LBL--27512

DE90 008073

Integrated Estimation of Commercial Sector End-Use Load Shapes and Energy Use Intensities

Final Report

January, 1989

Prepared for

Southern California Edison Company
and
California Energy Commission

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This research was sponsored by the Southern California Edison Company, by the Universitywide Energy Research Group at the University of California with funding from the California Energy Commission, and by the Assistant Secretary for Conservation and Renewable Energy, Office of Building and Community Systems of the U.S. Department of Energy under Contract N. DE-AC03-76SF00098.

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Executive Summary

The Southern California Edison Company (SCE) and the California Energy Commission (CEC) have contracted with the Energy Analysis Program of the Applied Science Division at the Lawrence Berkeley Laboratory (LBL) to develop an integrated set of commercial sector load shapes (LS) and energy utilization indices (EUI) for use in forecasting electricity demand. The objectives of this project are to conduct detailed analyses of SCE data on commercial building characteristics, energy use, and whole-building load shapes; and in conjunction with other data, to develop, test, and apply an integrated approach for the estimation of end-use LSs and EUIs. The project represents one of the first attempts to combine simulation-based, prototypical building analyses with direct reconciliation to measured hourly load data.

The project examined electricity and gas use for nine building types, including large offices, small offices, large retails, small retails, food stores, sitdown restaurants, fastfood restaurants[1], refrigerated warehouses, and non-refrigerated warehouses. For each building type, nine end uses were examined, including cooling, heating, ventilation, indoor lighting, outdoor lighting, miscellaneous equipment, water heating, cooking, and refrigeration. For the HVAC end uses (cooling, ventilation, and heating), separate analyses were performed for three climate zones: coastal, inland, and desert.

There were three parts to the project:

1. **Data.** Analysis and assessment of input data, including on-site surveys, load research data, mail surveys, submetered loads and weather files, and a review of existing EUI and LS studies;
2. **Methodology.** Development of a three-part, integrated methodology for estimating end-use LSs and EUIs, an assessment of the use of prototypical buildings, and limited validation using submetered data; and

[1] Sitdown and fastfood restaurants were ultimately combined into a single category for restaurants.

3. **Results.**

a) Development of prototypical buildings, followed by

b) The performance of energy use simulations, which led to preliminary estimates of LSs and EUIs

c) Modification of these preliminary estimates through direct reconciliation to measured whole-building load research data using historical weather data, and

d) Adjustments to final EUIs for use in SCE and CEC forecasting models.

In addition, we made a preliminary **evaluation** of the uncertainties associated with the data and the methodology.

Data

The primary data for the project consisted of approximately 450 on-site surveys and a year of hourly whole-building load (or load research) data from 1,323 billing accounts. Secondary data included the results from a recent SCE mail survey, other EUI and LS studies, historic southern California weather data, and submetered electricity data.

The on-site surveys, primarily, and the mail survey, secondarily, provided information on the characteristics and operation of commercial premises in the SCE service territory. The information was used to estimate preliminary non-HVAC EUIs and LSs and to develop prototypical descriptions of premises so we could estimate preliminary HVAC EUIs and LSs. The on-site surveys were developed by auditors who interviewed owners of premises and recorded building characteristics in a standardized format.

Load research data (LRD) and historic weather were used to develop average whole-building load shapes and to characterize the effects of weather on these averaged load shapes. This information was used in the reconciliation process that adjusted preliminary LSs and EUIs to match measured energy use. The load research data were collected by SCE as part of its ongoing analyses for rate design. Weather data for 1986 were obtained for the Los Angeles International Airport (representing a coastal climate), the Hollywood-Burbank Airport (representing an inland climate), and the Norton Air Force Base (representing a desert climate) from the National Climatic Data Center.

We spent considerable, unanticipated effort analyzing, cleaning, correcting, and processing these data. We estimate that nearly half our time was spent ensuring that the data would yield meaningful results. In the end, 75% of the original 454 on-site surveys and 60% of the original 1,323 LRD were used in the analysis (although many data points were eliminated because they reported information for building types not considered by this study).

In preparation for the development of our methodology and assessment of our results, we reviewed 11 EUI and three LS studies.

Methodology

A major analytical contribution of our work was the development of an integrated method for the estimation of LSs and EUIs that relies explicitly on measured LRD to reconcile preliminary engineering estimates. The method consists of three parts (see Figure EX-1).

First, we developed preliminary EUIs and LSs for the nine premise types using the Non-HVAC EUI/LS and DOE-2 Input Generator (NELDIG) and the DOE-2 building energy analysis program. NELDIG performs two functions: 1) it estimates *preliminary LSs and annual EUIs for non-HVAC end uses*, and 2) it prepares a *prototypical building input* for DOE-2. The prototypical buildings were then simulated using DOE-2 to obtain *preliminary EUIs and LSs for the HVAC end uses*. The averaging procedures relied on exogenously derived sample weights for each on-site survey.

Second, we constructed *average whole-building hourly loads*, by building type (and, where possible, by climate zone[2]) from the LRD[3] and *average electricity bills* from the billing data

[2] Separate large office, small office, large retail, and small retail whole-building load shapes were developed for three climate zones.

[3] We could not distinguish sitdown from fastfood restaurants in the LRD and were forced to combine them into a single building type.

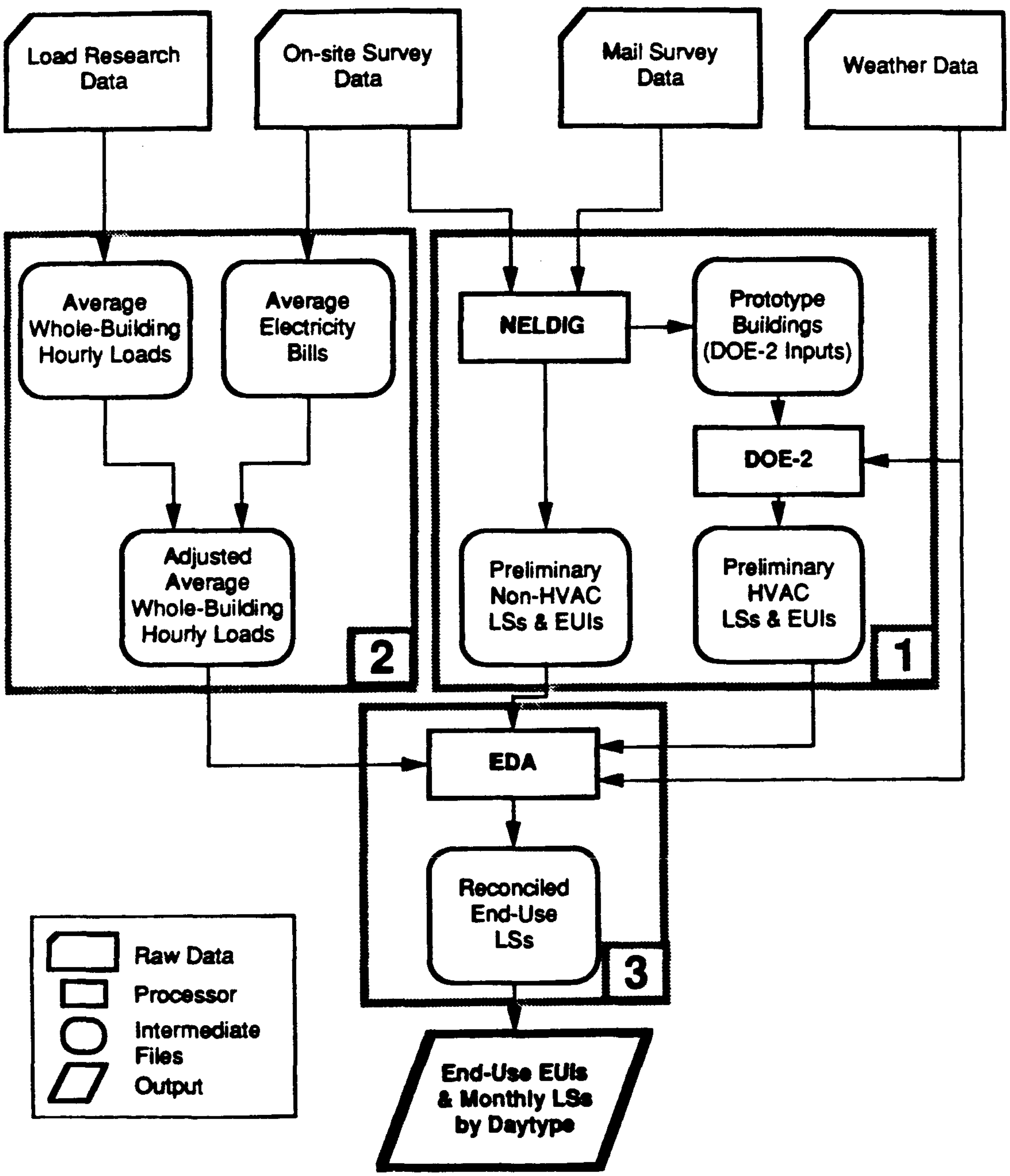
reported in the on-site surveys. This information was combined to produce an *adjusted average whole-building load* for each building type. The averaging procedures relied on exogenously derived sample weights for each LRD account.

Third, using the preliminary LS and EUI estimates by end use from the first step and the average hourly loads from the second step, we applied the End-use Disaggregation Algorithm (EDA) to obtain *reconciled end-use LSs*. The corresponding EUIs are simply the integration of the LSs for the entire year.

The validation of our estimation methodology was preliminary. We anticipated extensive use of submetered end-use load data for this purpose, but our efforts to acquire such data were unsuccessful. We did, however, obtain end-use load data for a single restaurant, as well as a calibrated DOE-2 input file, from the Seattle City Light Company (SCL). Our initial results in applying the developed methodology to this building illustrated the importance of measured end-use load data to determine the characteristics of non-HVAC end uses. We found that SCL's contractors had devoted considerable effort to calibrating the DOE-2 input. The nature of their calibration, however, precluded EDA from making significant adjustments to the initial conditions. That is, the simulation input was already very representative of the measured whole-building average load shape but was not representative of the actual load shapes of the constituent end uses (largely because of manual (mis)adjustment of the miscellaneous equipment load shape). Accordingly, application of the EDA could not improve the initial estimates because the total load was already (mis)calibrated.

An important methodological issue that arose in developing the DOE-2 prototypes was how best to aggregate and somehow "average" the features of many distinct buildings into those needed to describe a single, prototypical building. We examined two procedures for aggregating characteristics of individual premises into a single prototypical premise for a limited sample of on-site surveys for a small office and a sitdown restaurant. We found very close agreement for the non-HVAC EUIs; however, for the HVAC EUIs, we found substantial disagreement between the aggregated individual premises runs and the prototype runs.

Figure EX-1. Integrated Commercial LS and EUI Estimation Methodology. The method consists of three parts: 1) development of preliminary EUIs and LSs using NELDIG and DOE-2, 2) construction of average whole-building hourly loads, by building type, and 3) reconciliation of the preliminary EUIs and LSs with average whole-building hourly load, using EDA.



Results

We applied our methodology and developed EUIs and LSs for eight electricity end uses (electric heating was found to be insignificant in our sample) in eight building types (sitdown and fast-food restaurants were combined into a single building type). Table EX-1 summarizes the reconciled EUIs and Figures EX-2 through EX-9 summarize the reconciled LSs for the inland climate zone.

Comparison of the reconciled EUIs with previous studies showed reasonable agreement. A notable exception was lighting in the large office, which tends to exceed previous estimates. We traced the source of the large EUIs to the high average electricity bill developed for this building type from the on-site survey.

The reconciled load shapes showed much smoother transitions between day and night hours than those found in earlier studies or the initial simulated load shapes developed in the current project, which were the input to the EDA. We noted that simulations of prototypes, which were the basis for these load shapes, are fundamentally limited in their ability to capture the diversity of starting and stopping times found in the stock of commercial premises.

Perhaps the most important influence of EDA on the preliminary EUIs was that of exact reconciliation to the whole-building average load. As a result of this reconciliation, we found considerable differences between non-standard day and standard day profiles for several building types. We also observed that seasonal influences could be very important for many non-HVAC end uses.

The unique structure of the SCE and CEC forecasting models precluded direct use of the reconciled EUIs. Consequently, we developed methods to adjust the reconciled data to produce EUIs for the distinct combinations of building and equipment vintages and technologies required by each model.

Table EX-1. Reconciled Electricity EUIs (kWh/ft^2-yr) for Climate Zone 1 (LAX), Zone 2 (BUR), and Zone 3 (NOR)

	Indoor Lighting	Outdoor Lighting	Misc. Equip.	Refrig.	Cooking	Water Heating	Ventilation[1]	Cooling[1]	Total	
Small Office	5.47	1.24	3.59	0.23	0.04	0.15	0.97	2.77	15.52	LAX
							1.38	5.80	16.53	BUR
							1.23	8.92	18.41	NOR
Large Office	11.93	2.11	4.28	0.10	0.00	0.16	3.09	3.93	24.54	LAX
							3.30	3.91	25.94	BUR
							3.45	5.11	27.58	NOR
Small Retail	7.49	1.59	1.48	0.95	0.01	0.04	1.67	5.45	17.21	LAX
							1.82	6.54	17.40	BUR
							2.04	11.15	18.81	NOR
Large Retail	12.21	1.47	1.12	0.61	0.19	0.02	3.41	5.79	22.50	LAX
							3.71	4.94	22.76	BUR
							3.61	7.65	24.48	NOR
Food Store	11.96	2.01	1.77	23.17	0.24	0.03	2.14	0.00	40.27	
Ref Warehse	3.02	0.55	6.24	11.34	0.01	0.17	1.50	2.82	23.91	
NonRef Warehse	3.38	0.17	0.70	0.41	0.00	0.03	0.62	1.16	5.02	
Restaurant	7.94	4.09	4.89	10.78	4.46	0.03	7.49	12.25	51.91	

1. Cooling and ventilation EUIs were estimated separately for the Coastal region (represented by Los Angeles Airport weather), the Inland region (represented by Hollywood-Burbank Airport weather), and the Desert region (represented by Norton Air Force Base weather), in descending order.

Figure EX-2. Summary of Reconciled Load Shapes for Small Office in Climate Zone 2 (BUR)

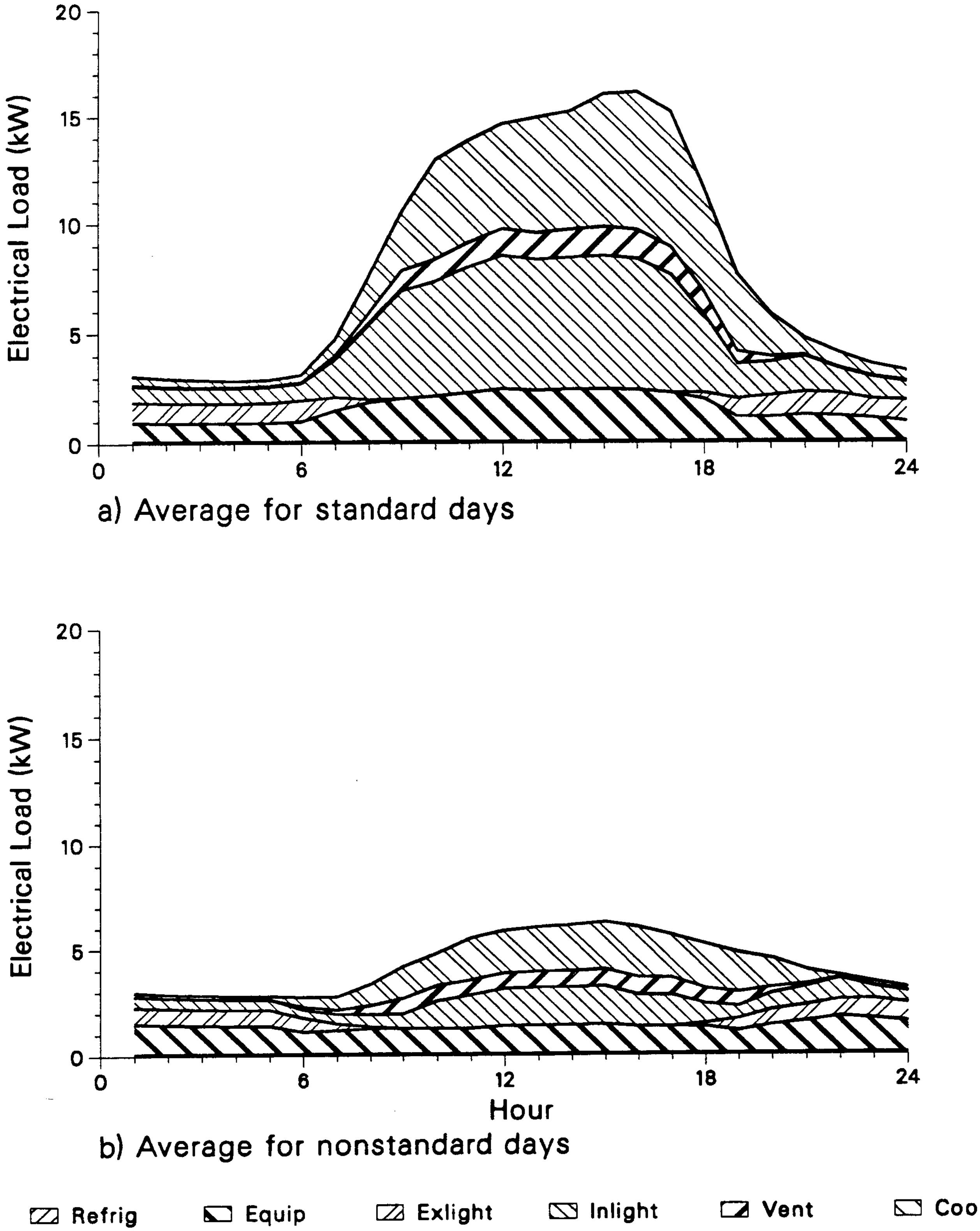


Figure EX-3. Summary of Reconciled Load Shapes for Large Office in Climate Zone 2 (BUR)

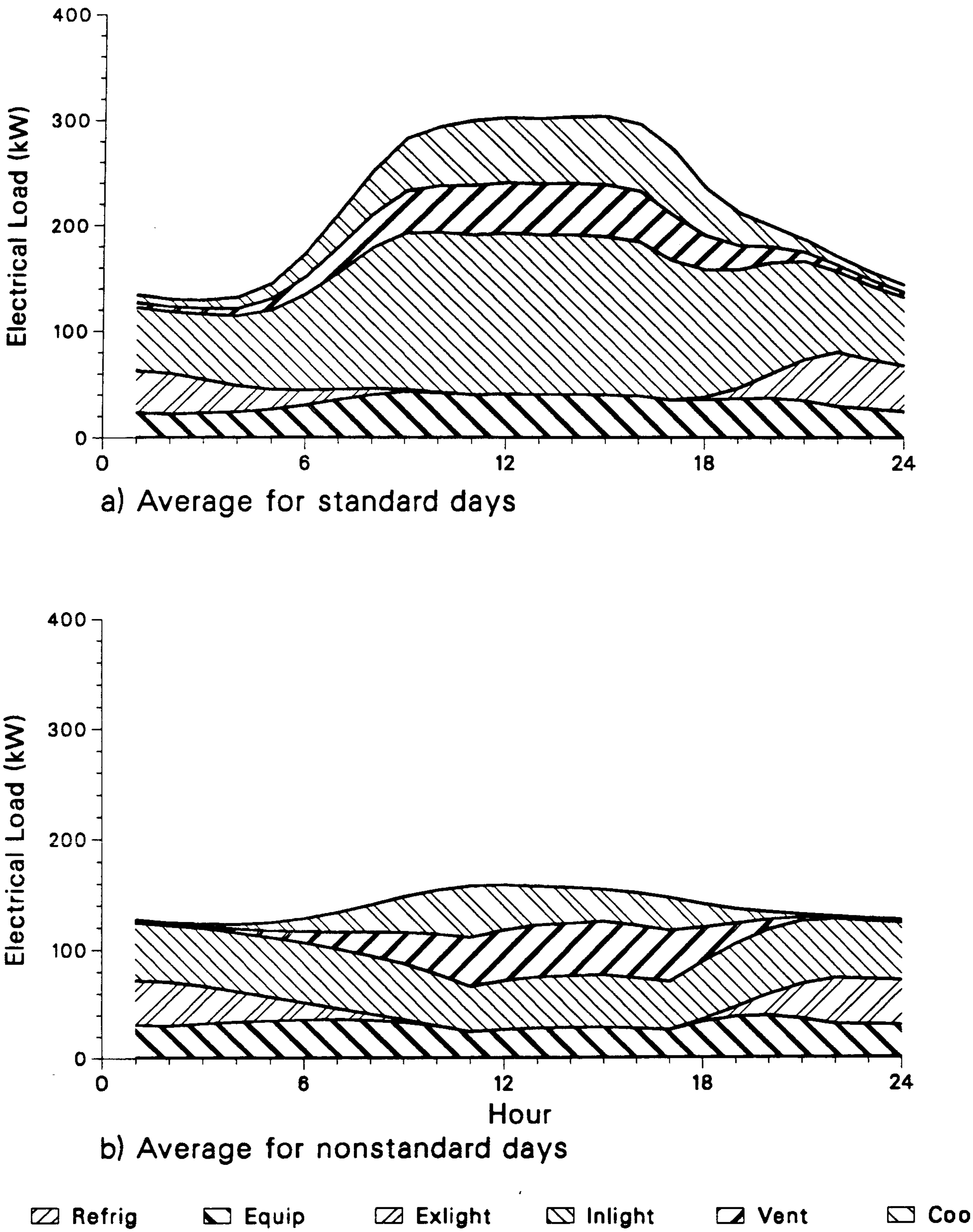


Figure EX-4. Summary of Reconciled Load Shapes for Small Retail in Climate Zone 2 (BUR)

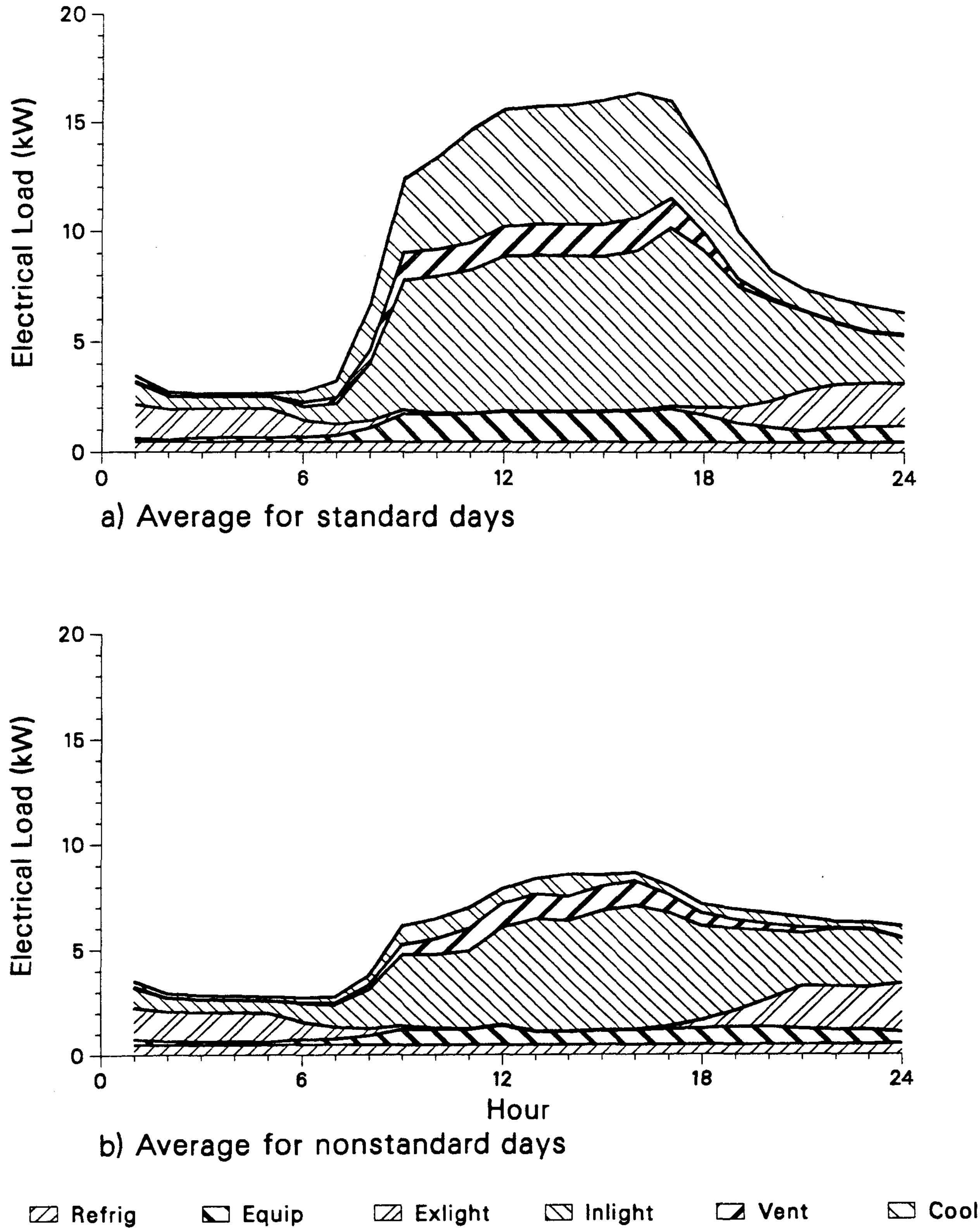


Figure EX-5. Summary of Reconciled Load Shapes for Large Retail in Climate Zone 2 (BUR)

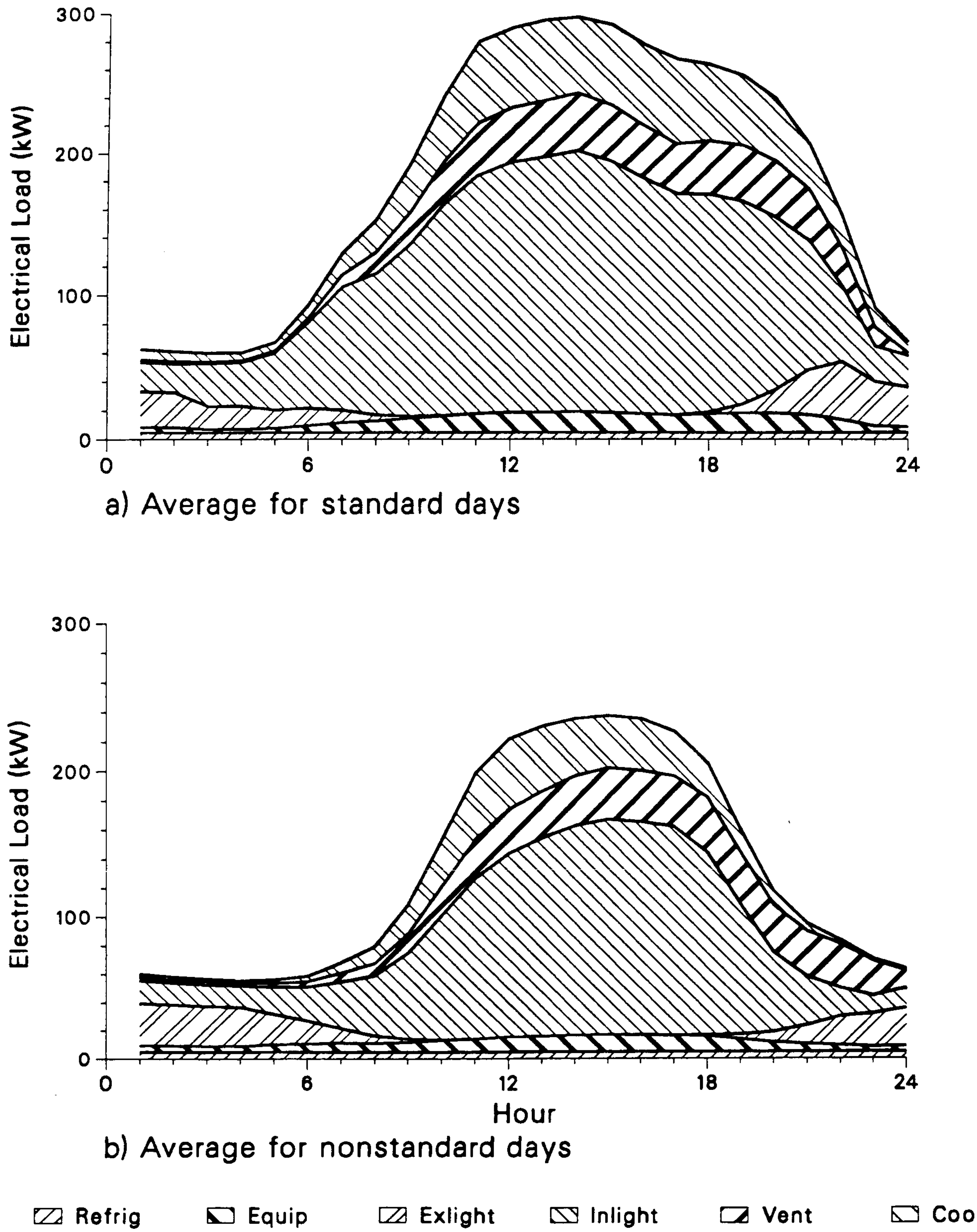


Figure EX-6. Summary of Reconciled Load Shapes for Food Store in Climate Zone 2 (BUR)

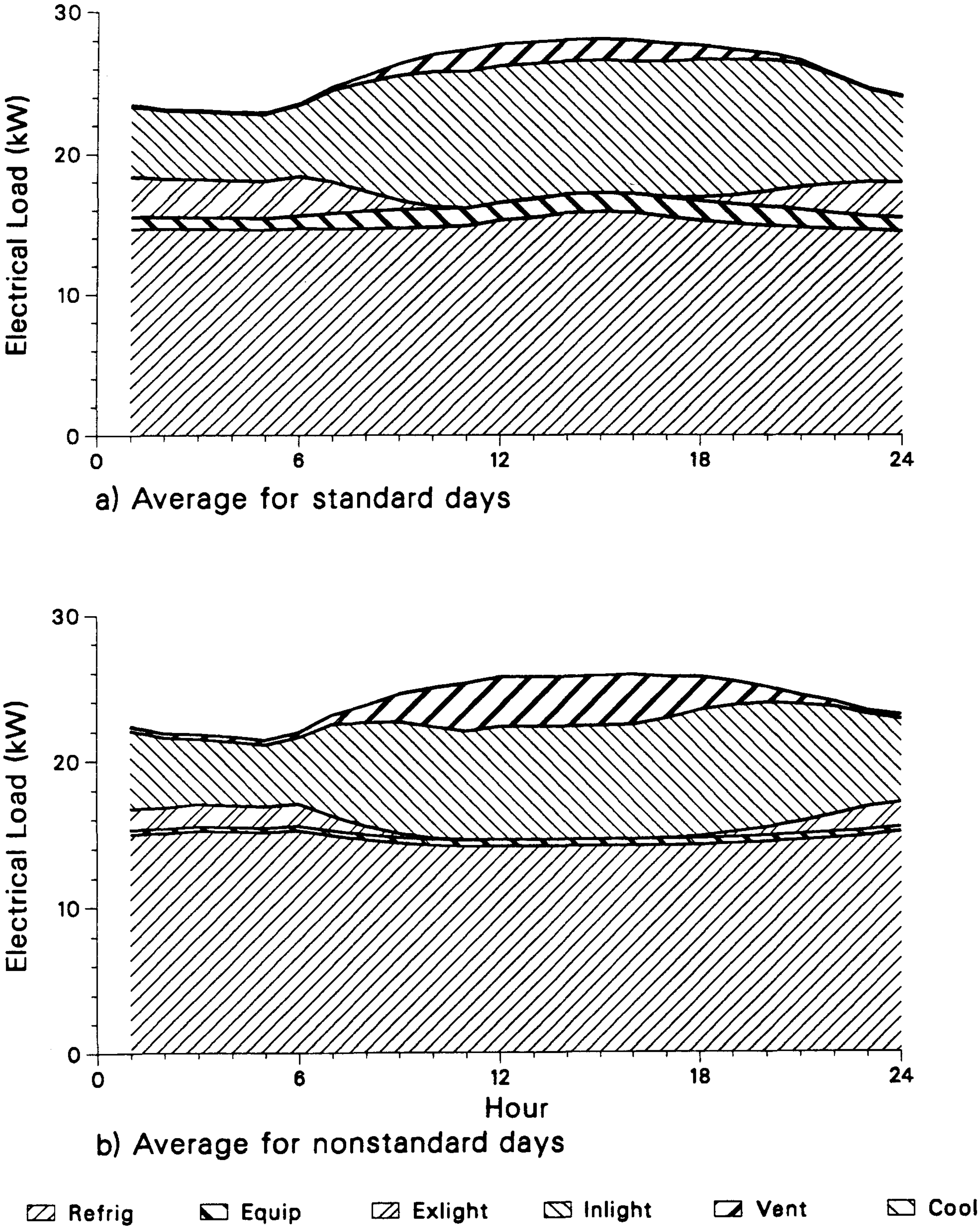


Figure EX-7. Summary of Reconciled Load Shapes for Refrigerated Warehouse in Climate Zone 2 (BUR)

