each of 28 conservation opportunities, these sheets list the conservation measure description, the estimated useful life of the measure, and the annual energy savings in terms of million BTU/year. Section 6.1 describes how to select the appropriate worksheet and fill out the blanks in order to determine the savings-to-investment ratio (SIR) for each measure.

In order to be cost effective the savings-to-investment ratios must be greater than 1.0. However, since the energy saving of many measures is reduced

Table 6.1. Cold Climate Simplified Analysis Worksheet

ECO DESCRIPTION	USEFUL LIFE	ENERGY SAVINGS	ADJ. FACTOR	ENERGY COST	UPW FACTOR	NPV OF SAVINGS	TOTAL NPV	CAPITAL COST	SIR
REJUVENATION	20	95 HEAT 127 ELEC	—	—	—	—	—	—	—
10% FOOD PREP CAPACITY REDUCTION	20	-23 HEAT 84 ELEC	—	—	—	—	—	—	—
10% FOOD PREP DIVERSITY REDUCTION	20	-22 HEAT 68 ELEC	—	—	—	—	—	—	—
LOW-TEMPERATURE DISH MACHINE	20	-120 HEAT 132 ELEC	—	—	—	—	—	—	—
WATER-COOLED REFRIGERATION CONDENSER	20	0 HEAT 36 ELEC	—	—	—	—	—	—	—
CURTAIN ON WALK-IN REFRIGERATOR DOOR	3	0 HEAT 15 ELEC	—	—	—	—	—	—	—
MOTION DETECTOR FOR DINING LIGHTS	20	-42 HEAT 58 ELEC	—	—	—	—	—	—	—
HIGH-EFFICIENCY FLUORESCENT LIGHTS	4	-22 HEAT 81 ELEC	—	—	—	—	—	—	—
PARABOLIC REFLECTORS FOR LIGHTS	20	-25 HEAT 92 ELEC	—	—	—	—	—	—	—
ELECTRONIC BALLASTS FOR FLUORESCENT	20	-39 HEAT 135 ELEC	—	—	—	—	—	—	—
R-11 WALL INSULATION	20	42 HEAT 10 ELEC	—	—	—	—	—	—	—
R-11 TO R-19 WALL INSULATION	20	15 HEAT 4 ELEC	—	—	—	—	—	—	—
R-19 TO R-30 WALL INSULATION	20	5 HEAT 1 ELEC	—	—	—	—	—	—	—
R-11 ROOF INSULATION	20	92 HEAT 43 ELEC	—	—	—	—	—	—	—
R-11 TO R-19 ROOF INSULATION	20	25 HEAT 9 ELEC	—	—	—	—	—	—	—

Table 6.1. Cold Climate Simplified Analysis Worksheet (contd.)

ECO DESCRIPTION	USEFUL LIFE	ENERGY SAVINGS	ADJ. FACTOR	ENERGY COST	UPW FACTOR	NPV OF SAVINGS	TOTAL NPV	CAPITAL COST	SIR
R-19 TO R-30 ROOF INSULATION	20	16 HEAT 7 ELEC	—	—	—	—	—	—	—
R-30 TO R-38 ROOF INSULATION	20	5 HEAT 2 ELEC	—	—	—	—	—	—	—
R38 TO R-49 ROOF INSULATION	20	10 HEAT 3 ELEC	—	—	—	—	—	—	—
TINTED WINDOW GLAZING	7	-12 HEAT 16 ELEC	—	—	—	—	—	—	—
DOUBLE-PANE WINDOWS	20	37 HEAT 12 ELEC	—	—	—	—	—	—	—
DOUBLE TO TRIPLE-PANE WINDOWS	20	20 HEAT 6 ELEC	—	—	—	—	—	—	—
EFFICIENT AIR CONDITIONERS	20	0 HEAT 76 ELEC	—	—	—	—	—	—	—
ECONOMIZER CYCLE COOLING	10	0 HEAT 148 ELEC	—	—	—	—	—	—	—
AIR-TO-AIR HEAT PUMP	20	1314 HEAT -657 ELEC	—	—	—	—	—	—	—
VARIABLE AIR VOLUME SYSTEM	20	29 HEAT 129 ELEC	—	—	—	—	—	—	—
GROUND SOURCE HEAT PUMP	20	1314 HEAT -438 ELEC	—	—	—	—	—	—	—
MAKEUP AIR EXHAUST HOODS	20	630 HEAT 0 ELEC	—	—	—	—	—	—	—
NIGHT SETBACK THERMOSTATS	20	233 HEAT 29 ELEC	—	—	—	—	—	—	—
HOT WATER HEAT PUMP	10	606 HEAT -303 ELEC	—	—	—	—	—	—	—

Table 6.2. Cool Climate Simplified Analysis Worksheet

ECO DESCRIPTION	USEFUL LIFE	ENERGY SAVINGS	ADJ. FACTOR	ENERGY COST	UPW FACTOR	NPV OF SAVINGS	TOTAL NPV	CAPITAL COST	SIR
REJUVENATION	20	80 HEAT 141 ELEC	—	—	—	—	—	—	—
10% FOOD PREP CAPACITY REDUCTION	20	-16 HEAT 86 ELEC	—	—	—	—	—	—	—
10% FOOD PREP DIVERSITY REDUCTION	20	-15 HEAT 70 ELEC	—	—	—	—	—	—	—
LOW-TEMPERATURE DISH MACHINE	20	-96 HEAT 135 ELEC	—	—	—	—	—	—	—
WATER-COOLED REFRIGERATION CONDENSER	20	0 HEAT 39 ELEC	—	—	—	—	—	—	—
CURTAIN ON WALK-IN REFRIGERATOR DOOR	3	0 HEAT 18 ELEC	—	—	—	—	—	—	—
MOTION DETECTOR FOR DINING LIGHTS	20	-32 HEAT 64 ELEC	—	—	—	—	—	—	—
HIGH-EFFICIENCY FLUORESCENT LIGHTS	4	-16 HEAT 85 ELEC	—	—	—	—	—	—	—
PARBOLIC REFLECTORS FOR LIGHTS	20	-17 HEAT 97 ELEC	—	—	—	—	—	—	—
ELECTRONIC BALLASTS FOR FLUORESCENT	20	-23 HEAT 142 ELEC	—	—	—	—	—	—	—
R-11 WALL INSULATION	20	38 HEAT 15 ELEC	—	—	—	—	—	—	—
R-11 TO R-19 WALL INSULATION	20	10 HEAT 5 ELEC	—	—	—	—	—	—	—
R-19 TO R-30 WALL INSULATION	20	9 HEAT 2 ELEC	—	—	—	—	—	—	—
R-11 ROOF INSULATION	20	69 HEAT 54 ELEC	—	—	—	—	—	—	—
R-11 TO R-19 ROOF INSULATION	20	15 HEAT 12 ELEC	—	—	—	—	—	—	—

Table 6.2. Cool Climate Simplified Analysis Worksheet (contd.)

ECO DESCRIPTION	USEFUL LIFE	ENERGY SAVINGS	ADJ. FACTOR	ENERGY COST	UPW FACTOR	NPV OF SAVINGS	TOTAL NPV	CAPITAL COST	SIR
R-19 TO R-30 ROOF INSULATION	20	12 HEAT 8 ELEC	—	—	—	—	—	—	—
R-30 TO R-38 ROOF INSULATION	20	2 HEAT 3 ELEC	—	—	—	—	—	—	—
R38 TO R-49 ROOF INSULATION	20	1 HEAT 2 ELEC	—	—	—	—	—	—	—
TINTED WINDOW GLAZING	7	-5 HEAT 23 ELEC	—	—	—	—	—	—	—
DOUBLE-PANE WINDOWS	20	28 HEAT 16 ELEC	—	—	—	—	—	—	—
DOUBLE TO TRIPLE-PANE WINDOWS	20	11 HEAT 9 ELEC	—	—	—	—	—	—	—
EFFICIENT AIR CONDITIONERS	20	0 HEAT 120 ELEC	—	—	—	—	—	—	—
ECONOMIZER CYCLE COOLING	10	0 HEAT 88 ELEC	—	—	—	—	—	—	—
AIR-TO-AIR HEAT PUMP	20	940 HEAT -470 ELEC	—	—	—	—	—	—	—
VARIABLE AIR VOLUME SYSTEM	20	15 HEAT 220 ELEC	—	—	—	—	—	—	—
GROUND SOURCE HEAT PUMP	20	940 HEAT -313 ELEC	—	—	—	—	—	—	—
MAKEUP AIR EXHAUST HOODS	20	470 HEAT 0 ELEC	—	—	—	—	—	—	—
NIGHT SETBACK THERMOSTATS	20	168 HEAT 25 ELEC	—	—	—	—	—	—	—
HOT WATER HEAT PUMP	10	530 HEAT -265 ELEC	—	—	—	—	—	—	—

Table 6.3. Warm Climate Simplified Analysis Worksheet

ECO DESCRIPTION	USEFUL LIFE	ENERGY SAVINGS	ADJ. FACTOR	ENERGY COST	UPW FACTOR	NPV OF SAVINGS	TOTAL NPV	CAPITAL COST	SIR
REJUVENATION	20	69 HEAT 150 ELEC	—	—	—	—	—	—	—
10% FOOD PREP CAPACITY REDUCTION	20	-4 HEAT 92 ELEC	—	—	—	—	—	—	—
10% FOOD PREP DIVERSITY REDUCTION	20	-4 HEAT 75 ELEC	—	—	—	—	—	—	—
LOW-TEMPERATURE DISH MACHINE	20	-64 HEAT 141 ELEC	—	—	—	—	—	—	—
WATER-COOLED REFRIGERATION CONDENSER	20	0 HEAT 45 ELEC	—	—	—	—	—	—	—
CURTAIN ON WALK-IN REFRIGERATOR DOOR	3	0 HEAT 24 ELEC	—	—	—	—	—	—	—
MOTION DETECTOR FOR DINING LIGHTS	20	-11 HEAT 77 ELEC	—	—	—	—	—	—	—
HIGH-EFFICIENCY FLUORESCENT LIGHTS	4	-6 HEAT 89 ELEC	—	—	—	—	—	—	—
PARBOLIC REFLECTORS FOR LIGHTS	20	-5 HEAT 77 ELEC	—	—	—	—	—	—	—
ELECTRONIC BALLASTS FOR FLUORESCENT	20	-19 HEAT 147 ELEC	—	—	—	—	—	—	—
R-11 WALL INSULATION	20	18 HEAT 15 ELEC	—	—	—	—	—	—	—
R-11 TO R-19 WALL INSULATION	20	10 HEAT 4 ELEC	—	—	—	—	—	—	—
R-19 TO R-30 WALL INSULATION	20	9 HEAT 3 ELEC	—	—	—	—	—	—	—
R-11 ROOF INSULATION	20	30 HEAT 55 ELEC	—	—	—	—	—	—	—
R-11 TO R-19 ROOF INSULATION	20	20 HEAT 14 ELEC	—	—	—	—	—	—	—

Table 6.3. Warm Climate Simplified Analysis Worksheet (contd.)

ECO DESCRIPTION	USEFUL LIFE	ENERGY SAVINGS	ADJ. FACTOR	ENERGY COST	UPW FACTOR	NPV OF SAVINGS	TOTAL NPV	CAPITAL COST	SIR
R-19 TO R-30 ROOF INSULATION	20	4 HEAT 7 ELEC	—	—	—	—	—	—	—
R-30 TO R-38 ROOF INSULATION	20	3 HEAT 3 ELEC	—	—	—	—	—	—	—
R38 TO R-49 ROOF INSULATION	20	6 HEAT 3 ELEC	—	—	—	—	—	—	—
TINTED WINDOW GLAZING	7	-2 HEAT 27 ELEC	—	—	—	—	—	—	—
DOUBLE-PANE WINDOWS	20	10 HEAT 13 ELEC	—	—	—	—	—	—	—
DOUBLE TO TRIPLE-PANE WINDOWS	20	4 HEAT 8 ELEC	—	—	—	—	—	—	—
EFFICIENT AIR CONDITIONERS	20	0 HEAT 172 ELEC	—	—	—	—	—	—	—
ECONOMIZER CYCLE COOLING	10	0 HEAT 121 ELEC	—	—	—	—	—	—	—
AIR-TO-AIR HEAT PUMP	20	521 HEAT -348 ELEC	—	—	—	—	—	—	—
VARIABLE AIR VOLUME SYSTEM	20	33 HEAT 129 ELEC	—	—	—	—	—	—	—
GROUND SOURCE HEAT PUMP	20	521 HEAT -261 ELEC	—	—	—	—	—	—	—
MAKEUP AIR EXHAUST HOODS	20	260 HEAT 0 ELEC	—	—	—	—	—	—	—
NIGHT SETBACK THERMOSTATS	20	89 HEAT 14 ELEC	—	—	—	—	—	—	—
HOT WATER HEAT PUMP	10	454 HEAT -227 ELEC	—	—	—	—	—	—	—

Table 6.4. Hot Climate Simplified Analysis Worksheet

ECO DESCRIPTION	USEFUL LIFE	ENERGY SAVINGS	ADJ. FACTOR	ENERGY COST	UPW FACTOR	NPV OF SAVINGS	TOTAL NPV	CAPITAL COST	SIR
REJUVENATION	20	52 HEAT 163 ELEC	—	—	—	—	—	—	—
10% FOOD PREP CAPACITY REDUCTION	20	7 HEAT 99 ELEC	—	—	—	—	—	—	—
10% FOOD PREP DIVERSITY REDUCTION	20	7 HEAT 82 ELEC	—	—	—	—	—	—	—
LOW-TEMPERATURE DISH MACHINE	20	-15 HEAT 148 ELEC	—	—	—	—	—	—	—
WATER-COOLED REFRIGERATION CONDENSER	20	0 HEAT 52 ELEC	—	—	—	—	—	—	—
CURTAIN ON WALK-IN REFRIGERATOR DOOR	3	0 HEAT 31 ELEC	—	—	—	—	—	—	—
MOTION DETECTOR FOR DINING LIGHTS	20	6 HEAT 95 ELEC	—	—	—	—	—	—	—
HIGH-EFFICIENCY FLUORESCENT LIGHTS	4	-8 HEAT 95 ELEC	—	—	—	—	—	—	—
PARBOLIC REFLECTORS FOR LIGHTS	20	-8 HEAT 108 ELEC	—	—	—	—	—	—	—
ELECTRONIC BALLASTS FOR FLUORESCENT	20	-14 HEAT 159 ELEC	—	—	—	—	—	—	—
R-11 WALL INSULATION	20	14 HEAT 19 ELEC	—	—	—	—	—	—	—
R-11 TO R-19 WALL INSULATION	20	7 HEAT 4 ELEC	—	—	—	—	—	—	—
R-19 TO R-30 WALL INSULATION	20	3 HEAT 5 ELEC	—	—	—	—	—	—	—
R-11 ROOF INSULATION	20	22 HEAT 73 ELEC	—	—	—	—	—	—	—
R-11 TO R-19 ROOF INSULATION	20	3 HEAT 17 ELEC	—	—	—	—	—	—	—

Table 6.4. Hot Climate Simplified Analysis Worksheet (contd.)

ECO DESCRIPTION	USEFUL LIFE	ENERGY SAVINGS	ADJ. FACTOR	ENERGY COST	UPW FACTOR	NPV OF SAVINGS	TOTAL NPV	CAPITAL COST	SIR
R-19 TO R-30 ROOF INSULATION	20	13 HEAT 12 ELEC	—	—	—	—	—	—	—
R-30 TO R-38 ROOF INSULATION	20	1 HEAT 3 ELEC	—	—	—	—	—	—	—
R38 TO R-49 ROOF INSULATION	20	4 HEAT 4 ELEC	—	—	—	—	—	—	—
TINTED WINDOW GLAZING	7	-1 HEAT 37 ELEC	—	—	—	—	—	—	—
DOUBLE-PANE WINDOWS	20	6 HEAT 17 ELEC	—	—	—	—	—	—	—
DOUBLE TO TRIPLE-PANE WINDOWS	20	7 HEAT 28 ELEC	—	—	—	—	—	—	—
EFFICIENT AIR CONDITIONERS	20	0 HEAT 254 ELEC	—	—	—	—	—	—	—
ECONOMIZER CYCLE COOLING	10	0 HEAT 111 ELEC	—	—	—	—	—	—	—
AIR-TO-AIR HEAT PUMP	20	182 HEAT -91 ELEC	—	—	—	—	—	—	—
VARIABLE AIR VOLUME SYSTEM	20	45 HEAT 128 ELEC	—	—	—	—	—	—	—
GROUND SOURCE HEAT PUMP	20	182 HEAT -61 ELEC	—	—	—	—	—	—	—
MAKEUP AIR EXHAUST HOODS	20	70 HEAT 0 ELEC	—	—	—	—	—	—	—
NIGHT SETBACK THERMOSTATS	20	14 HEAT 1 ELEC	—	—	—	—	—	—	—
HOT WATER HEAT PUMP	10	379 HEAT -189 ELEC	—	—	—	—	—	—	—

as other measures are implemented, a SIR of greater than 1.3 may be necessary to assure cost-effectiveness.