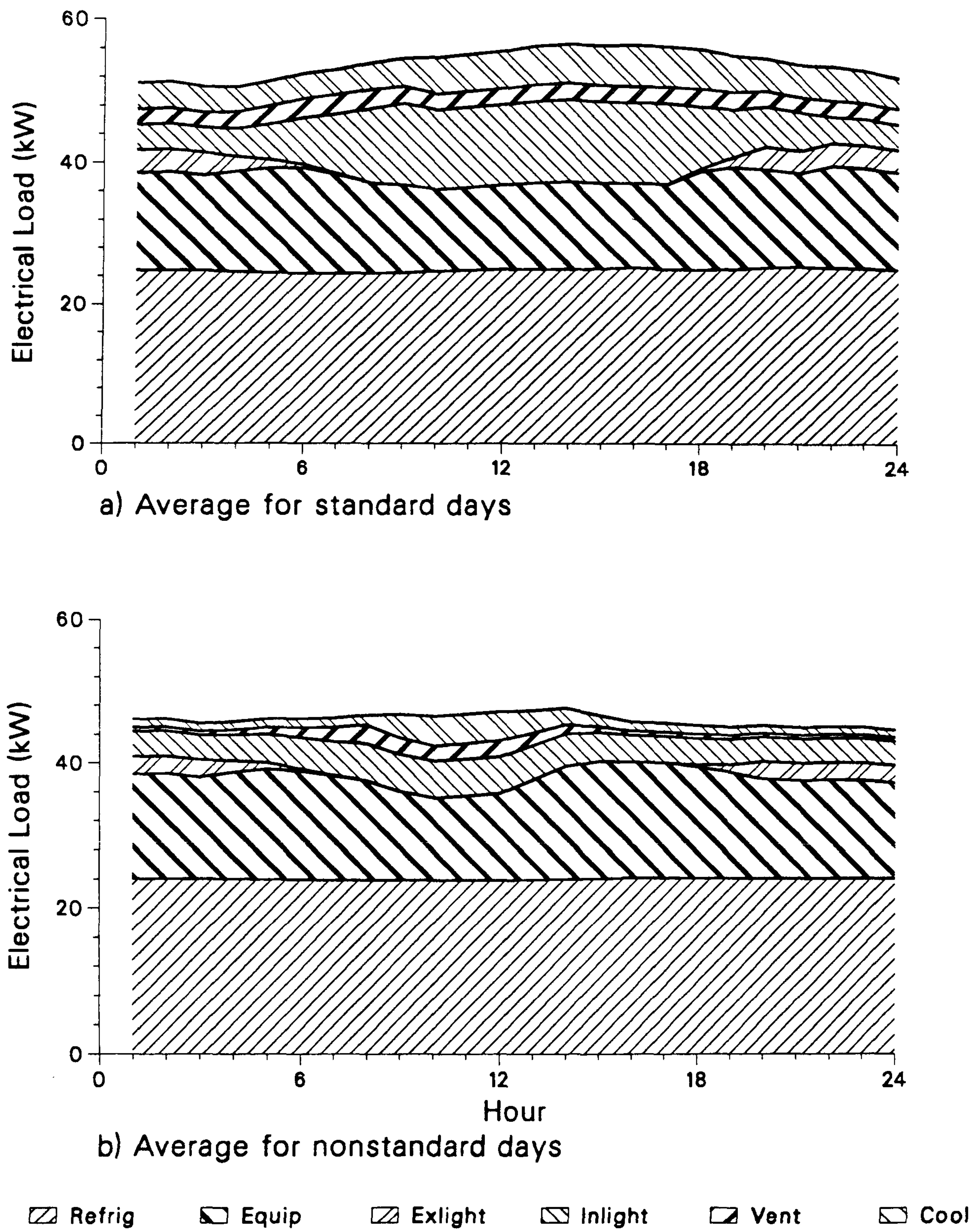


Figure EX-8. Summary of Reconciled Load Shapes for Non-Refrigerated Warehouse in Climate Zone 2 (BUR)

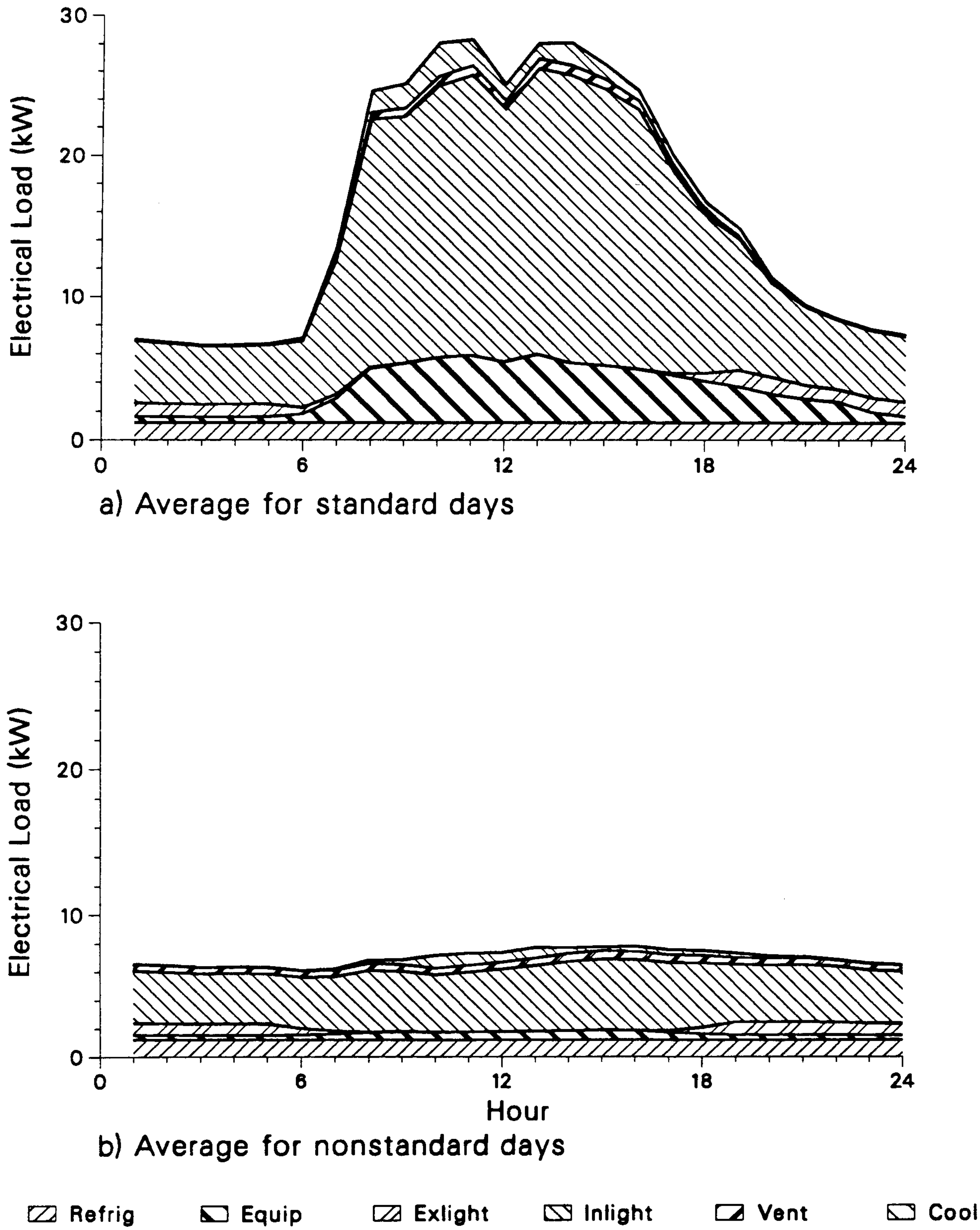
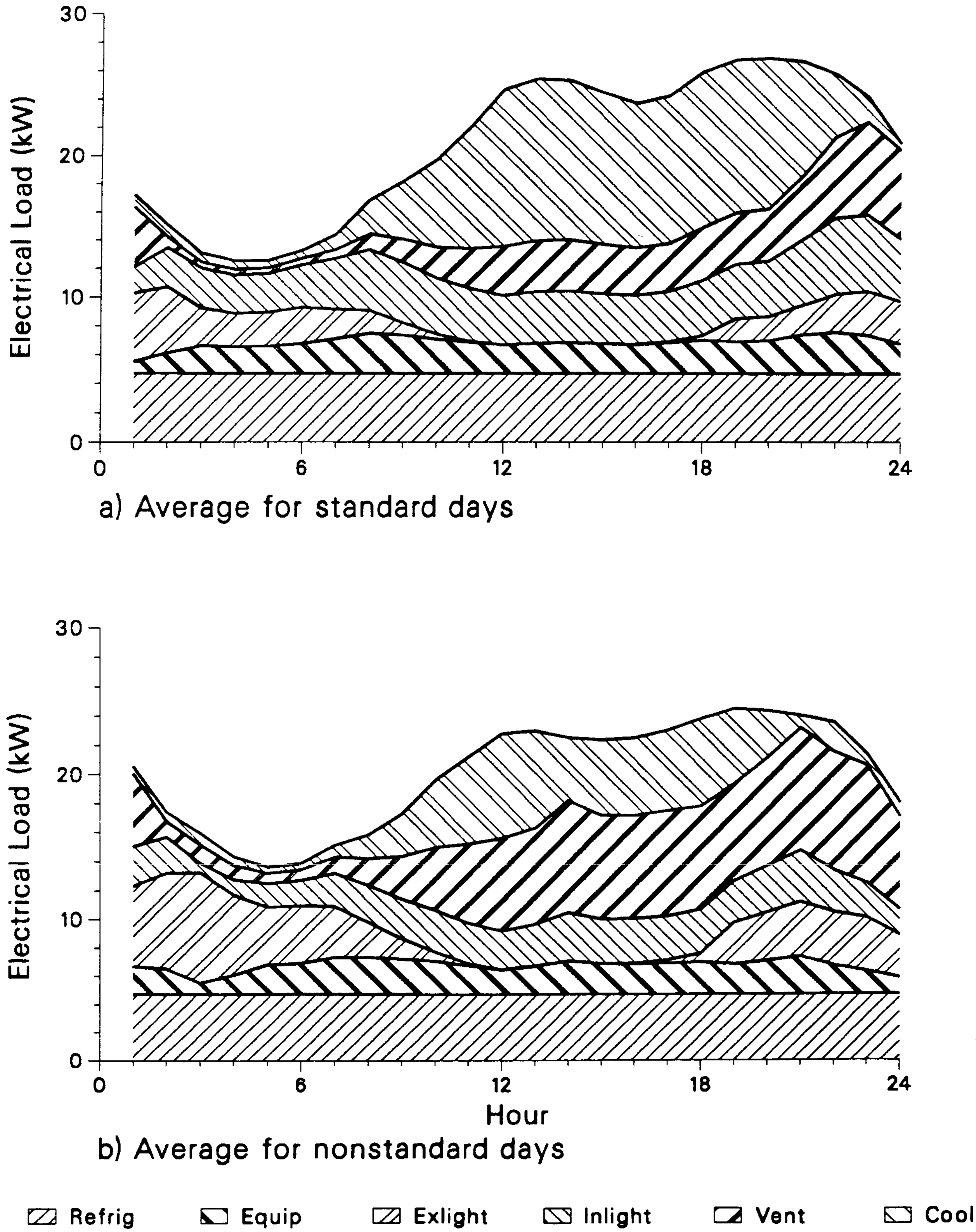


Figure EX-9. Summary of Reconciled Load Shapes for Restaurant in Climate Zone 2 (BUR)



Evaluation

We made a limited review of the major sources of uncertainty in the analysis. We identified three categories of uncertainty corresponding to the input data, the estimation method, and the formatting required for the final data. We hypothesized that the largest uncertainties were associated with the on-site survey data, our methods for developing weighting factors, and the use of those weighting factors to develop preliminary HVAC EUIs. To a large extent, these uncertainties were addressed in aggregate by the reconciliation to the whole-building load shape. Nevertheless, errors in the weighting factors used to develop the whole-building load shape affected our results. Also, individual end uses, with the possible exception of cooling and ventilation, were highly dependent on the preliminary estimates from the on-site survey data.

Adjustments to Reconciled EUIs for Use in Forecasting

The reconciled EUIs are not directly usable by the SCE and CEC forecasting models because the models require distinct EUIs for individual technologies and vintages that are indexed to building energy use in 1975. The impact of California's building and appliance energy efficiency standards (loosely, Titles 24 and 20) is of particular interest because a major challenge for the adjustment procedure is to "remove" the impacts of these standards from our reconciled EUIs.

Both CEC and SCE use end-use forecasting models that rely on estimates of energy use for buildings and equipment built to meet standards. The estimates used by CEC and SCE were developed using a combination of survey data, engineering judgement, and heat load simulations of prototypical buildings. The changes in energy use resulting from standards are expressed, for a given end use, as fractions relative to a base year of 1975 (prior to the enactment of either standard).

We have developed a hybrid method for adjusting the reconciled EUIs to reflect the impacts of standards, changing energy prices, and changing technologies. The focus of our method is on HVAC end uses because they are the end uses most affected by standards and because they interact strongly with the non-HVAC end uses. Our methodology and the adjusted EUIs by vintages are summarized in Chapter VIII.

Introduction and Summary

The Southern California Edison Company (SCE) and the California Energy Commission (CEC) have contracted with the Energy Analysis Program of the Applied Science Division at the Lawrence Berkeley Laboratory (LBL) to develop an integrated set of commercial sector load shapes (LS) and energy utilization indices (EUI) for use in forecasting electricity demand. The overall objectives of this project are to conduct detailed analyses of SCE data on commercial building characteristics, energy use, and whole-building load shapes, and, in conjunction with other data, to develop, test, and apply an integrated approach for the estimation of end-use LSs and EUIs. The project is one of the first attempts ever to combine simulation-based, prototypical building analyses with direct reconciliation to measured hourly load data.

In essence, there were three major parts to the project:

1. **Data:** analysis and assessment of input data, including on-site surveys, load research data, mail surveys, submetered loads and weather files (Tasks I and II), and a review of existing EUI and LS studies (Task III);
2. **Methodology:** development of a three-part, integrated methodology for estimating end-use LSs and EUIs (Tasks IV and V), including an assessment of the use of prototypical buildings (Task VI), and limited validation using submetered data (Task VII); and
3. **Results:** development of prototypical buildings and the performance of energy use simulations, which lead to preliminary estimates of LSs and EUIs, modification of these preliminary estimates by directly reconciling them to measured whole-building load research data using historical weather data, and adjustments to final EUIs for use in SCE and CEC forecasting models (Task VIII).

In addition, we made a preliminary **evaluation** of the uncertainties associated with the data and the methodology (Task IX).

The project included electricity and gas use for nine building types, including large offices, small offices, large retail, small retail, food stores, sitdown restaurants, fastfood restaurants[1], refrigerated warehouses, and non-refrigerated warehouses. For each building type, nine end uses were examined, including cooling, heating, ventilation, indoor lighting, outdoor lighting, miscellaneous equipment, water heating, cooking, and refrigeration. For the HVAC end uses (cooling, ventilation, and heating), separate analyses were performed for three climate zones: coastal, inland, and desert.

In the remainder of this section, we summarize our report according to the tasks developed in the work plan for the project,[2] as identified in the overview, above.

Task I. Data Base Preparation

The primary sets of data for the project consisted of approximately 450 on-site surveys and 1,000 load research billing accounts. Secondary sets of data included the results from a recent SCE mail survey, other EUI and LS studies, historic southern California weather data, and available submetered energy use data.

The on-site surveys, primarily, and the mail survey, secondarily, provided information on the characteristics and operation of commercial premises in the SCE service territory. This information was used to estimate preliminary non-HVAC EUIs and LSs and to develop descriptions of prototypical premises to estimate preliminary HVAC EUIs and LSs (Tasks V).

In total, approximately 75% of the original 454 on-site surveys were used for subsequent non-HVAC EUI and LS estimation and prototype development for the nine types of premises. The majority of surveys not used were eliminated because they reported on premises not covered by the current study. Nevertheless, we spent a significant amount of effort uncovering, correcting,

[1] Sitdown and fastfood restaurants were ultimately combined into a single category for restaurants.

[2] Akbari, H., Turiel, I., and Eto, J. "Integrated Estimation of Commercial Sector End-Use Load Shapes and Energy Use Intensities, A Joint Workplan prepared for Southern California Edison Company and California Energy Commission," Lawrence Berkeley Laboratory, January 25, 1988.

or filtering bad data from the on-site survey. In addition, the original high-rise and low-rise office classification scheme used in gathering the on-site survey data was replaced by a classification that relied on floor area and some premises were reclassified based on correspondence with the firm responsible for collecting the data.

Load research data and historic weather data were analyzed to develop average whole-building load shapes, and analyses were performed to characterize the effects of weather on load shape. This information was used to adjust the initial set of EUIs and LSs to a final calibrated set (Task VIII). Preparation of the LRD consisted of eliminating incomplete or spurious records and assigning types of premises to accounts identified only by SIC codes. Simple rules, based on annual consumption, were used to separate large and small retail and offices. Fastfood restaurants and sitdown restaurants could not be distinguished and were combined into a single category. In total, approximately 70% of the original 1,323 load research accounts were used to develop average whole-building load shapes for each of the types of premises (Task II). Once, again, the majority of unused LRD were for premises not evaluated in the current study.

Existing EUI and LS data were obtained to provide benchmarks for checking the reasonableness of our analyses (Task III). Southern California hourly weather data for 1986 were obtained for the Los Angeles Airport (representing the coastal climate), Hollywood-Burbank Airport (representing the inland climate), and Norton Air Force Base (representing the eastern, desert-like climate of the San Bernadino area). Although we anticipated use of submetered data to validate the overall method (Task VII), we were unable to obtain the data.

Task II. Data Base Integration

The goal of the data base integration task was to develop a consistent procedure for aggregating data from the on-site surveys and load research data by types of premises for preliminary estimation and final reconciliation of EUIs and LSs.

Integration of the on-site survey data by types of premises relied on the development of formal statistical weights for aggregating features of individual to those of representative premises. The weights were developed using information provided by SCE on the distribution of electricity consumption by SCE commercial sector accounts, stratified by types of premises.

Formal integration of the load research data according to types of premises was required for development of average whole-building load shapes by types of premises. The integration relied on the same distributions of electricity consumption as those used to aggregate the on-site survey data. Where the number of accounts was judged to be sufficiently large (i.e., more than five per region), aggregation by types of premises was performed separately for the three climate regions identified in Task I.

Once aggregated, the average whole-building load shapes were normalized to the statistically weighted, average, measured electricity consumption of the on-site survey premises to ensure consistency between the energy use of the prototypical premises (developed from on-site survey data) and the averaged, whole-building load shapes (developed from the load research data).

The final data base integration task was a regression analysis of the averaged whole-building hourly load shapes against historic weather data to determine the appropriate climate variables for use in the reconciliation process.

Task III. Review of Existing EUI and LS Studies

Existing EUI and LS data were reviewed to provide a reference point for our research. Review of the methods used and final values in use for forecasting constituted the baseline that we have attempted to improve with the current study. Our review focused on studies that used California data.

Our review of existing EUI studies found fairly good agreement on electric lighting, heating, and cooling EUIs. Other EUIs, notably electric miscellaneous in offices, retail, and food stores; electric refrigeration in restaurants and warehouses; electric cooking in restaurants; and electric water heating and ventilation for all types of premises exhibited the largest ranges. The major variations in gas EUIs were found in restaurants (all end uses) and food stores (cooking and water heating).

Our review of three LS studies, which included existing LSs in use by SCE and CEC, uncovered two significant features of existing EUIs. First, LSs were generally not consistent between studies (e.g., SCE and CEC had different load shapes for the same end use in the same type of premises), but these differences could often be related to differences in assumptions for operating hours. Second, for a given type of premises, LSs were often identical for each month and for peak and standard-days suggesting that, according to the studies, these end uses were not affected by seasonal or climatic influences.

Task IV. Development of an Estimation Method

The major analytical contribution of our work was the development of an integrated method for the estimation of EUIs and LSs that relied explicitly on measured LRD to reconcile preliminary engineering estimates. The method consisted of three parts (see Figure 1):

First, we developed preliminary EUIs and LSs for the nine types of premises using the Non-HVAC EUI/LS and DOE-2 Input Generator (**NELDIG**) and the **DOE-2** building energy analysis program. **NELDIG** performs two functions: 1) it estimates *preliminary LSs and annual EUIs for non-HVAC end uses*, and 2) it prepares a *prototypical building input* for DOE-2. The prototypical buildings were then simulated using DOE-2 to obtain *preliminary EUIs and LSs for the HVAC end uses*. The averaging procedures relied on exogenously derived sample weights for each on-site survey.

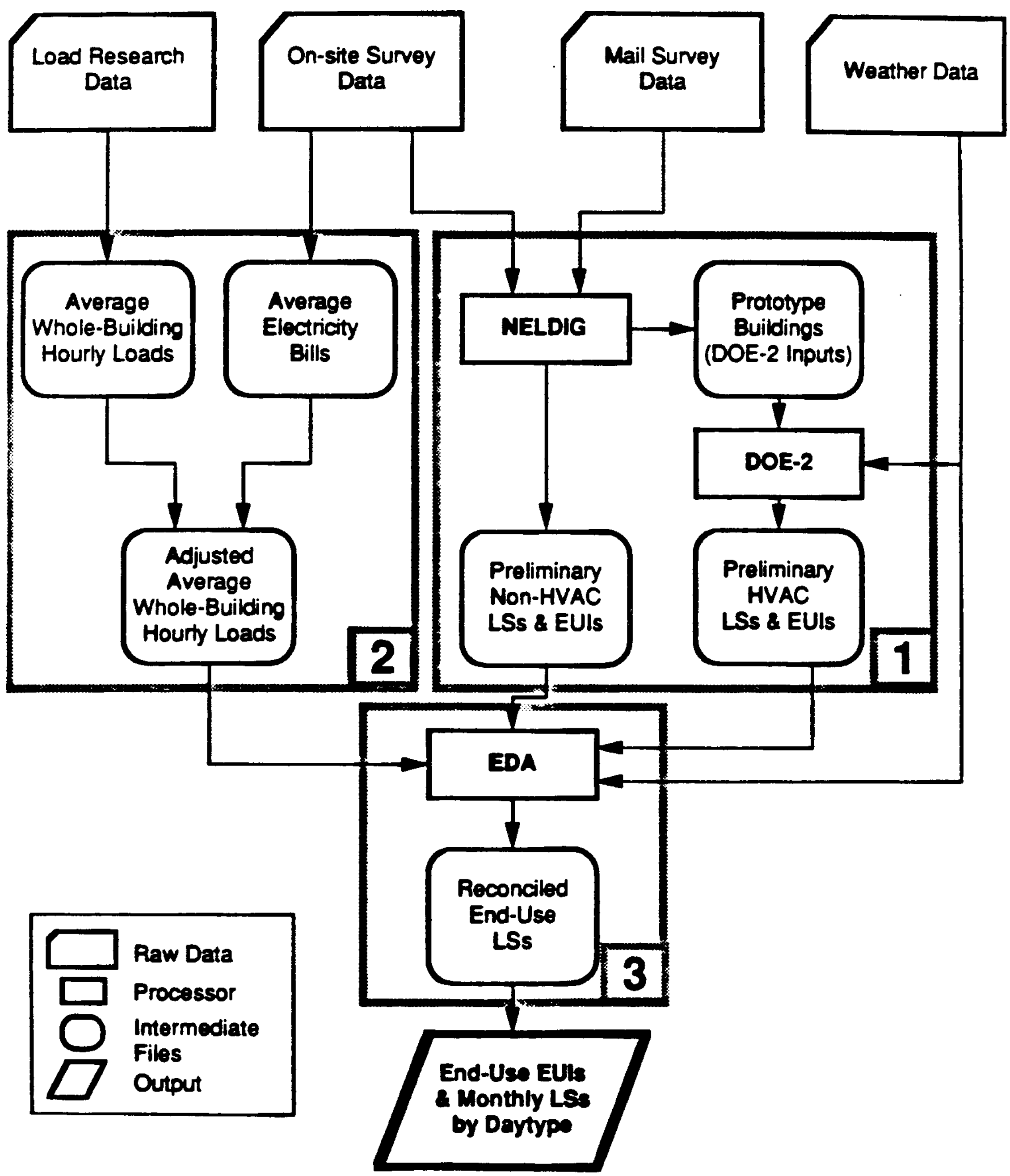
Second, we constructed *average whole-building hourly loads*, by building type (and, where possible, by climate zone[3]) from the LRD,[4] and *average electricity bills* from the billing data reported in the on-site surveys. This information was combined to produce an *adjusted average whole-building load* for each building type. The averaging procedures relied on exogenously derived sample weights for each LRD account.

Third, using the preliminary LS and EUI estimates by end use from the first step and the average hourly loads from the second step, we applied the End-use Disaggregation Algorithm (**EDA**) to obtain *reconciled end-use LSs*. The corresponding EUIs are simply the integration of the LSs for the entire year.

[3] Separate large office, small office, large retail, and small retail whole-building load shapes were developed for three climate zones.

[4] We could not distinguish sitdown from fastfood restaurants in the LRD, so we combined them into a single building type.

Figure 1. Integrated Commercial LS and EUI Estimation Methodology. The method consists of three parts: 1) development of preliminary EUIs and LSs using NELDIG and DOE-2, 2) construction of average whole-building hourly loads, by building type, and 3) reconciliation of the preliminary EUIs and LSs with average whole-building hourly load, using EDA.



Task V. DOE-2 Prototype Development

We used the DOE-2 building energy analysis program to develop preliminary EUIs and LSs for HVAC end uses. Our efforts to develop prototypical premises concentrated on accurate representation of the aggregated thermodynamic, rather than physical, characteristics of the individual premises. For example, we introduced a uniform shape for each prototype and introduced fairly simple HVAC systems and plants, exogenously.

Prior to simulation, we compared our prototypes to those used in previous analyses by SCE and CEC. We found that our prototypes had smaller floor areas and lower lighting levels than those used historically by SCE and CEC. The differences in floor area could be traced to our statistical weighting procedure, which tended to emphasize smaller buildings.

Exploring the reasons for the differences in lighting levels was deemed premature, because the most important basis for comparison was the resulting EUIs and LSs. For example, if lighting was adjusted upward by the reconciliation process (and it was for many types of premises; see Task VIII), then the preliminary lighting level assumption used in the prototype would be low, relative to its final value.

Task VI. Pilot Prototype Analysis

Prototypes are commonly used in forecasting commercial sector energy use. The basic idea is to create a description of prototypical premises that broadly represent a whole class of premises. The description is generally in the form of an input to a building energy simulation program. The objectives of this description are often two-fold. First, the results of the simulation can form the basis for estimates of space conditioning EUIs and load shapes. Second, the performance of technology options can be modeled explicitly through selective modifications of the simulation inputs.

The methodological question that arises in developing prototypes is how best to aggregate and "average" features of many distinct buildings into prototypical premises. We examined two procedures for aggregating characteristics of individual premises into those for prototypical premises; we used a limited sample of on-site survey data for two building types, a small office and a sitdown restaurant.

The first procedure, taken from the predecessor to the NELDIG program, used floor area as a statistical weight. The second procedure used the statistical weights developed in Task II. NELDIG and DOE-2 were run for individual premises and for two prototypical premises, each developed using one of these weighting procedures. The results of the individual premises runs were then aggregated to a single number using each of the two weighting procedures and compared to the results of the prototypes, which were developed initially, using one of the two procedures.

We found very close agreement for the non-HVAC EUIs, using both weighting procedures for both types of premises. For the HVAC EUIs, we found substantial disagreement between the aggregated individual premises runs and the prototype runs. This result was also observed for both types of premises and both weighting procedures. The statistical weighting procedure, however, appeared to perform somewhat better than the floor area weighting procedure.

Task VII. Initial Validation

We anticipated extensive use of submetered end-use load data to validate our method, but we were unable to acquire large amounts of such data (Task I). We did, however, obtain end-use load data for a single restaurant, as well as a calibrated DOE-2 input file, from the Seattle City Light Company (SCL).

Having the whole-building load shape, a DOE-2 input file, appropriate weather data, and the measured end-use loads appeared to ensure a successful validation of our method because we could essentially replicate our own estimation procedure (by running DOE-2), run the EDA reconciliation and check our results against the measured data. Our initial results were not encouraging; little adjustment was introduced by the EDA, because individual end-use loads had been calibrated incorrectly.

The small changes could be traced to the original DOE-2 input. SCL's contractors had devoted considerable effort to calibrating the DOE-2 input, so their simulation input was already very representative of the measured whole-building load shape (largely because of manual adjustment of the miscellaneous equipment load shape). Accordingly, application of the EDA could not improve the initial estimates because the total load was already in calibration, although individual end-uses were out of calibration.

Task VIII. Estimation of EUIs and LSs

There were three phases to our estimation process. First, we generated our initial estimates and reconciled them against the whole-building average load shapes (as described in Tasks I, II, IV and V). Second, we compared the resulting EUIs and LSs to those found in previous studies (from Task III). Third, we developed procedures to adjust the reconciled EUIs and LSs for distinct vintages and technology combinations, for use in the SCE and CEC forecasting models.

Significant differences were found between the preliminary total building EUI and the measured total EUI for the refrigerated warehouse, large office, and non-refrigerated warehouse. Generally this condition indicated that the reconciliation would result in a large adjustment to the preliminary EUIs. The exception to this rule was cooling and ventilation, in which the energy use was estimated directly from the regression analysis of whole-building load and historic weather.

Table 1 summarizes the reconciled EUIs. Comparison of the reconciled EUIs with previous studies shows reasonable agreement. A notable exception is lighting in the large office, which tends to exceed previous estimates. The source of the large EUIs is the high average electricity bill developed for this building type from the on-site survey.

The reconciled load shapes show much smoother transitions between day and night hours than those found in earlier studies or the initial simulated load shapes, developed in the current project that were the input to the EDA. We noted that simulations of prototypes, which were the basis for these load shapes are fundamentally limited with respect to their ability to capture the diversity of starting and stopping times found in the stock of commercial premises.

Table 1. Reconciled Electricity EUIs (kWh/ft^2-yr)

	Indoor Lighting	Outdoor Lighting	Misc. Equip.	Refrig.	Cooking	Water Heating	Ventilation[1]	Cooling[1]	Total	
Small Office	5.47	1.24	3.59	0.23	0.04	0.15	0.97	2.77	15.52	LAX
							1.38	5.80	16.53	BUR
							1.23	8.92	18.41	NOR
Large Office	11.93	2.11	4.28	0.10	0.00	0.16	3.09	3.93	24.54	LAX
							3.30	3.91	25.94	BUR
							3.45	5.11	27.58	NOR
Small Retail	7.49	1.59	1.48	0.95	0.01	0.04	1.67	5.45	17.21	LAX
							1.82	6.54	17.40	BUR
							2.04	11.15	18.81	NOR
Large Retail	12.21	1.47	1.12	0.61	0.19	0.02	3.41	5.79	22.50	LAX
							3.71	4.94	22.76	BUR
							3.61	7.65	24.48	NOR
Food Store	11.96	2.01	1.77	23.17	0.24	0.03	2.14	0.00	40.27	
Ref Warehse	3.02	0.55	6.24	11.34	0.01	0.17	1.50	2.82	23.91	
NonRef Warehse	3.38	0.17	0.70	0.41	0.00	0.03	0.62	1.16	5.02	
Restaurant	7.94	4.09	4.89	10.78	4.46	0.03	7.49	12.25	51.91	

1. Cooling and ventilation EUIs were estimated separately for the Coastal region (represented by Los Angeles Airport weather), the Inland region (represented by Hollywood-Burbank Airport weather), and the Desert region (represented by Norton Air Force Base weather), in descending order.

Perhaps the most important influence of EDA on the preliminary EUIs was the exact reconciliation to the whole-building average load; we found considerable differences between non-standard day and standard day profiles for several building types. We also observed that seasonal influences could be very important for many non-HVAC end uses.

The unique structure of the SCE and CEC forecasting models precluded direct use of the reconciled EUIs. Consequently, we developed methods to adjust the reconciled data to produce EUIs for the distinct combinations of building and equipment vintages and technologies required by each model. The method followed historic CEC and SCE practice of modifying the prototype descriptions to model the effects of changes from a base case. Nevertheless, its application differs from historic practice because the simulations are used as ratios only to adjust reconciled EUIs; in other words, the simulations did not replace the reconciled EUIs.

Task IX. Assessment of Uncertainty

We performed a limited review of the major sources of uncertainty in the analysis. We identified three general categories of uncertainty corresponding to the input data, the estimation method, and the formatting required for the final data. We hypothesized that the largest uncertainties were associated with the on-site survey data, our methods for developing weighting factors, and the use of those weighting factors to develop preliminary HVAC EUIs. To a large extent, these uncertainties were addressed in aggregate by reconciliation to the whole-building load shape. Nevertheless, our results were affected by errors in the weighting factors used to develop the whole-building load shape. Also, individual end uses, with the possible exception of cooling and ventilation, were highly dependent on the preliminary estimates from the on-site survey data.

Task I. Data Base Preparation

The primary sets of data for the project consisted of on-site surveys for approximately 450 premises and 1,000 load research billing accounts. Secondary sets of data included the results from a recent SCE mail survey, other EUI and LS studies, historic southern California weather data, and limited submetered energy use data. Table I-1 contains a summary of these data sources.

The on-site surveys, primarily, and the mail survey, secondarily, provided information on the characteristics and operation of commercial premises in the SCE service territory. This information was used to estimate preliminary non-HVAC EUIs and LSs (see Task IV) and to develop prototypical building descriptions to estimate HVAC EUIs and LSs (see Task V).

The load research and historic weather data were analyzed to develop average whole-building load shapes, and analyses were performed to characterize the effects of weather on load shapes. This information was used to adjust the initial set of EUIs and LSs to a final calibrated set (see Task VIII).

Existing EUI and LS data were obtained to provide benchmarks for checking the reasonableness of our analyses (see Task III). Southern California hourly weather data for 1986 were obtained for the Los Angeles Airport (representing the coastal climate), Hollywood-Burbank Airport (representing the inland climate), and Norton Air Force Base (representing the eastern, desert-like climate of the San Bernadino area). We anticipated submetered data to validate the overall method, but our efforts were compromised by the relative unavailability of data for the project (see Task VII).

Table I-1. Summary of Data Sources

Primary Sources:	
1.	1986 On-Site Survey and Billing Data (375)
2.	1986 Load Research Data (1031)
3.	1987 On-Site Survey of Load Research Buildings (19)
4.	1983-4 ADM-2 Input Files[1] (60)
Secondary Sources:	
5.	1985 SCE Mail Survey
6.	California and Other Utility EUI and LS Studies
7.	Submetered Data from Non-SCE Sources

[1] These data were not used in the final estimation process by mutual agreement with CEC and SCE.

On-Site Survey Data

SCE and CEC, through their contractor, ADM Associates, Inc. (ADM), developed three sets of detailed on-site surveys of characteristics, operation, and energy use for a total of 454 commercial premises (see Table I-2). These data formed our primary source of information for the development of descriptions of prototypical premises and preliminary EUIs and LSs.

The first and largest set of data consisted initially of 375 premises surveyed in 1986 and 1987 for CEC. The data consist of coded responses to a short audit of each of the premises. The audit form contained 31 pages of questions and was designed to be completed in less than a day by auditors interviewing representatives and collecting some data at each site (the form is reproduced in Appendix A). Details of the sampling methodology and the data collection process are contained in ADM reports [ADM 1987a, ADM 1987b]. The sample emphasized six business types: offices, food stores, restaurants, retail stores, warehouses, and hospitals. For five of the business types (i.e., excluding hospitals), three stratification schemes with two strata each were reported: building age (built before or after 1980), level of electricity use (high or low), and climatic area (inland or coastal). Our analysis revealed that the original sample design was not fully executed.

Table I-2. Summary of Data from the On-Site and 1985 Mail Survey

Building Type	1986-7 On-Site	1983-4 ADM-2 Inputs[1]	1987 On-Site[2]	1985 Mail Survey[3]
Office	**90**	**7**	**0**	**674**
Low-Rise	86			444
High-Rise	4			230
Retail Store	**79**	**9**	**3**	**492**
Department Store				77
Food/Liquor Store	**70**	**5**	**6**	**174**
Supermarket				101
Warehouse	**20**	**4**	**2**	**230**
Refrigerated	4	2		9
Non-Refrigerated	16	2		65
Schools[4]	**0**	**9**	**0**	**72**
Colleges/Trades[4]	**0**	**8**	**0**	**28**
Health[4]	**12**	**5**	**1**	**75**
Hospital[4]		3		33
Restaurant	**82**	**6**	**4**	**140**
Sit Down	62			
Fast Food	20			57
Hotel/Motel[4]	**0**	**2**	**2**	**47**
Miscellaneous[4]	**22**	**5**	**1**	**308**
Total	**375**	**60**	**19**	**2240**
		454		

notes:

1. SCE internal document.
2. from SIC mappings contained in CEC [1987a].
3. from SIC mappings contained in CEC [1987a] and reported business activity in mail survey (note: the mail survey uses large and small offices, the on-site survey uses high-rise and low-rise offices).
4. not examined in this study, but reported for completeness.

The second set of data consisted of a select group of 19 additional premises surveyed by ADM in 1987-8 for SCE. These data were developed using the same audit form, but were drawn from only accounts that were also part of the LRD sample. Discussions with SCE staff indicated no formal sampling procedure was used.

The third set of data consisted of 60 premises surveyed by ADM in 1983-4 for SCE. These data were developed using a similar, but older, audit form developed by ADM. Details of the sampling methodology and data collection process are sketchy, but it appears that no formal sampling procedure was employed. LBL received these data in the form of input files for ADM's building energy simulation program, ADM-2[1]. Ultimately, these data were omitted from our analyses, by joint agreement with SCE and CEC, because the data did not add to our information about under-represented types of premises.

The methods developed for assessing the quality of on-site survey data consistently reflected our primary objective in using these data: the development of prototypical building descriptions and preliminary EUIs and LSs. Table I-3 summarizes the suitability of data from the on-site survey and mail survey (to be described below) for this purpose. In particular, a great deal of effort was spent estimating annual energy use for non-HVAC end uses. These efforts also formed the basis for our development of prototypical EUIs and LSs; the details of our calculations are reported in Task IV. At this stage of the analysis, however, we used methods to identify outliers and trace the source of these outliers to specific data values.

[1] ADM had previously transferred the data from the audit forms into this format.

Table I-3a. Comparison of Primary Data Available for Prototype Development - General

Data Set:[1]	On-Site Survey 1986	ADM-2 1983-4	1985 Mail Survey
Floor Area	total area of premises, surveyed area, area by activity, enclosed area, conditioned (non-, heat, cool, vent) area, lighted area	conditioned area, ground floor area	total floor area of business, heated area, cooled area
Number of buildings	total within premises, total surveyed	not reported	percentage of building occupied
Age	year built, year of major renovation (and description)	not reported[2]	by strata (5-10 year intervals), year of major renovation (and description)
Location	county, zip code	not reported[2]	not reported
Building type	type of premises, SIC of premises	type of premises	main business activity

Footnotes:

1. 1986 On-Site Survey = ADM 1986 & 1987 On-site Surveys (394 premises)
   1983-4 ADM-2 = ADM 1983-4 ADM-2 Input Files (60 buildings)
   1985 Mail Survey = SCE 1985 Commercial Sector Mail Survey
2. Not reported on ADM-2 input forms, but reported on original 1983-4 on-site survey audit form.

Table I-3b. Comparison of Primary Data Available for Prototype Development - Structural

Data Set:	On-Site Survey 1986	ADM-2 1983-4	1985 Mail Survey
Number of floors	total, below ground level,	not reported[2]	above- and below ground
Exterior Walls	up to 2 different types, area by orientation, average R-value, absorptivity, density	area by orientation, average R-value, total opaque area, absorptivity, density, one of 3 pre-specified construction types (light, medium, heavy)	one of 3 pre-specified types (light, medium, heavy)
Exterior Shading	horizontal and vertical, orientation, dimensions	horizontal and vertical, orientation, dimensions	not reported
Windows	up to 2 different types, area by orientation, shading coefficient, percent shaded number of glazings, one of 4 pre-specified glazing types (clear, tinted, reflective, opaque)	area by orientation, shading coefficient, U-value	percent of exterior, one of 3 pre-specified types (clear, tinted, reflective)
Roof	area, average R-value, absorptivity, density	area, average R-value, absorptivity, density	not reported
Floor	one of 3 types (slab, crawl, unheated basement), area, average R-value	up to 2 different types, area, average R-value	not reported
Other	azimuth, ceiling height	ceiling height, azimuth, zoning	not reported

Table I-3c. Comparison of Primary Data Available for Prototype Development - Operation

Data Set:	On-Site Survey 1986	ADM-2 1983-4	1985 Mail Survey
Business hours	standard and non-standard day definitions, number of holidays, existence of seasonal changes, start and stop times for standard and non-standard days	standard days per week, holidays and operating hours per year	weekday, Saturday, Sunday, holiday start and stop times, continuous operation all year
Occupancy	maximum employees and visitors standard and non-standard days, average total on standard days, 3-period schedule for standard day	by zone, standard and non-standard day 24-hour profiles	average total for normal hours, number that are employees
Temperature Setting	heating and cooling 3-period schedule for standard day	zone heating and cooling standard and non-standard day 24-hour profiles	average summer and winter operating hour temperature, whether HVAC shuts off during non-working hours

Table I-3d. Comparison of Primary Data Available for Prototype Development - Non-HVAC End Uses

Data Set:	On-Site Survey 1986	ADM-2 1983-4	1985 Mail Survey
Lighting	indoor and outdoor connected load with 3-period hourly schedule for standard day	zone connected load and fraction contributing to space conditioning loads, outdoor lighting connected load, each with 24-hour schedule for standard and non-standard day	type by percent floor area illuminated, outdoor type and purpose
Hot Water	daily use, equipment type, fuel, tank capacity, rated input, pumping power, temperature, insulated, flow restriction devices; heated swimming pool location, area, fuel, cover, season	temperature, efficiency, electric, tank capacity, 24-hour use profile for standard and non-standard day	if laundry or food prep, equipment type, fuel
Refrigeration	up to 8 equipment types, usage, conditioned location, heat recovery, power rating, number, special features	power rating, use factor	refrigerator and freezer number of closed commercial and residential, linear feet of open vertical and horizontal, floor area of walk-in
Cooking	primary fuel, high efficiency models, up to 9 equipment types, operating hours per day, pilot lights, conditioned location, fuel, rating with three period hourly schedule for standard day	input rating by fuel with 24-hour use profile for standard and non-standard day	meals served/day, inventory (5) by fuel, dedicated HVAC type
Equipment	up to 10 electric and 2 non-electric equipment types, description, operating hours/day, total connected load, 3-period hourly schedule for standard day	zone space conditioning loads and building total connected by fuel, separate 24 hour use profile for standard and non-standard day for zone and building	number and whether installed during the last 2 years for mainframe, mini, pc/terminal, copiers

Table I-3e. Comparison of Primary Data Available for Prototype Development - HVAC

Data Set:	On-Site Survey 1986	ADM-2 1983-4	1985 Mail Survey
Distribution	select one of 9 ducted system types, reheat, zone reset, economizer cycle, minimum outside air, t-stat control features, duct insulation, select one of 6 non-ducted system types	one of 10 system types, economizer, minimum outside air, min/max supply air temp, preheat temp, throttling range, t-stat control features, night-cycle control, reheat delta-t, reheat control, PTAC two-speed control capacities, seasons for two-pipe systems	VAV, also see cooling and heating
Fans	supply and return CFM, power, high efficiency motor, variable speed drive 3-period hourly on/off schedule for standard day	supply CFM, power, static, efficiency, return power, single duct fan control features, min CFM ratio, 24-hour on/off profile for standard and non-standard day	see heating and cooling
Heating	up to 2 of 9 different types, fuel, input and output capacity, average efficiency, HW pump hp, area served, alternate fuel capability, heat recovery, flue gas analyzer	one of 8 fuel/equipment types, capacity, efficiency, HW pump kW, electric resistance capacity of heat pump, max and min shut-off temp	select one of 4 types, main fuel, secondary type and fuel, also provides cooling
Cooling	up to 2 of 12 different types, fuel, input and output capacity, average COP, CW pump hp, tower fan/pump power hp, area served, alternate fuel capability, evaporative precooler, chiller optimizers,	one of 8 chiller types, capacity, COP, CW pump kW, tower fan and pump kW	for primary type (central, room, swamp), package or central, fuel, secondary description, months of A/C operation

We used three procedures to evaluate data quality based on preliminary estimates of non-HVAC energy use, *comparison, calibration, and outlier evaluation.* The first procedure, *comparison,* was an overall check on the EUIs by type of premises. It consisted of comparing the means of our preliminary estimates of EUIs to EUIs estimated by other sources. These sources will be described at length in our discussion of Task III, review of EUI and LS studies. When there was significant disagreement between the estimates found in Task III and our estimates, we went back to our algorithms and made adjustments or, on a few occasions, found coding errors.

The second procedure, *calibration,* used the billing data for each building to assess the reasonableness of the non-HVAC EUIs estimated for that building. Before using the billing data, we analyzed the monthly electricity and gas energy use. We found out that of the original 375 on-site survey premises, we had gas billing data for 142 and electricity billing data for all 375. For twenty-two of the 142 premises, we had less than 10 months of gas data. For twenty-three premises, we had less than 10 months of electricity data. For the second set of on-site surveys (19 premises) we had no electricity data. The monthly electricity and natural gas use reported in the on-site survey covered the period from February 1986 to January 1987. We found that the monthly shoulder season electricity and gas use sometimes varied by a factor of 10 for consecutive months.

We took these large swings in energy consumption into account in the calibration procedure. The basic idea was that the sum of the estimated non-HVAC energy use in a given building should approximately equal total measured energy consumption, minus the seasonal, weather-dependent component of total consumption. Different approaches were used in order to eliminate HVAC energy use from the billing data. For natural gas energy consumption, average summer monthly energy use was multiplied by 12 to yield an estimate of non-HVAC gas consumption. For electrical energy use, the lowest monthly energy use was multiplied by 12 to estimate non-HVAC energy consumption. For some premises, the lowest monthly value was unreasonably low when compared to other fall or spring months. In such cases, we averaged these shoulder season values. The procedure could not be reliably applied to premises that either imported or exported energy to other premises or to partially surveyed premises, so such premises were eliminated from the analysis.

The third method for identifying suspicious data was to produce histograms of estimated non-HVAC EUIs and examine the *outliers*, in detail. Outliers were readily apparent through visual inspection of the histograms. For example, in one case, an unusually high water heating EUI led us to discover and change to 140°F a reported hot water tank temperature of 740°F. A shortcoming of this approach was that it did not permit identification of buildings with reasonable EUIs resulting from bad data.

Through application of the outlier procedure, we were able to identify 45 premises in the on-site survey with questionable data that could not be resolved by means of simple modifications to the data. A list identifying these buildings and the suspect data was sent to ADM for verification. A copy of this memo and of ADM's response are attached as Appendix B.

Despite efforts to correct for bad data exogenously, we were forced to incorporate data filters and correction procedures into our software to produce prototypes and preliminary EUIs and LSs for non-HVAC end uses (see Table I-4). Bad data were either corrected or deleted and re-reported as missing. Given limited resources, we restricted correction of bad data to several key entries: definitions of types of premises, standard/non-standard day definitions, schedule start/stop times and permissible levels, and selected physical characteristics of the building, such as wall areas. The more general treatment of bad data was to delete the questionable datum and replace the entry with a missing-value flag.

In addition to simple corrections or filters, the original high-rise and low-rise office classification scheme used in gathering the on-site survey data was replaced by a classification that relied on floor area, and some premises were reclassified based on correspondence with ADM.

Table I-4. Summary of Data Filtering and Editing Procedures

Variable	Error Condition	Corrective Action
Type of Premises	Misreported	Respecify per ADM (Appendix A);
Audit = Premises	Energy services purchased from others Energy services sold to others	Eliminate Eliminate
Day types per Week	Total less than 7	Add non-std. daytypes to equal 7
Schedules	Accounts for less than 24 hours	Respecify schedule
Profile Fractions	> 1.0 or < 0.0	Replace with missing value
Temperatures	> 100°F or < 40°F	Replace with 100°F for cooling Replace with 40°F for heating (only for off hours; missing value otherwise)
Walls	Absorptivity > 1.0 or < 0.0	Replace with missing value
Windows	Shading coefficients >1.0 or <0.0	Replace with missing value
Water Heating	Tank temperature > 212°F	Reset to 140°F.
Non-Std Day Profiles	Not reported in Survey	Use std. day profile values, but adjust operating hours
Equipment/Cooking	Not reported in Survey	Adjust consumption with usage/heat gain factors and reported operating hours
Refrigeration	Not reported in Survey	Adjust consumption with usage factors

In total, 347 or nearly 80% of the original 454 on-site surveys were used for subsequent non-HVAC EUI and LS estimation and prototype development for the nine types of premises (see Tasks IV and V). Thirty-eight on-site surveys were eliminated because they reported data for building types not examined in the current study (health, hotel/motel, and miscellaneous). Another 60, consisting of the 1983-84 ADM-2 inputs, were not used, as described earlier. Only nine on-site surveys were eliminated because of data errors that could not be corrected or addressed by other means.

Load Research Data

As part of its ongoing rate design efforts, SCE collects 15-minute-interval load research data (LRD) for all commercial accounts with time-of-use rate schedules (TOU-8) and for a random sample of accounts with GS-1 and GS-2 rate schedules. These data were a major component of our project because they provided us with a target for reconciliation of the initial estimates of EUIs and LSs generated from on-site survey data. Our analysis relied on LRD collected in 1986, in order to ensure consistency with our other sources of data.

The 1986 LRD was sent to us on two tape volumes containing 14 SAS data sets, one for each of the GS-1 and GS-2 data and one for each month of the TOU-8 data. Each record of each data set represents a single day of data from one account and contains 56 variables: 48 half-hourly load values and eight identifying numbers as follows:

1. *Billing Account Number* (11 digits) reported accounting information (the district, cycle, book, and folio numbers), but the position of the district and cycle numbers was not consistent and could not be relied on in our analysis. The cycle, book, and folio numbers were also subject to change.
2. *Building Type* (two digits) was a code related to the SIC code (see below). Unfortunately, SIC codes do not map directly into the types of premises used for the on-site survey data for offices and restaurants.
3. *Customer Number* (two digits) identified the particular customer and forms the Customer Account Number when combined with the billing account number.
4. *Date* (eight digits) identifies the starting date of each record (MM/DD/YY).
5. *Load Research Account Number* (eight digits) indicates the SCE district number by the first two digits.
6. *Premises Number* (eight digits) identified unique accounts in order to disaggregate SAS files into individual premise load files.
7. *SIC Code* (four digits) is the Standard Industrial Classification number for each account.
8. *SS Code* (one letter, two digits) existed for GS-1 and GS-2 data only and was not used in our analysis.

We used the following procedure to convert these data for use in our project:

A. Each line of data, representing one full day, was assigned to a type of premises based on its Premises Code, in order to assemble a complete year of data from the 12 monthly TOU-8 files.

B. The half hourly data were aggregated into hourly data.

C. The data were converted to local time (accounting for daylight savings time) by duplicating an hour of data at 2 a.m. on April 27 and deleting an hour of data at 2 a.m. on October 26. Data between these dates were shifted forward by one hour.

D. Missing data (indicated by "." in the SAS outputs) were converted to a value of -1, and unreadable data were converted to a value of -2.

E. The building files were assigned a new, unique eight-digit file names to allow them to be easily sorted and processed by type, location, and rate class.

The data base preparation efforts for the LRD were performed in three steps. First, building types were assigned to accounts based on SIC codes. Simple rules, based on annual consumption, were used to separate large and small retail and office buildings. Fastfood restaurants and sitdown restaurants could not be distinguished and were combined into a single category.

Second, because the sample size was large (unlike with the on-site survey sample), we eliminated records with incomplete data, rather than attempting to rehabilitate them. The GS-1 data file contained 161 accounts of which 108 contained a complete year of data. The GS-2 data file contained 131 accounts of which 106 were complete. The 12 monthly TOU-8 files contained 1,031 accounts of which 988 were complete. These results are summarized on Table I-5.

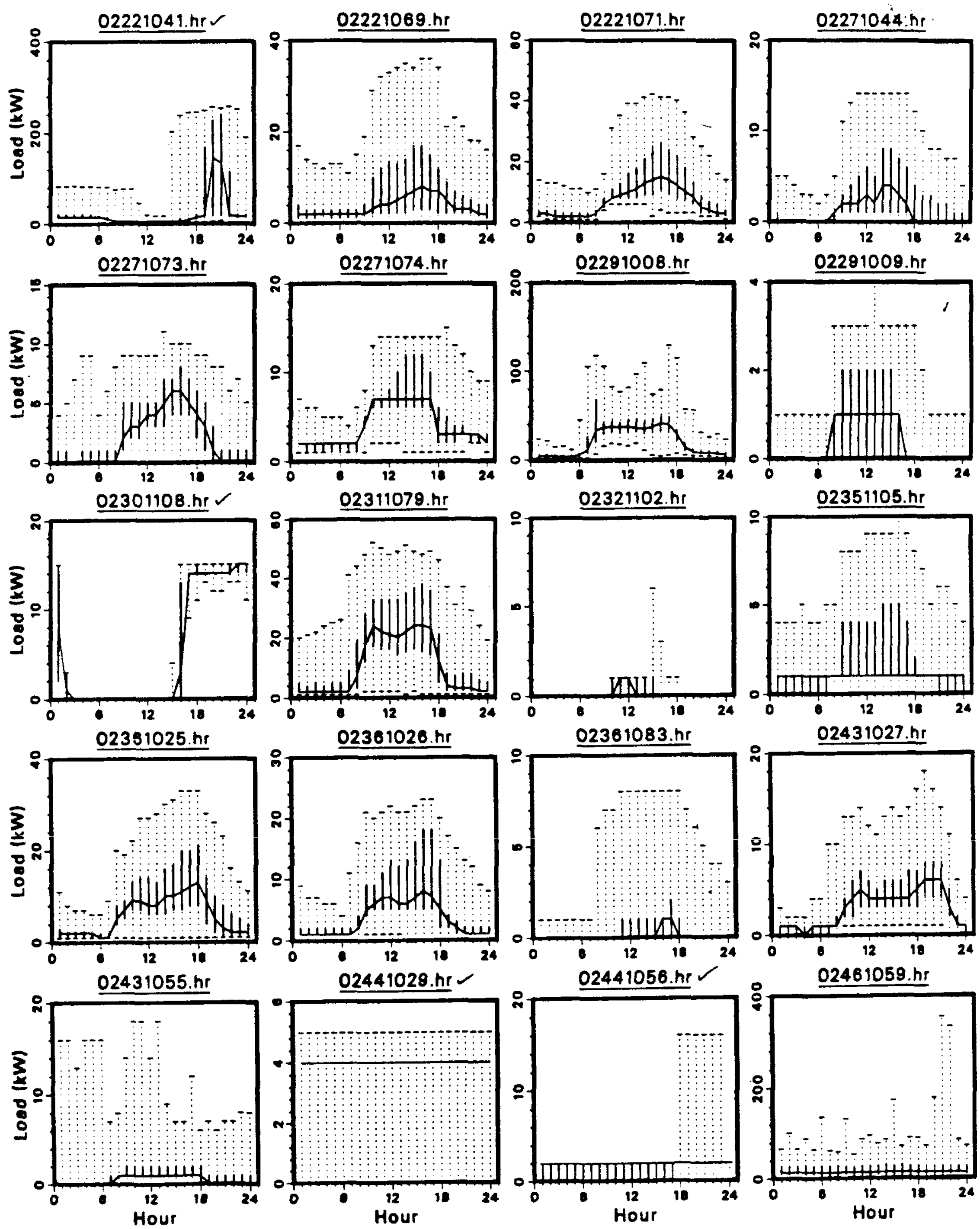
Table I-5. Summary of the 1986 SCE Commercial Class Load Research Data

Type of Premises	Total Number of Accounts	%	Complete Number of Accounts	%
GS-1				
Small Offices	45	28.0	31	28.7
Restaurants	7	4.3	3	2.8
Small Retail	33	20.5	21	19.4
Food Stores	5	3.1	5	4.6
Non-Refrig Warehouses	11	6.8	7	6.5
Schools	22	13.7	15	13.9
Colleges	1	0.6	0	0.0
Health Clinics	2	1.2	2	1.9
Miscellaneous	35	21.7	24	22.2
Total	**161**	**100.0**	**108**	**100.0**
GS-2				
Small Offices	33	25.2	30	28.3
Restaurants	8	6.1	7	6.6
Small Retail	24	18.3	18	17.0
Food Stores	24	18.3	16	15.1
Non-Refrig Warehouses	6	4.6	5	4.7
Schools	11	8.4	8	7.5
Health Clinics	3	2.3	3	2.8
Hotel & Motel	4	3.1	4	3.8
Miscellaneous	18	13.7	15	14.2
Total	**131**	**100.0**	**106**	**100.0**
TOU-8				
Large Offices	324	31.4	314	31.8
Dept Stores	223	21.6	205	20.7
Food Stores	19	1.8	19	1.9
Refrig Warehouses	20	1.9	20	2.0
Non-Refrig Warehouses	38	3.7	37	3.7
Schools	111	10.8	108	10.9
Colleges	54	5.2	53	5.4
Hospitals	107	10.4	102	10.3
Hotel & Motel	38	3.7	37	3.7
Miscellaneous	97	9.4	93	9.4
Total	**1031**	**100.0**	**988**	**100.0**

Third, complete records were then reviewed graphically (see Figure I-1 for an example) and spurious records were eliminated. We identified and deleted additional, questionable records using visual and other analysis of the daily hourly profiles. Sample criteria used in this process included: cross-checks between reported SIC codes and building definitions (for example, we deleted lumber yards from large retail stores), and spurious load shapes (for example, we deleted from the small office category one record that was apparently a dedicated circuit for outdoor lighting). The complete set of visual data from each complete load research record used in this analysis is reproduced in Appendix C.

In total, approximately 60% of the original 1,031 load research accounts were used to develop average whole-building load shapes by building type (see Task II). The majority of unused data were for premises not considered by the current project.

Figure I-1. **Sample of graphic summaries used to evaluate data from the load research accounts.** Each panel represents one year of data for a single account, which is identified by a unique, eight-digit code, as described in the text. The hourly mean values are connected by a solid line from hour 1 to hour 24. Vertical solid lines indicate the interquartile ranges about the hourly mean values. Dotted lines indicate the minimum and maximum hourly values found during the year. Note that the y-axis is scaled separately for each account. The account depicted on the extreme left of the middle row (# 02301108) is suspected to be a dedicated outdoor lighting circuit; based on this review, it was eliminated from subsequent analysis.



Submetered Data

We believe that comparison to submetered data is the best possible validation for our methods for estimating end-use EUIs and LSs from on-site survey data and LRD. Unfortunately, submetered data are extremely scarce[2]; we were not completely successful in obtaining the data that exist.

The two primary sources of these data are the Bonneville Power Administration (BPA) and the Sierra Pacific Power Company (SPP). BPA is currently operating the largest commercial building submetering program in the country. Called the End-use Load and Conservation Assessment Program (ELCAP), the study meters and analyzes hourly end-use energy consumption for nearly 300 commercial buildings [Stokes 1986]. The SPP project is smaller than the BPA project, involving hourly end-use metering for about 80 commercial buildings [SPP 1984].

Our negotiations with BPA and SPP were unsuccessful. BPA said providing data to others had interfered with their work. As a result, they have decided not to honor any more requests until further notice. SPP denied our request because of competitive concerns.

Fortunately, we were able to obtain end-use data from a third source, Seattle City Light (SCL). They provided us with detailed end-use data and DOE-2 inputs for a single restaurant. Our analysis of these data is described in Task VII.

[2] This condition is rapidly changing in California because of recently initiated end-use, commercial building, submetering projects by SCE and PG&E.

Mail Survey Data

Commercial sector mail survey data were an important secondary source for the project. We used these data to evaluate the representativeness of selected features of the prototypes developed from the on-site survey; we also used the data for guidance on features of the commercial building stock that were poorly represented in our sample of on-site surveys (e.g. HVAC characteristics).

For this project, we relied on SCE's 1985 commercial sector mail survey. The 1985 mail survey contains responses from nearly 4,000 customers. Extensive analyses of these data have already been performed by ADM Associates, Inc. and are summarized in ADM [1986]. We performed no additional data validation.

Weather Data

Historic (versus typical) weather data were needed for the initial DOE-2 simulation of space conditioning energy use, for the analysis of the LRD, and for the reconciliation of initial simulation results.

This task was complicated by the scarcity of high-quality weather data, especially recent historic data. For example, when forecasting SCE service territory space conditioning energy use, CEC and SCE currently estimate separate space conditioning EUIs and LSs corresponding to four distinct climate regions in southern California. The estimates for climate region are developed by weather data from a single site (typically, measured at an airport) within or similar to that of the climate region. But conditions at a single site may not accurately reflect conditions found throughout a region. Table I-6 compares the representative weather sites used by CEC and SCE.

Table I-6. Comparison of Weather Sites Used in Forecasting for the Southern California Edison Planning Area

SRC 1987[1]	CEC 1987[2]	CEC 1983[3]	SERA 1981[4]
all energy	**heating energy**	**all energy**	**heating energy**
Bakersfield ETMY	Fresno TMY	Fresno CTZ	Fresno TMY
Los Angeles ETMY	Los Angeles ETMY	Los Angeles CTZ	Long Beach ETMY
Burbank ETMY	Burbank CTZ	Burbank CTZ	Burbank CTZ
San Bernadino ETMY	San Bernadino CTZ	San Bernadino CTZ	San Bernadino CTZ
			El Toro ETMY
			Bakersfield ETMY
	cooling energy		**cooling energy**
	Fresno TMY		Fresno TMY
	Long Beach ETMY		Long Beach ETMY
	Burbank CTZ		Burbank CTZ
	San Bernadino CTZ		San Bernadino CTZ
			El Toro ETMY
			Bakersfield ETMY
	peak demand		
	Fresno		
	Long Beach		
	Burbank		
	March AFB		

Sources:

1. "End-Use Data Development: Initial Load Shape and Technology Data Base" [SRC 1987].
2. "California Energy Demand: 1987-2007, The SCE Planning Area Forms" [CEC 1987b].
3. "Commercial Building EUI Calculations, Base Year Estimates and Methods for Calculating Standards Impacts" [Jaske 1983].
4. "Methodological Elements for Re-estimation of Heating and Cooling Energy Use in Buildings" [SERA 1983a].

We followed SCE and CEC practice of choosing individual weather sites to represent the influence of weather over broader geographical regions. We used 1986 weather data from three sites: Los Angeles Airport (LAX), Burbank Airport (BUR), and Norton Air Force Base (NOR), which is representative of the San Bernadino area.

Generally speaking, the historic weather data received from the National Climatic Data Center were reasonably complete, except that for Burbank, which was missing considerable amounts of data. A majority of missing data were from early morning hours, so our analyses of HVAC end uses were not unduly compromised. We interpolated replacement values for daytime hours when necessary. Table I-7 summarizes the number of missing records for selected climatological variables.

Table I-7. Analysis of 1986 Weather Tapes

Weather Station	NOAA Number	ZIP	Missing Data (hours)			
			DBT	DPT	WBT	HUM
Norton AFB	23122	924	6	6	6	6
Hlywd-Burbank	23152	915	730	861	861	861
Los Angeles	23174	903	0	0	0	0

Task II. Data Base Integration

The goal of the data base integration task was to develop a consistent procedure for aggregating data from the on-site surveys and the LRD by building type, for preliminary estimation and final reconciliation of EUIs and LSs.

Integration of On-Site Survey Data

Table II-1 summarizes the number of on-site surveys that were ultimately used to develop prototypical building descriptions and preliminary non-HVAC. In total, 347 of the original 454 surveys were used.

Table II-1. On-Site Survey Data Used in Prototype Development

Premise	1986 On-Site Survey	1987 On-Site Survey
Large Office	14	1
Small Office	70	0
Large Retail	10	3
Small Retail	65	0
Food Store	73	6
Ref. Warehse.	4	1
NonRef. Warehse.	12	2
Sit Down Rest.	62	2
Fast Food Rest.	21	1
Total	**331**	**16**

Integration of the on-site survey data by type of premises relied upon the development of formal statistical weights for use in aggregating features of individual premises to those of representative premises. The weights were developed using information provided by SCE on the distribution of electricity consumption by SCE commercial sector accounts, stratified by type of premises.

The approach taken to develop weighting factors was based on an assumption that the each on-site survey represented information for a random sample from the universe of SCE billing accounts.[1] We used this assumption to map on-site survey buildings into billing account consumption strata that were differentiated by type of premises. The mapping was not perfect. We had to use consumption criteria of 400 and 500 MWh/yr for retail and offices, respectively, to separate large from small premises. We also had to combine fastfood and sitdown into a single category for restaurants because they were not distinguishable in the billing account files.

Once mapped, the weighting factor was simply the population of on-site surveys in a given frame divided into the total number of billing accounts within that frame. Table II-2 reports the resulting weighting factors.

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[1] This assumption was not strictly valid because of inconsistent sampling units, and non-random sampling. First, the on-site surveys represent premises, while the billing accounts represent meters. Second, as described in Task I, the on-site survey sampling process was not truly random.

Technically speaking, sample weights developed for on-site survey premises, to the degree that the survey premises were randomly drawn, can be used only to weight energy use to arrive at total consumption for SCE's commercial sector. Strictly speaking, therefore, these weights are not valid for any other purpose, such as weighting the physical, thermal, and operating characteristics of individual buildings of a given type of premises to those of a "prototypical" type of premises. This limitation reinforced the need for close scrutiny of the applicability of the prototype approach (see Tasks VI and IX).

Table II-2. Weighting Factors for Prototype Development from On-site Survey Data

	Demand Stratum - Upper Tier Boundaries (average kW)									
Premise	0.70	2.17	7.64	13.69	32.56	51.34	64.75	94.35	499.99	500+
SCE Commercial Sector Accounts[1]										
Food Store	---	800	99	132	254	94	31	68	83	32
Large Office	---	---	---	3	0	4	34	1247	330	
Large Retail	---	---	---	1	0	0	75	1146	198	
Non-Ref. Warehse.	9730	424	1529	---	3840	---	334	338	642	60
Ref. Warehse.	---	---	---	477	---	---	---	88	21	
Restaurants	---	4955	1757	3960	5832	1900	779	913	463	2
Small Office	61637	1592	5687	7306	9818	3000	995	1166	893	
Small Retail	24722	707	3783	5482	6384	1338	457	587	3	
Distribution of On-Site Surveys										
Food Store	0	1	8	4	8	4	2	4	42	6
Large Office	0	0	0	0	1	3	4	0	5	1
Large Retail	0	0	0	0	1	2	1	1	5	3
Non-Ref. Warehse.	2	2	1	0	2	0	3	1	1	2
Ref. Warehse.	0	0	0	0	1	0	0	0	3	1
Restaurants	0	2	19	8	17	21	12	2	2	3
Small Office	4	11	14	6	13	15	3	5	2	0
Small Retail	4	8	8	9	9	11	9	3	4	0
Sample Weights										
Food Store	---	800.0	12.4	33.0	31.8	23.5	15.5	17.0	2.0	5.3
Large Office	---	---	---	---	3.0	5.4	5.4	5.4	249.4	330.0
Large Retail	---	---	---	---	1.0	18.8	18.8	18.8	229.2	66.0
Non-Ref. Warehse.	4865.0	212.0	1529.0	---	1920.0	---	111.3	338.0	642.0	30.0
Ref. Warehse.	---	---	---	---	477.0	---	---	---	29.3	21.0
Restaurants	---	2477.5	92.5	495.0	343.1	90.5	64.9	456.5	231.5	0.7
Small Office	15409.3	144.7	406.2	1217.7	755.2	200.0	331.7	233.2	446.5	---
Small Retail	6180.5	88.4	472.9	609.1	709.3	121.6	50.8	195.7	0.8	---

[1]The SCE population was adjusted to match the non-zero entries for the distribution of on-site survey data.