Another way to use these worksheets is to calculate the net present value of energy savings and compare this to the total capital costs of the measure. So long as the net present value of energy savings exceeds the total capital costs, the measures are cost effective according to the FEMP criteria.

A sample application of these forms is provided below to demonstrate their use, and to develop summary conclusions and recommendations for cost effective energy efficiency improvements.

6.1 SAMPLE APPLICATIONS OF THE SIMPLE ANALYSIS METHOD

The results of the energy analysis using fuel costs and escalation rates for DOE Region 3 are shown in Tables 6.5 through 6.8 for an all-electric dining hall, and in Tables 6.9 through 6.12 for a dining hall with district heat. The costs are estimated for application to a new building, and have been properly calculated assuming a common lifetime of 20 years and a discount rate of 7%.

The column titled ADJ. FACTOR is included to account for specific performance adjustments. The most common adjustment will be for the fuel conversion efficiency. The energy savings listed on the forms assume 100% conversion efficiencies. In most cases the actual efficiency of heating equipment will be considerably lower. For district heat, an efficiency of 50% may be appropriate to account for the efficiency of the steam plant and distribution system. For standard oil-fired furnaces or boilers, an efficiency of 65% is often used. For standard natural gas furnaces and boilers, a value of 70% can be used. If a heat pump is used, an efficiency of 250% is possible, because only 1 W of power is needed to provide 2.5 W of heat. The appropriate adjustment factor is the reciprocal of the efficiency, or $1/E$.

A second type of adjustment that may be made relates to the interaction of energy conservation measures. For example, the performance of load reduction measures, such as additional insulation, is dependent upon the

TABLE 6.5. Sample Analysis for Cold Climate, Region 3 Fuel Costs, Electric Heat, New Building

ECO DESCRIPTION	USEFUL LIFE	ENERGY SAVINGS	ADJ. FACTOR	ENERGY COST	UPW FACTOR	NPV OF SAVINGS	TOTAL NPV	CAPITAL COST	SIR
REJUVENATION	20	95 HEAT	1	19.79	9.95	18706			
		127 ELEC	1	19.79	9.95	25008	43714	15500	NA
10% FOOD PREP CAPACITY REDUCTION	20	-23 HEAT	1	19.79	9.95	-4529			
		84 ELEC	1	19.79	9.95	16540	12012	10000	1.2
10% FOOD PREP DIVERSITY REDUCTION	20	-22 HEAT	1	19.79	9.95	-4332			
		68 ELEC	1	19.79	9.95	13390	9058	10000	0.9
LOW-TEMPERATURE DISH MACHINE	20	-120 HEAT	1	19.79	9.95	-23629			
		132 ELEC	1	19.79	9.95	25992	2363	11000	0.2
WATER-COOLED REFRIGERATION CONDENSER	20	0 HEAT	1	19.79	9.95	0			
		36 ELEC	1	19.79	9.95	7089	7089	3500	2.0
CURTAIN ON WALK-IN REFRIGERATOR DOOR	3	0 HEAT	1	19.79	9.95	0			
		15 ELEC	1	19.79	9.95	2954	2954	2500	1.2
MOTION DETECTOR FOR DINING LIGHTS	20	-42 HEAT	1	19.79	9.95	-8270			
		58 ELEC	1	19.79	9.95	11421	3151	2000	1.6
HIGH-EFFICIENCY FLUORESCENT LIGHTS	4	-22 HEAT	1	19.79	9.95	-4332			
		81 ELEC	1	19.79	9.95	15950	11618	6500	1.8
PARBOLIC REFLECTORS FOR LIGHTS	20	-25 HEAT	1	19.79	9.95	-4923			
		92 ELEC	1	19.79	9.95	18116	13193	5500	2.4
ELECTRONIC BALLASTS FOR FLUORESCENT	20	-39 HEAT	1	19.79	9.95	-7680			
		135 ELEC	1	19.79	9.95	26583	18903	14000	1.4
R-11 WALL INSULATION	20	42 HEAT	1	19.79	9.95	8270			
		10 ELEC	1	19.79	9.95	1969	10239	1500	6.8
R-11 TO R-19 WALL INSULATION	20	15 HEAT	1	19.79	9.95	2954			
		4 ELEC	1	19.79	9.95	788	3741	800	4.7
R-19 TO R-30 WALL INSULATION	20	5 HEAT	1	19.79	9.95	985			
		1 ELEC	1	19.79	9.95	197	1181	800	1.5
R-11 ROOF INSULATION	20	92 HEAT	1	19.79	9.95	18116			
		43 ELEC	1	19.79	9.95	8467	26583	5400	4.9
R-11 TO R-19 ROOF INSULATION	20	25 HEAT	1	19.79	9.95	4923			
		9 ELEC	1	19.79	9.95	1772	6695	1400	4.8
R-19 TO R-30 ROOF INSULATION	20	16 HEAT	1	19.79	9.95	3151			
		7 ELEC	1	19.79	9.95	1378	4529	3100	1.5
R-30 TO R-38 ROOF INSULATION	20	5 HEAT	1	19.79	9.95	985			
		2 ELEC	1	19.79	9.95	394	1378	3100	0.4
R38 TO R-49 ROOF INSULATION	20	10 HEAT	1	19.79	9.95	1969			
		3 ELEC	1	19.79	9.95	591	2560	3600	0.7
TINTED WINDOW GLAZING	7	-12 HEAT	1	19.79	9.95	-2363			
		16 ELEC	1	19.79	9.95	3151	788	5000	0.2
DOUBLE-PANE WINDOWS	20	37 HEAT	1	19.79	9.95	7286			
		12 ELEC	1	19.79	9.95	2363	9649	1600	6.0
DOUBLE TO TRIPLE-PANE WINDOWS	20	20 HEAT	1	19.79	9.95	3938			
		6 ELEC	1	19.79	9.95	1181	5120	400	12.8
EFFICIENT AIR CONDITIONERS	20	0 HEAT	1	19.79	9.95	0			
		76 ELEC	1	19.79	9.95	14965	14965	5000	3.0
ECONOMIZER CYCLE COOLING	10	0 HEAT	1	19.79	9.95	0			
		148 ELEC	1	19.79	9.95	29143	29143	3000	9.7
AIR-TO-AIR HEAT PUMP	20	1314 HEAT	1	19.79	9.95	258740			
		-657 ELEC	1	19.79	9.95	-129370	129370	13200	9.8
VARIABLE AIR VOLUME SYSTEM	20	29 HEAT	1	19.79	9.95	5710			
		129 ELEC	1	19.79	9.95	25401	31112	20000	1.6
GROUND SOURCE HEAT PUMP	20	1314 HEAT	1	19.79	9.95	258740			
		-438 ELEC	1	19.79	9.95	-86247	172494	17000	10.1
MAKEUP AIR EXHAUST HOODS	20	630 HEAT	1	19.79	9.95	124054			
		0 ELEC	1	19.79	9.95	0	124054	10000	12.4
NIGHT SETBACK THERMOSTATS	20	233 HEAT	1	19.79	9.95	45880			
		29 ELEC	1	19.79	9.95	5710	51591	1000	51.6
HOT WATER HEAT PUMP	10	606 HEAT	1	19.79	9.95	119328			
		-303 ELEC	1	19.79	9.95	-59664	59664	7200	8.3

TABLE 6.6. Sample Analysis for Cool Climate, Region 3 Fuel Costs, Electric Heat, New Building

ECO DESCRIPTION	USEFUL LIFE	ENERGY SAVINGS	ADJ. FACTOR	ENERGY COST	UPW FACTOR	NPV OF SAVINGS	TOTAL NPV	CAPITAL COST	SIR
REJUVENATION	20	80 HEAT	1	19.79	9.95	15753			
		141 ELEC	1	19.79	9.95	27823	43576	15500	NA
10% FOOD PREP CAPACITY REDUCTION	20	-16 HEAT	1	19.79	9.95	-3151			
		86 ELEC	1	19.79	9.95	16934	13784	10000	1.4
10% FOOD PREP DIVERSITY REDUCTION	20	-15 HEAT	1	19.79	9.95	-2954			
		70 ELEC	1	19.79	9.95	13784	10830	10000	1.1
LOW-TEMPERATURE DISH MACHINE	20	-96 HEAT	1	19.79	9.95	-18903			
		135 ELEC	1	19.79	9.95	26583	7680	11000	0.7
WATER-COOLED REFRIGERATION CONDENSER	20	0 HEAT	1	19.79	9.95	0			
		39 ELEC	1	19.79	9.95	7680	7680	3500	2.2
CURTAIN ON WALK-IN REFRIGERATOR DOOR	3	0 HEAT	1	19.79	9.95	0			
		18 ELEC	1	19.79	9.95	3544	3544	2500	1.4
MOTION DETECTOR FOR DINING LIGHTS	20	-32 HEAT	1	19.79	9.95	-6301			
		64 ELEC	1	19.79	9.95	12602	6301	2000	3.2
HIGH-EFFICIENCY FLUORESCENT LIGHTS	4	-16 HEAT	1	19.79	9.95	-3151			
		85 ELEC	1	19.79	9.95	16737	13587	6500	2.1
PARBOLIC REFLECTORS FOR LIGHTS	20	-17 HEAT	1	19.79	9.95	-3347			
		97 ELEC	1	19.79	9.95	19100	15753	5500	2.9
ELECTRONIC BALLASTS FOR FLUORESCENT	20	-23 HEAT	1	19.79	9.95	-4529			
		142 ELEC	1	19.79	9.95	27961	23432	14000	1.7
R-11 WALL INSULATION	20	38 HEAT	1	19.79	9.95	7483			
		15 ELEC	1	19.79	9.95	2954	10436	1500	7.0
R-11 TO R-19 WALL INSULATION	20	10 HEAT	1	19.79	9.95	1969			
		5 ELEC	1	19.79	9.95	985	2954	800	3.7
R-19 TO R-30 WALL INSULATION	20	9 HEAT	1	19.79	9.95	1772			
		2 ELEC	1	19.79	9.95	394	2166	800	2.7
R-11 ROOF INSULATION	20	69 HEAT	1	19.79	9.95	13587			
		54 ELEC	1	19.79	9.95	10633	24220	5400	4.5
R-11 TO R-19 ROOF INSULATION	20	15 HEAT	1	19.79	9.95	2954			
		12 ELEC	1	19.79	9.95	2363	5317	1400	3.8
R-19 TO R-30 ROOF INSULATION	20	12 HEAT	1	19.79	9.95	2363			
		8 ELEC	1	19.79	9.95	1575	3938	3100	1.3
R-30 TO R-38 ROOF INSULATION	20	2 HEAT	1	19.79	9.95	394			
		3 ELEC	1	19.79	9.95	591	985	3100	0.3
R38 TO R-49 ROOF INSULATION	20	1 HEAT	1	19.79	9.95	197			
		2 ELEC	1	19.79	9.95	394	591	3600	0.2
TINTED WINDOW GLAZING	7	-5 HEAT	1	19.79	9.95	-985			
		23 ELEC	1	19.79	9.95	4529	3544	5000	0.7
DOUBLE-PANE WINDOWS	20	28 HEAT	1	19.79	9.95	5513			
		16 ELEC	1	19.79	9.95	3151	8664	1600	5.4
DOUBLE TO TRIPLE-PANE WINDOWS	20	11 HEAT	1	19.79	9.95	2166			
		9 ELEC	1	19.79	9.95	1772	3938	400	9.8
EFFICIENT AIR CONDITIONERS	20	0 HEAT	1	19.79	9.95	0			
		120 ELEC	1	19.79	9.95	23629	23629	5000	4.7
ECONOMIZER CYCLE COOLING	10	0 HEAT	1	19.79	9.95	0			
		88 ELEC	1	19.79	9.95	17328	17328	3000	5.8
AIR-TO-AIR HEAT PUMP	20	940 HEAT	1	19.79	9.95	185096			
		-470 ELEC	1	19.79	9.95	-92548	92548	13200	7.0
VARIABLE AIR VOLUME SYSTEM	20	15 HEAT	1	19.79	9.95	2954			
		220 ELEC	1	19.79	9.95	43320	46274	20000	2.3
GROUND SOURCE HEAT PUMP	20	940 HEAT	1	19.79	9.95	185096			
		-313 ELEC	1	19.79	9.95	-61633	123463	17000	7.3
MAKEUP AIR EXHAUST HOODS	20	470 HEAT	1	19.79	9.95	92548			
		0 ELEC	1	19.79	9.95	0	92548	10000	9.3
NIGHT SETBACK THERMOSTATS	20	168 HEAT	1	19.79	9.95	33081			
		25 ELEC	1	19.79	9.95	4923	38004	1000	38.0
HOT WATER HEAT PUMP	10	530 HEAT	1	19.79	9.95	104363			
		-265 ELEC	1	19.79	9.95	-52181	52181	7200	7.2

TABLE 6.7. Sample Analysis for Warm Climate, Region 3 Fuel Costs, Electric Heat, New Building

ECO DESCRIPTION	USEFUL LIFE	ENERGY SAVINGS	ADJ. FACTOR	ENERGY COST	UPW FACTOR	NPV OF SAVINGS	TOTAL NPV	CAPITAL COST	SIR
REJUVENATION	20	69 HEAT 150 ELEC	1 1	19.79 19.79	11.67 11.67	15936 34642	50578	15500	NA
10% FOOD PREP CAPACITY REDUCTION	20	-4 HEAT 92 ELEC	1 1	19.79 19.79	11.67 11.67	-924 21247	20324	10000	2.0
10% FOOD PREP DIVERSITY REDUCTION	20	-4 HEAT 75 ELEC	1 1	19.79 19.79	11.67 11.67	-924 17321	16397	10000	1.6
LOW-TEMPERATURE DISH MACHINE	20	-64 HEAT 141 ELEC	1 1	19.79 19.79	11.67 11.67	-14781 32564	17783	11000	1.6
WATER-COOLED REFRIGERATION CONDENSER	20	0 HEAT 45 ELEC	1 1	19.79 19.79	11.67 11.67	0 10393	10393	3500	3.0
CURTAIN ON WALK-IN REFRIGERATOR DOOR	3	0 HEAT 24 ELEC	1 1	19.79 19.79	11.67 11.67	0 5543	5543	2500	2.2
MOTION DETECTOR FOR DINING LIGHTS	20	-11 HEAT 77 ELEC	1 1	19.79 19.79	11.67 11.67	-2540 17783	15243	2000	7.6
HIGH-EFFICIENCY FLUORESCENT LIGHTS	4	-6 HEAT 89 ELEC	1 1	19.79 19.79	11.67 11.67	-1386 20554	19169	6500	2.9
PARBOLIC REFLECTORS FOR LIGHTS	20	-5 HEAT 77 ELEC	1 1	19.79 19.79	11.67 11.67	-1155 17783	16628	5500	3.0
ELECTRONIC BALLASTS FOR FLUORESCENT	20	-19 HEAT 147 ELEC	1 1	19.79 19.79	11.67 11.67	-4388 33950	29562	14000	2.1
R-11 WALL INSULATION	20	18 HEAT 15 ELEC	1 1	19.79 19.79	11.67 11.67	4157 3464	7621	1500	5.1
R-11 TO R-19 WALL INSULATION	20	10 HEAT 4 ELEC	1 1	19.79 19.79	11.67 11.67	2309 924	3233	800	4.0
R-19 TO R-30 WALL INSULATION	20	9 HEAT 3 ELEC	1 1	19.79 19.79	11.67 11.67	2079 693	2771	800	3.5
R-11 ROOF INSULATION	20	30 HEAT 55 ELEC	1 1	19.79 19.79	11.67 11.67	6928 12702	19631	5400	3.6
R-11 TO R-19 ROOF INSULATION	20	20 HEAT 14 ELEC	1 1	19.79 19.79	11.67 11.67	4619 3233	7852	1400	5.6
R-19 TO R-30 ROOF INSULATION	20	4 HEAT 7 ELEC	1 1	19.79 19.79	11.67 11.67	924 1617	2540	3100	0.8
R-30 TO R-38 ROOF INSULATION	20	3 HEAT 3 ELEC	1 1	19.79 19.79	11.67 11.67	693 693	1386	3100	0.4
R38 TO R-49 ROOF INSULATION	20	6 HEAT 3 ELEC	1 1	19.79 19.79	11.67 11.67	1386 693	2079	3600	0.6
TINTED WINDOW GLAZING	7	-2 HEAT 27 ELEC	1 1	19.79 19.79	11.67 11.67	-462 6236	5774	5000	1.2
DOUBLE-PANE WINDOWS	20	10 HEAT 13 ELEC	1 1	19.79 19.79	11.67 11.67	2309 3002	5312	1600	3.3
DOUBLE TO TRIPLE-PANE WINDOWS	20	4 HEAT 8 ELEC	1 1	19.79 19.79	11.67 11.67	924 1848	2771	400	6.9
EFFICIENT AIR CONDITIONERS	20	0 HEAT 172 ELEC	1 1	19.79 19.79	11.67 11.67	0 39723	39723	5000	7.9
ECONOMIZER CYCLE COOLING	10	0 HEAT 121 ELEC	1 1	19.79 19.79	11.67 11.67	0 27945	27945	3000	9.3
AIR-TO-AIR HEAT PUMP	20	521 HEAT -348 ELEC	1 1	19.79 19.79	11.67 11.67	120325 -80370	39954	13200	3.0
VARIABLE AIR VOLUME SYSTEM	20	33 HEAT 129 ELEC	1 1	19.79 19.79	11.67 11.67	7621 29792	37414	20000	1.9
GROUND SOURCE HEAT PUMP	20	521 HEAT -261 ELEC	1 1	19.79 19.79	11.67 11.67	120325 -60278	60047	17000	3.5
MAKEUP AIR EXHAUST HOODS	20	260 HEAT 0 ELEC	1 1	19.79 19.79	11.67 11.67	60047 0	60047	10000	6.1
NIGHT SETBACK THERMOSTATS	20	89 HEAT 14 ELEC	1 1	19.79 19.79	11.67 11.67	20554 3233	23788	1000	23.8
HOT WATER HEAT PUMP	10	454 HEAT -227 ELEC	1 1	19.79 19.79	11.67 11.67	104851 -52425	52425	7200	7.3