Integration of Load Research Data

Formal integration of the LRD by building type was required for the development of average whole-building load shapes. The integration relied on the same distributions of electricity consumption as those used to aggregate the on-site survey data. For building types with more than five accounts in each region, aggregation was performed separately for the three climate regions identified in Task I.[2]

As with the on-site survey data, the mapping from billing accounts to premises was not perfect. We made the following assumptions:

1. Large Office includes all TOU-8 office buildings (mostly finance, insurance, real estate, and public administration), and GS-1 and GS-2 accounts of more than 500 MWh/consumption.
2. Small Office includes all GS-1 and GS-2 buildings of less than 500 MWh/yr consumption.
3. For Restaurants, SIC codes differentiate between eating and drinking places but not between sitdown and fastfood; we were forced to combine these premises for the purposes of reconciliation.
4. Large Retail includes all TOU-8 retail trade buildings, and GS-1 and GS-2 buildings of more than 400 MWh/yr consumption.
5. Small Retail includes GS-1 and GS-2 with a wide range of retail trade codes and less than 400 MWh/yr consumption.
6. Food Store includes food store buildings and a few liquor stores.
7. Refrigerated Warehouse includes all TOU-8 refrigerated warehouses and wholesale trade buildings dealing in frozen foods, dairy products, fish, and fresh fruits and vegetables.
8. Non-Refrigerated Warehouse includes all wholesale trade buildings dealing in durable goods.

[2] With the on-site survey, distinct climatic influences were introduced by simulating the resulting prototypical buildings with weather data for separate sites. With the LRD, against which the simulated data would be reconciled, these effects had to be taken into account at this phase through the development of separate, average, whole-building load shapes for each climate region.

The weighting factors used to aggregate individual LRD to average whole-building load shapes were developed using the same billing account information provided by SCE for the integration of the on-site survey data. TOU-8 accounts are a certainty sample, so the weighting factor for each account is 1. GS-1 and GS-2 accounts were drawn randomly. The weights used to aggregate data from the GS-1 and GS-2 accounts are reported in Table II-3.

The primary challenge for introducing climate variation was to develop mappings from the locations of individual LRD accounts, as represented by the location of the SCE districts that contain the LRD accounts, to the three climate regions used in the reconciliation process. Our analysis was based on review of southern California maps. Table II-4 reports the assignments of SCE district numbers to these climate regions.[3]

Table II-5 tabulates the number of load research data in each climate region. Based on these distributions, separate whole-building average load shapes were developed for the large and small office and retail premises for each climate zone. Single, whole-building average load shapes was developed for the food stores, non-refrigerated and refrigerated warehouses, and sitdown/fastfood restaurants.[4]

Once aggregated, the average whole-building load shapes were normalized to the weighted average measured electricity consumption of the on-site survey premises to ensure consistency between the energy use of the prototypical premises (developed from on-site survey data) and the averaged, whole-building load shapes (developed from the LRD). Discussion of weighted average electricity consumption for each building type is reserved for Task VIII because it is, in essence, the total EUI of the premise.

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[3] We have learned that SCE and CEC use different mapping assignments for forecasting. The likely impact of these differences is discussed in Task IX, Assessment of Uncertainties.

[4] Sufficient data existed to develop separate whole-building average load shapes for the food store, but, as will be described in Task VIII, simulation of the food store prototype did not result in significant cooling energy use variation by climate region. In this case, lack of variation from the simulations led us to combine the LRD into a single whole-building load shape for one climate zone.

Table II-3. Weighting Factors for Load Research Data Used in Average Load Shape Development

	Demand Stratum - Upper Tier Boundaries (average kW)									
Premise	0.70	2.17	7.64	13.69	32.56	51.34	64.75	94.35	499.99	500+
Distribution of GS-1 and GS-2 Load Research Data										
Large Office	0	0	0	0	0	0	0	3	11	1
Small Office	2	4	9	4	7	3	1	0	0	0
Restaurants	0	0	1	1	3	1	0	2	1	0
Large Retail	0	0	0	0	0	0	0	0	10	0
Small Retail	0	1	13	1	5	1	0	0	0	0
Food Stores	0	0	2	0	3	3	1	0	7	3
NonRef Ware	0	1	5	0	1	1	0	0	3	0
Sample Weights										
Large Office	----	----	----	----	----	----	----	11	113	330
Small Office	30819	398	632	1827	1403	1000	995	----	----	----
Restaurants	----	----	1757	3960	1944	1900	----	457	463	----
Large Retail	----	----	----	----	----	----	----	----	115	----
Small Retail	----	707	291	5482	1277	1338	----	----	----	----
Food Stores	----	----	50	----	85	31	31	----	12	11
NonRef Ware	----	424	306	----	3840	865	----	----	214	----

Table II-4. Assignment of SCE Districts to Climate Regions[1]

Climate Regions		
Coastal Los Angeles Airport	Inland Hollywood-Burbank	Desert Norton (San Bernadino)
Huntington Beach (33)[2] Santa Barbara (49) Santa Monica (42) Redondo Beach (44) Long Beach (46) Catalina (61) Ventura (39)	Montebello (22) Covina (26) Monrovia (27) Whittier (47) Thousand Oaks (35) Fullerton (48) San Fernando (59) Santa Ana (29) Compton (32) El Toro (43) Ontario (34) Inglewood (41)	San Bernadino (30) Redlands (31) Arrowhead (40) Barstow (72) Victorville (73) Perris (77) Hemet (78) Palm Springs (79) 29 Palms (84) Bishop (85) Ridgecrest (86) Blythe (87) Lancaster (36) Big Creek (50) San Joaquin Valley (51) Kernville (53)

1. We have learned that SCE and CEC use different mapping assignments for forecasting. The likely impact of these differences is discussed in Task IX, Assessment of Uncertainties.
2. SCE District name (District number).

Table II-5. Geographic Distribution of Load Research Data Used in Average Load Shape Development

	Climate Regions		
Premise	Coastal Los Angeles Airport	Inland Hollywood-Burbank	Desert Norton (San Bernadino)
Large Office	133	167	17
Small Office	3	16	11
Large Retail	73	121	18
Small Retail	4	8	9
Food Store	7	25	6
Ref. Warehse.	6	11	3
NonRef. Warehse.	6	30	3
Restaurant	5	3	1

Integration of Load Research and Weather Data

The final data base integration task was a regression analysis of the averaged whole-building hourly load shapes against historic weather data to determine the appropriate climatic variables for use in the reconciliation process. The goal of the analysis was to identify the most promising explanatory weather variables for use in the final reconciliation (see Task IV for a discussion of the reconciliation methodology).

The regression analysis consisted of multiple linear regressions of a number of individual LRD building load files with respect to dry-bulb temperature, wet-bulb temperature, dew-point temperature, and relative humidity. Other factors such as season, hour of day, day of week, and enthalpy were also investigated.

Initial regressions versus dry-bulb temperature alone showed that there were strong residual relationships with humidity indicators. Because of the strong intercorrelation of wet-bulb to dry-bulb temperature, dew point was selected as the second explanatory variable. Including dew point improved the fits significantly and resulted in more normally distributed residuals. More precise identification of the cooling season and removal of holidays also improved the fits.

The final regression results for each building type for summer and winter standard and non-standard days are contained in Appendix G. Separate results for each climate zone are presented for the Large and Small Office, and the Large and Small Retail building types. When the number of LRD within each climate zone was small, the LRD were combined and only a single set of regressions was performed, using Burbank weather data.

Task III. Energy Use Intensity and Load Shape Review

Existing EUI and LS data were reviewed as a reference point for our research. The methods and final values presently in use for forecasting are the baseline that we have attempted to improve. We focus on studies using California data.

We follow historic practice, in which EUIs and LSs are developed independently, with separate reviews of EUI and LS studies. Because we will compare our findings to these data in Task VIII, here we describe the studies and our initial observations in comparing them to one another.

Description of Previous EUI Studies

We are aware of 11 commercial sector EUI studies that have been carried out over the past six years. Of these, six were conducted for California utilities. Other studies have been carried out for Florida Power and Light (FPL), Northeast Utilities, Wisconsin Power and Light (WEPCO), and New York State Electric and Gas [RER 1987, NEU 1985, 1986a, 1986b, 1987a, 1987b, McMenamin 1986, Parti 1986]. One study was national [Parti 1984].

The methodologies used can be grouped into four general categories:

1. Submetering of energy using equipment;
2. Computer simulation of prototypical buildings;
3. Statistical studies using conditional demand analysis; and
4. Energy auditor estimates and bill disaggregation from on-site visits,

An in-depth review of these methods can be found in Turiel [1987].

Pacific Gas & Electric. The first Pacific Gas and Electric study, hereafter referred to as PG&E, utilized 5,540 responses from a 1982 mail survey to estimate average EUIs for nine business types and seven end uses [McCollister 1985]. The EUIs were calculated using the conditional demand technique with engineering formulations for the end-use specifications. EUIs were estimated for natural gas and electricity end uses.

Pacific Gas & Electric (by CEC). The second study for the PG&E service territory, hereafter referred to as PG&E(CEC1), was based on energy auditors' estimates of percentage of utility bills attributable to each end use [Schultz 1984]. There were 8,000 commercial buildings in this data base. The energy audits were conducted from 1980 through 1983. EUIs were estimated for eight electrical and four natural gas end uses in 11 commercial building types.

Southern California Edison. The first Southern California Edison study, hereafter referred to as SCE, used 5,486 responses to a 1982 mail survey to calculate electricity EUIs for eight business types and seven end uses [Ignelzi 1984]. EUIs were calculated using the conditional demand technique. The miscellaneous end use category included lighting and assorted electrical equipment such as computers and elevators. Refrigerated warehouses were not surveyed and the health category did not include any hospitals. A large number of EUIs were not estimated in this study.

Southern California Edison (by SRC). A second study for the SCE service territory, hereafter referred to as SCE(SRC), utilized the simulation method to develop end-use energy consumption and load shape estimates for 11 commercial building types [SRC 1987]. The initial building prototypes were developed from the SCE 1983 mail survey of commercial buildings. Modifications to these prototypes were made with the use of preliminary data from the 1985 mail survey. The ADM-2 program was used to estimate hourly end-use loads and end-use energy consumption. Typical Meteorological Year (TMY) weather data were used for four planning areas. When the results of the simulations appeared unreasonable (compared to EPRI estimates [GIT 1986]), the inputs were modified and new estimates were obtained.

San Diego Gas and Electric. The San Diego Gas and Electric study, hereafter referred to as SDG&E, utilized data obtained from 1,000 responses to 1984 and 1986 mail and phone surveys [McCollister 1987]. The conditional demand technique with engineering formulations was used for this study. EUIs were estimated for 11 business types and for 11 electrical and five gas end uses.

California Energy Commission. The California Energy Commission has utilized a simulation methodology to develop EUI estimates for utility service territories throughout California [CEC 1987a]. Initial EUIs that are indexed to or based on 1975 energy use (developed in CEC [1983] and SERA [1983a and 1983b]) were updated to represent the 1985 building stock. Commercial sector mail surveys for 1982 and Dodge data for floor space were used to develop floor space growth rates and equipment saturation data. These data were inputs to models that predicted new EUIs. The Pacific Gas and Electric service territory was an exception to these procedures. For this utility, the CEC incorporated audit data described previously to develop 1985 EUIs [Schultz 1984]. We have designated the data from this study as follows: SCE (CEC), PG&E (CEC), and SDG&E (CEC).

Nonresidential Building Energy Consumption Survey. This national study used data from the 1979 Nonresidential Building Energy Consumption Survey [EIA 1983] to estimate average electricity EUIs for the entire U.S. [Parti 1984]. Annual energy consumption data for approximately 5,500 buildings were available.[1] The conditional demand technique was used to obtain average climate EUIs for 10 business types and five end uses. In this Parti study, the miscellaneous end use category included lighting and refrigeration in addition to miscellaneous electric equipment.

Florida Power and Light. The Florida Power and Light estimates were developed from a large on-site data collection effort involving about 1,200 buildings [RER 1987]. The estimates for this hot climate were derived using the bill disaggregation method with the on-site data. The commercial sector was divided into 12 business types. Electrical, natural gas, and oil EUIs were estimated for eight end uses.

Northeast Utilities. The Northeast Utilities estimates were developed from a series of on-site audits of offices, retail buildings and institutional buildings [NEU 1985, 1986a, 1986b, 1987a, 1987b]. Grant applications to the Institutional Conservation Program (ICP)[2] were also used as a source of data. The simulation approach was applied to prototypical buildings. EUI estimates

[1] The three California conditional demand studies used monthly billing data for their analyses.

[2] The DOE Institutional Conservation Program has provided about $660 million in matching grants for energy conservation in schools, hospitals, and colleges since its inception in 1979. The program has records on building energy use (pre-retrofit) and on the cost and estimated energy savings of installed retrofits, in the form of a comprehensive computerized data base.

were developed for eight end uses for electricity, natural gas, and oil.

Wisconsin Electric Power. The Wisconsin Electric Power study used data from customers requesting commercial audits and an on-site survey [McMenamin 1986]. Initial estimates were developed using the bill disaggregation technique applied to the audit data. Adjustments were made to insure consistency with intensities obtained from the on-site survey.

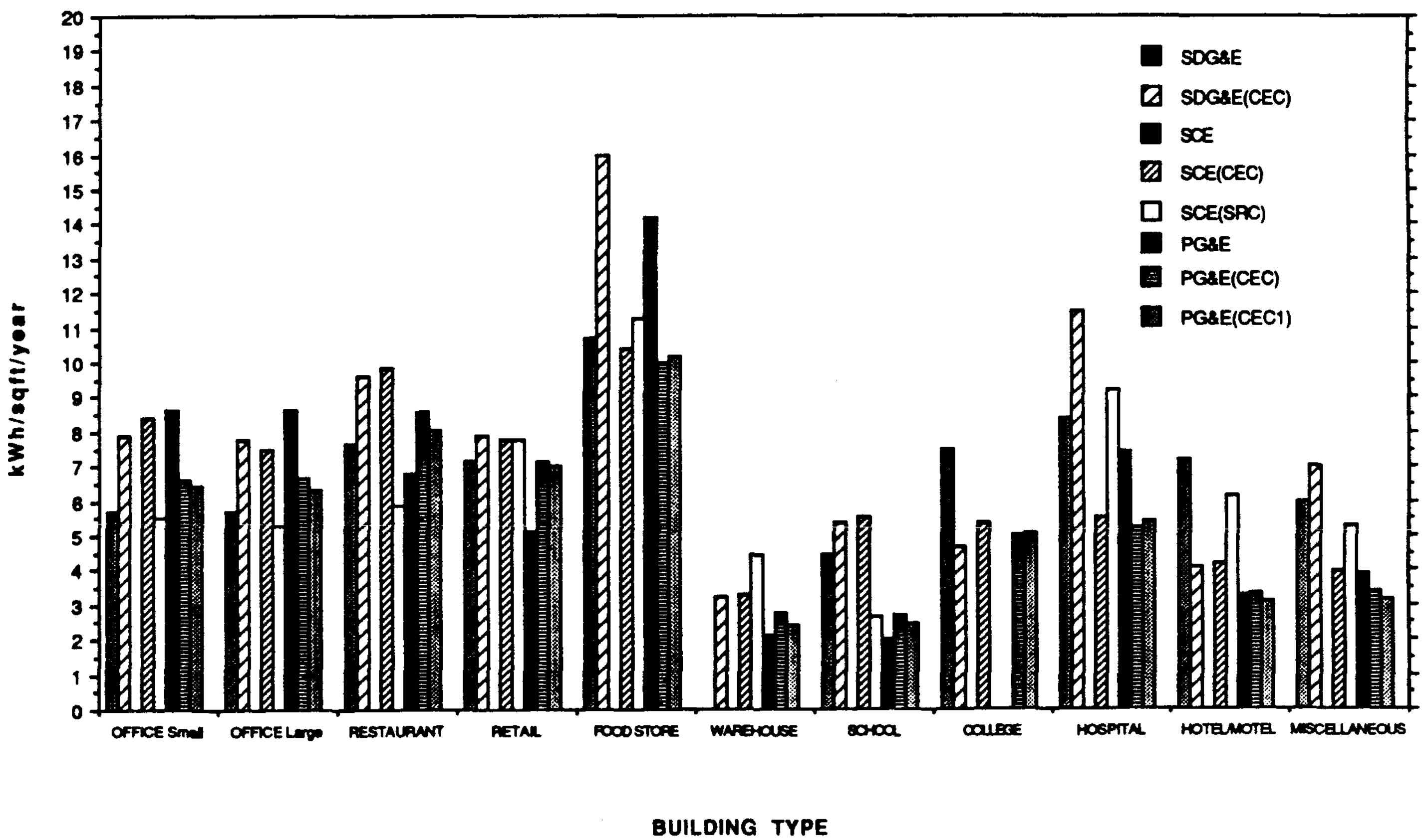
New York State Electric & Gas. The New York State Electric & Gas Corporation (NYSEG) study used data from 3,470 responses to a mail survey [Parti 1986]. EUIs were estimated with the conditional demand technique for seven electricity end uses. Lighting and miscellaneous were combined into a single end use.

Comparison of EUI Studies

In this subsection, we restrict discussion to our initial observations contrasting the studies. The figures used in our discussion will be used again in Task VIII.

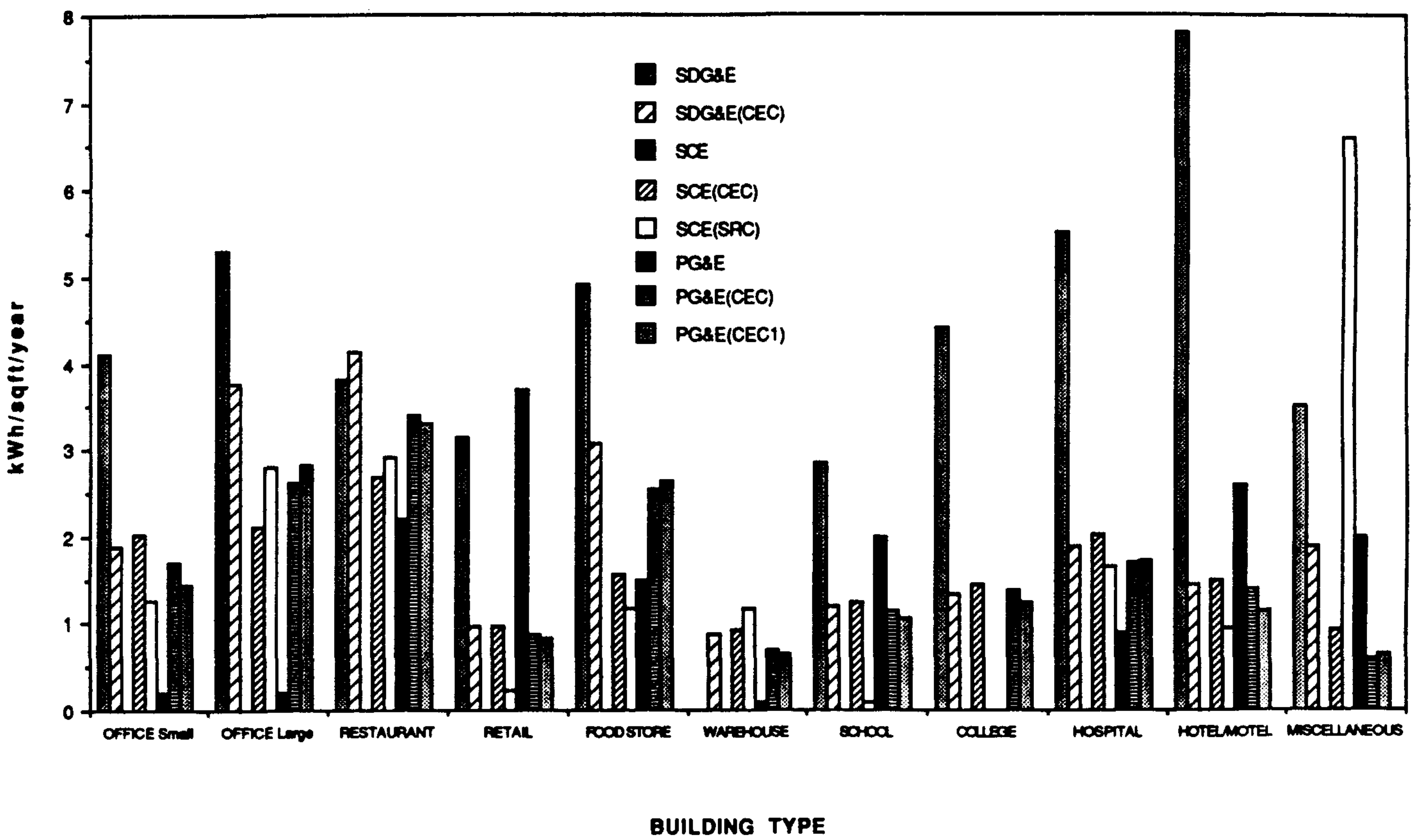
For lighting, agreement among studies was generally good (see Figure III-1). Food stores had the highest EUI for this end use, with a range from 10 to 16 kWh/ft^2-yr. Offices and retail stores both had similar EUI ranges (5.5-8.5 kWh/ft^2-yr). The agreement among studies was not as good for schools, hospitals, and lodging. Some variation in lighting energy use was expected among studies because of differing equipment efficiency and usage, but we did not expect as much as we found for the latter business types.

FIGURE III-1 LIGHTING EUIs COMPARISON



For miscellaneous electrical equipment, the estimates among building types ranged from about 1.0 to 3.0 kWh/ft^2-yr (see Figure III-2). The SDG&E study estimated higher miscellaneous electricity use than the other studies for almost all building types.[3] When the SDG&E study is removed, the agreement among studies is improved significantly.

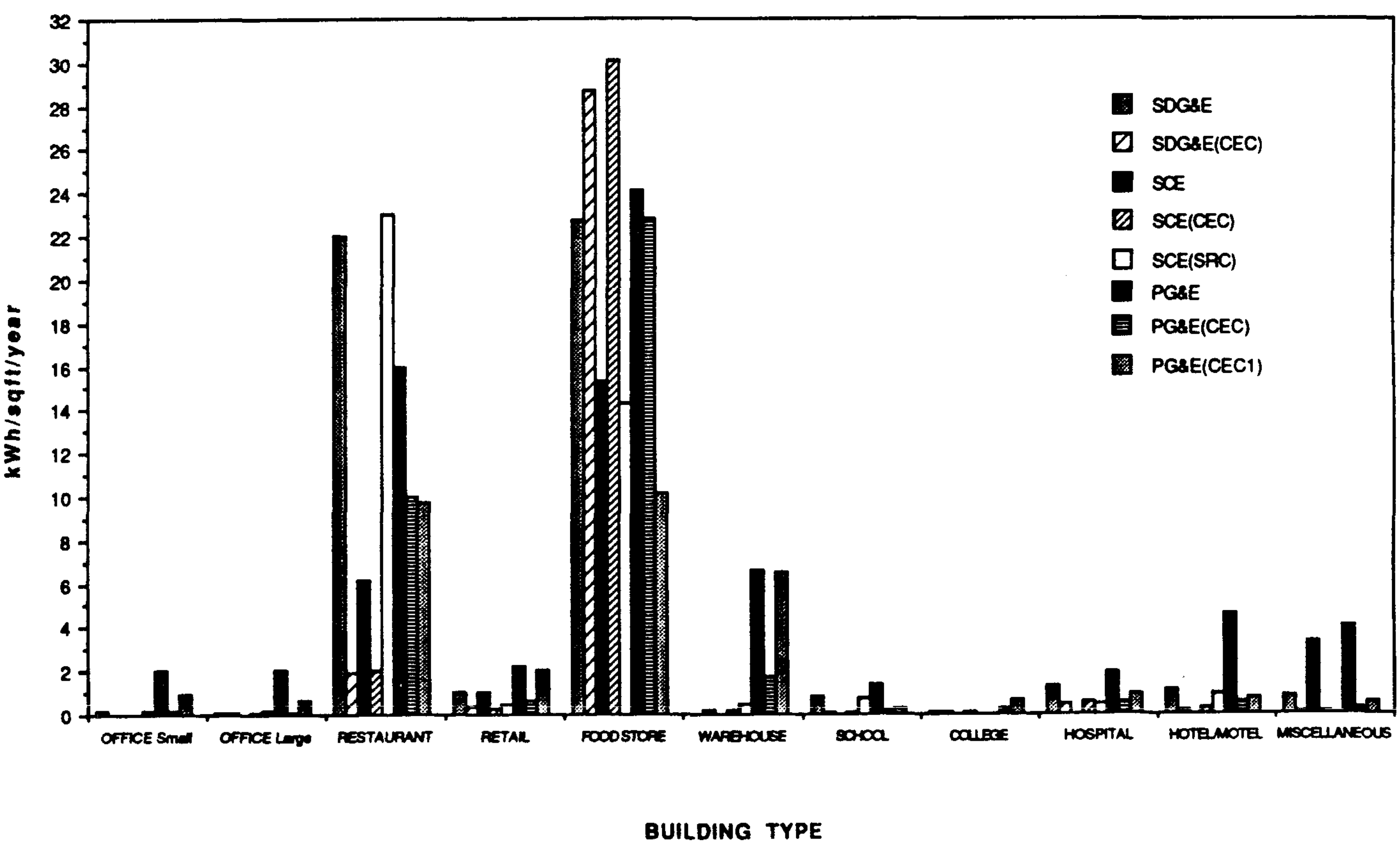
FIGURE III-2 ELECTRICAL MISCELLANEOUS EUIs COMPARISON



[3] We speculate that the reason may be the SDG&E's inclusion of ventilation in miscellaneous end uses.

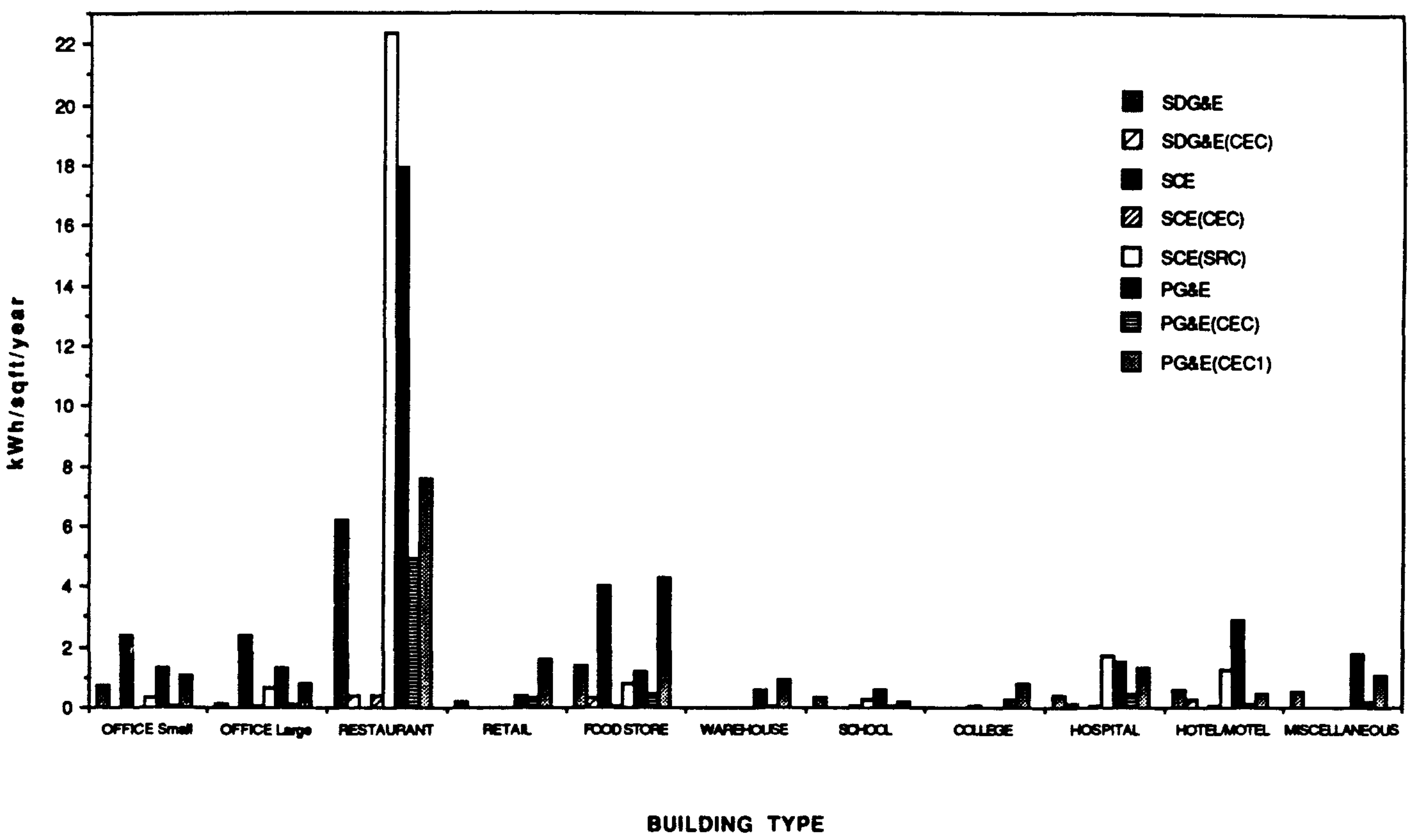
Figure III-3 shows that restaurants and food stores had the highest refrigeration EUI. This is reasonable since large capacity refrigeration equipment is most prevalent in these two business types. The EUI for food stores ranged from about 10 to 30 kWh/ft^2-yr, while the EUI for restaurants ranged from about 2 to 22 kWh/ft^2-yr. The CEC study estimates for refrigeration in the SDG&E and SCE service territories were low compared to the other studies. The warehouse category, which is a combination of refrigerated and non-refrigerated buildings, had the next highest refrigeration EUI, although it was much lower than for food stores and restaurants.

FIGURE III-3 REFRIGERATION EUIs COMPARISON



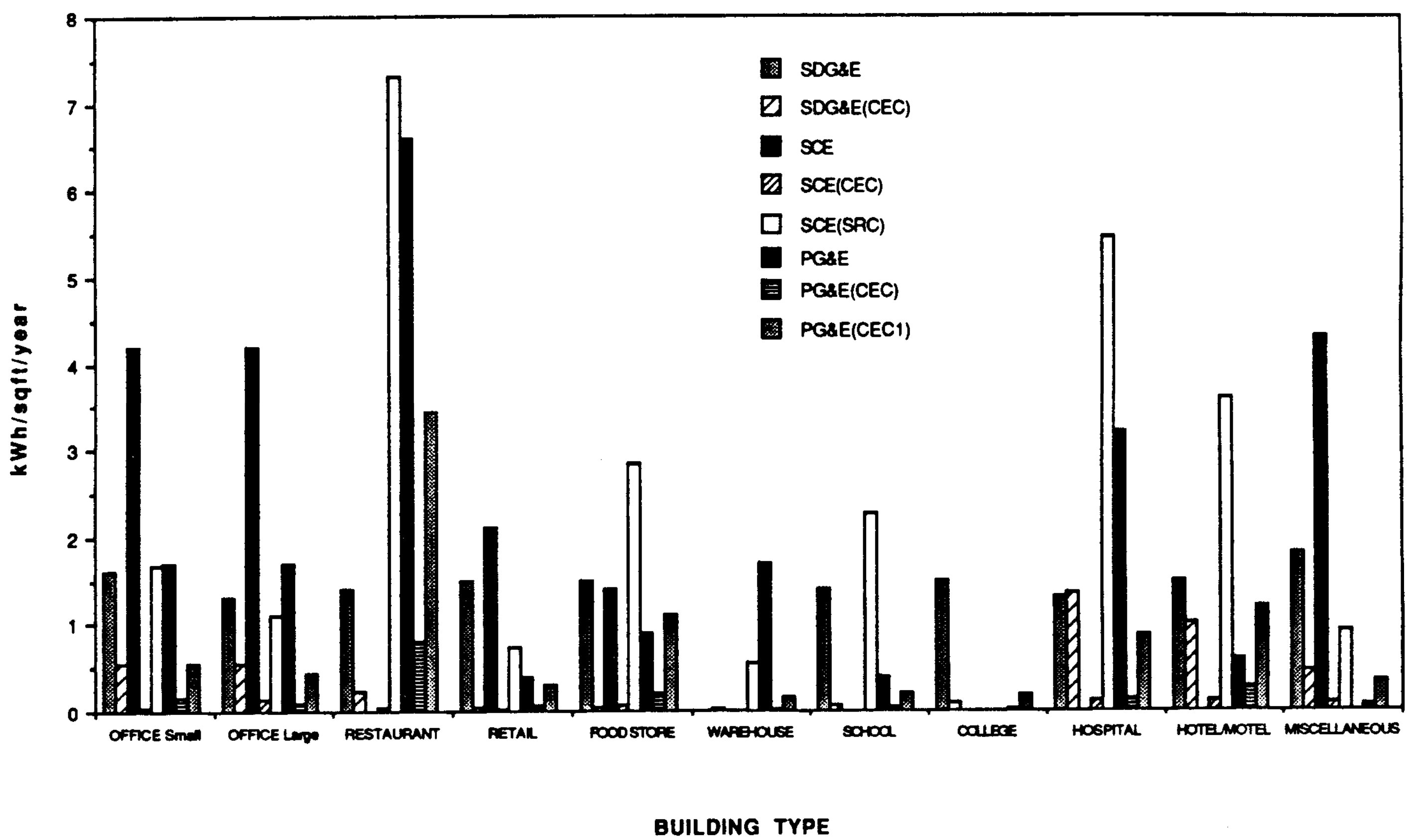
The largest cooking EUIs were found for restaurants; there was a range of from less than 1.0 to 22 kWh/ft^2-yr (see Figure III-4). Again, the CEC estimates for SDG&E and SCE were low compared to the other studies. Several other business types (food stores, hospitals, and lodging) had EUIs ranging from about 1 to 4 kWh/ft^2-yr.

FIGURE III-4 ELECTRICAL COOKING EUIs COMPARISON



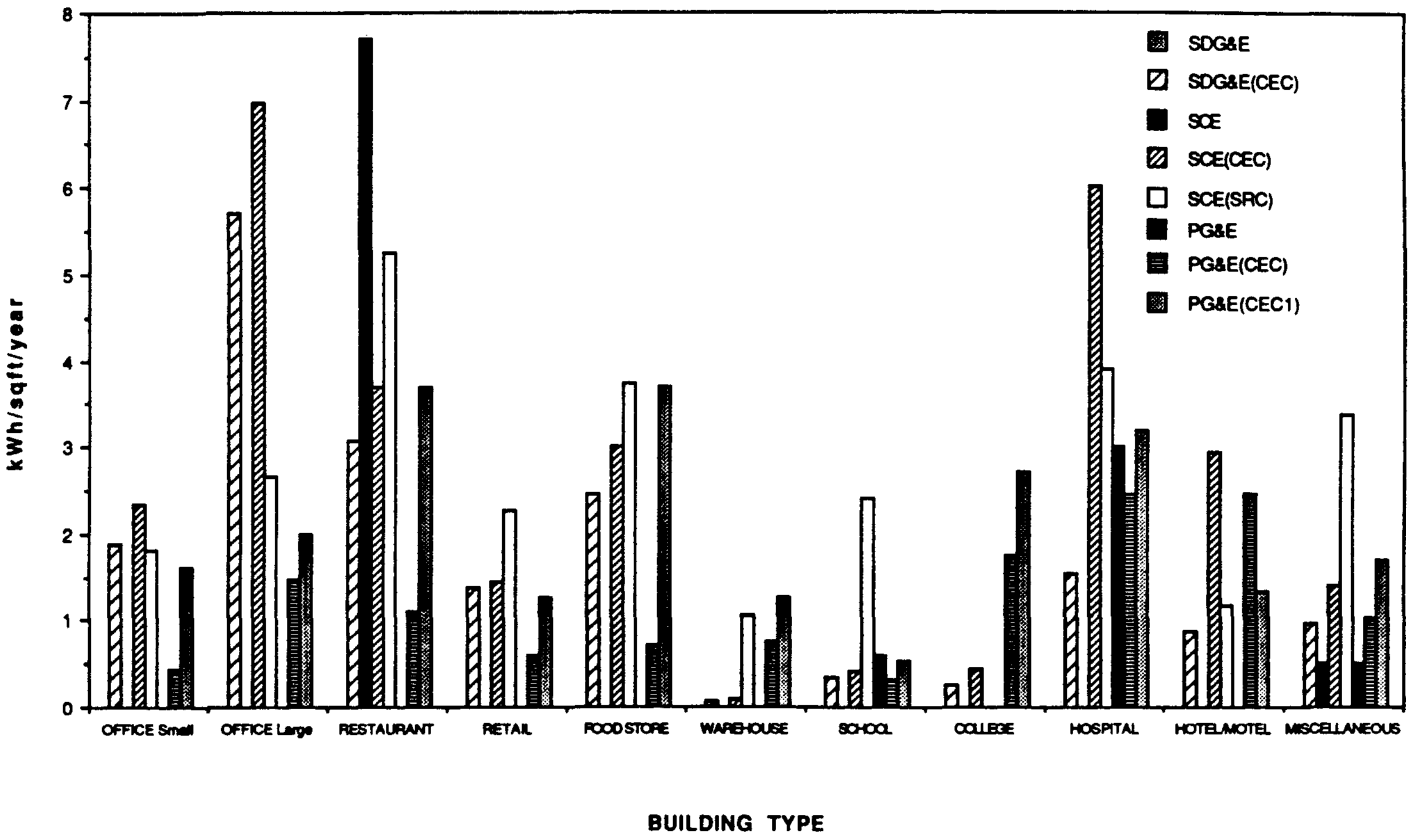
Restaurants also had the largest water heating EUI (see Figure III-5). The range of estimates however, was quite large (<1.0 to 7 kWh/ft^2-yr). There was poor agreement among the studies for this end use.

FIGURE III-5 ELECTRICAL WATER HEATING EUIs COMPARISON



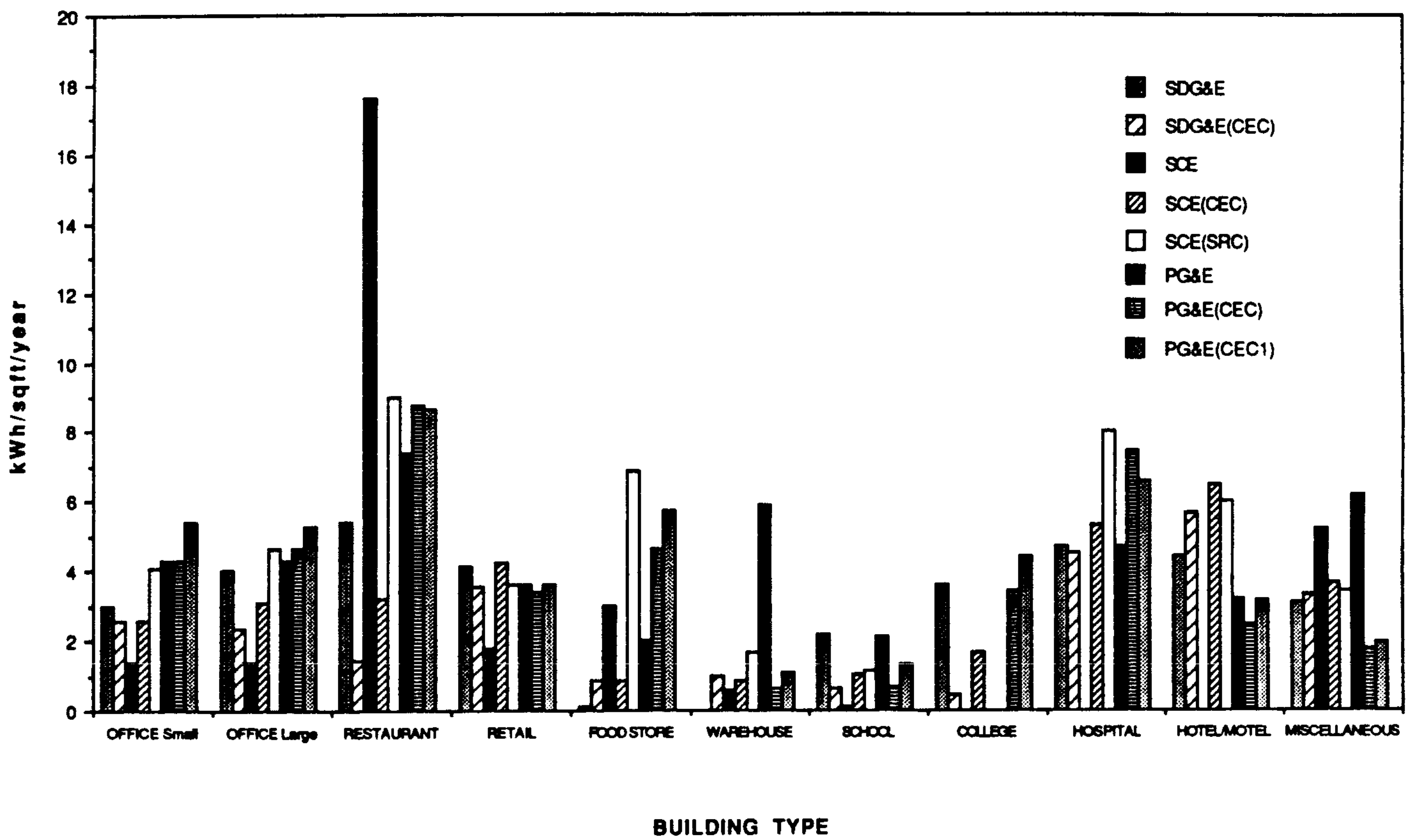
Ventilation EUIs were generally highest for large offices, restaurants, and hospitals (see Figure III-6). The agreement among studies was poor; there was often a factor of four or five range for any building type.

FIGURE III-6 VENTILATION EUIs COMPARISON



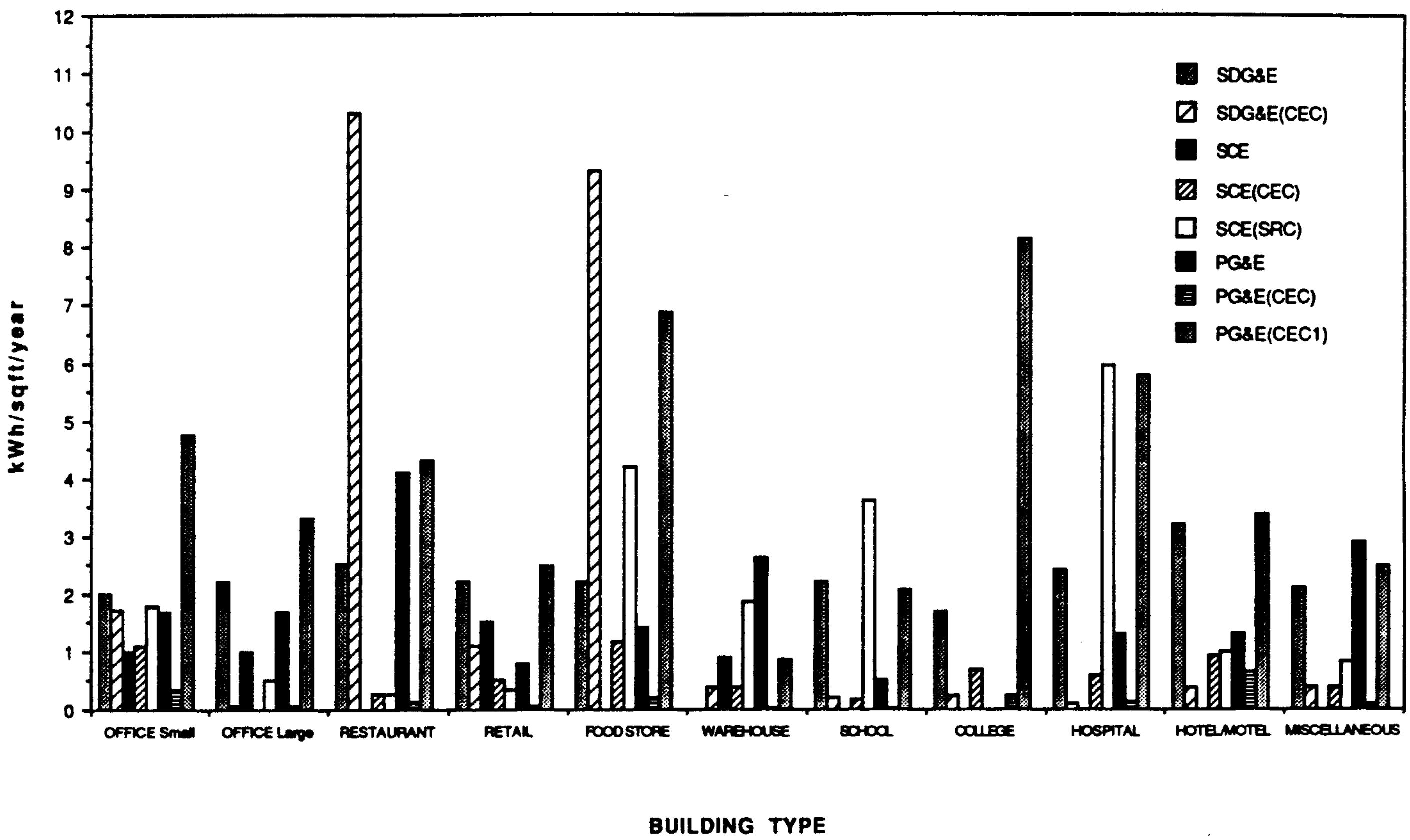
For most building types, the average EUI for cooling appeared to be around 3.0 kWh/ft^2-yr (see Figure III-7). Restaurants, hospitals, and lodging had the highest cooling EUIs, about 6 kWh/ft^2-yr. Some of the variation in cooling EUIs was due to the differences in climate among the three utility regions. Additionally, the definition of floor space was different among the studies. For example, the PG&E and SDG&E studies used conditioned floor space for cooling and space heating end uses. The large difference between the conditioned and unconditioned floor area. in warehouses may account for the relatively high EUI from the PG&E study for this building type.

FIGURE III-7 AIR CONDITIONING EUIs COMPARISON



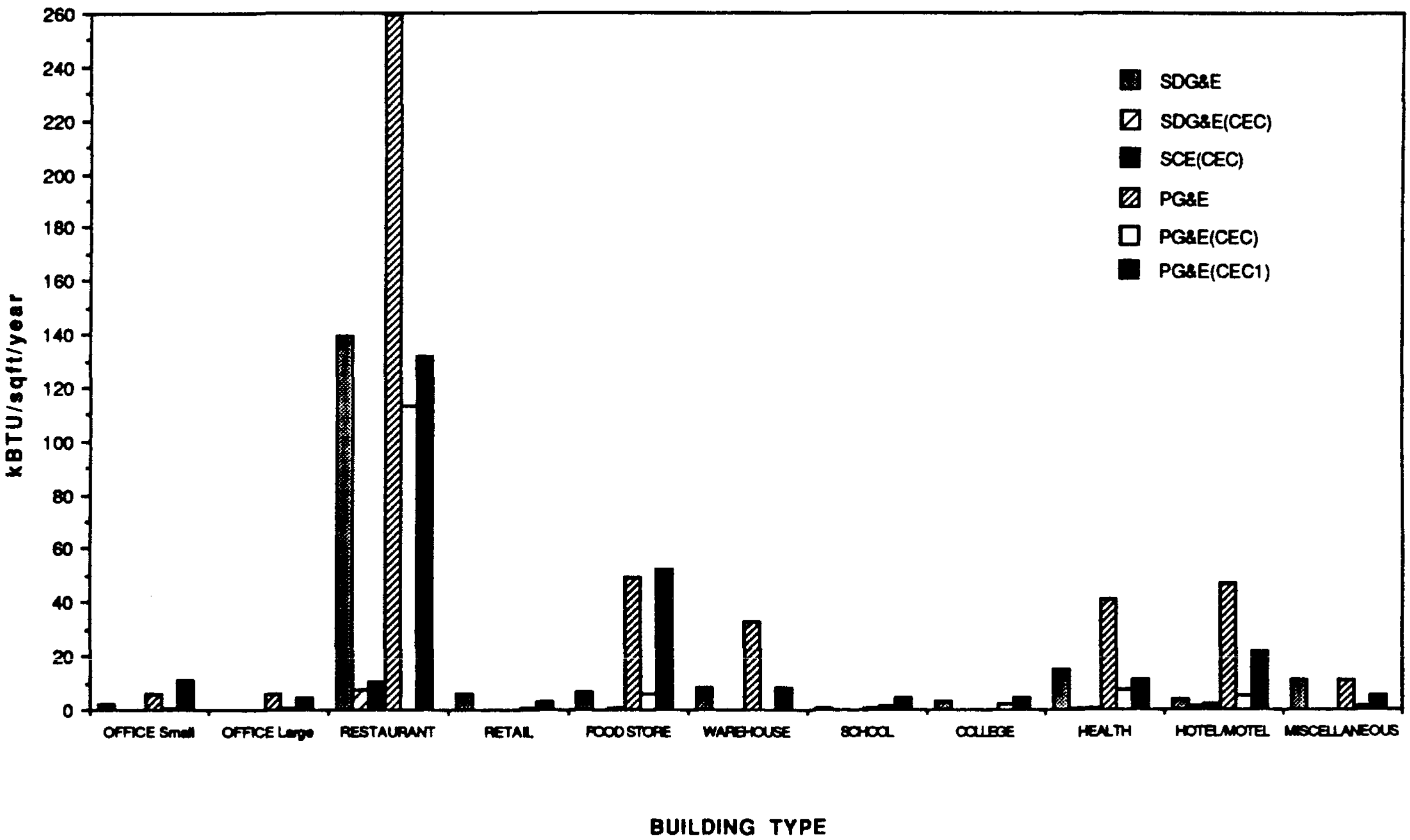
Except for a few high estimates from the SCE(CEC) and the PG&E(CEC1) studies, the electric heating EUIs were low, ranging from 1 to 2 kWh/ft^2-yr (see Figure III-8).

FIGURE III-8 ELECTRICAL SPACE HEATING EUIs COMPARISON



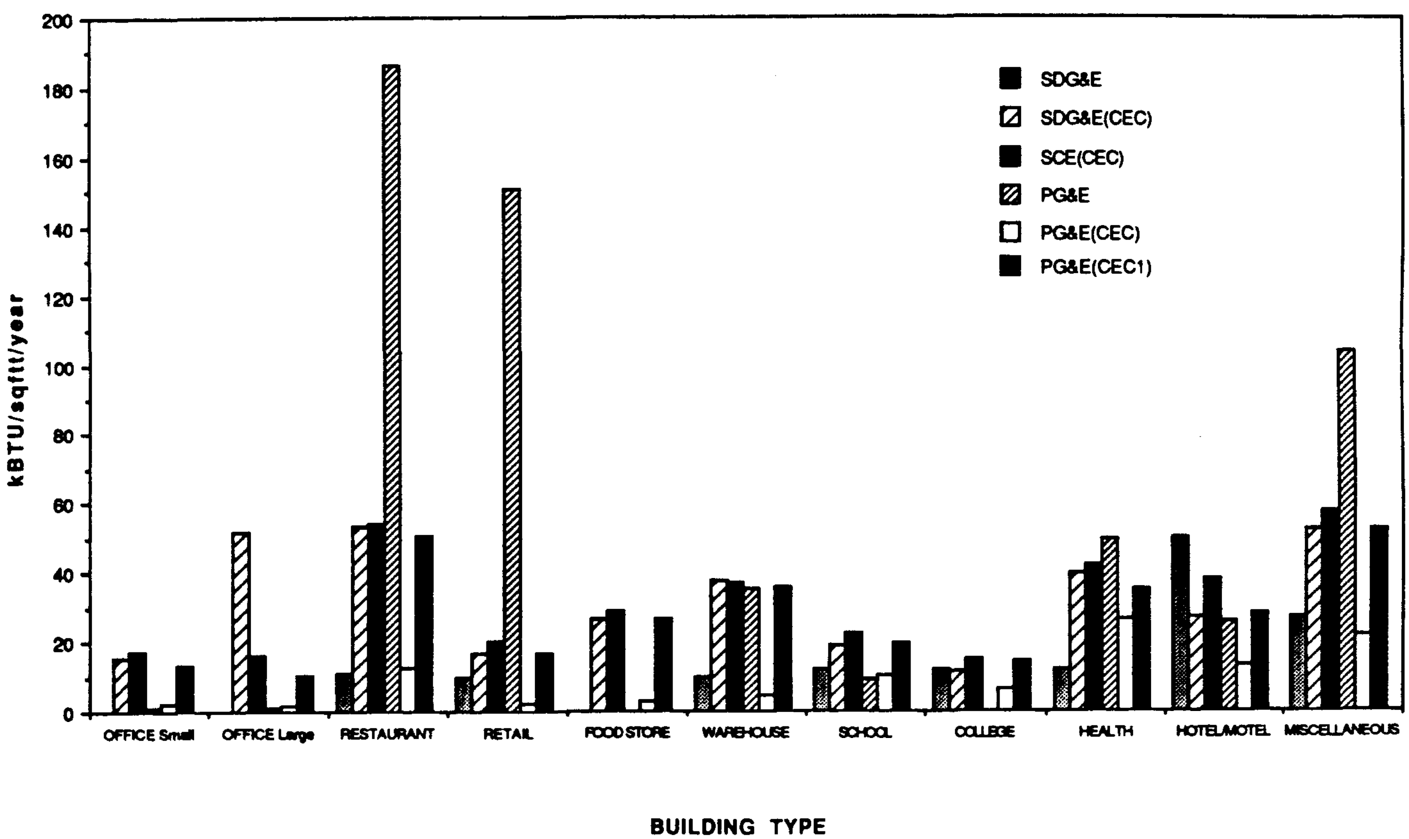
We also compared estimates of natural gas EUIs for four end uses (space and water heating, cooking, and miscellaneous). Miscellaneous includes such uses as gas fireplaces in restaurants, gas dryers, and Bunsen burners in schools. Restaurants, as expected, had the highest EUIs for gas cooking (see Figure III-9). The range of estimates however, was extremely wide. The CEC estimated ~10 kBtu/ft^2-yr. The other four estimates range from 110 to 260 kBtu/ft^2-yr). There was good agreement in most building types because the EUIs are low to begin with. Food stores showed the second highest cooking EUI. The PG&E conditional demand study consistently estimated the highest cooking EUI among building types.

FIGURE III-9 COOKING GAS EUIs COMPARISON



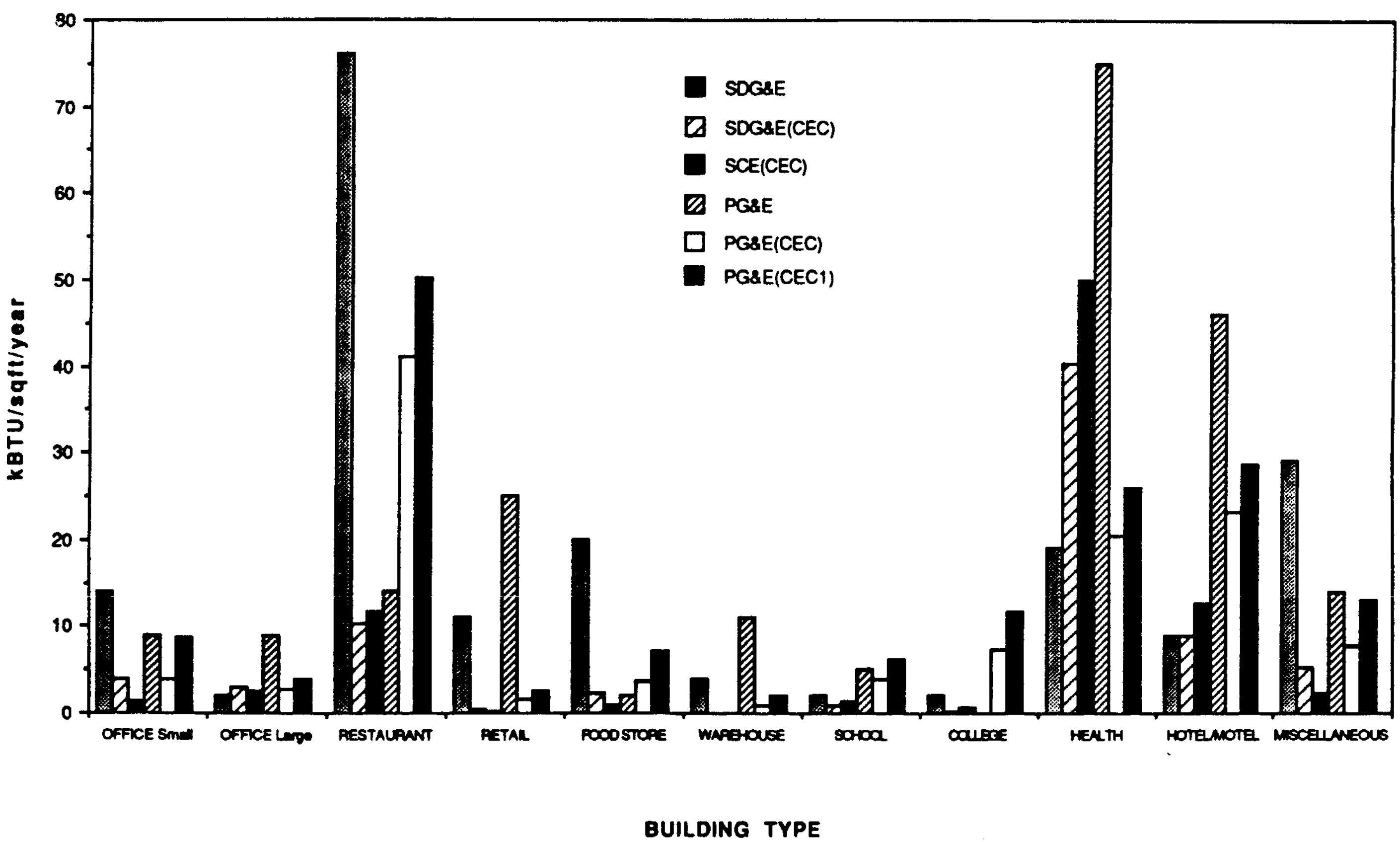
Restaurants, health facilities and lodging exhibited the highest EUIs for miscellaneous gas EUI (see Figure III-10). The PG&E conditional demand study estimated very high miscellaneous EUIs for restaurants and retail stores. If these two values are excluded, the agreement among studies would be quite good. Gas dryers probably contribute significantly to the high miscellaneous gas EUIs in restaurants, health facilities, and lodging.

FIGURE III-10 MISCELLANEOUS GAS EUIs COMPARISON



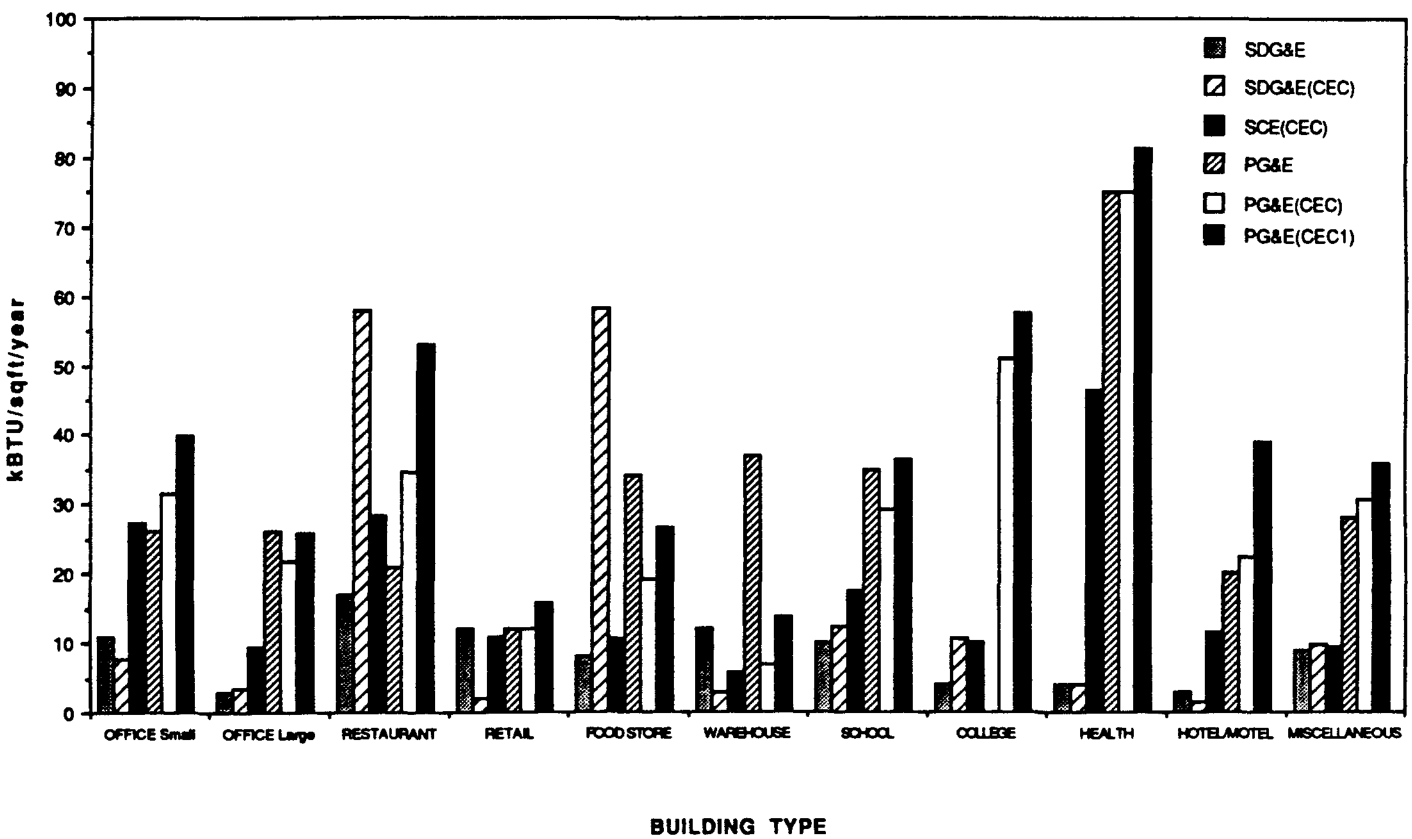
Restaurants, health facilities, and lodging showed the greatest use of gas-fired water heaters (see Figure III-11). This is a reasonable result because they all tend to have equipment requiring hot water, such as dishwashers, clothes washers, and showers. The range of estimates for each of these building types is quite wide. For example, for restaurants, the gas water heating EUI ranges from 10 to 75 kBtu/ft^2-yr. It is interesting to compare these gas water heating EUIs to the electric water heating EUIs. The maximum electric water heating EUI is about 25.6 kBtu/ft^2-yr. If efficiency were the only factor affecting the difference between gas and electric water heating EUIs, the gas water heating EUI would be expected to be around 37 kBtu/ft^2-yr. Instead, the gas water heating EUI was twice that value. This may be a result of the relatively higher saturation of gas water heaters in restaurants that use a lot of hot water.

FIGURE III-11 WATER HEATING GAS EUIs COMPARISON



The variation of gas space heating EUIs among building types was not very great (see Figure III-12). PG&E service territory usually had the highest space heating EUI, which was expected because of colder-than-average weather in the area. The health business type had the highest space heating EUI. This was expected because of large ventilation requirements, long hours of operation, and high indoor temperatures. As for water heating, it is interesting to compare gas and electric space heating EUIs. The PG&E service territory gas space heating EUIs were approximately 30 kBtu/ft^2-yr across most building types, whereas the electric space heating EUIs were about 6.8 kBtu/ft^2-yr across building types. The expected ratio of gas to electric EUI, if equipment efficiency were the only factor, would be at most about 2.0. Instead, the ratio of EUIs was 4.4. Again, it appears that gas space heating systems have been installed in buildings that use more heat. Another possibility, which also applies to our water heater findings, is that our estimates for electric space and water heating were too low relative to the gas space and water heating estimates.

FIGURE III-12 SPACE HEATING GAS EUIs COMPARISON



Description of Previous Load Shape Studies

In this section, we review and compare available end-use load shape (LS) data. There were fewer commercial sector LS studies available than EUI studies. We identified three major sources of load-shape data for forecasting (two in California and one outside California): SCE load-shape data base developed by the Synergic Resources Corporation (SRC); CEC peak demand model load shapes; and selected studies prepared for Northeast Utilities. In the following subsections, we review each methodology and the resulting load shapes. We then compare the load shapes across studies.

SCE Load Shape Forecasting Inputs. SCE currently employs an extensive data base of load shape information in its demand forecasting system. The inputs were developed by SRC and are reported in [SRC 1987].

To develop end use load shapes, computer simulation of prototypical building loads was used (with the ADM2 building energy simulation program), and followed by a reconciliation to SCE's class load. According to the SRC report, however, the final reconciliation was never fully carried out (on page III-6, SRC 1987): "The 1987 effort was intended to correct problems with the preliminary database constructed in 1986. The commercial sector shapes, therefore, were *not* reconciled as part of the short-term 1987 effort." Also, on page IV-14: "We were not able to achieve reconciliation for the commercial sector using all of the end-use components." We have, therefore, assumed that the load-shape data from the SRC study in this report reflect only simulation results.

Load shapes were developed for 13 building types, eight end uses, and four climate zones using prototypical buildings. These prototypes and end uses are summarized in Table III-1. For each prototype, end use, and climate zone, both a base case and several technology options were developed. The primary source of data for development of the prototypes was SCE's 1983 mail survey. The report states that the following secondary data sources were also reviewed: "Florida Power and Light, Northeast Utilities, NBECS, ASHRAE, and some preliminary data of SCE's 1985 mail survey" [SRC 1987].

The load-shape data from the SRC study were obtained for each base case combination of building type, end use, and planning area, for three day types (peak, weekday, and weekend day) for 12 months of the year.