TABLE 6.8. Sample Analysis for Hot Climate, Region 3 Fuel Costs, Electric Heat, New Building

ECO DESCRIPTION	USEFUL LIFE	ENERGY SAVINGS	ADJ. FACTOR	ENERGY COST	UPW FACTOR	NPV OF SAVINGS	TOTAL NPV	CAPITAL COST	SIR
REJUVENATION	20	52 HEAT 163 ELEC	1 1	19.79 19.79	9.95 9.95	10239 32096	42336	15500	NA
10% FOOD PREP CAPACITY REDUCTION	20	7 HEAT 99 ELEC	1 1	19.79 19.79	9.95 9.95	1378 19494	20873	10000	2.1
10% FOOD PREP DIVERSITY REDUCTION	20	7 HEAT 82 ELEC	1 1	19.79 19.79	9.95 9.95	1378 16147	17525	10000	1.8
LOW-TEMPERATURE DISH MACHINE	20	-15 HEAT 148 ELEC	1 1	19.79 19.79	9.95 9.95	-2954 29143	26189	11000	2.4
WATER-COOLED REFRIGERATION CONDENSER	20	0 HEAT 52 ELEC	1 1	19.79 19.79	9.95 9.95	0 10239	10239	3500	2.9
CURTAIN ON WALK-IN REFRIGERATOR DOOR	3	0 HEAT 31 ELEC	1 1	19.79 19.79	9.95 9.95	0 6104	6104	2500	2.4
MOTION DETECTOR FOR DINING LIGHTS	20	6 HEAT 95 ELEC	1 1	19.79 19.79	9.95 9.95	1181 18706	19888	2000	9.9
HIGH-EFFICIENCY FLUORESCENT LIGHTS	4	-8 HEAT 95 ELEC	1 1	19.79 19.79	9.95 9.95	-1575 18706	17131	6500	2.6
PARBOLIC REFLECTORS FOR LIGHTS	20	-8 HEAT 108 ELEC	1 1	19.79 19.79	9.95 9.95	-1575 21266	19691	5500	3.6
ELECTRONIC BALLASTS FOR FLUORESCENT	20	-14 HEAT 159 ELEC	1 1	19.79 19.79	9.95 9.95	-2757 31309	28552	14000	2.0
R-11 WALL INSULATION	20	14 HEAT 19 ELEC	1 1	19.79 19.79	9.95 9.95	2757 3741	6498	1500	4.3
R-11 TO R-19 WALL INSULATION	20	7 HEAT 4 ELEC	1 1	19.79 19.79	9.95 9.95	1378 788	2166	800	2.7
R-19 TO R-30 WALL INSULATION	20	3 HEAT 5 ELEC	1 1	19.79 19.79	9.95 9.95	591 985	1575	800	2.0
R-11 ROOF INSULATION	20	22 HEAT 73 ELEC	1 1	19.79 19.79	9.95 9.95	4332 14374	18706	5400	3.5
R-11 TO R-19 ROOF INSULATION	20	3 HEAT 17 ELEC	1 1	19.79 19.79	9.95 9.95	591 3347	3938	1400	2.8
R-19 TO R-30 ROOF INSULATION	20	13 HEAT 12 ELEC	1 1	19.79 19.79	9.95 9.95	2560 2363	4923	3100	1.6
R-30 TO R-38 ROOF INSULATION	20	1 HEAT 3 ELEC	1 1	19.79 19.79	9.95 9.95	197 591	788	3100	0.3
R38 TO R-49 ROOF INSULATION	20	4 HEAT 4 ELEC	1 1	19.79 19.79	9.95 9.95	788 788	1575	3600	0.4
TINTED WINDOW GLAZING	7	-1 HEAT 37 ELEC	1 1	19.79 19.79	9.95 9.95	-197 7286	7089	5000	1.4
DOUBLE-PANE WINDOWS	20	6 HEAT 17 ELEC	1 1	19.79 19.79	9.95 9.95	1181 3347	4529	1600	2.8
DOUBLE TO TRIPLE-PANE WINDOWS	20	7 HEAT 28 ELEC	1 1	19.79 19.79	9.95 9.95	1378 5513	6892	400	17.2
EFFICIENT AIR CONDITIONERS	20	0 HEAT 254 ELEC	1 1	19.79 19.79	9.95 9.95	0 50015	50015	5000	10.0
ECONOMIZER CYCLE COOLING	10	0 HEAT 111 ELEC	1 1	19.79 19.79	9.95 9.95	0 21857	21857	3000	7.3
AIR-TO-AIR HEAT PUMP	20	182 HEAT -91 ELEC	1 1	19.79 19.79	9.95 9.95	35838 -17919	17919	13200	1.4
VARIABLE AIR VOLUME SYSTEM	20	45 HEAT 128 ELEC	1 1	19.79 19.79	9.95 9.95	8861 25205	34066	20000	1.7
GROUND SOURCE HEAT PUMP	20	182 HEAT -61 ELEC	1 1	19.79 19.79	9.95 9.95	35838 -12012	23826	17000	1.4
MAKEUP AIR EXHAUST HOODS	20	70 HEAT 0 ELEC	1 1	19.79 19.79	9.95 9.95	13784 0	13784	10000	1.4
NIGHT SETBACK THERMOSTATS	20	14 HEAT 1 ELEC	1 1	19.79 19.79	9.95 9.95	2757 197	2954	1000	3.0
HOT WATER HEAT PUMP	10	379 HEAT -189 ELEC	1 1	19.79 19.79	9.95 9.95	74629 -37216	37413	7200	5.2

TABLE 6.9. Sample Analysis for Cold Climate, Region 3 Fuel Costs, Steam Heat, New Building

ECO DESCRIPTION	USEFUL LIFE	ENERGY SAVINGS	ADJ. FACTOR	ENERGY COST	UPW FACTOR	NPV OF SAVINGS	TOTAL NPV	CAPITAL COST	SIR	
REJUVENATION	20	95 HEAT 127 ELEC	2 1	1.93 19.79	11.67 9.95	4279 25008	29287	15500	NA	
10% FOOD PREP CAPACITY REDUCTION	20	-23 HEAT 84 ELEC	2 1	1.93 19.79	11.67 9.95	-1036 16540	15504	10000	1.6	
10% FOOD PREP DIVERSITY REDUCTION	20	-22 HEAT 68 ELEC	2 1	1.93 19.79	11.67 9.95	-991 13390	12399	10000	1.2	
LOW-TEMPERATURE DISH MACHINE	20	-120 HEAT 132 ELEC	2 1	1.93 19.79	11.67 9.95	-5406 25992	20587	11000	1.9	
WATER-COOLED REFRIGERATION CONDENSER	20	0 HEAT 36 ELEC	2 1	1.93 19.79	11.67 9.95	0 7089	7089	3500	2.0	
CURTAIN ON WALK-IN REFRIGERATOR DOOR	3	0 HEAT 15 ELEC	2 1	1.93 19.79	11.67 9.95	0 2954	2954	2500	1.2	
MOTION DETECTOR FOR DINING LIGHTS	20	-42 HEAT 58 ELEC	2 1	1.93 19.79	11.67 9.95	-1892 11421	9529	2000	4.8	
HIGH-EFFICIENCY FLUORESCENT LIGHTS	4	-22 HEAT 81 ELEC	2 1	1.93 19.79	11.67 9.95	-991 15950	14959	6500	2.3	
PARBOLIC REFLECTORS FOR LIGHTS	20	-25 HEAT 92 ELEC	2 1	1.93 19.79	11.67 9.95	-1126 18116	16990	5500	3.1	
ELECTRONIC BALLASTS FOR FLUORESCENT	20	-39 HEAT 135 ELEC	2 1	1.93 19.79	11.67 9.95	-1757 26583	24826	14000	1.8	
R-11 WALL INSULATION	20	42 HEAT 10 ELEC	2 1	1.93 19.79	11.67 9.95	1892 1969	3861	1500	2.6	
R-11 TO R-19 WALL INSULATION	20	15 HEAT 4 ELEC	2 1	1.93 19.79	11.67 9.95	676 788	1463	800	1.8	
R-19 TO R-30 WALL INSULATION	20	9 HEAT 2 ELEC	2 1	1.93 19.79	11.67 9.95	405 394	799	800	1.0	
R-11 ROOF INSULATION	20	92 HEAT 43 ELEC	2 1	1.93 19.79	11.67 9.95	4144 8467	12611	5400	2.3	
R-11 TO R-19 ROOF INSULATION	20	25 HEAT 9 ELEC	2 1	1.93 19.79	11.67 9.95	1126 1126	1772	2898	1400	2.1
R-19 TO R-30 ROOF INSULATION	20	16 HEAT 7 ELEC	2 1	1.93 19.79	11.67 9.95	721 1378	2099	3100	0.7	
R-30 TO R-38 ROOF INSULATION	20	5 HEAT 2 ELEC	2 1	1.93 19.79	11.67 9.95	225 394	619	3100	0.2	
R38 TO R-49 ROOF INSULATION	20	10 HEAT 3 ELEC	2 1	1.93 19.79	11.67 9.95	450 591	1041	3600	0.3	
TINTED WINDOW GLAZING	7	-12 HEAT 16 ELEC	2 1	1.93 19.79	11.67 9.95	-541 3151	2610	5000	0.5	
DOUBLE-PANE WINDOWS	20	37 HEAT 12 ELEC	2 1	1.93 19.79	11.67 9.95	1667 2363	4030	1600	2.5	
DOUBLE TO TRIPLE-PANE WINDOWS	20	20 HEAT 6 ELEC	2 1	1.93 19.79	11.67 9.95	901 1181	2082	400	5.2	
EFFICIENT AIR CONDITIONERS	20	0 HEAT 76 ELEC	2 1	1.93 19.79	11.67 9.95	0 14965	14965	5000	3.0	
ECONOMIZER CYCLE COOLING	10	0 HEAT 148 ELEC	2 1	1.93 19.79	11.67 9.95	0 29143	29143	3000	9.7	
AIR-TO-AIR HEAT PUMP	20	1314 HEAT -657 ELEC	2 1	1.93 19.79	11.67 9.95	59191 -129370	-70179	13200	-5.3	
VARIABLE AIR VOLUME SYSTEM	20	29 HEAT 129 ELEC	2 1	1.93 19.79	11.67 9.95	1306 25401	26708	20000	1.3	
GROUND SOURCE HEAT PUMP	20	1314 HEAT -438 ELEC	2 1	1.93 19.79	11.67 9.95	59191 -86247	-27056	17000	-1.6	
MAKEUP AIR EXHAUST HOODS	20	630 HEAT 0 ELEC	2 1	1.93 19.79	11.67 9.95	28379 0	28379	10000	2.8	
NIGHT SETBACK THERMOSTATS	20	233 HEAT 29 ELEC	2 1	1.93 19.79	11.67 9.95	10496 5710	16206	1000	16.2	
HOT WATER HEAT PUMP	10	606 HEAT -303 ELEC	2 1	1.93 19.79	11.67 9.95	27298 -59664	-32366	7200	-4.5	

TABLE 6.10. Sample Analysis for Cool Climate, Region 3 Fuel Costs, Steam Heat, New Building

ECO DESCRIPTION	USEFUL LIFE	ENERGY SAVINGS	ADJ. FACTOR	ENERGY COST	UPW FACTOR	NPV OF SAVINGS	TOTAL NPV	CAPITAL COST	SIR
REJUVENATION	20	80 HEAT 141 ELEC	2 1	1.93 19.79	11.67 9.95	3604 27823	31427	15500	NA
10% FOOD PREP CAPACITY REDUCTION	20	-16 HEAT 86 ELEC	2 1	1.93 19.79	11.67 9.95	-721 16934	16214	10000	1.6
10% FOOD PREP DIVERSITY REDUCTION	20	-15 HEAT 70 ELEC	2 1	1.93 19.79	11.67 9.95	-676 13784	13108	10000	1.3
LOW-TEMPERATURE DISH MACHINE	20	-96 HEAT 135 ELEC	2 1	1.93 19.79	11.67 9.95	-4324 26583	22258	11000	2.0
WATER-COOLED REFRIGERATION CONDENSER	20	0 HEAT -39 ELEC	2 1	1.93 19.79	11.67 9.95	0 -7680	-7680	3500	-2.2
CURTAIN ON WALK-IN REFRIGERATOR DOOR	3	0 HEAT 18 ELEC	2 1	1.93 19.79	11.67 9.95	0 3544	3544	2500	1.4
MOTION DETECTOR FOR DINING LIGHTS	20	-32 HEAT 64 ELEC	2 1	1.93 19.79	11.67 9.95	-1441 12602	11161	2000	5.6
HIGH-EFFICIENCY FLUORESCENT LIGHTS	4	-16 HEAT 85 ELEC	2 1	1.93 19.79	11.67 9.95	-721 16737	16017	6500	2.5
PARBOLIC REFLECTORS FOR LIGHTS	20	-17 HEAT 97 ELEC	2 1	1.93 19.79	11.67 9.95	-766 19100	18335	5500	3.3
ELECTRONIC BALLASTS FOR FLUORESCENT	20	-23 HEAT 142 ELEC	2 1	1.93 19.79	11.67 9.95	-1036 27961	26925	14000	1.9
R-11 WALL INSULATION	20	38 HEAT 15 ELEC	2 1	1.93 19.79	11.67 9.95	1712 2954	4665	1500	3.1
R-11 TO R-19 WALL INSULATION	20	10 HEAT 5 ELEC	2 1	1.93 19.79	11.67 9.95	450 985	1435	800	1.8
R-19 TO R-30 WALL INSULATION	20	9 HEAT 2 ELEC	2 1	1.93 19.79	11.67 9.95	405 394	799	800	1.0
R-11 ROOF INSULATION	20	69 HEAT 54 ELEC	2 1	1.93 19.79	11.67 9.95	3108 10633	13741	5400	2.5
R-11 TO R-19 ROOF INSULATION	20	15 HEAT 12 ELEC	2 1	1.93 19.79	11.67 9.95	676 2363	3039	1400	2.2
R-19 TO R-30 ROOF INSULATION	20	12 HEAT 8 ELEC	2 1	1.93 19.79	11.67 9.95	541 1575	2116	3100	0.7
R-30 TO R-38 ROOF INSULATION	20	2 HEAT 3 ELEC	2 1	1.93 19.79	11.67 9.95	90 591	681	3100	0.2
R38 TO R-49 ROOF INSULATION	20	1 HEAT 2 ELEC	2 1	1.93 19.79	11.67 9.95	45 394	439	3600	0.1
TINTED WINDOW GLAZING	7	-5 HEAT 23 ELEC	2 1	1.93 19.79	11.67 9.95	-225 4529	4304	5000	0.9
DOUBLE-PANE WINDOWS	20	28 HEAT 16 ELEC	2 1	1.93 19.79	11.67 9.95	1261 3151	4412	1600	2.8
DOUBLE TO TRIPLE-PANE WINDOWS	20	11 HEAT 9 ELEC	2 1	1.93 19.79	11.67 9.95	496 1772	2268	400	5.7
EFFICIENT AIR CONDITIONERS	20	0 HEAT 120 ELEC	2 1	1.93 19.79	11.67 9.95	0 23629	23629	5000	4.7
ECONOMIZER CYCLE COOLING	10	0 HEAT 88 ELEC	2 1	1.93 19.79	11.67 9.95	0 17328	17328	3000	5.8
AIR-TO-AIR HEAT PUMP	20	940 HEAT -470 ELEC	2 1	1.93 19.79	11.67 9.95	42343 -92548	-50205	13200	-3.8
VARIABLE AIR VOLUME SYSTEM	20	15 HEAT 220 ELEC	2 1	1.93 19.79	11.67 9.95	676 43320	43996	20000	2.2
GROUND SOURCE HEAT PUMP	20	940 HEAT -313 ELEC	2 1	1.93 19.79	11.67 9.95	42343 -61633	-19290	17000	-1.1
MAKEUP AIR EXHAUST HOODS	20	470 HEAT 0 ELEC	2 1	1.93 19.79	11.67 9.95	21172 0	21172	10000	2.1
NIGHT SETBACK THERMOSTATS	20	168 HEAT 25 ELEC	2 1	1.93 19.79	11.67 9.95	7568 4923	12491	1000	12.5
HOT WATER HEAT PUMP	10	530 HEAT -265 ELEC	2 1	1.93 19.79	11.67 9.95	23874 -52181	-28307	7200	-3.9