Table III-1. SCE Protypical Buildings and End Uses

Building Prototypes	End Uses[1]
Large office with central HVAC	Heating
Large office with packaged HVAC	Cooling
Small office	Ventilation
Fast food restaurant	Lighting
Department store with central HVAC	Refrigeration
Department store with packaged HVAC	Water Heating
Small attached retail	Cooking
Supermarket	Miscellaneous
Refrigerated warehouse	
Non-refrigerated warehouse	
Primary and secondary school	
Hospital	
Hotel/motel	

1. Not all end uses are considered for all building prototypes.

CEC Peak Demand Forecasting Inputs. The CEC forecasts electricity peak loads for up to eight end uses in 11 building types (see Table III-2) [CEC 1987]. Unlike the SCE forecasting model, the CEC's peak forecasting model performs an hourly load calculation *only for the system peak day*. An earlier CEC report documents the source of these load-shape data [CEC 1979]. The data underlying the heating and cooling load shapes were provided to us on computer tapes.

HVAC and non-HVAC load shapes for the peak day are developed separately but follow the same two-step approach. In step one, daily energy consumption is estimated from annual EUIs. In step two, the daily consumption is apportioned among the 24 hours of the peak day.

Table III-2. CEC Protypical Buildings and End Uses

Building Prototypes	End Uses[1]
Large office	Heating
Small office	Cooling
Restaurant	Ventilation
Retail	Lighting
Food store	Refrigeration
Warehouse	Hot water
Elementary school	Cooking
University/College	Miscellaneous
Hospital	
Hotel/motel	
Miscellaneous	

1. Not all end uses are considered for all building prototypes.

Non-HVAC End Uses. The peak day forecast for non-HVAC end uses begins with a fixed and constant allocation of annual electricity consumption to "standard days." The allocation factor differs by building type and is based on an assumed building operating schedule. For example, large office buildings operate five days each week. This schedule yields about 250 working days per year, excluding holidays. Non-HVAC end uses, consequently, are assumed to use 1/250 of their annual electricity use during each standard day. Ventilation, although not strictly a non-HVAC end use, is calculated using this same method, and a seasonal factor is also used. The peak day end-use consumption is then allocated to hourly use, using a similar fixed and constant allocation scheme in which the daily integral of the hourly load shape values is set equal to one. Because the model was not designed to forecast hourly energy use for the entire year, these inputs provide no information on hourly load shapes for other days of the year besides the peak day. By assumption, the non-HVAC load shapes are independent of climate.

HVAC End Uses. Cooling electricity use (EUI) is allocated to daily consumption using a weighted three day average of cooling degree days (base 50° F).

$$\mathbf{CDCS_{b,t} = CACS_b * CDCDD_t}$$

$$\mathbf{CDCDD_t = (0.6CDD_t + 0.3CDD_{t-1} + 0.1CDD_{t-2})/ACDD}$$

where,

CDCS	= Daily cooling electric EUI for premises, type b, day t
CACS	= Annual cooling electric EUI for premises, type b
CDCDD	= Three-day weighted cooling degree days
CDD	= Cooling degree days, base 50° F
ACDD	= Annual average CDD

Space heating energy use is allocated to the peak day by considering only the heating degree days (base 65°F) on the peak day.

Temperature humidity indices (THIs) are used to allocate peak day energy use to hourly loads. The THI matrix consists of dimensionless load values that are a function of time of day and temperature/humidity. The load shape is calculated by first summing the load values from the hourly temperature/humidity conditions on the peak day and then apportioning energy use by the contribution of the individual hourly values to this daily sum. The DOE-1.4M building energy simulation program was used to develop the THI matrices for 11 building types and two vintages.

Northeast Utilities Load Shape Data. Load-shape data for several building types have been developed for Northeast Utilities. The building types studied include new offices [NEU 1985], existing offices [NEU 1987a], restaurants, warehouses, hotels/motels, and miscellaneous [NEU 1987b], educational and health [NEU 1986b], and retail [NEU 1986a].

NEU 1985 was based on computer simulation of prototypical new office buildings. The prototypes were developed from an on-site survey of 18 large, 15 medium, and 28 small office buildings. Winter peak day, winter week day, summer peak day, and summer weekday load shapes were developed for all buildings, and aggregated results for all building types were obtained. The end uses that were considered include heating, cooling, ventilation, lighting, water heating, refrigeration, cooking, and miscellaneous.

NEU 1987a presents end-use energy consumption and load shapes for office buildings. The method used to develop these load shapes was a DOE-2 simulation of a prototypical office building. The prototype was created from information contained in a survey of office buildings that was conducted by Northeast Utilities. Load shapes were developed for a base case and three packages of energy conservation measures. Small, medium, and large office buildings were studied separately. For each building, load shapes were estimated for three fuel options (all-electric, natural gas, fuel oil). Separate load shapes were developed for winter peak, winter weekday, winter weekend day, typical October weekday, typical October weekend day, summer peak day, summer weekday, and summer weekend day for heating, cooling, water heating, refrigeration, cooking, lighting, and miscellaneous end uses. The source of these data was computer simulation.

In our comparisons, we have considered only summer and winter peak and weekday (for a total of four load shapes) for the base-case, all-electric, small and large office buildings (a total of eight load shapes).

The NEU 1986a study included retail stores, food stores and personal services. The analysis is based on audit information collected for 255 food and non-food stores. Audit data were analyzed using statistical techniques and simple engineering calculation (rather than simulation) to obtain EUIs for heating, cooling, ventilation, lighting, water heating, cooking, refrigeration, and miscellaneous end uses. Aggregate sector total load shapes for food and non-food stores were also estimated. Since the estimated load shapes are sectoral aggregates rather than averages, we have not used the results in our comparisons.

NEU 1986b developed load shapes for educational and health buildings. The input data to this study are from 60 ICP buildings and supplementary (complementary) on-site surveys of 62 buildings. Prototypes were developed for 10 buildings types (primary school, secondary school, college dormitory, college classroom/administration building, college student center/dining, vocational/technical school, hospital, nursing home, large and small physician's office) and eight end uses (heating, cooling, ventilation, lighting, water heating, refrigeration, cooking, miscellaneous). Using ADM-2, EUIs were estimated for all end uses. Aggregate summer peak day and winter peak day load shapes were presented graphically for schools, colleges, and health buildings. End-use load shapes include heating, cooling, ventilation, lighting, hot water, and others.

NEU 1987b developed load shapes for restaurants, warehouses, hotels/motels and miscellaneous buildings. The input data to this study were information obtained from on-site audits of 262 hotel/motel, warehouse, restaurant, and miscellaneous buildings.

Load Shape Comparisons

LBL used the data in these reports to plot load shapes for all building types, for seven end uses (heating, cooling, lighting, hot water, cooking, refrigeration, and miscellaneous), and for summer and winter peak and typical days.

Table III-3 summarizes the load-shape data that we have used in our comparison. The following should be noted:

- SCE uses load-shape data for all 12 months of the year, CEC uses only one set of hourly load-shape data (for the peak day), and NEU has two load shapes (one for summer one for winter).
- The non-HVAC end-use load shapes for all of the studies do not change across seasons.
- The cooling load shapes for CEC were calculated using typical year weather data and the THI matrices.
- The Northeast Utilities load-shape data did not provide fractions for daily consumptions. Consequently, the upper parts of the load shape curves were left blank.

The load-shape data from the three sources differ widely in their development and application. In order to establish a common framework for comparing end-use load shapes we have followed the CEC's lead by developing a compact representation of the load shapes for comparison.

1. First, we calculate daily allocation factors that apportion annual end-use consumption to daily consumption.
2. Second, we apportion daily consumption to hourly consumption with hourly allocation factors, whose 24-hour integral adds up to one. Figure III-13 is an example; all figures are reproduced in Appendix D.

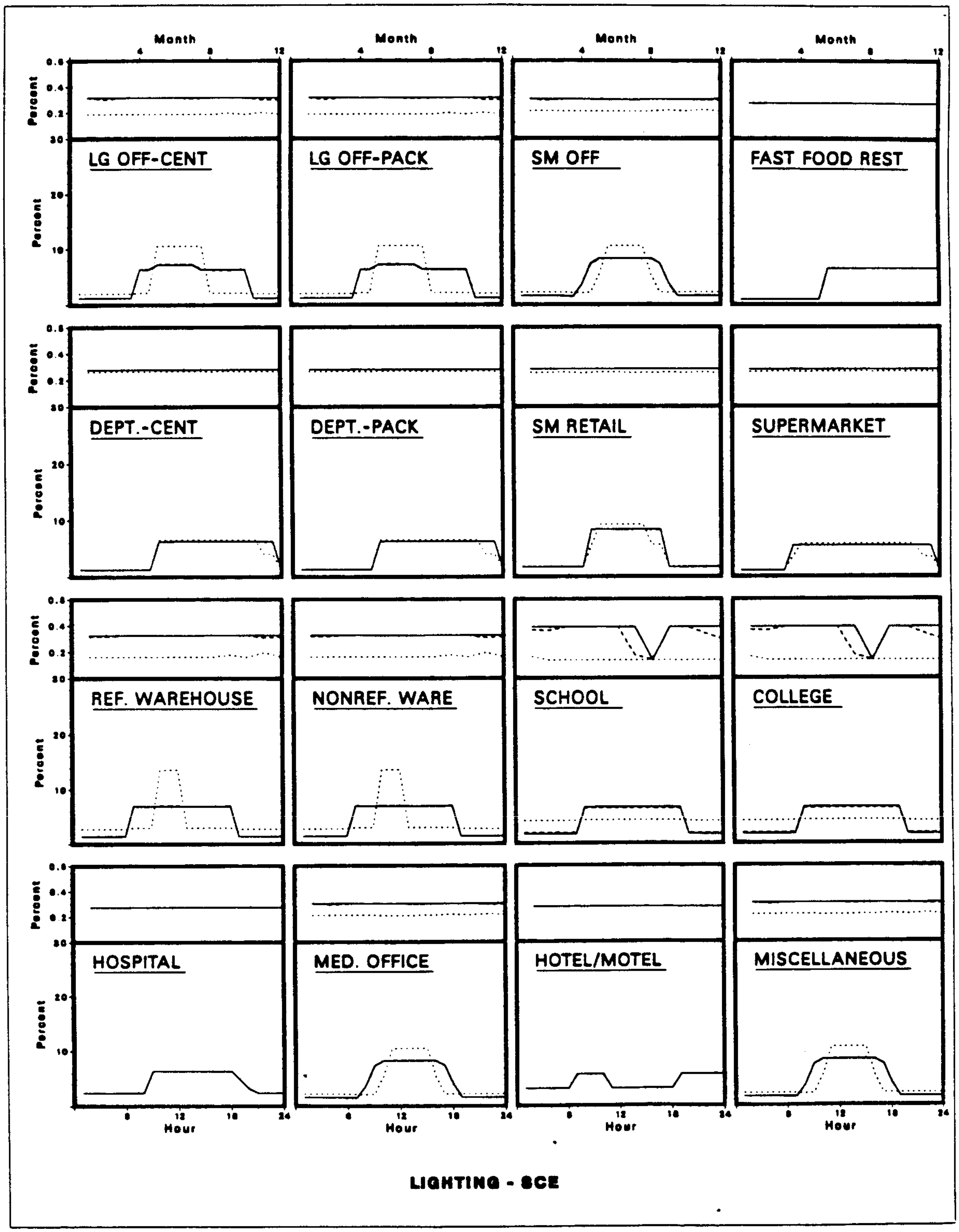
Table III-3. Load Shape Comparison - Data Summary

	Southern California Edison	California Energy Commission	Northeast Utilities
Types of days	Peak, Standard Weekend	Peak	Peak, Standard Weekend[5]
Load shapes for:	12 Months	Winter, Summer	Winter, Summer
Building Types:			
Large Office	•[1]	•	•
Small Office	•	•	•
Retail	•[1,2]	•	•[5]
Restaurant	•[3]	•	•
Food Store	•	•	•[5]
Warehouse	•[4]	•	•
School	•	•	•[5]
College	•	•	•[5]
Hospital	•	•	•[5,6]
Medical Office	•		
Hotel/Motel	•	•	•
Miscellaneous	•	•	•[5]
End Uses:			
Heating	•	•[9]	•
Cooling	•	•[9]	•
Ventilation	•	•	•[7]
Lighting	•	•	•
Cooking		•	•
Refrigeration	•[8]	•	•
Water Heating		•	•
Other	•	•	•

Notes:

1. Load shapes for large office and department store were simulated with both central and package air conditioning units.
2. Separate load shapes were estimated for small retail and department store.
3. Load shapes were estimated only for fastfood restaurant.
4. Separate load shapes were estimated for refrigerated and non-refrigerated warehouses.
5. We have omitted presentation of data from this category.
6. Northeast Utilities load shapes for hospitals included all categories of health buildings.
7. Ventilation was included in heating and cooling end uses for all building types but office.
8. Refrigeration load shape was only estimated for refrigerated warehouse.
9. Load shapes for heating and cooling were calculated using THI matrices.

Figure III-13 **Summary presentation of load shape data.** Each end-use load shape presentation is divided into two parts. The top part presents fractional data, so that when the EUI is multiplied by a fraction, the resulting number is the daily energy use for the given month and the given day type. The bottom part of the graph shows hourly load-shape data for three day types. The hourly end-use load is calculated by multiplying daily consumption by the hourly load-shape fraction. Except where peak, standard, and weekend data are shown in separate graphs, solid lines represent peak days, dashed lines represent standard days, and dotted lines represent weekend days.



Non-HVAC End Uses. Figures D-1 to D-4 (in Appendix D) summarize lighting, miscellaneous, water heating, cooking, and refrigeration load shapes for all building types and all climate regions. The sub-figures (a), (b), and (c) represent load shape data from SCE, CEC, and NEU reports, respectively. Whenever load-shape data from a given report were not available for an end use, the subsequent figure was omitted. The SCE data included monthly peak day, monthly average weekday, and monthly average weekend-day load shapes for all 12 months of the year. There is not significant month to month variation for these load shapes. The CEC load-shape data are only for the peak day of the year. Therefore, there is not a one to one comparison for all months of the year. The Northeast Utilities' data included summer and winter load shapes for all three day types for some end uses.

Lighting. Figure D-1 shows the load-shape data from all three sources. In general, the load shapes are quite different and a detailed comparison is difficult. We observed that:

- The fractions of daily consumptions between CEC and SCE data were within about 25% of each other, except for the small office, school, and college;
- The load shapes differed mainly during the shoulder hours. Hours of full operation varied among these studies;
- CEC and NEU load shapes indicated zero nighttime lighting for school and for small office;
- CEC uses an almost flat lighting load shape for warehouses, but a very complicated load shape for the miscellaneous building;
- Peak and weekday load shapes for SCE were nearly identical, except for the school and college.

Miscellaneous end uses. Again, there are more differences than similarities among these load shapes (see Figure D-2). We observed:

- The fraction of daily consumptions between CEC and SCE data was again within about 25% of each other, except for the small office, school, and college;
- Peak and weekday load shapes for SCE were also nearly identical, except for the school and college;
- CEC uses the same load shape for both the elementary school and college;

- Load shapes for supermarket (food store), warehouse, school, college, hospital, and hotel/motel differed considerably.

Water heating, cooking, and refrigeration. Figures D-3, D-4, and D-5 show the load shapes for these end uses. Note that SCE's report did not give load shapes for these end uses, except for the supermarket refrigeration (which exhibited no variation, either diurnal or seasonal). We observed:

- CEC's load shape for hotels showed very high nighttime water heating energy use;
- CEC's load shapes for the large and small office appeared to neglect water heater standby losses;
- CEC's flat load shape for warehouse cooking was unexpected;
- CEC uses a flat refrigeration load shape for all building types;
- NEU profiles for water heating in restaurants and warehouses were also flat.

HVAC End Uses. As expected, the variations in the ventilation and HVAC end uses among the three reports were even greater than the ones found for the non-HVAC end uses. SCE data included load shapes for three day types for 12 months of the year. These data indicated that there was significant variation in ventilation and HVAC end uses for each of SCE's four planning areas. CEC reported heating and cooling load shapes in the form of weather data and THI matrices. The NEU did not report ventilation data except for offices.

We have used the load shapes from a single SCE planning area as the basis for comparison of the SCE data. The planning area we selected was based on a review of the load shapes for the large office building. Figure D-6 shows the cooling, ventilation, and heating end-use load shapes of the large office, for each of the four planning areas. Because the load shapes for all planning areas (except for Planning Area 2, a coastal zone) were similar, we chose to concentrate on only the load-shape data for Planning Area 1 for further comparisons.

Ventilation. Figure D-7 shows the ventilation load shapes from SCE, CEC, and NEU reports, respectively. We observed:

- For the SCE data, except for large offices, the ventilation load shapes for all 12 months of the year were nearly identical. Also, for most building types, there was no significant variation between peak and standard day;
- CEC assumes the same load shape for all building types[4];
- NEU combines ventilation with heating and cooling for all building types except offices.

Cooling. Figure D-8 shows the cooling load shapes from SCE, CEC, and NEU, respectively. Normalizing load shapes for these end uses can be misleading. Normalized load shapes suppress seasonal and operational effects, which can vary markedly. For example, winter month cooling loads may appear more "peaky" than those in the summer, because they are being normalized to different quantities.

As one would expect, the load shapes for large offices exhibited less monthly variation than do those for other buildings. The school load shapes were interesting because in the month when school is not in session, August, the load shape is similar to the weekend load shape. Also, the January weekend load shape appears to be similar to the standard-day load shape (although much smaller in magnitude).

The CEC load shapes were calculated from THI matrices for each building type using typical year weather data for the four planning areas: Bakersfield (BAKR, corresponding with planning area 1 from SCE), Burbank (BRBK, planning area 3), Los Angeles Airport (LAX, planning area 2), and San Bernadino (SNBR, planning area 4). The monthly variation was calculated from the daily cooling degree days for each planning area, and did not vary from building to building.

The load shapes did not vary much from planning area to planning area. The load shapes for hotels and hospitals were identical and quite flat, probably because of nighttime occupancy. One might expect, however, that the hospital would have a larger daytime peak, because of "office hours" during the day.

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[4] This may be due to a misunderstanding in our interpretation of the CEC data on ventilation load shapes.

The NEU cooling load shapes for small and large offices included both peak and standard days.

Heating. Figure D-9 shows the heating load shapes from SCE, and NEU, respectively. Because CEC load shapes were for only peak days, which occur during the summer, we have not presented them.

The heating load shapes for SCE were the least uniform of all the load shapes studied. This comes in part from the fact that during swing seasons there is small heating use, so small and perhaps random fluctuations in demand are magnified when the load shape is normalized, creating confusing results. These months are, however, less important since their overall magnitudes are quite small.

The NEU load shapes for heating for small and large offices included both peak and standard days. It should be remembered that "peak heating," especially in the northeast, occurs in winter, and cannot be added with peak (summer) cooling to determine an overall peak consumption.

In summary, our review of three LS studies, which included existing LSs in use by SCE and CEC, uncovered two significant features of existing EUIs. First, LSs were generally not consistent among studies (e.g., SCE and CEC had different load shapes for the same end use in the same building type), but these differences could often be related to differences in assumptions for operating hours. Second, for a given building type within one study, LSs were often identical for each month and for peak and standard days suggesting that, according to the studies, these end uses were not affected by seasonal or climatic influences.

Task IV. Development of an Estimation Method

The major analytical contribution of our work was the development of an integrated method for the estimation of EUIs and LSs, which relies explicitly on measured LRD to reconcile preliminary engineering estimates. The method consisted of three steps and three major software tools (see Figure IV-1).

First, we developed preliminary prototypical EUIs and LSs for the nine types of premises, using the integrated on-site survey data and the non-HVAC EUI/LS and DOE-2 Input Generator (NELDIG) and the DOE-2 building energy analysis program. NELDIG performed two functions: 1) it estimated LSs and annual EUIs for non-HVAC end uses, and 2) it prepared prototypical building input data (described more fully in Task V). The prototypical buildings were then simulated, using DOE-2, to obtain EUIs and LSs for the HVAC end uses.

Second, using the LRD and monthly billing data from the on-site surveys (as described in Task II), we constructed average whole-building hourly load shapes for eight types of premises[1]

Third, using the initial building loads by end use from the first step and the average hourly loads from the second step, we applied the End-use Disaggregation Algorithm (EDA) to obtain adjusted, reconciled end-use load profiles for all building types. The corresponding EUIs are simply the integration of the hourly profiles for the entire year.

In this section, we review the major software tools used in the analysis, NELDIG and EDA, describe their linkages, and summarize the remaining software tools used. Discussion of the development of DOE-2 prototypes is reserved for Task V.

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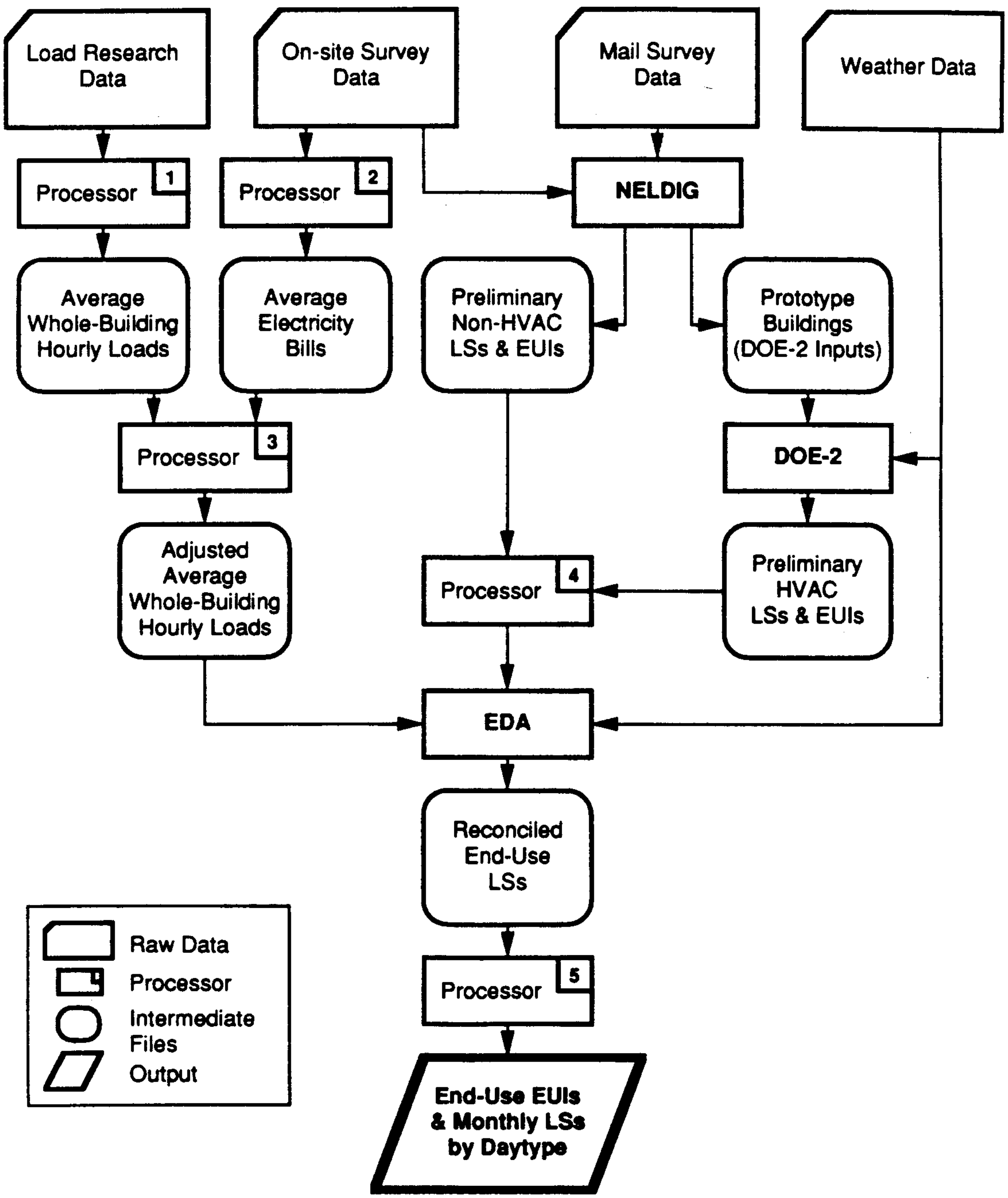
[1] Sitdown and fastfood restaurants were combined, as described in Task I.

Figure IV-1. Integrated Commercial LS and EUI Estimation Methodology. The method consists of three parts: 1) development of preliminary EUIs and LSs using NELDIG and DOE-2, 2) construction of average whole-building hourly loads, by building type, and 3) reconciliation of the preliminary EUIs and LSs with average whole-building hourly load, using EDA.



Non-HVAC EUI/LS and DOE-2 Input Generator (NELDIG)

A major component of our method for estimating end-use EUIs and LSs was the development of initial estimates of these quantities from the survey data. We embodied this task in a software tool called NELDIG.

NELDIG is a Fortran program that performs the following functions:

1. Reads on-site survey data, selectively edit or remove incorrectly specified data (as described in Task I);
2. Calculates non-HVAC EUIs and load shapes and the components of these that contribute to space HVAC loads;
3. Generates a complete DOE-2 input for use in calculating annual and hourly space-HVAC energy use; and
4. Produces a summary report of building characteristics and non-HVAC energy use and load shapes.

These functions can be performed using audit data from either a single premise or from a group of premises. Our use of the software to generate information from a single on-site survey was used in the pilot prototype analysis (Task VI).

NELDIG is based on two older programs developed by ADM for CEC, called the Preprocessor and Ingen. The Ingen program aggregates individual building data from an earlier audit data form used by CEC and produces a DOE-2 or an ADM-2 simulation input for a prototype that is intended to be representative of the group of individual buildings taken together [ADM 1983].[2] The Preprocessor converts data from the format of the more recent on-site survey to that used by Ingen.

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[2] The aggregation procedure in Ingen uses floor area as a statistical weight. We examine the use of this procedure and compare it to our use of weights based on energy consumption in Task VI.

We combined and substantially enhanced these two programs with the development of NELDIG. Enhancements included the introduction of exogenous statistical weights, complete revision of the calculation of non-HVAC EUIs, explicit treatment of missing values, and generation of DOE-2 System and Plant inputs. Table IV-1 compares selected features of the Ingen/Preprocessor with those of NELDIG.

In this subsection, we describe our methods for estimating non-HVAC EUIs. The data editing and processing steps are described in Task I. The DOE-2 input generation will be described in Task IV. Complete descriptions of the prototypes are reported in Task VIII.

The most general equation for estimating annual energy use for a given non-HVAC end use is:

$$EUI = \left[\sum_{i=1}^{n} W_i * U_i * \sum_{j=1}^{3} N_j * \sum_{k=1}^{24} F_{jk} \right] / \left[A * 1000 \right]$$

where:

EUI	= annual energy use (kWh/ft^2-yr or $kBtu/ft^2$-yr)
W_i	= connected load or maximum rating of equipment i (W or Btu/hr)
n	= number of different pieces of equipment for an end use
N_j	= annual numbers of days of type j (days)
F_{jk}	= profile fraction, by end use, of total rating in use each hour k of day type j (dimensionless)
U_i	= usage factor for equipment i (dimensionless)
A	= gross enclosed floor area of building (ft^2)

The use of both a profile fraction, F_{jk}, and a usage factor, U_i, is redundant because, for each end use, either F_{jk} or U_i was set equal to 1.0. In the on-site survey, F_{jk}s were reported for each end use (except water heating and refrigeration) to represent an aggregate fraction of the connected load of all equipment that was using energy in a given hour. Supplemental data from other studies for certain equipment types within a given end use (notably cooking and miscellaneous equipment) allowed us to further refine the profile information by assigning usage factors, U_i, to individual equipment types. For these two end uses, usage factors were multiplied times the hours of operation for each piece of equipment. U_i was assigned a value of unity for indoor and outdoor lighting.

Table IV-1. Comparison of LBL's NELDIG with CEC's Ingen/Preprocessor

Feature	LBL NELDIG	CEC Ingen/Preproc.
general		
data filters, editing	yes	no
single-building runs	yes	no
title-24/20 compliance	yes	no
summary output report	yes	no
lighting, equipment, cooking, fan, refrigeration		
distinguish internal loads from heat gains	yes	no
develop non-standard day schedule	yes	no
develop closed day schedule	yes	no
special non-HVAC calculations		
misc. equipment, refrig., cooking usage factors	yes	no
DOE water heater energy use calculation	yes	no
building features		
exogenous building shape	yes	yes
variable HVAC zoning	yes	yes
exogenous HVAC specification	yes	no
non-conditioned area	yes	no
aggregation procedures		
simple weighting	yes	no
floor area weighting	yes	yes
exogenous weights	yes	no
alternative schedule treatments	yes	no
simulation inputs		
DOE-2 LOADS	yes	yes
DOE-2 SYSTEMS/PLANT	yes	no
ADM-2	no	yes

Although the equation permits the use of 24 hourly profile fractions (F_{jk}s), the on-site survey only allowed reporting for a maximum of three unique profile values. In administering the survey, the auditor was required to identify up to three distinct operating regimes (corresponding to operating hours from, say, midnight to opening, opening to closing, and closing to midnight) and estimate the average fraction of the connected load for a given end use in each regime. Thus, the auditor's task of developing profiles was reduced to one of simply estimating a start and stop time for each end use. This simplification effectively eliminated diurnal transitional periods between one operating regime and another.

The on-site survey provided most but not all of these data for each end use. In general, connected loads were reported for all end uses (W_i), as well as the number of standard and non-standard days per week (N_j/week).[3] Standard day hourly profiles (F_{jk}) were available for all end uses except refrigeration and water heating, but non-standard day profiles were not available for any end use. Usage factors (U_i), in addition to those implicit in F_{jk}, were not available. As a result, we had to use data in the on-site survey, in conjunction with other data, to derive values for the missing data. The derivations tended to vary somewhat by end use; we describe these differences in order of increasing complexity in the following paragraphs.

Refrigeration. The estimation of refrigeration EUIs was the most straightforward, conceptually, but data used to perform the estimation were among the weakest, empirically. By assumption, refrigeration runs continuously, so F_{jk} is equal to 1.0 for all j and k (accordingly, there is no profile of F_{jk}s in the on-site survey). The difficulty is that refrigeration systems cycle throughout the day and data on U_i are scarce. The on-site survey asks the auditor to estimate usage levels (low, medium, high) for refrigeration equipment, but no further quantitative data were requested. Based on other analyses, primarily Jaske [1983], we developed usage factors that were a function of business type and reported usage level. Table IV-2 summarizes the values used. The three usage factors correspond to low, medium, and high use, respectively, in the on-site survey responses.

[3] In general, one can assume that standard days refer to weekdays and that non-standard days refer to weekends and holidays.

Table IV-2. Refrigeration Usage Factors (U_i)

Building Type	Usage Factor		
	Low	Medium	High
Small Office	0.1	0.2	0.3
Large Office	0.1	0.2	0.3
Retail	0.1	0.2	0.3
Food Stores	0.5	0.6	0.7
Refr. Warehouse	0.5	0.6	0.7
Non-Refr. Warehouse	0.1	0.2	0.3
Health	0.3	0.4	0.5
Sit-down Restaurant	0.3	0.4	0.5
Fast-Food Restaurant	0.3	0.4	0.5

Outdoor Lighting. Although hourly profiles of outdoor lighting, F_{jk}, were reported for only the standard day of operation, we assumed the profile would be identical for non-standard days. We assumed also that the reported profile values required no further adjustment to the U_is, which were set equal to 1.0.

Indoor lighting. The absence of hourly profiles, F_{jk}, for operation of indoor lighting on non-standard days could not be addressed with the simplifying assumption used for outdoor lighting. Instead, other aspects of building operation were considered. We used the reported building operating hours for standard and non-standard days to adjust the standard day indoor lighting hourly profile for non-standard days. In other words, the fraction of connected load in a given regime of operation remained unchanged, but the duration of this operating regime was adjusted. For each day, as with outdoor lighting, U_i was set equal to 1.0.

Separate adjustment rules were developed depending on whether the non-standard day hours for building operation were more or fewer than those for the standard day of operation. If the number of lighting operating hours was greater than the building operating hours on the standard day, then the lighting operating hours on non-standard days were set so that they exceeded the non-standard day building operating hours by the same amount. If lighting operating hours were fewer than the standard day building operating hours, we assumed that lighting operating hours divided by standard day building operating hours were held constant for the non-standard day.

Miscellaneous Equipment. EUIs for miscellaneous equipment were calculated by summing the products of installed power (in Watts), daily usage (in hours), and usage factor for each piece of miscellaneous electrical equipment. Installed power and hours of usage on a standard day were obtained from the on-site survey. For non-standard days, we used the same adjustment procedure used for indoor lighting. The usage factors are reported in Table IV-3. They were largely based on a report by Alereza and Breen [1984]; however, usage factors for computers and printers were obtained from a report by Norford, et al. [1988]. Large equipment (>10 kW) received special attention. For some of these equipment types (for example, x-ray machines), we changed the usage factors based on engineering judgment.