TABLE 6.11. Sample Analysis for Warm Climate, Region 3 Fuel Costs, Steam Heat, New Building

ECO DESCRIPTION	USEFUL LIFE	ENERGY SAVINGS	ADJ. FACTOR	ENERGY COST	UPW FACTOR	NPV OF SAVINGS	TOTAL NPV	CAPITAL COST	SIR
REJUVENATION	20	69 HEAT 150 ELEC	2 1	1.93 19.79	11.67 9.95	3108 29537	32645	15500	NA
10% FOOD PREP CAPACITY REDUCTION	20	-4 HEAT 92 ELEC	2 1	1.93 19.79	11.67 9.95	-180 18116	17936	10000	1.8
10% FOOD PREP DIVERSITY REDUCTION	20	-4 HEAT 75 ELEC	2 1	1.93 19.79	11.67 9.95	-180 14768	14588	10000	1.5
LOW-TEMPERATURE DISH MACHINE	20	-64 HEAT 141 ELEC	2 1	1.93 19.79	11.67 9.95	-2883 27764	24881	11000	2.3
WATER-COOLED REFRIGERATION CONDENSER	20	D HEAT 45 ELEC	2 1	1.93 19.79	11.67 9.95	0 8861	8861	3500	2.5
CURTAIN ON WALK-IN REFRIGERATOR DOOR	3	0 HEAT 24 ELEC	2 1	1.93 19.79	11.67 9.95	0 4726	4726	2500	1.9
MOTION DETECTOR FOR DINING LIGHTS	20	-11 HEAT 77 ELEC	2 1	1.93 19.79	11.67 9.95	-496 15162	14667	2000	7.3
HIGH-EFFICIENCY FLUORESCENT LIGHTS	4	-6 HEAT 89 ELEC	2 1	1.93 19.79	11.67 9.95	-270 17525	17255	6500	2.7
PARBOLIC REFLECTORS FOR LIGHTS	20	-5 HEAT 77 ELEC	2 1	1.93 19.79	11.67 9.95	-225 15162	14937	5500	2.7
ELECTRONIC BALLASTS FOR FLUORESCENT	20	-19 HEAT 147 ELEC	2 1	1.93 19.79	11.67 9.95	-856 28946	28090	14000	2.0
R-11 WALL INSULATION	20	18 HEAT 15 ELEC	2 1	1.93 19.79	11.67 9.95	811 2954	3764	1500	2.5
R-11 TO R-19 WALL INSULATION	20	10 HEAT 4 ELEC	2 1	1.93 19.79	11.67 9.95	450 788	1238	800	1.5
R-19 TO R-30 WALL INSULATION	20	9 HEAT 3 ELEC	2 1	1.93 19.79	11.67 9.95	405 591	996	800	1.2
R-11 ROOF INSULATION	20	30 HEAT 55 ELEC	2 1	1.93 19.79	11.67 9.95	1351 10830	12181	5400	2.3
R-11 TO R-19 ROOF INSULATION	20	20 HEAT 14 ELEC	2 1	1.93 19.79	11.67 9.95	901 2757	3658	1400	2.6
R-19 TO R-30 ROOF INSULATION	20	4 HEAT 7 ELEC	2 1	1.93 19.79	11.67 9.95	180 1378	1559	3100	0.5
R-30 TO R-38 ROOF INSULATION	20	3 HEAT 3 ELEC	2 1	1.93 19.79	11.67 9.95	135 591	726	3100	0.2
R38 TO R-49 ROOF INSULATION	20	6 HEAT 3 ELEC	2 1	1.93 19.79	11.67 9.95	270 591	861	3600	0.2
TINTED WINDOW GLAZING	7	-2 HEAT 27 ELEC	2 1	1.93 19.79	11.67 9.95	-90 5317	5226	5000	1.0
DOUBLE-PANE WINDOWS	20	10 HEAT 13 ELEC	2 1	1.93 19.79	11.67 9.95	450 2560	3010	1600	1.9
DOUBLE TO TRIPLE-PANE WINDOWS	20	4 HEAT 8 ELEC	2 1	1.93 19.79	11.67 9.95	180 1575	1755	400	4.4
EFFICIENT AIR CONDITIONERS	20	0 HEAT 172 ELEC	2 1	1.93 19.79	11.67 9.95	0 33869	33869	5000	6.8
ECONOMIZER CYCLE COOLING	10	0 HEAT 121 ELEC	2 1	1.93 19.79	11.67 9.95	0 23826	23826	3000	7.9
AIR-TO-AIR HEAT PUMP	20	521 HEAT -348 ELEC	2 1	1.93 19.79	11.67 9.95	23469 -68525	-45056	13200	-3.4
VARIABLE AIR VOLUME SYSTEM	20	33 HEAT 129 ELEC	2 1	1.93 19.79	11.67 9.95	1487 25401	26888	20000	1.3
GROUND SOURCE HEAT PUMP	20	521 HEAT -261 ELEC	2 1	1.93 19.79	11.67 9.95	23469 -51394	-27925	17000	-1.6
MAKEUP AIR EXHAUST HOODS	20	260 HEAT 0 ELEC	2 1	1.93 19.79	11.67 9.95	11712 0	11712	10000	1.2
NIGHT SETBACK THERMOSTATS	20	89 HEAT 14 ELEC	2 1	1.93 19.79	11.67 9.95	4009 2757	6766	1000	6.8
HOT WATER HEAT PUMP	10	454 HEAT -227 ELEC	2 1	1.93 19.79	11.67 9.95	20451 -44699	-24248	7200	-3.4

TABLE 6.12. Sample Analysis for Hot Climate, Region 3 Fuel Costs, Steam Heat, New Building

ECO DESCRIPTION	USEFUL LIFE	ENERGY SAVINGS	ADJ. FACTOR	ENERGY COST	UPW FACTOR	NPV OF SAVINGS	TOTAL NPV	CAPITAL COST	SIR
REJUVENATION	20	52 HEAT 163 ELEC	2 1	1.93 19.79	11.67 9.95	2342 32096	34439	15500	NA
10% FOOD PREP CAPACITY REDUCTION	20	7 HEAT 99 ELEC	2 1	1.93 19.79	11.67 9.95	315 19494	19809	10000	2.0
10% FOOD PREP DIVERSITY REDUCTION	20	7 HEAT 82 ELEC	2 1	1.93 19.79	11.67 9.95	315 16147	16462	10000	1.6
LOW-TEMPERATURE DISH MACHINE	20	-15 HEAT 148 ELEC	2 1	1.93 19.79	11.67 9.95	-676 29143	28467	11000	2.6
WATER-COOLED REFRIGERATION CONDENSER	20	0 HEAT 52 ELEC	2 1	1.93 19.79	11.67 9.95	0 10239	10239	3500	2.9
CURTAIN ON WALK-IN REFRIGERATOR DOOR	3	0 HEAT 31 ELEC	2 1	1.93 19.79	11.67 9.95	0 6104	6104	2500	2.4
MOTION DETECTOR FOR DINING LIGHTS	20	6 HEAT 95 ELEC	2 1	1.93 19.79	11.67 9.95	270 18706	18977	2000	9.5
HIGH-EFFICIENCY FLUORESCENT LIGHTS	4	-8 HEAT 95 ELEC	2 1	1.93 19.79	11.67 9.95	-360 18706	18346	6500	2.8
PARBOLIC REFLECTORS FOR LIGHTS	20	-8 HEAT 108 ELEC	2 1	1.93 19.79	11.67 9.95	-360 21266	20906	5500	3.8
ELECTRONIC BALLASTS FOR FLUORESCENT	20	-14 HEAT 159 ELEC	2 1	1.93 19.79	11.67 9.95	-631 31309	30678	14000	2.2
R-11 WALL INSULATION	20	14 HEAT 19 ELEC	2 1	1.93 19.79	11.67 9.95	631 3741	4372	1500	2.9
R-11 TO R-19 WALL INSULATION	20	7 HEAT 4 ELEC	2 1	1.93 19.79	11.67 9.95	315 788	1103	800	1.4
R-19 TO R-30 WALL INSULATION	20	3 HEAT 5 ELEC	2 1	1.93 19.79	11.67 9.95	135 985	1120	800	1.4
R-11 ROOF INSULATION	20	22 HEAT 73 ELEC	2 1	1.93 19.79	11.67 9.95	991 14374	15365	5400	2.8
R-11 TO R-19 ROOF INSULATION	20	3 HEAT 17 ELEC	2 1	1.93 19.79	11.67 9.95	135 3347	3483	1400	2.5
R-19 TO R-30 ROOF INSULATION	20	13 HEAT 12 ELEC	2 1	1.93 19.79	11.67 9.95	586 2363	2949	3100	1.0
R-30 TO R-38 ROOF INSULATION	20	1 HEAT 3 ELEC	2 1	1.93 19.79	11.67 9.95	45 591	636	3100	0.2
R38 TO R-49 ROOF INSULATION	20	4 HEAT 4 ELEC	2 1	1.93 19.79	11.67 9.95	180 788	968	3600	0.3
TINTED WINDOW GLAZING	7	-1 HEAT 37 ELEC	2 1	1.93 19.79	11.67 9.95	-45 7286	7241	5000	1.4
DOUBLE-PANE WINDOWS	20	6 HEAT 17 ELEC	2 1	1.93 19.79	11.67 9.95	270 3347	3618	1600	2.3
DOUBLE TO TRIPLE-PANE WINDOWS	20	7 HEAT 28 ELEC	2 1	1.93 19.79	11.67 9.95	315 5513	5829	400	14.6
EFFICIENT AIR CONDITIONERS	20	0 HEAT 254 ELEC	2 1	1.93 19.79	11.67 9.95	0 50015	50015	5000	10.0
ECONOMIZER CYCLE COOLING	10	0 HEAT 111 ELEC	2 1	1.93 19.79	11.67 9.95	0 21857	21857	3000	7.3
AIR-TO-AIR HEAT PUMP	20	182 HEAT -91 ELEC	2 1	1.93 19.79	11.67 9.95	8198 -17919	-9720	13200	-0.7
VARIABLE AIR VOLUME SYSTEM	20	45 HEAT 128 ELEC	2 1	1.93 19.79	11.67 9.95	2027 25205	27232	20000	1.4
GROUND SOURCE HEAT PUMP	20	182 HEAT -61 ELEC	2 1	1.93 19.79	11.67 9.95	8198 -12012	-3813	17000	-0.2
MAKEUP AIR EXHAUST HOODS	20	70 HEAT 0 ELEC	2 1	1.93 19.79	11.67 9.95	3153 0	3153	10000	0.3
NIGHT SETBACK THERMOSTATS	20	14 HEAT 1 ELEC	2 1	1.93 19.79	11.67 9.95	631 197	828	1000	0.8
HOT WATER HEAT PUMP	10	379 HEAT -189 ELEC	2 1	1.93 19.79	11.67 9.95	17073 -37216	-20144	7200	-2.8

efficiency of the heating and cooling systems. As the system efficiencies are increased, the energy savings due to load reduction measures will diminish proportionately.

The energy costs are determined from the current issue of Energy Prices and Discount Factors for Life-Cycle Cost Analysis (Lippiatt 1987). The energy costs that apply for DOE Region 3 are listed on page 32. From this we find that commercial sector electricity is \$19.79/Btu $\times 10^6$ and coal-produced steam is valued at \$1.93/Btu $\times 10^6$.

Next, the uniform present worth factors for each measure are determined from the appropriate table from the same reference (Lippiatt 1987), p.7. To determine the appropriate factor, first find the column for the fuel used. Then select the row that corresponds to the useful life of the conservation measures. The lifetimes estimated for the prototype measures are listed on the forms. Remember, for comparative analyses, a 20-year life should be assumed, and the capital costs should be adjusted accordingly.

To determine the net-present-value of the energy savings, multiply the energy savings by the adjustment factor by the energy cost by the uniform present worth factor for each fuel. Be careful to keep track of the sign, because the next step involves summing the NPV for each fuel to estimate the total NPV for each measure. For a measure to be cost-effective, it must cost less than the total NPV of energy savings. To determine the relative cost-effectiveness of various measures, enter an estimate of the capital costs over a 20-year lifetime and divide this number into the total NPV. The result--the savings to investment ratios--should be entered in the last column.

The results of these sample analysis are summarized in Tables 6.13 and 6.14 by displaying the saving-to-investment ratios calculated for the all electric and district heated new dining halls in each climate type, respectively. The greater this ratio, the more cost-effective the conservation opportunity. If the saving to investment ratio is less than 1.0, the measure is not cost-effective. Where district heat is available some of the measures result in negative savings to investment ratios. This results from the fact that a more expensive fuel (electricity) is being substituted for cheaper

**TABLE 6.13. Summary of Savings to Investment Ratios, Region 3 Fuel Costs,
Electric Heat, New Building**

ECO DESCRIPTION	COLD SIR	COOL SIR	WARM SIR	HOT SIR
10% FOOD PREP CAPACITY REDUCTION	1.4	1.6	2	2.4
10% FOOD PREP DIVERSITY REDUCTION	1.1	1.3	1.6	2.1
LOW-TEMPERATURE DISH MACHINE	0.3	0.8	1.6	2.8
WATER-COOLED REFRIGERATION CONDENSERS	2.4	2.6	3	3.4
CURTAIN ON WALK-IN REFRIGERATOR DOORS	1.4	1.7	2.2	2.9
MOTION DETECTOR FOR DINING LIGHTS	1.8	3.7	7.6	11.7
HIGH-EFFICIENCY FLUORESCENT LIGHTS	2.1	2.5	2.9	3.1
PARBOLIC REFLECTORS FOR LIGHTS	2.8	3.4	3	4.2
ELECTRONIC BALLASTS FOR FLUORESCENT FIXTURES	1.6	2	2.1	2.4
R-11 WALL INSULATION	8	8.2	5.1	5.1
R-11 TO R-19 WALL INSULATION	5.5	4.3	4	3.2
R-19 TO R-30 WALL INSULATION	1.7	3.2	3.5	2.3
R-11 ROOF INSULATION	5.8	5.3	3.6	4.1
R-11 TO R-19 ROOF INSULATION	5.6	4.5	5.6	3.3
R-19 TO R-30 ROOF INSULATION	1.7	1.5	0.8	1.9
R-30 TO R-38 ROOF INSULATION	0.5	0.4	0.4	0.3
R38 TO R-49 ROOF INSULATION	0.8	0.2	0.6	0.5
TINTED WINDOW GLAZING	0.2	0.8	1.2	1.7
DOUBLE-PANE WINDOWS	7.1	6.4	3.3	3.3
DOUBLE TO TRIPLE-PANE WINDOWS	15	11.5	6.9	20.2
EFFICIENT AIR CONDITIONERS	3.5	5.5	7.9	11.7
ECONOMIZER CYCLE COOLING	11.4	6.8	9.3	8.5
AIR-TO-AIR HEAT PUMP	11.5	8.2	3	1.6
VARIABLE AIR VOLUME SYSTEM	1.8	2.7	1.9	2
GROUND SOURCE HEAT PUMP	11.9	8.5	3.5	1.6
MAKEUP AIR EXHAUST HOODS	14.5	10.9	6	1.6
NIGHT SETBACK THERMOSTATS	60.5	44.6	23.8	3.5
HOT WATER HEAT PUMP	9.7	8.5	7.3	6.1

TABLE 6.14. SUMMARY OF SAVINGS TO INVESTMENT RATIOS REGION 3 FUEL COSTS,
DISTRICT HEAT, NEW BUILDING

ECO DESCRIPTION	COLD SIR	COOL SIR	WARM SIR	HOT SIR
10% FOOD PREP CAPACITY REDUCTION	1.6	1.6	1.8	2
10% FOOD PREP DIVERSITY REDUCTION	1.2	1.3	1.5	1.6
LOW-TEMPERATURE DISH MACHINE	1.9	2	2.3	2.6
WATER COOLED REFRIGERATION CONDENSERS	2	-2.2	2.5	2.9
CURTAIN ON WALK-IN REFRIGERATOR DOORS	1.2	1.4	1.9	2.4
MOTION DETECTOR FOR DINING LIGHTS	4.8	5.6	7.3	9.5
HIGH-EFFICIENCY FLUORESCENT LIGHTS	2.3	2.5	2.7	2.8
PARBOLIC REFLECTORS FOR LIGHTS	3.1	3.3	2.7	3.8
ELECTRONIC BALLASTS FOR FLUORESCENT FIXTURES	1.8	1.9	2	2.2
R-11 WALL INSULATION	2.6	3.1	2.5	2.9
R-11 TO R-19 WALL INSULATION	1.8	1.8	1.5	1.4
R-19 TO R-30 WALL INSULATION	1	1	1.2	1.4
R-11 ROOF INSULATION	2.3	2.5	2.3	2.8
R-11 TO R-19 ROOF INSULATION	2.1	2.2	2.6	2.5
R-19 TO R-30 ROOF INSULATION	0.7	0.7	0.5	1
R-30 TO R-38 ROOF INSULATION	0.2	0.2	0.2	0.2
R38 TO R-49 ROOF INSULATION	0.3	0.1	0.2	0.3
TINTED WINDOW GLAZING	0.5	0.9	1	1.4
DOUBLE-PANE WINDOWS	2.5	2.8	1.9	2.3
DOUBLE TO TRIPLE-PANE WINDOWS	5.2	5.7	4.4	14.6
EFFICIENT AIR CONDITIONERS	3	4.7	6.8	10
ECONOMIZER CYCLE COOLING	9.7	5.8	7.9	7.3
AIR-TO-AIR HEAT PUMP	-5.3	-3.8	-3.4	-0.7
VARIABLE AIR VOLUME SYSTEM	1.3	2.2	1.3	1.4
GROUND SOURCE HEAT PUMP	-1.6	-1.1	-1.6	-0.2
MAKEUP AIR EXHAUST HOODS	2.8	2.1	1.2	0.3
NIGHT SETBACK THERMOSTATS	16.2	12.5	6.8	0.8
HOT WATER HEAT PUMP	-4.5	-3.9	-3.4	-2.8

fossil fuels. Although site energy consumption is reduced, the costs of this energy increase by the fuel-switching.

7.0 CONCLUSIONS AND RECOMMENDATIONS

This section provides general conclusions and recommendations for the analysis of energy conservation potential in USAF dining halls. The relative energy intensity of the prototype facility is indicated, and the analysis methods are reviewed. The results of the sample analysis presented in Section 6 are reviewed to make general statements regarding the cost-effectiveness of the energy conservation measures examined.

7.1 GENERAL CONCLUSIONS

Food service facilities are known to be among the most energy intensive commercial building types, owing to the substantial food preparation, sanitation, and ventilation energy demands. The prototype dining hall was found to consume an estimated 480,000 Btu/ft²/yr. Seven other restaurants metered for the NRA had energy use intensities ranging from 390,000 to 730,000 Btu ft²/yr, placing the dining hall in the lower quartile. This is partially due to the relatively large size of this facility. Private sector restaurants generally have smaller kitchens, office/storage areas, and dining rooms.

The end-use consumption levels on a use per square foot basis for the dining hall are generally comparable to the other facilities. The requirements for HVAC are on the high side, however, due to the low levels of insulation and the inefficient air conditioning and heating systems in the prototype.

The energy use measurements taken at the prototype facility provide valuable insights into the energy use shares and consumption profiles. In addition, these measurements were very useful for calibrating the simulation model used to estimate energy savings. Once initialized, the ASEAM 2.1 simulation model was quick and easy to use, and capable of simulating the performance of all but one of the conservation measures evaluated. Of particular value is the parametric processor, which permits a series of comparative analyses to be conducted automatically. This feature was used to conduct extensive sensitivity analyses to ensure the reasonableness of the energy savings estimates.

Although the model has the capability to conduct detailed life-cycle-cost analyses, this feature was not used for this study. Instead, the tabular approach for the economic analysis was developed for use by those not familiar with computers and simulation modeling. Based upon four carefully selected climate types, this approach combines the results of ASEAM 2.1 simulations with the life-cycle costing methods mandated for federal building conservation assessments.

Application of all the measures found to be cost-effective for the prototype facility would result in a reduction of energy use from 20 to 35%, without adversely affecting comfort or quality of service. The total cost of these measures ranges from approximately \$75,000 to \$125,000 per facility. The cost-effective energy savings and justified conservation measure costs are greatest where fuel prices are high and climates are extreme.

7.2 GENERAL RECOMMENDATIONS

This section provides general conclusions and recommendations for improving the energy efficiency of USAF dining halls. To confirm the appropriateness of these general recommendations for a particular case study, it is necessary to carry out the simplified analysis procedure or run the ASEAM model. The conclusions presented here are based upon a sensitivity analysis using a single set of fuel costs, estimated costs for conservation measures applied to the prototype dining hall, and two fuel supply scenarios in each of the four climate types.

All of the load reduction measures listed in the tables are cost effective in all climate types with district heat. The same is true if the building is all electric, except for the low temperature dishmachines, where the waste heat would otherwise offset space heating requirements. The cost effective level of wall and roof insulation is very dependent upon climate type and the costs of heating fuel. However, R-19 wall and roof insulation is cost-effective in all cases for new construction. Inexpensive triple pane windows are also cost effective in new construction, however, window tinting is only cost effective in the warm and hot climates. Since these are load reduction

measures their cost effectiveness would be lower if substantial system efficiency improvements are made.

With respect to system efficiency improvements, the use of night set-back thermostats is very cost effective, particularly in colder climates. This cost effectiveness will be somewhat lower where electricity is the heating fuel and peak demand charges are based upon early morning peaks. Use of more efficient air conditioning systems, variable air volume distribution systems, and economizer cycles are cost effective in all cases. Heat pumps for space heating and water heating are cost effective only if electricity is used for these functions.

7.3 LIMITATIONS OF THE SIMPLIFIED METHOD

As a simplified method, many assumptions are made. The greatest leap is the assumption that the characteristics of the building to be retrofitted are identical to those of the prototype. The next greatest leap is that the climate area properly reflects the conditions of the building's location. Finally, the simulations assume that buildings are properly maintained and operated. If this is not the case, savings may be considerably lower than estimated. For these reasons, the results of the simplified analysis should be used only as a guide for further analysis rather than as a rigorous estimate of actual savings.

The simplified method can reveal the sensitivity of climate effects by carrying out the analysis for several climate areas. This is particularly called for if the location of interest lies far from the selected climate location on Figure 3.6. Additional sensitivities can be analyzed by altering adjustment factors, fuel prices, uniform present worth factors, or capital costs. Such sensitivities are usually quite useful if the savings-to-investment ratios are close to 1.0, so as to better determine the likelihood that the measures will be cost-effective.

Because of these limitations of the simple method, and the requirement to examine a limited set of conservation options, Appendix B provides a description of the ASEAM2.1 input file for the prototype dining hall. The FEMP periodically conducts workshops on the use of this model at no charge to

federal users, and many users may be able to master the program by using a tutorial provided with the software. With the detailed inputs derived from Appendix B to start with, modifications to examine the specific characteristics of the building in question will be simple in most cases. The model can then be run with local weather data (if available) to develop a more accurate estimate of energy savings, life-cycle costs, and savings-to-investment ratios for a wide variety of energy conservation opportunities.

8.0 REFERENCES

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APPENDIX A

ASEAM 2.1 MODELING AND CALIBRATION PROCESS

APPENDIX A

ASEAM 2.1 MODELING AND CALIBRATION PROCESS

GENERAL BUILDING DESCRIPTION

The building is an Air Force dining hall located in Dover, Delaware, and has over 12,000 ft² of conditioned floor area. For the simulation model, this area was divided into 10 zones. The zoning is based on four major factors:

- internal walls
- use patterns
- exposure
- model limit of 10 zones maximum.

Internal walls separate most of the zones. The dining rooms are treated as separate zones because they have different use patterns and exposure. The storage area and small office are combined because the small office has little floor area.

The building is heated by hot water supplied to four fan coils and five convectors. Cooling is supplied by two vapor compression air conditioning units, one for the east side and one for the west side of the building. The kitchen, however, is not cooled. Sixteen exhaust fans remove heat and odors while a heating and ventilating unit, along with the fans of the packaged air conditioning units, supply fresh makeup air.

CALIBRATION AND BASE CASE DEVELOPMENT

Before the impact of energy conservation measures can be evaluated, the base case must be defined. Definition consists of specifying building envelope parameters, lighting, equipment, occupancy levels and schedules, heating, ventilation, and air conditioning (HVAC) systems and plant.

Building Envelope Parameters

A detailed breakdown of envelope parameters is given in Appendix B. Items specified for each zone are external wall areas and orientations, roof areas, window and door areas. Heat conductances (U-values) are entered for each. Shading coefficients for windows and space mass parameters are also specified along with infiltration.

In addition to external envelope characterization, internal zone parameters are specified. The temperatures of each zone were obtained from the metered data which, along with internal wall areas and conductances, allow ASEAM to account for interzonal conduction.

In ASEAM, infiltration by crack length and number of air changes can both be specified and are additive. Since the dining hall is designed to be slightly pressurized, infiltration can be ignored, except for three situations. In the cashier's office, the AC-1 return draws more than the supply. Thus, 6 air changes per hour (ACH) infiltration was estimated. Similarly, in the locker room, imbalance of exhaust and supply is about 0.5 ACH. The fact that the dishwashing area exhaust fans do not work means that hot air from the heating and ventilating unit (H&V) and the dishwasher is introduced into the dining areas. In the summertime, this puts additional load on the air conditioners. This is modeled in ASEAM by adding infiltration to the dining areas and by adding 25% of the dishwasher capacity to dining room unhooded equipment.

Lighting

The lighting throughout the building is fluorescent except in the snack line (Zone 1) where fluorescent lighting was replaced with decorative incandescent fixtures.

Table A.1 shows lighting by zone (summarized from Appendix B) and compares the nameplate capacity (light bulb count) to measured peaks. In some cases, the measured channels are "polluted" with minor equipment and outlets. Thus, the sum of lighting and equipment consumption is used to calibrate the model.

TABLE A.1. LIGHTING CAPACITIES

<u>Zone</u>	<u>Nameplate Capacity, kW</u>	<u>Nameplate Capacity, W/ft²</u>	<u>Annual Peak Hour, kW</u>
1	6.14	1.57	14.8
2	8.68	2.23	8.62
3	1.15	1.38	1.89
4	6.07	2.29	8.57
5	0.97	1.00	1.44
6	2.14M	5.81M	0.42
7	1.12M	1.37M	1.46

M = Mixed with Equipment

Lighting schedules from each zone were found from analyzing the metered hourly data and entered into the model as occupied, unoccupied and monthly diversity factors. It was found that the monthly diversity factors can vary substantially from zone to zone, but there are not enough schedule input columns in ASEAM to accommodate a set of monthly diversity factors for each zone. Thus, a single set of monthly diversity factors for all zones is used.

Equipment

The dining hall equipment is all electric (ASEAM cannot model nonelectric equipment) and is hooded or unhooded.

Table A.2 summarizes total equipment capacity by zone along with the measured peak hour. The breakdown by hooded and unhooded equipment is detailed in Appendix B. Table A.3 shows the information taken from drawings and site visits that was used to produce Table A.2 and ASEAM inputs.

Equipment schedules were obtained for hooded and unhooded equipment by zone from the metered data. Monthly diversity factors varied dramatically from zone to zone and between hooded and unhooded equipment.

However, because of ASEAM's limited schedule input, only one set of monthly diversity factors was entered to represent both types of equipment in

TABLE A.2. TOTAL EQUIPMENT CAPACITIES

<u>Zone</u>	<u>Nameplate Capacity, kW</u>	<u>Nameplate Capacity, W/ft²</u>	<u>Annual Peak Hour, kW</u>
1	22.8	5.85	21.3
2	37.1	9.52	29.0
3	50.0	59.7	59.7
4	202.9	76.6	92.7
5	21.8	22.5	11.8
6	M	M	M
7	M	M	M

M = Mixed with Lights

all zones. Because of this limitation, it would be very difficult to evaluate specific equipment modifications.

Internal gains from hooded equipment are treated by ASEAM as recommended in the American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (ASHRAE 1985) fundamentals. However, ASEAM does not adjust the internal gain fraction.

OCCUPANCY

Occupancy capacity by zone is summarized from Appendix B in Table A.4.

Occupancy schedules for the Air Force Dining Hall vary slightly from day to day, but generally do not have a weekday/weekend pattern. This is fortunate, because ASEAM does not distinguish weekdays and weekends.

The day is divided into occupied and unoccupied periods based on an overall activity level. The monthly diversity factors for the two dining rooms are obtained from meal count data collected by the Air Force. Monthly diversity factors for the kitchen, dishwashing room, office, storage, and locker areas were assumed.

The sensible and latent loads per person shown in Appendix B are based on assumed activity level and ASHRAE Fundamentals.

TABLE A.3. INDIVIDUAL EQUIPMENT CAPACITIES

<u>Zone</u>	<u>Item</u>	<u>Number</u>	<u>Total Capacity, kW</u>	<u>Hooded</u>
Snack Line (1)	toaster	1	5.0	
	griddle	1	16.0	
	ice and water dispenser	1	0.67(a)	
	milk dispenser	2	0.37(a)	
	beverage dispensers	2	0.37	
	ice tea dispenser	1	0.19(b)	
Meal Line (2)	refrigeration	1	0.19	
	salad case	1	1.1(a)	
	dessert case	1	1.1(a)	
	toaster	1	5.0	
	lowrator dinner plates	2	1.0	
	griddle	1	16.0	Y
Dishwashing (3)	sandwich unit	1	0.25	
	hot table	1	9.0	Y
	coffee maker	1	1.0	
	ice and water dispenser	1	0.67(a)	
	milk dispenser	2	0.37	
	beverage dispenser	2	0.37	
Kitchen (4)	ice tea dispenser	1	0.19(b)	
	refrigeration	2	0.37	
	cash register	1	0.67(a)	
	soup station	1	N/A(c)	
	salad bar	1	N/A	
	dishwasher	1	50.0	
Storage (5)	steamer	3	N/A	Y
	double steam kettle	1	12.0	YY
	steam kettle	1	N/A	YY
	jet cooker(b)	2	37.4(a)	YY
	deep fat fryer	2	29.1(a)	YY
	oven	2	29.1(a)	YY

(a) Computed from current and voltage

(b) Not used

(c) N/A = not applicable

TABLE A.4. OCCUPANCY

<u>Zone</u>	<u>Capacity</u>
1	150
2	150
3	3
4	10
5	2
6	3
10	10

HVAC Systems

The dining hall is served by four HVAC systems, two vapor compression air conditioners, one heating and ventilating unit, and multiple hot water heating coils and convectors. In addition, there are sixteen exhaust fans. Table A.5 shows the HVAC system equipment.

This system configuration must be restructured to fit ASEAM modeling. System component capacities were broken out by zone based on measured air flow rate to the zone. For each zone, the heating components, cooling components and fan components were added to obtain heating (BUTH), cooling (tons), and fan capacity (kW and CFM) for each zone. Then, Zones 1 and 2 were modeled as having their own single re-heat with direct expansion cooling systems, and Zones 3 and 7 were modeled with H&V unit heating and Zones 4, 5, and 6 were modeled by multi-zone reheat with direct expansion cooling. This model underestimates heating demand because the air supplied from the H&V unit to the kitchen hoods is not included. Thus, infiltration is added to Zone 3 to make up the difference. The detailed breakdown by zone is in Appendix B.

Plant

The plant consists of an electricity source and a district heating source. In ASEAM, this is also where hot water is specified. Specifying hot water consists of water heater capacity, annual average water demand, temperatures and losses. There is no provision for occupied, unoccupied or monthly diversity factors.

TABLE A.5. SYSTEM

Unit	Heating Capacity, KBH	Cooling Capacity, ton	Fan Capacity, kW	Compressor Capacity, kW	Pump Capacity, kW	Comments
AC-1	156	27.8	12	19.5	-	
AC-2	156	28.1	12	19.7	-	
H&V	956	-	10	-	-	
Air curtains(2)	-	-	.25	-	-	
Hot water circulating pumps	-	-	-	-	1.49	
Domestic hot water generator	1200	-	-	-	-	
Domestic hot water pump	-	-	-	-	0.19	
UH-1	6.7	-	0.02	-	-	
UH-2	33.5	-	0.2	-	-	
C-1	1.5	-	-	-	-	
C-2	3.8	-	-	-	-	
C-3	6.6	-	-	-	-	
Exhaust Fans(a)						
Zone 1 EF-11,15 and 2	-	-	0.50	-	-	EF-15 serves Zones 1
Zone 2 EF-12,15	-	-	0.27	-	-	
Zone 3 EF-13,14	-	-	0.56	-	-	Not operating
Zone 4 EF-1,2,3,4,5,9,10	-	-	2.05	-	-	
Zone 5 EF-7,8	-	-	0.37	-	-	Not used
Zone 6 None	-	-	0	-	-	
Zone 7 EF-6	-	-	0.19	-	-	

(a) EF-16 serves the mechanical room, which is not included in the building model.

Because both the hot water for consumption and heating are served by district heat, ASEAM adds them together without reporting them individually.

ANNUAL CONSUMPTION CALIBRATION

Calibration consisted of matching both annual and monthly consumptions. The results of the annual consumption calibration are shown in Table A.6. The confidence in heating calibration is low because we lacked sufficient metered data. The confidence in air conditioning is better than for heating because we had more data. Light, equipment and fan confidences are high because we had the best data for these. The reason that lights and equipment are not shown separately is that some of the metered data channels are mixed with lights and equipment.