Table IV-3. Miscellaneous Electric Equipment Usage Factors

Name	Use Factor	Name	Use Factor	Name	Use Factor	Name	Use Factor	Name	Use Factor
2 REGIS	0.8	CALCULA	0.8	CUTTERS	1.00	EQ. SCA	1.00	IMMASE	1.00
5 H.P.	1.0	CAMERA	1.00	DAMPER	-1	EVAP. C	-1	INDIVID	1.00
6 REGIS	0.8	CANDY M	1.00	DATA CH	0.34	EXAMINI	1.00	INSECT	1.00
7 REGIS	0.8	CARPET	1.00	DATA PO	0.34	EXHAUAT	-2	JOINER	1.00
ADDING	0.8	CASAH R	1.00	DATA PR	0.34	EXHAUST	-2	JUICE D	1.00
AGITATO	1.00	CASG RE	0.8	DATA SY	0.34	FAN	-2	JUKE BO	1.00
AIR BLO	1.00	CASH RE	0.8	DELI EQ	1.00	FAN UNI	-2	KIDDIE	1.00
AIR COM	0.5	CEILING	1.00	DENTAL	0.10	FANS	-2	KILN	1.00
AIR CUR	1.00	CHARGER	1.00	DESSERT	1.00	FILM DR	1.00	LABELER	1.00
AIR DOO	1.00	CHARGIN	1.00	DIAGNOS	1.00	FILM PR	1.00	LARGE K	1.00
ALPHA S	1.00	CHECK P	0.8	DICTAPH	1.0	FISCHE	1.0	LATHE M	1.00
AQUA MA	1.00	CHECK R	0.8	DISHWAS	0.4	FISH TA	1.00	LATHE/D	1.00
AQUA VE	1.00	CHECKIN	0.8	DISK DR	0.34	FLOOR W	1.00	LETTER	0.7
AQYA VE	1.00	CIG. MA	1.0	DISPENS	1.00	FLY FAN	1.00	LETTERI	0.7
AUTO CL	1.00	CIGARET	1.0	DISPLAY	1.00	FLYFAN	1.00	LIFTS A	1.00
AUTOMAT	1.0	CIRCULA	1.00	DISPOSA	1.00	FORM BL	1.00	MAGNETI	0.34
AUTOSCA	1.00	CLOCK	1.0	DOOR FA	1.00	FORM PR	1.00	MAIL DI	0.7
BAILER	1.00	CLOCKS	1.0	DOUGH R	1.00	GAME MA	1.00	MAIL SO	0.7
BAILING	1.00	CLOTHES	1.00	DRILL	1.00	GARBAGE	1.00	MAINFRA	0.34
BAND SA	1.00	COFFEE	0.2	DRILL M	1.00	GAS PUM	1.00	MANNESM	1.00
BANDSAW	1.00	COFFEE&	0.2	DRILL P	1.00	GLUE &	1.00	MEAT CU	1.00
BAR-B-Q	1.00	COFFEEM	0.2	DRINK D	1.00	GRINDER	1.00	MEAT GR	1.00
BARBA,A	1.00	COKE &	0.2	DRINK M	0.2	HAIR DR	1.00	MEAT PA	1.00
BATTERY	1.00	COKE DI	0.2	DRINK P	0.2	HAND DR	1.00	MEAT SA	1.00
BBQ/DES	1.00	COKE MA	0.2	DRINKIN	0.2	HEAT LA	1.00	MEAT SL	1.00
BELT SA	1.00	COLOR C	0.5	DRYER	1.00	HEAT SE	1.00	MEAT WR	1.00
BIG SCR	1.00	COMPACT	1.00	DRYERS	1.00	HOBART	1.00	MECANIC	1.00
BISK/WA	1.00	COMPRES	0.5	DUMB WA	1.00	HOBART/	1.00	MECH. C	1.00
BLENDER	1.00	COMPTR	0.34	EDGE BE	1.00	HOT CHO	0.2	MICRO	1.0
BLOW DR	1.00	COMPUTE	0.34	ELEC. M	1.00	HOT DRI	1.00	MICROFI	1.0
BLOWER	1.00	CONNECT	1.00	ELEC. P	1.00	HOT GLU	1.00	MICROIM	0.34
BLUE LI	1.00	CONVEYO	1.00	ELEC. S	1.00	HOT WEL	1.00	MICROWA	1.0
BLUE RA	1.00	COOLING	1.00	ELEC. T	0.9	HOTWATE	0.2	MICROWV	1.0
BOILER	-1	COPIER	0.5	ELECT.	0.9	HYDRALI	0.75	MILK DI	1.00
BOX CRU	1.00	COPIERS	0.5	ELECTRI	1.00	HYDRO C	1.00	MIXER	1.00
BOX RAM	1.00	COPY MA	0.5	ELECTRO	0.9	IBM PC	0.34	MIXERS	1.00
BRAKE L	1.00	COPYING	0.5	ELEVATO	0.5	IBM SYS	0.34	MOBILE	1.00
BUG KIL	1.00	CPU MAI	0.34	ENGINE	1.00	ICE BOX	1.00	MONITOR	0.34
BUN WAR	1.00	CROCK P	1.00	ENLARGE	1.00	ICE MAK	1.00	MOTOR	1.00
BUTCHER	1.00	CRUSHER	1.00	ENVIRON	1.00	ICEY MA	1.00	MOTORS	1.00

Source: Jaske (1983).

Table IV-3. Miscellaneous Electric Equipment Usage Factors, cont.

Name	Use Factor	Name	Use Factor	Name	Use Factor	Name	Use Factor
MULTIPL	1.00	PROOFIN	1.00	SLICER	1.00	VENDING	1.00
MUSIC A	1.00	PUMP MO	1.00	SLICER/	1.00	VENT FA	-2
MUSIC E	1.00	PUMPS	1.00	SLICERS	1.00	VENT SY	-2
NEON LI	1.00	RADIO	1.0	SMALL C	1.00	VENTILA	-2
NEON SI	1.00	RADIO R	1.0	SMALL R	1.00	VIDEO C	1.00
OFFICE	1.00	RADIO S	1.0	SMOKE-E	1.00	VIDEO E	1.00
OUTDOOR	1.00	RADIO/C	1.0	SNACK M	1.00	VIDEO G	1.00
OVEN	0.26	RADIO/T	1.0	SNACK/C	1.00	VIDEO M	1.00
P. A. S	1.00	RADIOS	1.0	SOFT DR	1.00	VIDEO R	1.00
P.C./PR	0.34	RANGE	1.00	SOLDIER	1.00	VIDEO T	1.00
P/C - P	0.34	RAVIOLL	1.00	SOUND E	1.0	VIDEO/C	1.00
PANAL S	1.00	RC ORIC	1.00	SOUND G	1.0	WASHER	1.00
PAPER C	1.00	RECEIVE	1.0	SOUND S	1.0	WASHERS	1.00
PAPER P	1.00	REFRIG.	0.2	SOUP WA	1.00	WATER C	0.2
PARTS O	1.00	REFRIGE	0.2	STAMP M	1.00	WATER F	0.2
PC/PRIN	0.34	REGISTE	0.8	STEAM C	1.00	WATER M	1.00
PEPSI D	0.2	REPRO.	0.5	STEREO	1.0	WATER P	1.00
PEPSI M	0.2	RES. ST	1.00	STEREOS	1.0	WELDER	1.00
PERFORM	1.00	RHYTHM	1.00	SURVEIL	1.00	WHEEL A	1.00
PERSONA	0.34	RIVETER	1.00	TABLE S	1.00	WHEEL B	1.00
PERSONN	0.34	ROLLER	1.00	TAPE DR	0.34	WIDE SC	1.00
PHONE S	1.0	ROTISSE	1.00	TAPE MA	1.0	WRAPING	1.00
PHOTOCO	0.5	SAUNAS	1.00	TEA MAK	0.2	WRAPPER	1.00
PHOTOTY	0.9	SAW	1.00	TELE. I	1.0	WRAPPIN	1.00
PINBALL	1.00	SAW VAC	1.00	TELEPHO	1.0	X-RAY D	0.10
PLAINER	1.00	SAWDUST	1.00	TELEVIS	1.0	XEROX M	0.5
PLANERS	1.00	SAWS	1.00	TELLERT	0.34		
PLASTIC	1.00	SCALE	1.00	TERMINA	0.34		
POLISHE	1.00	SCREEN	1.00	TOASTER	0.2		
POOL PU	1.00	SECURIT	1.00	TRANSAC	1.0		
POP DIS	1.00	SHAKE M	1.00	TRASH C	1.00		
POPCORN	1.00	SHAKERS	1.00	TV	1.0		
PORTABL	1.00	SHARP P	0.34	TV/VCR	1.0		
POSTAL	1.00	SHARPEN	1.00	TV/VCR"	1.0		
POWER S	1.00	SHEATHI	1.00	TYPEWRI	0.9		
PRESSES	1.00	SIGN	1.00	ULTRA S	1.00		
PRINT S	1.00	SIGNS	1.00	UPHOLD	1.00		
PRINT-O	1.00	SING LI	1.00	VACUUM	1.00		
PRINTER	0.34	SKIMMER	1.00	VACUUMS	1.00		
PRINTIN	1.00	SLICEER	1.00	VCR	1.0		

Source: Jaske (1983).

Cooking (electric and non-electric). Cooking EUIs were estimated using the same approach as described above for miscellaneous equipment. Usage factors are based on Alereza and Breen [1984]. The usage factors are shown in Table IV-4. Hours of operation and connected loads were taken from the on-site survey. Daily hours of operation for standard days were reported for each piece of cooking equipment, and we used these data to replace the information reported in the standard-day, hourly profiles for cooking. To account for cooking energy use on non-standard days, we used the same methods developed for indoor lighting to adjust the reported operating hours.

Table IV-4. Cooking Usage and Heat Gain Factors For Electric Cooking (U_i)

	Electric		Gas	
Equipment Type	use factor	heat gain factor	use factor	heat gain factor
oven	0.14	0.04	0.14	0.03
stove	0.59	0.28	0.59	0.20
grill	0.50	0.08	0.50	0.05
broiler	0.55	0.20	0.55	0.10
fryer	0.03	0.0	0.03	0.01
microwave	1.00	1.00	n/a	n/a
dishwasher	0.40	0.40	0.40	0.20
food warmer	1.00	1.00	1.00	0.50
other	0.40	0.40	0.40	0.20

Source: Alereza and Breen (1984).

Water Heating. Estimating water heating EUIs required the greatest use of data in addition to those contained in the on-site survey. In particular, hourly profile data, F_{jk}, were not reported in the survey. Instead, we relied on reported daily hot water consumption (which we assumed to be consumption for standard days), maximum building occupancy, and the hourly profile of occupancy (all for standard days) to calculate the volume of hot water consumed per person-hour on the standard day. We then used this value, along with a non-standard day occupancy schedule (calculated, as with lighting, from standard and non-standard day building operating hours) to calculate non-standard day hot water consumption. Once the daily consumptions were known, we relied upon the following equation, taken from the Department of Energy's test procedure for calculating water heating energy efficiency [DOE 1985].

$$\text{Daily EUI} = \left[8.25\ G\ \frac{T_w - T_{in}}{E_r} \right] + 8.25\ V \left(T_t - T_a \right) S \left(24 - t \right)$$

with

$$t = 8.25\ G\ \frac{T_w - T_{in}}{E_r\, Q}$$

where:

G	= standard and non-standard day hot water use (gal/day)
Q	= rated input (Btu/hr)
E_r	= recovery efficiency (dimensionless)
T_w	= hot water temperature (°F)
T_{in}	= inlet temperature (°F)
T_a	= ambient temperature (°F)
T_t	= average tank temperature (°F)
V	= tank capacity (gal)
S	= standby loss factor (hr^{-1})
t	= burner operation hours (hr)

and by assumption:

E_r	= 0.7, for gas-fired
	= 1.0, for electric
T_{in}	= 62.5°F
T_a	= average of winter and summer setpoint, if conditioned
	= 60°F, if unconditioned
T_t	= T_w
S	= 0.04, for gas-fired
	= 0.01, for electric

End-Use Disaggregation Algorithm (EDA)

The end-use disaggregation algorithm, EDA, was used to reconcile the preliminary load shapes (estimated by NELDIG for the non-HVAC end uses and by DOE-2 for the HVAC end uses) with the average whole-building load research data. A recent article describing the algorithm in detail is reproduced in Appendix E. This section is an overview of major features.

EDA is a deterministic method that primarily utilizes the statistical characteristics of the measured, hourly, whole-building load and its inferred dependence on temperature. Simulation is only used to supply information that is not evident from the load/temperature relationship. In the EDA, the sum of the end uses is constrained, at hourly intervals, to be equal to the measured whole-building load. This constraint provides a reality check that is not always possible with pure simulation. In addition, the load/temperature relationship helps to characterize the HVAC end use, providing an additional constraint on the remaining end uses and preventing some of the errors possible with simple proration. Finally, EDA also attempts to deal with the fluctuations of hourly loads by incorporating observed statistical variation.

The primary component of the EDA is regression of hourly loads with climatic variables.[4] Because the weather dependency of the building load changes with season, we use two season-specific (summer and winter) sets of weather regression coefficients. The weather regression equations are used to separate the load predicted by the regression, $\mathbf{L_{REG}}$, into a weather-dependent part, $\mathbf{L_{TD}}$, and a weather-independent part, $\mathbf{L_{TI}}$. We assume the weather-dependent load is attributable to HVAC equipment. The weather-independent load is the sum of loads such as lighting and miscellaneous equipment, as well as weather-independent cooling at base weather $\mathbf{T_{BASE}}$. Because the regression will provide no information about how to break down the weather-independent load, we simply prorate it according to the loads predicted by simulation. The actual load at a particular hour on a particular day will probably not lie on the best-fit regression line, so the difference, Δ, between the actual load, $\mathbf{L_{ACT}}$, and $\mathbf{L_{REG}}$ is split between the two parts of the load.

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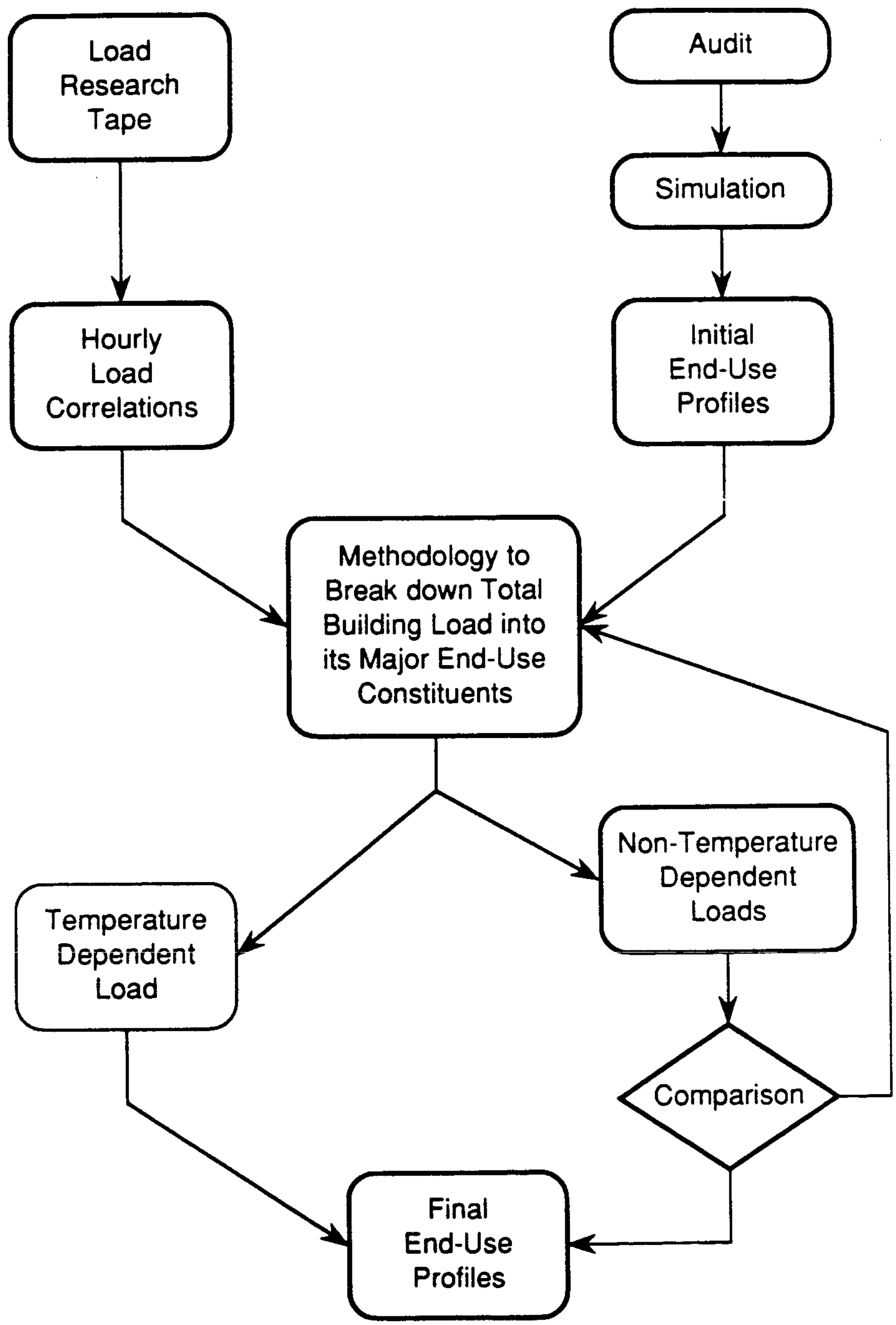
[4] See the discussion in Task II for a description of the climatic parameters selected for the current study.

A flow chart of the EDA and its data requirements are shown schematically in Figure IV-2. For each building, the inputs to the EDA are:

- the actual hourly whole-building load ($\mathbf{L_{ACT}}$) during a given period of time;
- the actual measured outside weather conditions ($\mathbf{T_{ACT}}$) during this same period of time;
- statistics from the regression of load with the selected weather variables, calculated separately for summer and winter: regression coefficients $\mathbf{a_W}$, $\mathbf{b_W}$, $\mathbf{a_S}$, and $\mathbf{b_S}$; the base weather condition, $\mathbf{T_{BASE}}$; and
- the results of simulating the building at the base weather condition.

A detailed description of the EDA and a comparison of its performance versus pure simulation is reported in Akbari *et al.* [1988] (see Appendix E).

Figure IV-2 **Flowchart of End-use Disaggregation Algorithm, (EDA).** Method developed by LBL for breaking down hourly load research data into end-uses. This diagram also shows the required input data to EDA.



Other Software Tools

We also developed five simple programs to process data for our major software tools or final outputs. In this section, we briefly describe each program. All descriptions are keyed to Figure IV-1.

Processor 1 combines exogenously derived weights with data from individual LRD accounts to produce average hourly load shapes by building type for an entire year. When there were more than five LRD accounts in a climate region (large and small office and retail), these aggregations were performed separately for three climate zones.

Processor 2 is analogous to processor 1. It combines exogenously derived weights with data from individual on-site survey premises to produce an average electricity bill by building type. Because the number of on-site survey data in individual climate regions was small, this aggregation is performed once for the entire service territory. Climatic variations in HVAC energy use were later reintroduced using separate DOE-2 simulations to scale this average bill up or down for each climate region.

Processor 3 combines the outputs of processor 1 and processor 2 to produce an adjusted average hourly load shape by building type for an entire year. First, hourly loads from processor 1 are summed for the entire year. Second, a scaling factor is calculated from the ratio of this energy use to that from the average of electricity bills in the on-site survey. Third, this scaling factor is multiplied by every hour. The result is a normalized load whose integral for the entire year equals the average bill from processor 2.

Processor 4 performs two tasks. First, it takes schedule information from the NELDIG prototype summaries (reproduced in Appendix F) and calculates hourly load profiles for the entire year for each non-HVAC end use. Second, it reads the DOE-2 hourly output reports and reformats them, by HVAC end use, for use by EDA.

Processor 5 formats EDA output data for summary presentations. The ouput of EDA is a reconciled load shape by end use for 8,760 hours. Processor 5 combines these data to produce monthly summaries of average standard, average non-standard, and peak day hourly electricity use for each end use.

Task V. DOE-2 Prototype Development

We used the DOE-2 building energy analysis program to develop preliminary EUIs and LSs for the HVAC end uses. In this section, we describe our procedures for developing prototypical building inputs for the DOE-2 program. These procedures are contained in the NELDIG program described in Task IV. We conclude the section by comparing our prototypes to those used previously by SCE and CEC.

The DOE-2 Building Energy Analysis Program

The DOE-2 program was developed by the Lawrence Berkeley and the Los Alamos National Laboratories to provide architects and engineers with a state-of-the-art tool for estimating building heating and cooling energy use [Curtis 1984]. The calculations are performed in three sequential steps, which correspond to three subprograms (Loads, Systems, and Plant). First, calculations are made in the Loads subprogram for: heating and cooling loads based on the geometry, thermal integrity, internal conditions of a building, along with local weather conditions, including solar position and intensity. Second, in the Systems subprogram, the energy needed to satisfy these loads by air-side HVAC equipment and packaged HVAC units is calculated. Third, in the Plant subprogram, the energy used to provide heating and cooling in buildings with central plants is calculated. The program was of special relevance for the current project, because its calculations are performed in one-hour time-steps, which were essential for analyzing hourly electrical load shapes.

The DOE-2 program is similar to all building energy analysis programs in that, strictly speaking, the program only calculates heating and cooling energy use requirements. Energy used for non-HVAC end uses, such as lighting, are merely mechanical manipulations of input data (e.g., lighting energy intensity, schedules of operation, etc.). Because of the large interactions between energy use for most non-HVAC end uses and space conditioning energy use, however, meaningful calculation of space conditioning energy use requires that the patterns of energy use for non-HVAC end uses be accounted for consistently in HVAC energy use calculations.

DOE-2 Input Development

The development of an input for a DOE-2 simulation from the on-site survey data can be separated into five components: *Physical characteristics, Thermal integrity, Internal loads, Schedules of operation, HVAC equipment and zoning*. We discuss each, in turn.

Physical Characteristics. Precise descriptions of the primary physical features of the premises under consideration (floor area, height, window and wall areas, overhangs, etc.) are a critical input to a DOE-2 simulation and provisions for reporting these data were contained in the on-site survey data forms. However, we made one significant assumption, that *all premises were square in shape and that all features, including wall and window area, and overhangs, are evenly distributed on each facade.* Similarly, internal loads are distributed uniformly within the thermal zones of the premises.

This assumption creates potential for inconsistency between the thermodynamic and physical description of premises. For example, in describing the configuration of walls and roofs for single-story premises, the assumption of a square floor plan means that the roof area might not equal the floor area enclosed by the walls of the structure. Although thermodynamically representative of the energy performance of the structure, such premises cannot be thought of as a structure, that could actually be built. These, at first glance, "impossible" results occurred often for our prototypes, which represent an aggregation of features of many premises.

The justification for the assumption was that our primary interest in the DOE-2 simulation was in an accurate representation of the energy performance of the building. Accordingly, we were less concerned about the consistency of the building's description from other standpoints.

In addition, we also fixed the thickness of the walls and roofs exogenously. These assumptions, however, did not change the overall thermal resistance or capacity of the wall, relative to the original thickness of the components. However, they did affect the rate of heat gain/loss through the wall. These assumptions are summarized in Table V-1.

Table V-1. Assumptions for DOE-2 Input Generation

Assumption	Value	Unit	Source
Physical			
Wall Thickness	10	inch	CEC Ingen
Roof Thickness	12	inch	CEC Ingen
Thermal Integrity			
Wall Heat Capacity	0.25	Btu/lb.°F	CEC Ingen
Roof Heat Capacity	0.25	Btu/lb.°F	CEC Ingen
Window U-Value - 1-pane	1.470[1]	$Btu/ft^2 °F$	DOE-2 default
Window U-Value - 2-pane	0.574[1]	$Btu/ft^2 °F$	DOE-2 default

1. includes inside air film coefficient.

Thermal Integrity. The state-of-the-art status accorded the DOE-2 program stems largely from its sophisticated treatment of heat transfer (specifically, transient heat transfer). The program's ability is compromised only by the lack of sufficiently detailed information on a building's thermal properties. The on-site survey data forms contain provisions for the reporting of most of these data. For several critical pieces of information, however, engineering judgment was used to supplement data not reported on the survey. Table V-1 reports these assumptions.

Internal Loads. To estimate space conditioning energy use, DOE-2 requires that internal loads be represented explicitly. Two types of internal loads are of importance: 1) those resulting from heat generated or removed by energy-using equipment, and 2) those resulting from heat generated by occupants.

Heat generated by energy-using equipment and contributing to space conditioning loads is generally equal to the energy used by the equipment. Three major exceptions are vented cooking equipment, split-system refrigeration equipment, and fluorescent lighting vented to the return air system.[1] With vented cooking equipment only a fraction of the heat generated by the equipment

[1] We found no vented fluorescent systems in the on-site surveys.

contributes to space conditioning loads; the rest is exhausted outside the building. (See the discussion of the methods used to calculate cooking EUIs in Task IV and Table IV-4.) With split-system refrigeration equipment, heat is extracted from a space and rejected at a location outside the conditioned area of the premise. The net effect on the interior space, for the purposes of DOE-2, is a local heat sink.

The maximum number of building occupants and visitors was reported on the on-site survey. We followed historic CEC practice for office buildings, which assumes that average building occupancy equaled the number of normal building occupants plus 1/10 the number of visitors [ADM 1983]. For other types of premises, we assumed that the average building occupancy equaled the number of normal building occupants plus 1/2 the number of visitors.

The location of refrigeration compressors was reported in the on-site survey. For compressors located outside or in non-conditioned spaces, we assumed that the effect on the cooling load for the conditioned space was equal to twice the rated kW of the compressors. This assumption corresponds to approximately 65% of the cooling effect of the compressors (at an average COP of 3.0) contributing to space conditioning loads [BESG 1984].

Schedules of Operation. Schedules of building activities are the dominant influence on building energy use. They were reported in the on-site survey data as up to three levels of usage for three contiguous time periods during a standard day. Our discussions of non-HVAC EUI and load shape estimation report our treatments of these schedules (Task IV).

HVAC Equipment and Zoning. We developed two generic HVAC system and plant combinations for use in our DOE-2 simulations, a package single zone reheat system (PSZ) and a central, single zone reheat system (SZRH). For each premise type, we specified the system exogenously, based on data from the 1985 SCE Commercial Sector Mail Survey. The survey indicated that only large office and retail premises had considerable numbers of central systems; all other premises had predominantly packaged HVAC systems. Consequently, both systems were specified for the large office and retail prototypes.

We also assigned a fixed number of thermal zones for each prototype. Small buildings can be adequately represented by a single thermal zone, but larger buildings and building with particular functions require additional zones. The large office and large retail premises were modeled with five zones corresponding to four perimeter zones being served by one HVAC system and a core or interior zone being served by a separate HVAC system. Sitdown and fastfood restaurants were modeled with two zones corresponding to the cooking and non-cooking areas on the premises; each zone has its own HVAC system. For the restaurant, the contribution of cooking energy to space conditioning loads was restricted to only the cooking areas of the premises.

Comparison of LBL Prototypes to Existing SCE and CEC Prototypes

Historically, both SCE and CEC have relied on prototypes and simulations (among other data) for EUI and LS estimation. It is instructive to compare the physical characteristics of our prototypes to those used in previous studies. However, the most important evaluation of our efforts to develop descriptions of prototypical premises is in Task VIII, where we compare our reconciled EUIs and LSs to those found in previous studies.

Summaries from the NELDIG program for each prototype are contained in Appendix F. Task VIII will also describe selected features of the prototypes in the context of the reconciliation process. In this section, we restrict our attention to features that can be compared to reported features of previous SCE and CEC prototypes.

Descriptions of the SCE prototypes are contained in SCE [1987] and will be referred to as SCE(1987). We have chosen the "Base Case" prototypes for comparison, although several modifications to this prototype were analyzed in the report. These prototypes were developed from an analysis of the 1983 SCE commercial sector mail survey. The methods used to develop the prototypes are not fully documented.

Descriptions of the CEC prototypes were taken from a recent set of DOE-2 input files for five of the types of premises developed for CEC by ADM; these will be referred to as CEC(1985).[2] We

[2] These files were used by LBL in an earlier project for CEC [Eto 1987].

have chosen the "1974 Hittman" prototypes for comparison.[3] These prototypes were developed from the same basic methodology used by LBL in the current project; data from individual premises were combined to yield representative premises.[4] The data were obtained from audits of commercial sector premises located primarily in the Sacramento area.

Tables V-2, -3, and -4 report selected building and operational features of the LBL, SCE(1987), and CEC(1985) prototypes, respectively. The most striking difference in the physical characteristics of the buildings lies in the floor area of the prototypes. Both the SCE(1987) and CEC(1985) prototypes are significantly larger than the LBL prototypes. In the case of the CEC(1985) prototypes, we can trace this result to the weighting and aggregation procedure used by the CEC, which emphasized the characteristics of the largest buildings.[5]

The primary issue associated with floor area is that it is a loose proxy for the surface area-to-volume ratio of a building. A building with greater floor area will tend to to be less influenced by weather because the external surface area of the building is proportionally smaller than that of a building with less floor area. Thus, although specific differences in size will be suppressed through the normalization of energy use by floor area (for EUI development), we can expect smaller prototypes to exhibit greater sensitivity to climate. This finding is tempered, somewhat, by the higher levels of thermal integrity found in the LBL prototypes.

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4 Specific differences from this earlier methodology were documented in Table IV-1.

5 Task VI examines the effect of this aggregation procedure on EUIs.

Table V-2. Summary of LBL Commercial Building Prototypes: Building Characteristics and Schedules

Type of Premises	Floor Area	Window/Wall Ratio	Wall R-Value	Roof R-Value	Shading Coefficient	Occupancy sqft/person	Std Day Op Hrs
Small Office	3,800	0.14	6.83	15.62	0.71	234	10
Large Office	66,147	0.31	5.24	15.77	0.63	256	14
Small Retail	4,360	0.10	6.92	15.09	0.82	246	9
Large Retail	67,628	0.08	4.78	30.99	0.82	466	12
Food Store	5,627	0.08	5.77	14.20	0.88	177	9
Ref. Warehse.	18,980	0.02	4.22	8.05	0.73	321	12
NonRef. Warehse.	25,702	0.09	6.51	10.06	0.72	1371	7
Sit Down Rest.	5,252	0.12	6.59	12.85	0.78	69	13
Fast Food Rest.	1,391	0.08	5.64	9.05	0.80	82	11

Table V-3. Summary of SCE(1987) Commercial Building Prototypes: Building Characteristics and Schedules

Type of Premises	Floor Area	Window/Wall Ratio	Wall R-Value	Roof R-Value	Shading Coefficient	Occupancy sqft/person	Std Day Op Hrs
Small Office	11,934	0.19	3.44	7.94	0.64	166	10
Large Office	149,000	0.26	2.37	8.13	0.64	204	15
Small Retail	6,235	0.17	3.44	7.94	0.64	160	9
Large Retail	154,240	0.16	2.37	7.94	0.64	237	12
Food Store	18,744	0.17	3.44	7.94	0.64	187	13
Ref. Warehse.	87,000						
Non-Ref. Warehse.	25,829	0.15	3.44	4.69	0.64	1291	10
Fast Food Rest.	1,934	0.19	3.44	7.94	0.64	59	12

Table V-4. Summary of CEC(1985) Commercial Building Prototypes: Building Characteristics and Schedules

Type of Premises	Floor Area	Wall R-Value	Roof R-Value	Shading Coefficient	Occupancy sqft/person	Std Day Op Hrs
Low-rise Office	70,126	3.6	7.1	0.62	206	14
High-rise Office	350,504	4.5	5.9	0.56	184	13
Small Retail	73,983	2.9	6.3	0.92	226	12
Large Retail	158,799	2.9	5.0	0.84	286	12
Small Food Store	2,104	5.6	6.7	0.92	33	17

Tables V-5, -6, and -7 report selected energy use and HVAC characteristics for the the LBL, SCE(1987), and CEC(1985) prototypes, respectively. In general, the LBL prototypes have lower lighting levels than either the SCE(1987) or CEC(1985) prototypes. The CEC(1985) prototypes, possibly because of their size, rely predominantly on central, or built-up HVAC systems.

It is difficult to draw definitive conclusions from these comparisons because the ultimate basis for comparison is the result of applying these definitions to the EUIs and LSs for a given building type. Even with lighting, comparison is difficult because the implied lighting EUI of the LBL prototype will change as a result of reconciliation with the load research data. If the reconciliation results in an upward adjustment (we found this to be true for our reconciliations), then the level used in the initial prototype will have been low relative the final value.

Table V-5. Summary of LBL Commercial Building Prototypes: Internal Load and HVAC System Characteristics

Type of Premises	Lighting W/sqft	Equipment W/sqft	Heating °F	Cooling °F	HVAC System	Min Outside Air (%)
Small Office	1.27	0.88	68.9	74.7	PSZ	21
Large Office	1.59	0.48	72.4	73.2	PSZ,SZRH	14
Small Retail	1.61	1.92	71.6	73.1	PSZ	24
Large Retail	1.65	0.28	71.5	75.0	PSZ,SZRH	17
Food Store	1.59	1.91	72.7	74.2	PSZ	19
Ref. Warehse.	1.04	6.18	66.1	70.8	PSZ	2
NonRef. Warehse.	0.64	0.24	71.4	74.0	PSZ	10
Sit Down Rest.	1.09	5.35	71.7	74.5	PSZ	40
Fast Food Rest.	1.38	5.11	68.0	73.5	PSZ	31

Table V-6. Summary of SCE(1987) Commercial Building Prototypes: Internal Load and HVAC System Characteristics

Type of Premises	Lighting W/sqft	Heating °F	Cooling °F	HVAC System	Minimum Outside Air (%)
Small Office	2.0	70	74	PSZ	20
Large Office	2.0	71	73	VAVS,PSZ	20
Small Retail	2.0	74	70	PSZ	20
Large Retail	2.12	70	73	SZRH,PSZ	20
Supermarket	2.0	69	74	PSZ	11
Non-Ref. Warehse.	1.0	73	71	PSZ	20
Fastfood	3.0	74	71	PSZ	20

Table V-7. Summary of CEC(1985) Commercial Building Prototypes: Internal Load and HVAC System Characteristics

Type of Premises	Lighting W/sqft	Heating °F	Cooling °F	HVAC System	Minimum Outside Air (cfm/person)
Low-Rise Office	2.70	70.9	73.6	MZS	41
High-Rise Office	2.54	72.3	74.3	DDS	37
Small Retail	2.19	72.9	76.5	MZS	45
Large Retail	2.57	70.0	75.8	MZS	56
Small Food Store	1.74	71.1	74.9	PSZ	7

PSZ - Package Single Zone System
SZRH - Single Zone Reheat System
VAV - Variable Air Volume System
MZS - Multi Zone System
DDS - Dual Duct System

Task VI. Pilot Prototype Analysis

Prototypes are commonly used in forecasting commercial sector energy use. The basic idea is to create a description of a representative premises that stands for a whole class of premises. The description is generally in the form of an input to a building energy simulation program. Often there are two objectives for this choice of description. First, the results of the simulation can form the basis for estimates of space conditioning EUIs and load shapes. Second, the performance of technology options can be modeled explicitly through selective modifications of the simulation inputs.