Calibrated and Base Case Models

A calibrated model is produced to develop confidence in the modeling assumptions by matching metered evidence. A Base Case is then produced from the calibrated model to be more representative of all Air Force Dining Halls.

Lights and Equipment Monthly Calibration

The results of the light and equipment calibration are shown in Figure A.1. The model and metered data match very well. This match is for the whole building and cannot be demonstrated for each zone by end-use because ASEAM has an insufficient number of schedule inputs.

Heating Monthly Calibration

The heating could not be calibrated on a monthly basis because the hot water heating system was not fully instrumented. However, an estimate of annual heating was obtained from one-time flow measurements and one week of measured temperature differences across heating coils in January, 1987. Infiltration in Zone 3 was added so that the model prediction was close to the estimated annual heating consumption.

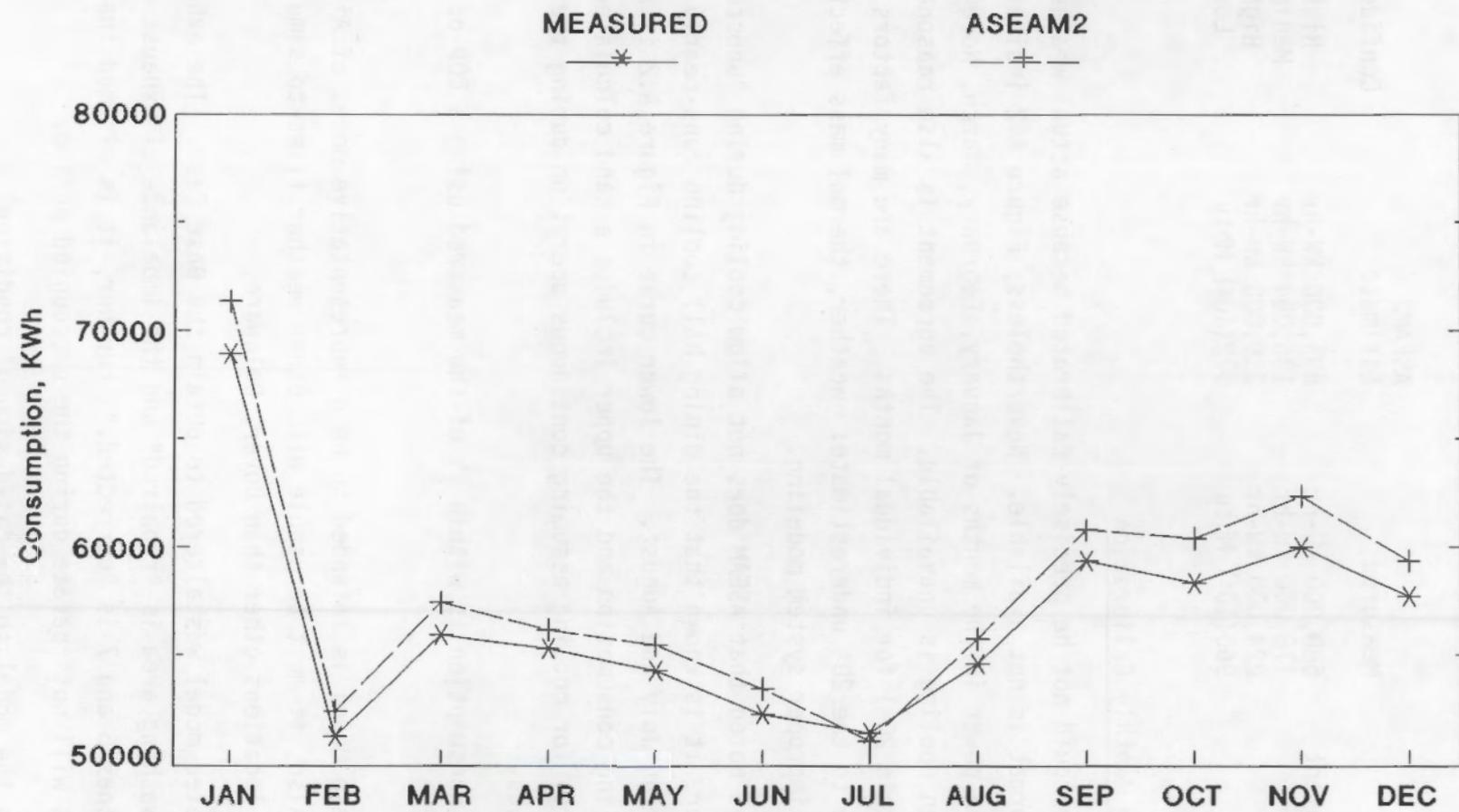


FIGURE A.1. Comparison of Measured and ASEAM 2.1 Estimated Lighting and Equipment Energy Consumption

TABLE A.6. ANNUAL CONSUMPTION COMPARISON

End-Use	Measured	ASEAM2 Estimate	Confidence
Lights and Equipment	680,000 kW-hr	693,000 kW-hr	High
Cooling	178,000 kW-hr	186,094 kW-hr	Medium
Fans	224,000 kW-hr	219,000 kW-hr	High
Heating	960(10 ⁶) Mbtu	972(10 ⁶) Mbtu	Low

Fans and Cooling Monthly Calibration

The cooling could not be precisely calibrated because actual weather data in ASEAM format is not available. Nevertheless, Figure A.2 indicates good agreement for fan power in the months of January, February, March, November, and December when cooling is unavailable. The agreement is also reasonable for cooling (within 20%) for individual months. There are many factors that could contribute to the 20% underestimate: weather, thermal mass effects, and potentially improper system modeling.

It should be noted that ASEAM does not allow cooling during "unoccupied" periods. However, it is known that the dining hall cooling runs nearly continuously during July and August. The lower curve in Figure A.2 is ASEAM's estimate of cooling consumption and the upper includes a hand calculated estimate of energy for cooling assuming continuous operation during the unoccupied periods.

The annual consumption is within 2% of the measured using a COP of 1.9.

BASE CASE MODEL

The Base Case Model is intended to be a representative model of Air Force Dining Halls. Also, it must be usable with other weather files to simulate dining halls in locations other than Dover, Delaware.

The calibrated model was altered to obtain the Base Case. The exhaust fan in the dishwashing area is "repaired" and the imbalance of exhaust and supply air in Zones 6 and 7 is "corrected." Further, it is assumed that the air conditioners will not operate during the unoccupied period.

This brings the model to the "as-designed" condition.

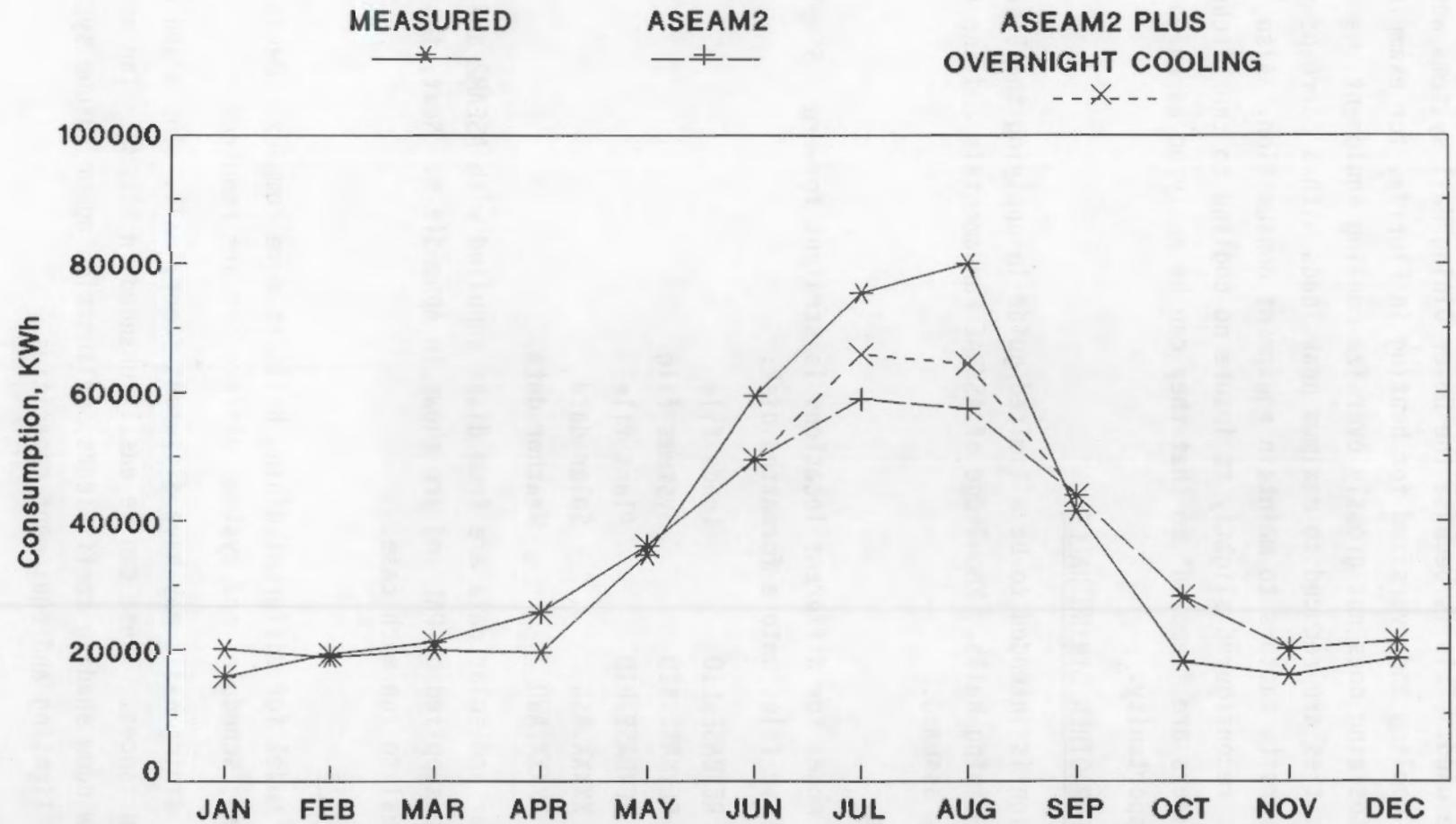


FIGURE A.2. Comparison of Measured and ASEAM 2.1 Estimated Fans and Cooling Energy

In order to perform analyses for other locations, ASEAM's autosizing feature must be used. This is because the Dover Dining Hall systems would be undersized for cooling and oversized for heating in Florida, for example. To insure that autosizing does not grossly oversize cooling equipment, nameplate equipment capacities are reduced to maximum peak loads with a corresponding increase in diversity factors to maintain equipment consumption. Also, the system model is reconfigured slightly to insure no cooling to the kitchen. Lastly, economizers are "removed" so that they can be analyzed as an energy conservation opportunity.

USE OF ASEAM2 FOR OTHER DINING HALLS

This section is intended to be a limited guide in applying the Base Case model to other dining halls. Knowledge of ASHRAE Fundamentals and the ASEAM2 User's Guide is assumed.

Other Locations

Using the model for different locations is straight forward. Simply copy the following five files onto a formatted disk:

1. REVBASE.LID	Loads file
2. REVBASE.SID	Systems file
3. REVBASE.PID	Plant file
4. XXXXX.NSD	Solar data
5. XXXXX.AWD	Weather data.

The weather and solar data are from disks supplied with ASEAM2 and the other files are supplied by PNL and are shown in Appendix B. Next, follow the ASEAM2 manual to run each case.

Other Dining Halls

Using the model for different dining halls is more complex. Decisions regarding zoning, schedules and systems differences are required.

Different dining halls may have different floor, wall, window and door areas and conductances. These can be easily changed in ASEAM2. The areas to watch for are window shading coefficients, malfunctioning or unique system equipment, and lighting and equipment capacities.

In the Base Case model, Zone 3 has 6 ACH infiltration to account for H&V unit air tempering of exhaust hood air. This may not be necessary or correct for other dining halls. Lighting and equipment capacities can be adjusted by the ratio of nameplate ratings. In the Base Case model, the capacities are annual peaks, not nameplate ratings.

Schedules or diversity factors can easily be changed, however, determination of the desired values is difficult. For dining hall occupancy schedules, meal count data can be used to obtain diversity factors. To obtain diversity factors for lights and equipment requires metered data.

System modeling is not confined to four systems as in the Base Case. The user may select and arrange ASEAM2 systems to fit the dining hall of interest. It is desirable to keep the number of systems in ASEAM small to facilitate updates and to minimize run-time.

APPENDIX B

ASEAM INPUT SCREENS FOR BASE CASE

APPENDIX B

ASEAM INPUT SCREENS FOR BASE CASE

The input screens for the Base Case Air Force Dining Hall are presented by loads, systems, and plant input screens.

LOADS INPUT TO ASEAM2

DATA ECHO FOR LOADS INPUT FILE: REVBASE.LID

BUILDING/PROJECT DATA

Building File Name : AF_DOVER
Building Name : Revised Base Case
Project Number : Correct Original

Building Address : DOVER DELAWARE

Building Type : RESTAURANT

Building gross floor area : 12928 ft²
Building net conditioned area : 12584 ft²
Number of zones : 7

Building Location
North latitude : 39.08 deg
West longitude : 75.28 deg
Time Zone Number : 5
Daylight Savings Time :

Typical Weekday Operating Schedule
Occupancy start hour : 6
Operating hours/day : 16

Summer Thermostat Schedule
Beginning month : April
Ending month : October

Typical Occupied Schedule
Weekdays from : 600 to 2400
Saturdays from : 600 to 2400
Sundays from : 600 to 2400

ZONE DATA FOR ZONE 1 - WEST DINING AREA, SNACK

Zone label : WEST DINING AREA, SNACK
Zone function : DINING
Zone area : 3898 ft2
Floor to ceiling height : 10 ft

Thermostat Set Point Temperatures

Summer occupied temperature : 74 deg F
Winter occupied temperature : 70 deg F
Winter unoccupied temperature : 70 deg F

LIGHTING DATA FOR ZONE 1 - WEST DINING AREA, SNACK

	Ltg Func 1	Ltg Func 2	Ltg Func 3	Ltg Func 4
Function name	: DINING	BATHROOM	VESTIBULE	NA
Function area (ft2)	: 3748	100	50	
Installed watts/ft2	:			
(times) Percent function area	:			
Total installed watts	: 5636	204	300	
Daylighting analysis	: No	No	No	
Lighting system type	:			
Percent light heat to space	: 80	80	80	
'A' Classification	: .55	.55	.55	
'B' Classification	: C	C	C	
Diversity factors - occupied	: 50.4	50.4	50.4	
Diversity factors - unoccupied	: 47.9	47.9	47.9	
Monthly diversity table number	: 4	4	4	

PEOPLE DATA FOR ZONE 1 - WEST DINING AREA, SNACK

Number of people in zone : 150
Sensible load per person : 255 BTUH per person
Latent load per person : 325 BTUH per person

Diversity factor - occupied : 34
Diversity factor - unoccupied : 0
Monthly diversity table number : 1

ELECTRIC EQUIPMENT DATA FOR ZONE 1 - WEST DINING AREA, SNACK

	Type 1	Type 2
Electric equipment name	: SER-UNHOODE	SER-HOODED
Total installed watts	: 11000	7400
Hooded	: No	Yes
Diversity factors - occupied	: 36.3	36.3
Diversity factors - unoccupied	: 22.0	22.0
Monthly diversity table number	: 3	3

WALL DATA FOR ZONE 1 - WEST DINING AREA, SNACK

	Wall 1	Wall 2	Wall 3	Wall 4
Name	: N	S	W	NA
Wall orientation	: North	South	West	
Area (ft2)	: 202	635	727	
U-Factor (BTUH/ft2-deg F)	: 0.111	.111	.111	
Wall construction group	: A	A	A	
Color correction	: Medium	Medium	Medium	

ROOF DATA FOR ZONE 1 - WEST DINING AREA, SNACK

	Roof 1	Roof 2
Name	: WEST	NA
Area (ft2)	: 3898	
U-Factor (BTUH/ft2-deg F)	: .124	
Roof construction code	: 8	
Color correction	: Dark	
Suspended ceiling plenum	: Yes	

WINDOW DATA FOR ZONE 1 - WEST DINING AREA, SNACK

	Window 1	Window 2	Window 3	Window 4
Name	: S	W	NA	NA
Window orientation	: South	West		
Fenestration area (ft ²)	: 130	263		
Shading coefficient	: .64	.64		
U-Factor (BTUH/ft ² -deg F)	: 1.01	1.01		
Space mass code	: Heavy	Heavy		
Crack length (lin ft)	: 0	0		
Leakage coefficient	: 0	0		

Inputs Required for Shading

Window shading model number	: 0	0
Percent window area	:	

INFILTRATION DATA FOR ZONE 1 - WEST DINING AREA, SNACK

Occupied air change rate	: 0 air changes per hour
Unoccupied air change rate	: 0 air changes per hour

MISCELLANEOUS CONDUCTION FOR ZONE 1 - WEST DINING AREA, SNACK

	Type 1	Type 2:
Name	: from kitchen	from dishwa
Area (ft ²)	: 348	430
U-Factor (BTUH/ft ² -deg F)	: 0.31	0.31
Ref temperature at design summer (deg F):	85	78
Ref temperature at design winter (deg F):	82	78

OPERATING USE PROFILE (DIVERSITY) DATA

		Occupied Period	Unoccupied Period	Month Table #	Sched (1-4)
People	- Avg % of full occupancy	: 34	0	1	
Lights					
DINING	- Avg % of installed capacity	: 50.4	47.9	4	
BATHROOM	- Avg % of installed capacity	: 50.4	47.9	4	
VESTIBULE	- Avg % of installed capacity	: 50.4	47.9	4	
NA	- Avg % of installed capacity	:			
Electric Equipment					
SER-UNHOODED	- Avg % of installed capacity	: 36.3	22.0	3	
SER-HOODED	- Avg % of installed capacity	: 36.3	22.0	3	
Miscellaneous Sensible Loads					
NA	- Avg % of installed capacity	:			
NA	- Avg % of installed capacity	:			

ZONE DATA FOR ZONE 2 - EAST DINING

Zone label : EAST DINING
Zone function : DINING
Zone area : 3898 ft2
Floor to ceiling height : 10 ft

Thermostat Set Point Temperatures

Summer occupied temperature : 74 deg F
Winter occupied temperature : 70 deg F
Winter unoccupied temperature : 70 deg F

LIGHTING DATA FOR ZONE 2 - EAST DINING

Ltg Func 1 Ltg Func 2 Ltg Func 3 Ltg Func 4

Function name	:	DINING	BATHROOM	VESTIBULE	NA
Function area (ft2)	:	3748	100	50	
Installed watts/ft2	:				
(times) Percent function area :					
Total installed watts	:	8178	204	300	
Daylighting analysis	:	No	No	No	
Lighting system type	:				
Percent light heat to space	:	80	80	80	
'A' Classification	:	.55	.55	.55	
'B' Classification	:	C	C	C	
Diversity factors - occupied	:	63.0	63.0	63.0	
Diversity factors - unoccupied	:	59.2	59.2	59.2	
Monthly diversity table number	:	4	4	4	

PEOPLE DATA FOR ZONE 2 - EAST DINING

Number of people in zone : 150
Sensible load per person : 255 BTUH per person
Latent load per person : 325 BTUH per person

Diversity factor - occupied : 34
Diversity factor - unoccupied : 0
Monthly diversity table number : 1

ELECTRIC EQUIPMENT DATA FOR ZONE 2 - EAST DINING

	Type 1	Type 2
Electric equipment name	: SER UNHOODE	SER HOODED
Total installed watts	: 14300	10700
Hooded	: No	Yes
Diversity factors - occupied	: 36.3	36.3
Diversity factors - unoccupied	: 22.0	22.0
Monthly diversity table number	: 3	3

WALL DATA FOR ZONE 2 - EAST DINING

	Wall 1	Wall 2	Wall 3	Wall 4
Name	: N	E	S	NA
Wall orientation	: North	East	South	
Area (ft2)	: 202	727	635	
U-Factor (BTUH/ft2-deg F)	: .111	.111	.111	
Wall construction group	: A	A	A	
Color correction	: Medium	Medium	Medium	

ROOF DATA FOR ZONE 2 - EAST DINING

	Roof 1	Roof 2
Name	: EAST	NA
Area (ft2)	: 3898	
U-Factor (BTUH/ft2-deg F)	: .124	
Roof construction code	: 8	
Color correction	: Dark	
Suspended ceiling plenum	: Yes	

WINDOW DATA FOR ZONE 2 - EAST DINING

	Window 1	Window 2	Window 3	Window 4
Name	: E	S	NA	NA
Window orientation	: East	South		
Fenestration area (ft ²)	: 263	130		
Shading coefficient	: .64	.64		
U-Factor (BTUH/ft ² -deg F)	: 1.01	1.01		
Space mass code	: Heavy	Heavy		
Crack length (lin ft)	: 0	0		
Leakage coefficient	: 0	0		

Inputs Required for Shading

Window shading model number	: 0	0
Percent window area	:	

INFILTRATION DATA FOR ZONE 2 - EAST DINING

Occupied air change rate	: 0 air changes per hour
Unoccupied air change rate	: 0 air changes per hour

MISCELLANEOUS CONDUCTION FOR ZONE 2 - EAST DINING

	Type 1	Type 2:
Name	: from kitchen	from dishwa
Area (ft ²)	: 70	430
U-Factor (BTUH/ft ² -deg F)	: 0.31	0.31
Ref temperature at design summer (deg F):	85	78
Ref temperature at design winter (deg F):	82	78

OPERATING USE PROFILE (DIVERSITY) DATA

		Occupied Period	Unoccupied Period	Month	Sched Table # (1-4)
People	- Avg % of full occupancy	: 34	0	1	
Lights					
DINING	- Avg % of installed capacity	: 63.0	59.2	4	
BATHROOM	- Avg % of installed capacity	: 63.0	59.2	4	
VESTIBULE	- Avg % of installed capacity	: 63.0	59.2	4	
NA	- Avg % of installed capacity	:			
Electric Equipment					
SER UNHOODED	- Avg % of installed capacity	: 36.3	22.0	3	
SER HOODED	- Avg % of installed capacity	: 36.3	22.0	3	
Miscellaneous Sensible Loads					
NA	- Avg % of installed capacity	:			
NA	- Avg % of installed capacity	:			

ZONE DATA FOR ZONE 3 - DISHWASHER

Zone label : DISHWASHER
Zone function : SANITATION
Zone area : 837 ft²
Floor to ceiling height : 10 ft

Thermostat Set Point Temperatures

Summer occupied temperature : 78 deg F
Winter occupied temperature : 78 deg F
Winter unoccupied temperature : 78 deg F

LIGHTING DATA FOR ZONE 3 - DISHWASHER

Ltg Func 1 Ltg Func 2 Ltg Func 3 Ltg Func 4

Function name	: D WASH	NA	NA	NA
Function area (ft ²)	: 837			

Installed watts/ft² :
(times) Percent function area :
Total installed watts : 1152

Daylighting analysis : No

Lighting system type : FL
Percent light heat to space : 80
'A' Classification : .55
'B' Classification : C

Diversity factors - occupied : 94.8
Diversity factors - unoccupied : 89.1
Monthly diversity table number : 4

PEOPLE DATA FOR ZONE 3 - DISHWASHER

Number of people in zone : 3
Sensible load per person : 345 BTUH per person
Latent load per person : 435 BTUH per person

Diversity factor - occupied : 50
Diversity factor - unoccupied : 0
Monthly diversity table number : 2

ELECTRIC EQUIPMENT DATA FOR ZONE 3 - DISHWASHER

	Type 1	Type 2
Electric equipment name	: HOODED	NA
Total installed watts	: 53700	
Hooded	: Yes	
Diversity factors - occupied	: 36.3	
Diversity factors - unoccupied	: 22.0	
Monthly diversity table number	: 3	

ROOF DATA FOR ZONE 3 - DISHWASHER

	Roof 1	Roof 2
Name	: D_WASH	NA
Area (ft2)	: 837	
U-Factor (BTUH/ft2-deg F)	: .124	
Roof construction code	: 8	
Color correction	: Dark	
Suspended ceiling plenum	: Yes	

INFILTRATION DATA FOR ZONE 3 - DISHWASHER

Occupied air change rate	: 0 air changes per hour
Unoccupied air change rate	: 0 air changes per hour

MISCELLANEOUS CONDUCTION FOR ZONE 3 - DISHWASHER

	Type 1	Type 2:
Name	: to zone1	to zone2
Area (ft2)	: 430	430
U-Factor (BTUH/ft2-deg F)	: 0.31	0.31
Ref temperature at design summer (deg F):	74	74
Ref temperature at design winter (deg F):	70	70

OPERATING USE PROFILE (DIVERSITY) DATA

		Occupied Period	Unoccupied Period	Month	Sched Table # (1-4)
People	- Avg % of full occupancy	: 50	0		2
Lights					
D WASH	- Avg % of installed capacity	: 94.8	89.1		4
NA	- Avg % of installed capacity	:			
NA	- Avg % of installed capacity	:			
NA	- Avg % of installed capacity	:			
Electric Equipment					
HOODED	- Avg % of installed capacity	: 36.3	22.0		3
NA	- Avg % of installed capacity	:			
Miscellaneous Sensible Loads					
NA	- Avg % of installed capacity	:			
NA	- Avg % of installed capacity	:			

ZONE DATA FOR ZONE 4 - KITCHEN

Zone label : KITCHEN
Zone function : COOK
Zone area : 2650 ft2
Floor to ceiling height : 10 ft

Thermostat Set Point Temperatures

Summer occupied temperature : 85 deg F
Winter occupied temperature : 82 deg F
Winter unoccupied temperature : 73 deg F

LIGHTING DATA FOR ZONE 4 - KITCHEN

	Ltg Func 1	Ltg Func 2	Ltg Func 3	Ltg Func 4
Function name	: K	NA	NA	NA
Function area (ft2)	: 2650			
Installed watts/ft2	:			
(times) Percent function area	:			
Total installed watts	: 6072			
Daylighting analysis	: No			
Lighting system type	: FL			
Percent light heat to space	: 80			
'A' Classification	: .55			
'B' Classification	: C			
Diversity factors - occupied	: 83.8			
Diversity factors - unoccupied	: 78.9			
Monthly diversity table number	: 4			

PEOPLE DATA FOR ZONE 4 - KITCHEN

Number of people in zone : 10
Sensible load per person : 345 BTUH per person
Latent load per person : 435 BTUH per person

Diversity factor - occupied : 100
Diversity factor - unoccupied : 0
Monthly diversity table number : 2

ELECTRIC EQUIPMENT DATA FOR ZONE 4 - KITCHEN

	Type 1	Type 2
Electric equipment name	: HOODED	UN-HOODED
Total installed watts	: 75900	8530
Hooded	: Yes	No
Diversity factors - occupied	: 36.3	36.3
Diversity factors - unoccupied	: 22.0	22.0
Monthly diversity table number	: 3	3

WALL DATA FOR ZONE 4 - KITCHEN

	Wall 1	Wall 2	Wall 3	Wall 4
Name	: W	N	NA	NA
Wall orientation	: West	North		
Area (ft2)	: 563	303		
U-Factor (BTUH/ft2-deg F)	: .111	.111		
Wall construction group	: A	A		
Color correction	: Medium	Medium	Medium	

ROOF DATA FOR ZONE 4 - KITCHEN

	Roof 1	Roof 2
Name	: KITCHEN	NA
Area (ft2)	: 2650	
U-Factor (BTUH/ft2-deg F)	: .124	
Roof construction code	: 8	
Color correction	: Dark	
Suspended ceiling plenum	: Yes	

INFILTRATION DATA FOR ZONE 4 - KITCHEN

Occupied air change rate	: 0.00 air changes per hour
Unoccupied air change rate	: 0 air changes per hour

CONDUCTION FOR ZONE 4 - KITCHEN

	Type 1	Type 2:
Name	: to zones	1267 to zone 5
Area (ft ²)	: 1186	408
U-Factor (BTUH/ft ² -deg F)	: 0.31	.031
Ref temperature at design summer (deg F):	74	74
Ref temperature at design winter (deg F):	70	70

OPERATING USE PROFILE (DIVERSITY) DATA

People	- Avg % of full occupancy	Occupied	Unoccupied	Month	Sched
		Period	Period	Table #	(1-4)
		: 100	0	2	
Lights					
K	- Avg % of installed capacity	: 83.8	78.9	4	
NA	- Avg % of installed capacity	:			
NA	- Avg % of installed capacity	:			
NA	- Avg % of installed capacity	:			
Electric Equipment					
HOODED	- Avg % of installed capacity	: 36.3	22.0	3	
UN-HOODED	- Avg % of installed capacity	: 36.3	22.0	3	
Miscellaneous Sensible Loads					
NA	- Avg % of installed capacity	:			
NA	- Avg % of installed capacity	:			

ZONE DATA FOR ZONE 5 - STORAGE

Zone label : STORAGE
Zone function : STORAGE
Zone area : 970 ft²
Floor to ceiling height : 10 ft

Thermostat Set Point Temperatures

Summer occupied temperature : 74 deg F
Winter occupied temperature : 70 deg F
Winter unoccupied temperature : 70 deg F

LIGHTING DATA FOR ZONE 5 - STORAGE

	Ltg Func 1	Ltg Func 2	Ltg Func 3	Ltg Func 4
Function name	: OFFICE	STORAGE	NA	NA
Function area (ft ²)	: 150	420		
Installed watts/ft ²	:			
(times) Percent function area	:			
Total installed watts	: 336	636		
Daylighting analysis	: No	No		
Lighting system type	:			
Percent light heat to space	: 80	80		
'A' Classification	: .55	.55		
'B' Classification	: C	C		
Diversity factors - occupied	: 41.4	41.4		
Diversity factors - unoccupied	: 33.6	33.6		
Monthly diversity table number	: 4	4		

PEOPLE DATA FOR ZONE 5 - STORAGE

Number of people in zone : 2
Sensible load per person : 255 BTUH per person
Latent load per person : 255 BTUH per person

Diversity factor - occupied : 100
Diversity factor - unoccupied : 0
Monthly diversity table number : 2

ELECTRIC EQUIPMENT DATA FOR ZONE 5 - STORAGE

	Type 1	Type 2
Electric equipment name	: OFFICE	refrigeration
Total installed watts	: 0	1060D
Hooded	: No	No
Diversity factors - occupied	: 36.3	36.3
Diversity factors - unoccupied	: 22.0	22.0
Monthly diversity table number	: 3	3

WALL DATA FOR ZONE 5 - STORAGE

	Wall 1	Wall 2	Wall 3	Wall 4
Name	: E	NA	NA	NA
Wall orientation	: East			
Area (ft2)	: 627			
U-Factor (BTUH/ft2-deg F)	: .111			
Wall construction group	: A			
Color correction	: Medium	Medium	Medium	

ROOF DATA FOR ZONE 5 - STORAGE

	Roof 1	Roof 2
Name	: STORAGE	NA
Area (ft2)	: 970	
U-Factor (BTUH/ft2-deg F)	: .124	
Roof construction code	: 8	
Color correction	: Dark	
Suspended ceiling plenum	: Yes	

INFILTRATION DATA FOR ZONE 5 - STORAGE

Occupied air change rate	: 0.00 air changes per hour
Unoccupied air change rate	: 0 air changes per hour

OPERATING USE PROFILE (DIVERSITY) DATA

		Occupied Period	Unoccupied Period	Month Sched Table # (1-4)
People	- Avg % of full occupancy	: 100	0	2
Lights				
OFFICE	- Avg % of installed capacity	: 41.4	33.6	4
STORAGE	- Avg % of installed capacity	: 41.4	33.6	4
NA	- Avg % of installed capacity	:		
NA	- Avg % of installed capacity	:		
Electric Equipment				
OFFICE	- Avg % of installed capacity	: 36.3	22.0	3
refrigeration	- Avg % of installed capacity	: 36.3	22.0	3
Miscellaneous Sensible Loads				
NA	- Avg % of installed capacity	:		
NA	- Avg % of installed capacity	:		

ZONE DATA FOR ZONE 6 - OFFICE

Zone label : OFFICE
Zone function : OFFICE
Zone area : 368 ft2
Floor to ceiling height : 10 ft

Thermostat Set Point Temperatures

Summer occupied temperature : 74 deg F
Winter occupied temperature : 70 deg F
Winter unoccupied temperature : 70 deg F

LIGHTING DATA FOR ZONE 6 - OFFICE

	Ltg Func 1	Ltg Func 2	Ltg Func 3	Ltg Func 4
Function name	: OFFICE	VESTIBULE	NA	NA
Function area (ft2)	: 265	123		
Installed watts/ft2	:			
(times) Percent function area	:			
Total installed watts	: 1504	634		
Daylighting analysis	: No	No		
Lighting system type	:			
Percent light heat to space	: 80	80		
'A' Classification	: .55	.55		
'B' Classification	: C	C		
Diversity factors - occupied	: 11.6	11.6		
Diversity factors - unoccupied	: 11.1	11.1		
Monthly diversity table number	: 4	4		

PEOPLE DATA FOR ZONE 6 - OFFICE

Number of people in zone : 3
Sensible load per person : 255 BTUH per person
Latent load per person : 255 BTUH per person

Diversity factor - occupied : 100
Diversity factor - unoccupied : 0
Monthly diversity table number : 2

WALL DATA FOR ZONE 6 - OFFICE

	Wall 1	Wall 2	Wall 3	Wall 4
Name	: N	E	NA	NA
Wall orientation	: North	East		
Area (ft2)	: 259	253		
U-Factor (BTUH/ft2-deg F)	: .111	.111		
Wall construction group	: A	A		
Color correction	: Medium	Medium	Medium	

ROOF DATA FOR ZONE 6 - OFFICE

	Roof 1	Roof 2
Name	: OFFICE	NA
Area (ft2)	: 368	
U-Factor (BTUH/ft2-deg F)	: .124	
Roof construction code	: 8	
Color correction	: Dark	
Suspended ceiling plenum	: Yes	

WINDOW DATA FOR ZONE 6 - OFFICE

	Window 1	Window 2	Window 3	Window 4
Name	: N	NA	NA	NA
Window orientation	: North			
Fenestration area (ft2)	: 26			
Shading coefficient	: .94			
U-Factor (BTUH/ft2-deg F)	: 1.01			
Space mass code	: Heavy			
Crack length (lin ft)	: 0			
Leakage coefficient	: 0			

Inputs Required for Shading

Window shading model number	: 0
Percent window area	:

DOOR (EXTERNAL) DATA FOR ZONE 6 - OFFICE

	Type 1	Type 2
Name	: OFFICE	NA
Area (ft2)	: 35	
U-Factor (BTUH/ft2-deg F)	: .41	
Crack length (lin ft)	: 25	
Leakage coefficient	: 6	

INFILTRATION DATA FOR ZONE 6 - OFFICE

Occupied air change rate	: 0 air changes per hour
Unoccupied air change rate	: 0 air changes per hour

MISCELLANEOUS CONDUCTION FOR ZONE 6 - OFFICE

	Type 1	Type 2:
Name	: from kitchen	NA
Area (ft2)	: 325	
U-Factor (BTUH/ft2-deg F)	: 0.31	
Ref temperature at design summer (deg F)	: 85	
Ref temperature at design winter (deg F)	: 82	

OPERATING USE PROFILE (DIVERSITY) DATA

		Occupied Period	Unoccupied Period	Month Sched Table # (1-4)
People	- Avg % of full occupancy	: 100	0	2
Lights				
OFFICE	- Avg % of installed capacity	: 11.6	11.1	4
VESTIBULE	- Avg % of installed capacity	: 11.6	11.1	4
NA	- Avg % of installed capacity	:		
NA	- Avg % of installed capacity	:		
Electric Equipment				
NA	- Avg % of installed capacity	:		
NA	- Avg % of installed capacity	:		
Miscellaneous Sensible Loads				
NA	- Avg % of installed capacity	:		
NA	- Avg % of installed capacity	:		

ZONE DATA FOR ZONE 7 - EMPLOYEE

Zone label : EMPLOYEE
Zone function : LOCKER
Zone area : 816 ft2
Floor to ceiling height : 10 ft

Thermostat Set Point Temperatures

Summer occupied temperature : 74 deg F
Winter occupied temperature : 70 deg F
Winter unoccupied temperature : 70 deg F

LIGHTING DATA FOR ZONE 7 - EMPLOYEE

	Ltg Func 1	Ltg Func 2	Ltg Func 3	Ltg Func 4
Function name	: BATHROOM	HALLWAY	NA	NA
Function area (ft2)	: 562	254		
Installed watts/ft2	:			
(times) Percent function area :				
Total installed watts	: 860	258		
Daylighting analysis	: No	No		
Lighting system type	:			
Percent light heat to space	: 80	80		
'A' Classification	: .55	.55		
'B' Classification	: C	C		
Diversity factors - occupied	: 64.7	64.7		
Diversity factors - unoccupied	: 65.8	65.8		
Monthly diversity table number	: 4	4		

PEOPLE DATA FOR ZONE 7 - EMPLOYEE

Number of people in zone : 10
Sensible load per person : 255 BTUH per person
Latent load per person : 255 BTUH per person

Diversity factor - occupied : 20
Diversity factor - unoccupied : 0
Monthly diversity table number : 2

WALL DATA FOR ZONE 7 - EMPLOYEE

	Wall 1	Wall 2	Wall 3	Wall 4
Name	: N	W	NA	NA
Wall orientation	: North	West		
Area (ft2)	: 475	253		
U-Factor (BTUH/ft2-deg F)	: .111	.111		
Wall construction group	: A	A		
Color correction	: Medium	Medium	Medium	

ROOF DATA FOR ZONE 7 - EMPLOYEE

	Roof 1	Roof 2
Name	: EMPLOYEE	NA
Area (ft2)	: 816	
U-Factor (BTUH/ft2-deg F)	: .124	
Roof construction code	: 8	
Color correction	: Dark	
Suspended ceiling plenum	: Yes	

WINDOW DATA FOR ZONE 7 - EMPLOYEE

	Window 1	Window 2	Window 3	Window 4
Name	: N	NA	NA	NA
Window orientation	: North			
Fenestration area (ft2)	: 15			
Shading coefficient	: .94			
U-Factor (BTUH/ft2-deg F)	: 1.01			
Space mass code	: Heavy			
Crack length (lin ft)	: 0			
Leakage coefficient	: 0			

Inputs Required for Shading

Window shading model number	: 0
Percent window area	:

DOOR (EXTERNAL) DATA FOR ZONE 7 - EMPLOYEE

	Type 1	Type 2
Name	: EMPLOYEE	NA
Area (ft2)	: 35	
U-Factor (BTUH/ft2-deg F)	: .41	
Crack length (lin ft)	: 25	
Leakage coefficient	: 6	

INFILTRATION DATA FOR ZONE 7 - EMPLOYEE

Occupied air change rate	: 0 air changes per hour
Unoccupied air change rate	: 0 air changes per hour

MISCELLANEOUS CONDUCTION FOR ZONE 7 - EMPLOYEE

	Type 1	Type 2:
Name	: from kitchen	NA
Area (ft2)	: 143	
U-Factor (BTUH/ft2-deg F)	: 0.31	
Ref temperature at design summer (deg F)	: 85	
Ref temperature at design winter (deg F)	: 82	

OPERATING USE PROFILE (DIVERSITY) DATA

		Occupied Period	Unoccupied Period	Month	Sched Table # (1-4)
People	- Avg % of full occupancy	: 20	0	2	
Lights					
BATHROOM	- Avg % of installed capacity	: 64.7	65.8	4	
HALLWAY	- Avg % of installed capacity	: 64.7	65.8	4	
NA	- Avg % of installed capacity	:			
NA	- Avg % of installed capacity	:			
Electric Equipment					
NA	- Avg % of installed capacity	:			
NA	- Avg % of installed capacity	:			
Miscellaneous Sensible Loads					
NA	- Avg % of installed capacity	:			
NA	- Avg % of installed capacity	:			

MONTHLY DIVERSITY FACTORS

	Mon Sch 1	Mon Sch 2	Mon Sch 3	Mon Sch 4
January	: 82.	100	126	105
February	: 75	100	98	103
March	: 89	100	96	106
April	: 86	100	96	111
May	: 88	100	90	113
June	: 90	100	90	111
July	: 91	100	76	131
August	: 100	100	92	106
September	: 88	100	109	100
October	: 87	100	108	85.
November	: 80	100	114	94
December	: 75	75	102	100

SYSTEMS INPUT TO ASEAM2

DATA ECHO FOR SYSTEMS INPUT FILE - REV BASDC.SID
SYSTEM TYPE - SINGLE ZONE REHEAT
SYSTEM LABEL - Single Zone Reheat for Zone 1

ZONES ASSIGNED TO SYSTEM 1 - Single Zone Reheat for Zone 1

Load Zone	Zone Label
1	WEST DINING AREA

HEATING PARAMETERS FOR SYSTEM 1 - Single Zone Reheat for Zone 1

Heating plant type	: District Heating
Heating available below	: 70 deg F
Heating availability	: Jan through Dec
Design heating discharge temperature	: 110 deg F

COOLING PARAMETERS FOR SYSTEM 1 - Single Zone Reheat for Zone 1

Cooling plant type	: District Cooling
Outside temperature below which cooling is off	: 55 deg F
Cooling availability	: Jan through Dec
Design cooling coil discharge temperature	: 50 deg F

PREHEAT PARAMETERS FOR SYSTEM 1 - Single Zone Reheat for Zone 1

Preheat plant type	: None
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HUMIDIFICATION PARAMETERS FOR SYSTEM 1 - Single Zone Reheat for Zone 1

Humidification plant type	: None
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BASEBOARD PARAMETERS FOR SYSTEM 1 - Single Zone Reheat for Zone 1

Baseboard plant type	: None
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FAN PARAMETERS FOR SYSTEM 1 - Single Zone Reheat for Zone 1

Total supply fan power required	: Defaulted
Supply fan temperature rise	: 2 deg F
Total return fan power required	: 0 KW
Return fan temperature rise	: 0 deg F
Unoccupied cycle fan control method	: On Continuously

OUTSIDE AIR PARAMETERS FOR SYSTEM 1 - Single Zone Reheat for Zone 1

Occupied Cycle	
Outside air damper control method	: Fixed Dampers
Minimum percent outside air intake	: 10 %
Unoccupied Cycle	
Outside air damper control method	: Fixed Dampers
Minimum percent outside air intake	: 10 %

ZONE AIR PARAMETERS FOR SYSTEM 1 - Single Zone Reheat for Zone 1

Zonal air volume method	: Autosized
Percent of design default air flow	: 80 %

DATA ECHO FOR SYSTEMS INPUT FILE - REV BASDC.SID
SYSTEM TYPE - SINGLE ZONE REHEAT
SYSTEM LABEL - Single Zone Reheat for Zone 2

ZONES ASSIGNED TO SYSTEM 2 - Single Zone Reheat for Zone 2

Load Zone	Zone Label
2	EAST DINING

HEATING PARAMETERS FOR SYSTEM 2 - Single Zone Reheat for Zone 2

Heating plant type	: District Heating
Heating available below	: 65 deg F
Heating availability	: Jan through Dec
Design heating discharge temperature	: 110 deg F

COOLING PARAMETERS FOR SYSTEM 2 - Single Zone Reheat for Zone 2

Cooling plant type	: District Cooling
Outside temperature below which cooling is off	: 55 deg F
Cooling availability	: Jan through Dec
Design cooling coil discharge temperature	: 50 deg F

PREHEAT PARAMETERS FOR SYSTEM 2 - Single Zone Reheat for Zone 2

Preheat plant type	: None
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HUMIDIFICATION PARAMETERS FOR SYSTEM 2 - Single Zone Reheat for Zone 2

Humidification plant type	: None
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BASEBOARD PARAMETERS FOR SYSTEM 2 - Single Zone Reheat for Zone 2

Baseboard plant type	: None
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FAN PARAMETERS FOR SYSTEM 2 - Single Zone Reheat for Zone 2

Total supply fan power required	: Defaulted
Supply fan temperature rise	: 2 deg F
Total return fan power required	: 0 KW
Return fan temperature rise	: 0 deg F
Unoccupied cycle fan control method	: On Continuously

OUTSIDE AIR PARAMETERS FOR SYSTEM 2 - Single Zone Reheat for Zone 2

Occupied Cycle	
Outside air damper control method	: Fixed Dampers
Minimum percent outside air intake	: 10 %
Unoccupied Cycle	
Outside air damper control method	: Fixed Dampers
Minimum percent outside air intake	: 10 %

ZONE AIR PARAMETERS FOR SYSTEM 2 - Single Zone Reheat for Zone 2

Zonal air volume method	: Autosized
Percent of design default air flow	: 80 %

DATA ECHO FOR SYSTEMS INPUT FILE - REV BASDC.SID

SYSTEM TYPE - HEAT & VENT UNIT

SYSTEM LABEL - Heat & Vent Unit for Zones 3 and 7

ZONES ASSIGNED TO SYSTEM 3 - Heat & Vent Unit for Zones 3 and 7

Load Zone	Zone Label
3	DISHWASHER
7	EMPLOYEE

HEATING PARAMETERS FOR SYSTEM 3 - Heat & Vent Unit for Zones 3 and 7

Heating plant type	: District Heating
Heating available below	: 65 deg F
Heating availability	: Jan through Dec
Design heating discharge temperature	: 110 deg F

PREHEAT PARAMETERS FOR SYSTEM 3 - Heat & Vent Unit for Zones 3 and 7

Preheat plant type	: None
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HUMIDIFICATION PARAMETERS FOR SYSTEM 3 - Heat & Vent Unit for Zones 3 and 7

Humidification plant type	: None
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BASEBOARD PARAMETERS FOR SYSTEM 3 - Heat & Vent Unit for Zones 3 and 7

Baseboard plant type	: None
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FAN PARAMETERS FOR SYSTEM 3 - Heat & Vent Unit for Zones 3 and 7

Total supply fan power required	: 2.6 KW
Supply fan temperature rise	: 2 deg F
Unoccupied cycle fan control method	: On Continuously

ZONE AIR PARAMETERS FOR SYSTEM 3 - Heat & Vent Unit for Zones 3 and 7

Zonal air volume method : Entered by Zone
Zonal fan power method :
Percent of design default fan KW : %

ZONE CFM PARAMETERS FOR SYSTEM 3 - Heat & Vent Unit for Zones 3 and 7

Loads Zone #	Zone Name or Label	Zone CFM
3	DISHWASHER	: 4840
7	EMPLOYEE	: 660

DATA ECHO FOR SYSTEMS INPUT FILE - REVBASEDC.SID
SYSTEM TYPE - CONSTANT VOLUME REHEAT
SYSTEM LABEL - Constant Volume Reheat for Zones 4,5,6

ZONES ASSIGNED TO SYSTEM 4 - Constant Volume Reheat for Zones 4,5,6

Load Zone	Zone Label
4	KITCHEN
5	STORAGE
6	OFFICE

HEATING PARAMETERS FOR SYSTEM 4 - Constant Volume Reheat for Zones 4,5,6

Heating plant type	: District Heating
Heating available below	: 65 deg F
Heating availability	: Jan through Dec
Design heating discharge temperature	: 110 deg F

COOLING PARAMETERS FOR SYSTEM 4 - Constant Volume Reheat for Zones 4,5,6

Cooling plant type	: District Cooling
Outside temperature below which cooling is off	: 55 deg F
Cooling availability	: Jan through Dec
Design cooling coil discharge temperature	: 50 deg F
Discriminator control	: Yes
Maximum cooling coil discharge temperature	: 60 deg F

PREHEAT PARAMETERS FOR SYSTEM 4 - Constant Volume Reheat for Zones 4,5,6

Preheat plant type	: None
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HUMIDIFICATION PARAMETERS FOR SYSTEM 4 - Constant Volume Reheat for Zones 4,5,6

Humidification plant type	: None
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BASEBOARD PARAMETERS FOR SYSTEM 4 - Constant Volume Reheat for Zones 4,5,6

Baseboard plant type	: None
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FAN PARAMETERS FOR SYSTEM 4 - Constant Volume Reheat for Zones 4,5,6

Total supply fan power required	:	7.5 KW
Supply fan temperature rise	:	2 deg F
Total return fan power required	:	0 KW
Return fan temperature rise	:	0 deg F
Unoccupied cycle fan control method	:	On Continuously

OUTSIDE AIR PARAMETERS FOR SYSTEM 4 - Constant Volume Reheat for Zones 4,5,6

Occupied Cycle

Outside air damper control method	:	Fixed Dampers
Minimum percent outside air intake	:	10 %

Unoccupied Cycle

Outside air damper control method	:	Fixed Dampers
Minimum percent outside air intake	:	10 %

ZONE AIR PARAMETERS FOR SYSTEM 4 - Constant Volume Reheat for Zones 4,5,6

Zonal air volume method	:	Entered by Zone
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ZONE CFM PARAMETERS FOR SYSTEM 4 - Constant Volume Reheat for Zones 4,5,6

Loads Zone #	Zone Name or Label	Zone CFM
4	KITCHEN	: 1321
5	STORAGE	: 567.3
6	OFFICE	: 240

PLANT INPUT TO ASEAM 2

DATA ECHO FOR PLANT INPUT FILE: REV BASDC.PID

ENERGY COSTS/CONVERSIONS

Fuel Type	Energy Units	Unit Cost	Conversion Factors (BTU/Unit)	
			Site	Source
Electricity	KWH	\$0.0700	3,413	11,600
Natural Gas	Therms	\$0.0000	100,000	100,000
#2 Oil	Gallons	\$0.0000	138,700	138,700
#4 Oil	Gallons	\$0.0000	141,000	141,000
#6 Oil	Gallons	\$0.0000	149,700	149,700
Dist Heating	MBTU	\$ 9.0000	1,000,000	1,390,000
Dist Cooling	MBTU	\$ 9.0000	1,000,000	1,000,000

MISCELLANEOUS ENERGY CONSUMPTION

DOMESTIC HOT WATER

Domestic Hot Water Energy Source : District
Domestic Hot Water Heating Capacity : Autosized
Peak hourly DHW usage : gal/hour
Average hourly DHW usage - occupied cycle : 10 gal/hour
Average hourly DHW usage - unoccupied cycle : 1 gal/hour
DHW Temperatures
Domestic hot water supply temperature : 130 deg F
DHW inlet temperature - design summer : 55 deg F
DHW inlet temperature - design winter : 45 deg F
Circulating Pumps
Circulating pump KW - occupied cycle : 0 KW
Circulating pump KW - unoccupied cycle : 0 KW
Domestic Hot Water Efficiency and Losses
Design DHW heating efficiency : 85 %
DHW losses - occupied cycle : 50 BTUH
DHW losses - unoccupied cycle : 50 BTUH

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