The methodological issue that arises when developing prototypes is how best to aggregate and somehow "average" the features of many distinct buildings into those needed to describe a single, prototypical building. We examined two procedures for aggregating characteristics of individual premises into those for prototypical premises, using a limited sample of on-site survey data for two building types, a small office and a sitdown restaurant.

The first procedure, taken from the predecessor to the NELDIG program, used floor area as a statistical weight. The second procedure used the statistical weights developed in Task II. NELDIG and DOE-2 were run for all individual premises and for two prototypical premises, each developed using one of these weighting procedures. The results of the runs for individual premises were then aggregated to a single number using each of the two weighting procedures and compared to the results of the prototypes, which were developed initially, using one of the two procedures.

For this pilot analysis, we chose a random sample of seven small offices ranging in floor area from 117 to 27,000 ft^2 and six restaurants ranging in floor area from 700 to 10,800 ft^2. The heating system was assumed to be gas fueled and the cooling system was assumed to be electrically driven for the prototypes and for the individual buildings. The non-HVAC EUIs were obtained with the same algorithms described in Task IV except for differences in the weighting scheme. For the prototypical building, each component of the EUI equations is separately weighted before the product of terms is obtained. For example, for lighting, the number of operating hours per day, and the installed lighting power are separately averaged with the chosen weights before multiplication. The space conditioning EUIs (cooling, heating, and ventilation) were obtained from the output of DOE-2 simulations.

Small Office Analysis

We divide our comparison of individual to prototype buildings into two parts: non-HVAC comparisons and space conditioning comparisons. The results of the non-HVAC comparisons are shown in Table VI-1. The electrical end uses analyzed were indoor and outdoor lighting, miscellaneous electrical, refrigeration, and water heating. One of the premises had electric cooking data and one had gas water heating data in this sample. There were no premises with gas cooking data. The first seven rows show the data for individual premises. The floor area, sample weight, and EUIs for each of five end uses are shown. The next six rows compare prototypical EUIs to EUIs for individual premises. The first three rows summarize the results of weighting by floor area only, and the last three rows summarize the results of weighting by the sample weight. The comparisons of EUIs obtained from prototypes and from averages of individual premises showed that there was little difference between the prototype and individual premises methods. That is, except for refrigeration, both methods yield approximately the same EUIs. This result was true for either weighting scheme. However, there were differences in the magnitudes of some of the resulting average EUIs. In conclusion, using the second weighting scheme, the prototype method works as well as the individual premises approach for non-HVAC EUIs. This result comes as no surprise because NELDIG is designed to develop prototypical non-HVAC EUIs by this method.

We performed a similar analysis for the space conditioning EUIs. Table VI-2 summarizes these results for space heating, cooling and ventilation. We note first the large spread of individual EUIs for space heating, from 0.5 to 60.2 kBtu/ft^2. Ventilation EUIs are in a much narrower range, from 1.3 to 3.1 kBtu/ft^2. Here we found significant differences between the prototype and individual premises approaches to obtaining space conditioning EUIs. Cooling and ventilation EUIs were more similar for the two approaches than was the case for space heating. We can see the weights change the magnitude of the results: using the sample weight, the prototype space heating EUI is 5.5 kBtu/ft^2; without the sample weight the same EUI becomes 1.0 kBtu/ft^2.

Table VI-1. Non-HVAC EUI Comparison For Small Offices

Premises ID	Area	Weight	Indoor Lighting kWh/sqft	Outdoor Lighting kWh/sqft	Miscellaneous kWh/sqft	Refrigeration kWh/sqft	Electric Water Heating kWh/sqft
15	13500	133.4	6.20	0.22	6.26	0.29	0.24
88	7086	133.4	4.37	0.20	0.42	0.00	0.02
188	1800	603.4	13.02	0.75	4.97	0.63	0.00
238	117	8781.4	3.69	0.00	0.00	0.00	0.00
284	1350	2495.1	5.88	0.00	1.95	0.23	0.23
328	1000	2495.1	5.18	0.00	0.74	0.00	0.00
373	26792	320.7	2.37	0.13	1.87	0.00	0.03
Floor Area Weighted							
Prototype			4.15	0.19	2.90	0.38	0.09
Individual Building			4.17	0.19	2.91	0.32	0.09
% Difference			*0*	*1*	*0*	*19*	*2*
Weighted by Sample Weight							
Prototype			4.42	0.20	2.26	0.34	0.10
Individual Building			4.47	0.20	2.27	0.32	0.10
% Difference			*1*	*0*	*0*	*6*	*0*

For five of seven premises, the cooling EUI was higher than the space heating EUI, as expected. The two exceptions were for the two smallest premises: 117 and 1,000 ft^2. The 117 ft^2 premises had an extremely high space heating EUI relative to all the other premises. This probably accounted somewhat for the large difference (15.7% using the second weighting scheme) between the prototypical and individual premises approaches for space heating. For cooling and ventilation, the differences were 6.3% and 11%, respectively. In conclusion, using the second weighting scheme, there were differences between the two EUI calculation approaches of 6.3%, 11%, and 15.7% for cooling, ventilation and space heating, respectively.

Table VI-2. Space Conditioning EUI Comparison For Small Offices

Premises ID	Area	Weight	Space Heating kBtu/sqft	Space Cooling kWh/sqft	Ventilation kWh/sqft
15	13500	133.4	0.52	2.48	3.10
88	7086	133.4	1.86	1.50	1.58
188	1800	603.4	3.94	3.29	2.82
238	117	8781.4	60.17	7.49	1.83
284	1350	2495.1	5.42	2.02	1.34
328	1000	2495.1	14.14	1.75	1.87
373	26792	320.7	0.50	3.15	2.61
Floor Area Weighted					
Prototype			0.95	2.87	2.31
Individual Building			1.34	2.71	2.55
% Difference			*29*	*6*	*9*
Weighted by Sample Weight					
Prototype			5.53	2.69	2.01
Individual Building			6.56	2.87	2.26
% Difference			*16*	*6*	*11*

Restaurant Analysis

As with the small office, we divide our comparison of individual to prototype restaurant buildings into two parts: non-HVAC comparisons and space conditioning comparisons. The results of the non-HVAC comparisons are shown in Table VI-3. The electric end uses analyzed were indoor and outdoor lighting, miscellaneous electrical, refrigeration, and cooking. None of the premises had electrical water heating. The first six rows show the individual premise data. The floor area, sample weight, and EUIs for each of five end uses are shown. The comparisons of EUIs obtained from prototypes and from averages of individual premises showed that the differences between the prototype and individual premises methods were greater than those found for the small office buildings. Except for refrigeration, the results with the second weighting scheme improved relative to the first weighting scheme. The range of percent of difference between prototypes and average of individual premises decreased (excluding refrigeration) from about 12%-30% for the first weighting scheme to 0-10% for the second weighting scheme. There were large differences in the magnitudes of some of the resulting average EUIs. The results for the refrigeration EUI were strongly affected by the extremely high value for the smallest restaurant: 40.3 kWh/ft^2. These small premises also had the highest sample weight, which strongly affected the comparison between prototype and average of individual premises. Except for refrigeration, we can conclude that, when using the second weighting scheme, the prototype method performs as well as the individual premises approach for non-HVAC EUIs

Table VI-4 summarizes the results for space heating, cooling, and ventilation EUIs. As with the small office, we again found significant differences between the prototype and individual premises approaches to obtaining space conditioning EUIs. Once again, we found wide spreads for both space heating and space cooling, from 1.3 to 20.0 kBtu/ft^2 and from 2.5 to 37.4 kBtu/ft^2 respectively. Ventilation EUIs were much higher for restaurants than for offices, because of large ventilation requirements and long operating hours.

For five of six premises, the cooling EUIs were higher than the space heating EUIs, as expected. The only exception was for the 1,200ft^2 premises: 11.9 kBtu/ft^2 for heating and 11.4 kBtu/ft^2 for cooling. The premises with the largest floor area (10,800ft^2) had an extremely low space cooling EUI relative to other premises. This probably accounted somewhat for the large

Table VI-3. Non-HVAC EUI Comparison For Restaurant

Premises ID	Area	Weight	Indoor Lighting kWh/sqft	Outdoor Lighting kWh/sqft	Miscellaneous kWh/sqft	Refrigeration kWh/sqft	Electric Cooking kWh/sqft
7	700	1979.4	9.55	1.50	3.96	40.30	0.00
16	10800	53.6	2.58	0.59	2.61	7.60	6.50
207	1200	1979.4	3.05	0.00	0.22	5.51	0.00
240	4800	107.2	0.00	7.10	1.97	6.30	2.37
280	5580	107.2	3.97	3.00	0.16	10.69	1.04
337	2800	473.5	0.19	0.00	0.74	14.19	3.04
Floor Area Weighted							
Prototype			2.76	1.91	2.20	12.51	4.89
Individual Building			2.47	2.66	1.69	9.53	4.00
% Difference			*-12*	*28*	*-30*	*-31*	*-22*
Weighted by Sample Weight							
Prototype			4.16	2.56	1.54	21.77	3.51
Individual Building			3.93	2.56	1.42	15.01	3.19
% Difference			*-6*	*0*	*-8*	*-45*	*-10*

difference (29.4% using the second weighting scheme) between the prototypical and individual premises approaches for space cooling. For space heating and ventilation, the differences were 0.73% and 6.21%, respectively. The magnitudes of the space heating, cooling and ventilation EUIs were strongly affected by the weighting scheme. As in other cases, the second weighting scheme provided somewhat better agreement between the prototype method and the average of individual premises than the first weighting scheme.

Table VI-4. Space Conditioning EUI Comparison For Restaurant

Premises ID	Area	Weight	Space Heating kBtu/sqft	Space Cooling kWh/sqft	Ventilation kWh/sqft
7	700	1979.4	20.03	35.17	17.93
16	10800	53.6	1.32	2.46	23.87
207	1200	1979.4	11.88	11.44	6.17
240	4800	107.2	2.92	9.89	20.55
280	5580	107.2	2.51	37.44	26.24
337	2800	473.5	5.01	14.65	9.92
Floor Area Weighted					
Prototype			2.06	20.59	24.22
Individual Building			3.27	14.00	21.27
% Difference			*37*	*-47*	*-14*
Weighted by Sample Weight					
Prototype			9.72	23.72	12.83
Individual Building			9.79	18.33	13.68
% Difference			*1*	*-29*	*6*

Task VII. Initial Validation

We anticipated submetered end-use load data to validate our method, but our efforts to acquire large amounts of such data were unsuccessful (Task I). We did, however, obtain end-use load data, as well as a calibrated DOE-2 input file for a single restaurant, from the Seattle City Light Company (SCL).

Accordingly, the materials presented in this chapter are exploratory, and we draw no specific conclusions. The objectives of this section are to: 1. document the work performed to date to validate EDA, and 2. provide insights on how EDA can be modified based on detailed end-use metered data.

Description of SCL Submetered Data

Building Description. The end-use data provided by SCL were for a fastfood restaurant constructed in 1976. The building has a gross floor area of 2,490 ft^2, with a partial second story containing some office and storage space. The restaurant has both inside dining facilities and a drive-up window. The operating hours of the inside dinning room were from 6 am until midnight, Monday through Friday; the drive-up window remained open until 2 am. On Saturday and Sunday, both the drive up window and the dining area were open 24 hours. The hourly average number of customers served in the dining area was 15 on weekdays and 25 on weekends.

The building floor plan was a 38'x49' first story and a 22'x27' second story with built-up roofing over a plywood deck. The roof over the second floor area contained one inch of rigid insulation. The remainder of the roof contained six inches of R-19 insulation. The exterior walls were concrete block. The upper level had framed walls with a shake finish. The building had 429 ft^2 of single glazed window, all located in the dining area. The customer entrance was a double glass door.

Kitchen equipment (including French fryers, taco fryers, malt machine, walk-in cooler, walk-in freezer, and ice machine) was the major electric load in the building. The kitchen equipment also included a natural gas grill. The kitchen was ventilated, so only a portion of the load from kitchen equipment contributed to internal heat gains. Internal lighting of the dining room area was low-wattage incandescent with an intensity of 2.4 W/ft^2. The work area lighting was fluorescent (with incandescent lighting in the office and restroom) with an intensity of 1.3 W/ft^2. External lighting included mercury vapor parking lot lighting and fluorescent raceway/parapet and sign lighting, all controlled manually. Hot water was provided by an electric hot water heater.

The building had two packaged rooftop HVAC units (with direct expansion cooling and gas heating), one serving the dining area and the other serving the work area. The heating and cooling set points were 70°F and 75°F, respectively. The capacity of the constant volume fans serving the dining room and work area was 4,000 and 2,600 CFM, respectively. Two exhaust fans with a total capacity of 2,755 CFM and a make-up fan with a capacity of 2,884 CFM served the grill area. The restroom exhaust fan had a capacity of 485 CFM. All kitchen fans were controlled manually.

DOE-2 Simulation. SCL's contractor divided the building into three zones: a dining area (977 ft^2), work area (1,513 ft^2), and an attic. Building gas and electric energy use were simulated, using a Seattle/Tacoma TMY weather tape, and compared with the monthly electricity bills. The input parameters were then modified so that the simulated results matched each month's electricity billing data within 15 %. The procedure apparently used was to manually adjust the miscellaneous equipment profile until reasonable agreement with an average load shape and total monthly energy was achieved. However, no attempt was made to reconcile the simulated peak electric demand with the monthly recorded electricity peak demand.

End-Use Submetered Data. We received a year of submetered data collected from March 1, 1985 to Feb 28, 1986. The end uses metered included food preparation equipment, two A/C units, three lighting circuits, kitchen exhaust and make up fans as well as refrigeration equipment, and hot water heater; these were recorded with a total of four distinct channels for data. One channel reported the total building electricity. Another reported the space cooling electricity, including supply fans. The refrigeration channel included kitchen exhaust and makeup fans. The lighting channel included both interior and exterior lighting.

Validation

The validation process included a DOE-2 simulation of the building to obtain hourly end-use profiles, regression of the measured whole-building load against dry-bulb temperature, disaggregation of the whole-building load into end uses (using EDA), and comparison of EDA results with measured end uses.

DOE-2 Simulation. The heating, cooling, and ventilation loads of the building were simulated using the DOE-2.1C computer program and the 1985 Seattle/Tacoma weather tape. The first two months of the hourly output of the simulation were appended to the end of the year to match the monitoring period of the building. This resulted in a small discontinuity in the load at the end of the year. According to the simulation, space heating and gas grills used 158.7 kBtu/ft^2 of natural gas per year. The simulation reported total electricity consumption of the building at 385 kWh/ft^2 per year. Kitchen equipment, lighting, and refrigeration loads accounted for 38.8%, 26.5%, and 19.7%, respectively, of the total electric usage of the building. Space cooling and HVAC auxiliary, and DHW accounted for only 10.6% and 4.4%, respectively, of the total electric load. The simulation results, as noted previously, had been calibrated to be within 15% of the recorded electricity bills.

Measured and Simulated Whole-Building Demand. Figures VII-1 and -2 summarize the average measured and simulated whole-building loads for standard days, respectively. The figures show the minimum, maximum, and inter-quartile ranges for data. It is interesting to note that the *average* simulated hourly loads compared favorably with the measured data (largely because of calibration of the DOE-2 inputs) but that the ranges are quite different. Indeed, regressions of the measured whole-building load showed essentially no correlation of the load with respect to the outside conditions, yet the DOE-2 simulated data were strongly correlated to outside weather conditions. For the disaggregation process, we assumed the the observed load/temperature variation was non-existent and used the simulated cooling load as the initial condition for EDA.

Figure VII-1. Total Monitored Restaurant Load
Average for Standard Days

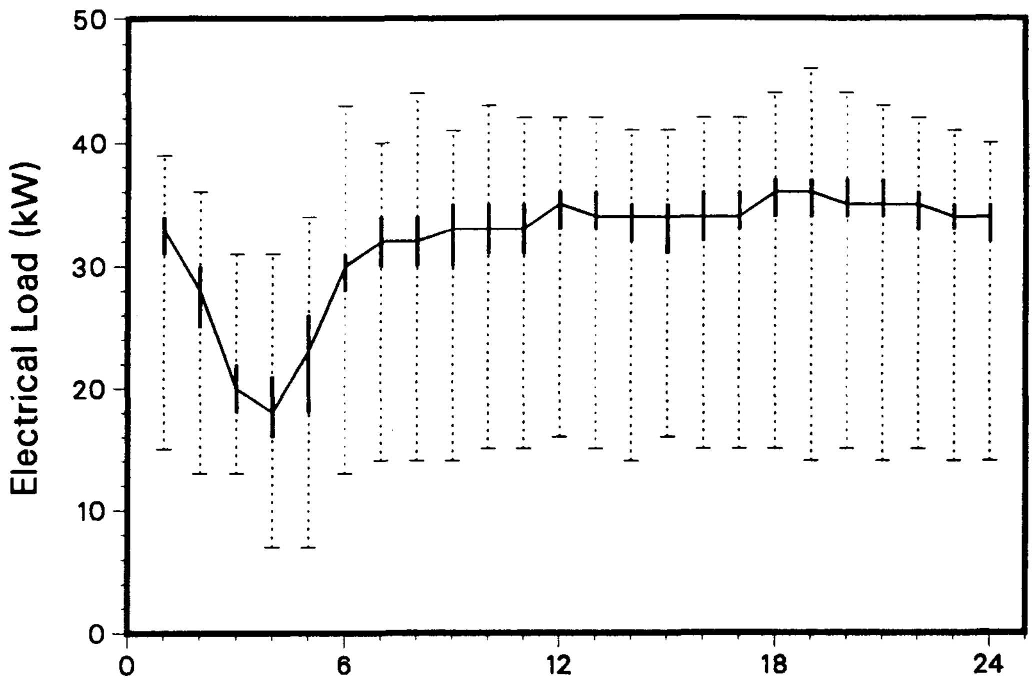
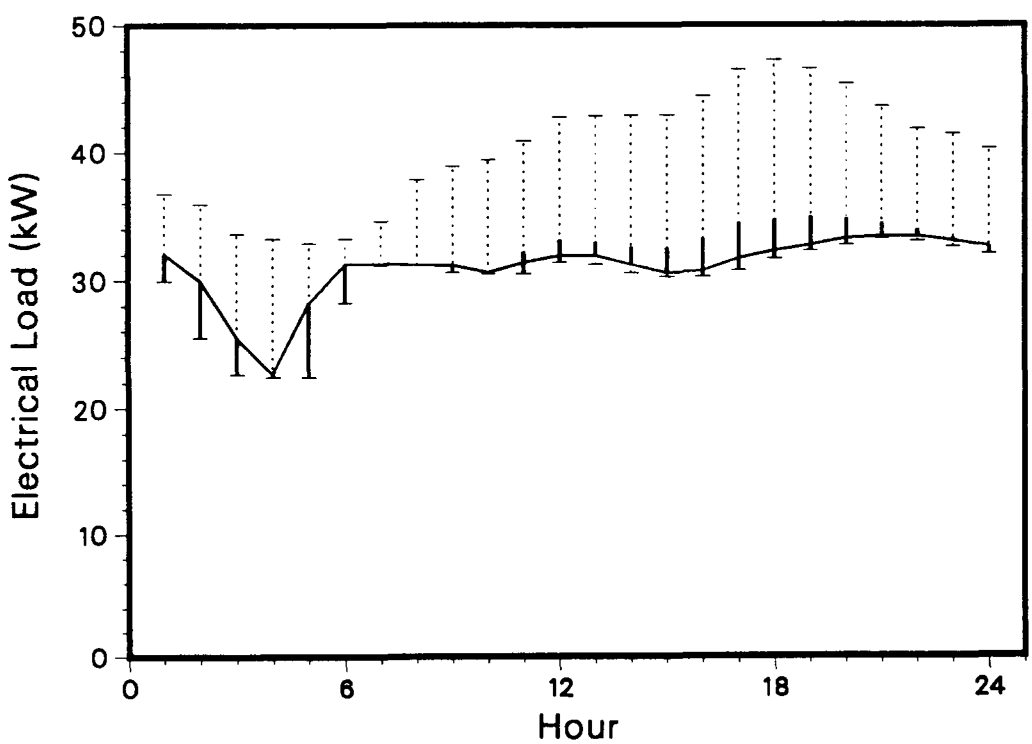


Figure VII-2. Total Simulated Restaurant Load
Average for Standard Days



EDA Results. The input to EDA consisted of the simulated end-use profiles (see Figure VII-3) and the measured whole-building load. Generally speaking, the end-use initial conditions were simplistic in that they assumed: constant DHW, refrigeration, and ventilation load throughout the day; and small differences between the nighttime and daytime lighting loads. The simulation results suggested large equipment loads but a small cooling load during the night. When the simulated profiles were compared with the measured data (see Figure VII-4), we found that although the whole-building loads compare closely to one another, the end-use load profiles are vastly different. The simulated refrigeration and cooling loads were larger than those found through submetering, and the equipment load was much smaller. At the present time, EDA primarily adjusts load shapes, and only secondarily adjusts overall load levels. This suggests that, in the future, using the total annual or monthly *end-use* energy consumption as a constraint for the EDA application will bring the EDA results much closer to the submetered data.

Figure VII-3. Simulated Restaurant Loads
Average for August Standard Days

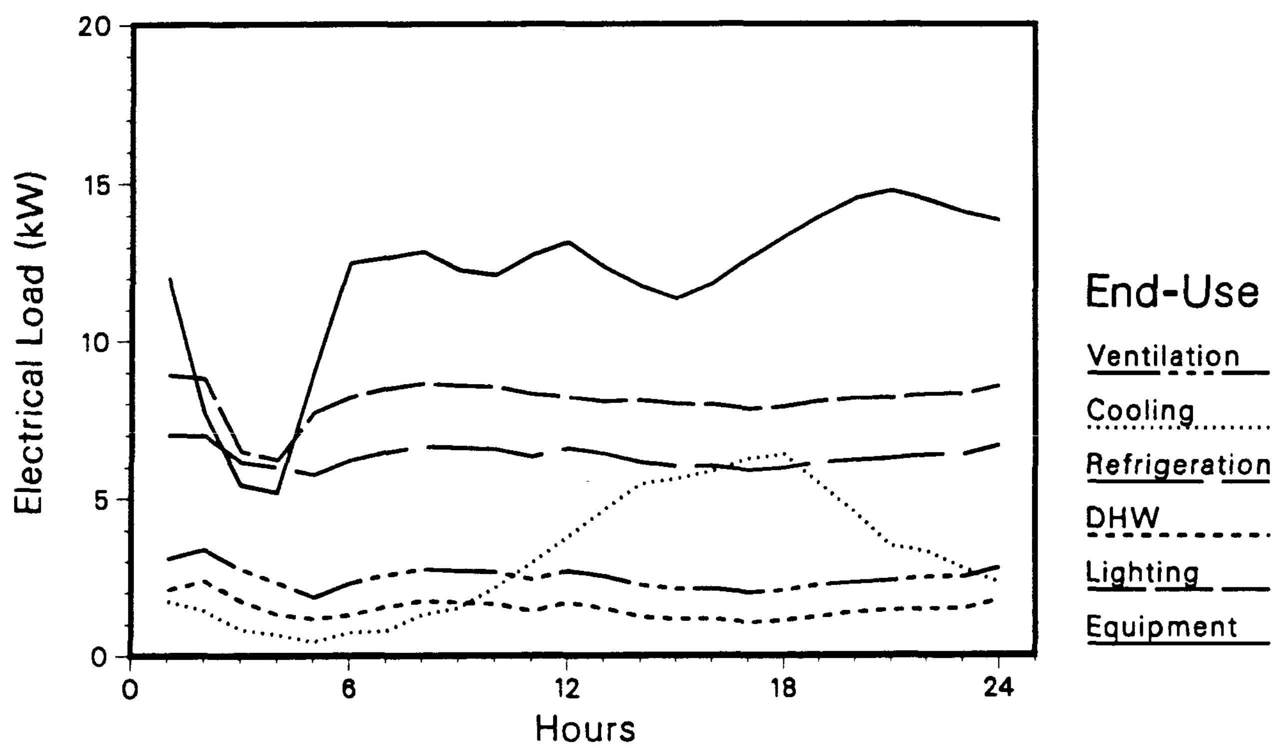


Figure VII-4. Monitored Restaurant Loads
Average for August Standard Days

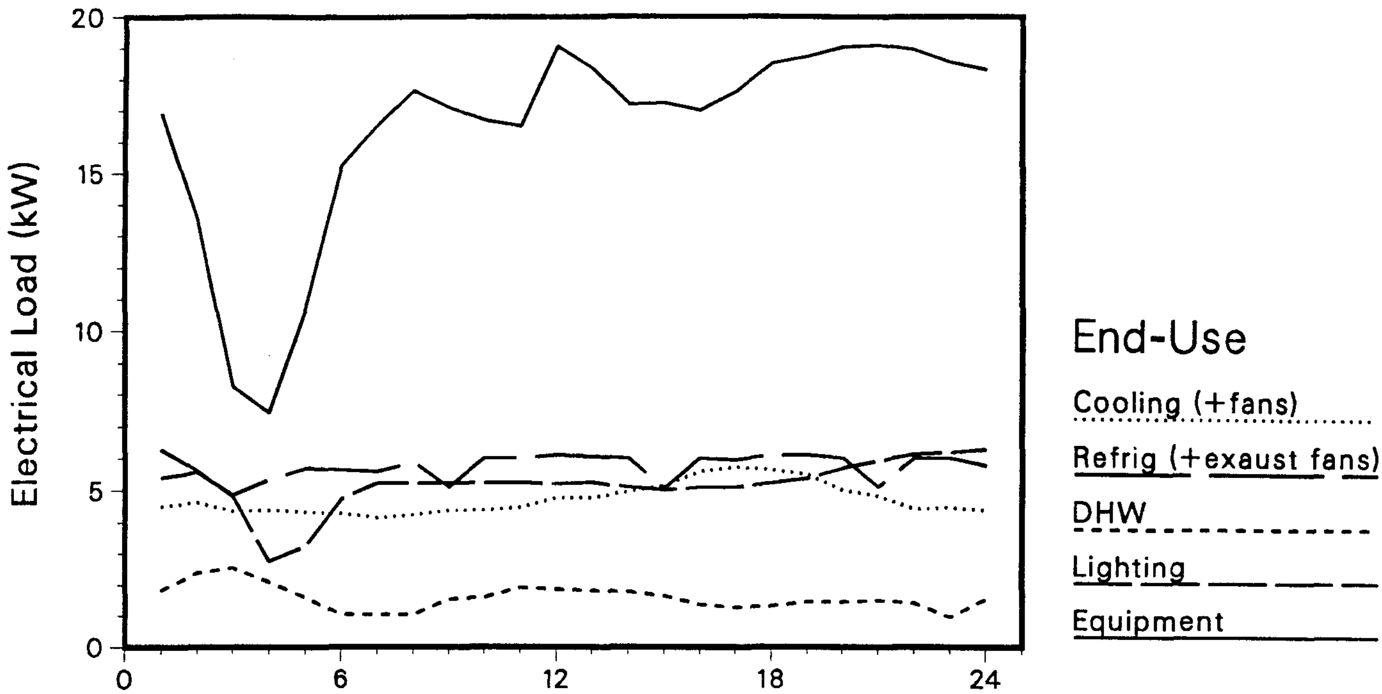
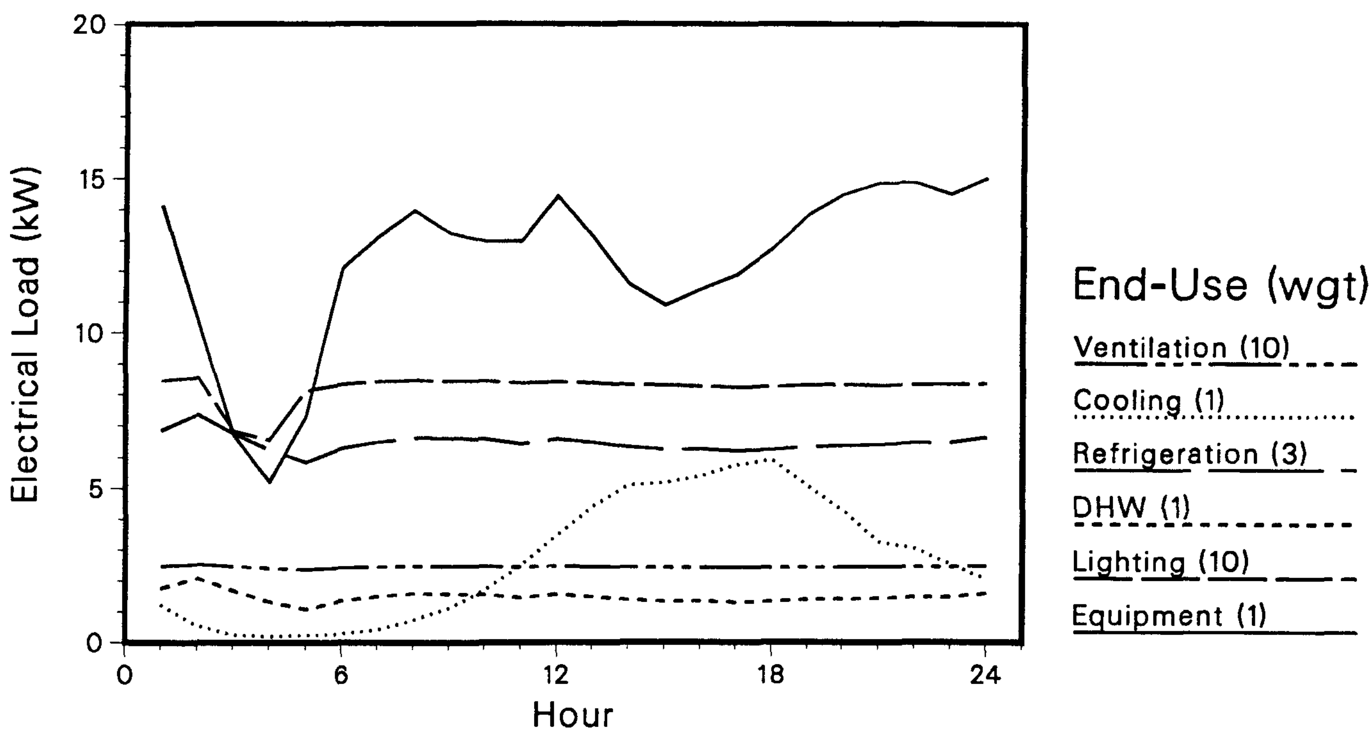


Figure VII-5. EDA Adjusted Restaurant Loads
Average for August Standard Days



The average EDA output end-use profiles for August, without using the annual end-use energy data, are presented in Figure VII-5. As expected, the shape of the end-use profiles was improved but the overall levels (which determine annual energy use) were not significantly different from those of the initial conditions. In this case, the reason for small changes in total energy from the initial conditions is that the differences between the the whole-building measured and simulated loads were small from the start. In fact, if the whole-building measured and simulated loads were the same, the EDA would not adjust the initial load profiles at all. Changing the confidence factors[1] of the end uses in the EDA disaggregation process did not improve the intensity of the final results substantially.

The discrepancies between the EDA calculations and the measured data could be explained by the interaction of several effects: poor initial conditions such as the highly weather dependent cooling load (from the simulation), an inaccurate lighting profile, and, most importantly, SCL contractors' manual modification of the equipment profile to match the total measured load. The resulting small differences between the simulated and measured whole-building loads prevented the EDA from significantly improving the intensity of the initial (incorrectly specified) profiles.

This example demonstrates the importance of using end-use data to refine and further develop EDA. We reiterate that the major advantage of the EDA is to obtain cooling energy load from the measured whole-building data. This superiority of EDA is demonstrated by this example.

EDA currently does not recognize characteristic differences between non-weather dependent end uses because such information can be only obtained from measured data. We plan to continue the validation process for this building. We will use measured end-use load characteristics directly as an additional input to EDA, and we anticipate improved accuracy as a result. Early results using this refined version of EDA are encouraging.

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[1] Confidence factors are used to introduce the degree of confidence one has about the initial conditions. They are used to restrict/increase the degree of adjustment available to EDA in the reconciliation process.

Task VIII. LS and EUI Estimation

The estimation of LSs and EUIs involved three steps. First, we generated preliminary LS and EUI estimates and reconciled them with the average whole-building load shapes using the methods described in Tasks IV and V. In this section, we preface narrative descriptions of the application of our methods and reconciled LSs and EUIs for each building type with an overview of the reconciliation process. Second, we compared the reconciled LSs and EUIs to those found in previous studies (from Task III). These comparisons formed the basis for a preliminary evaluation of the data, method, and results of the project. Many of these observations are discussed in the following section, in which we provide a review of uncertainty (Task IX). Third, we developed procedures that adjusted the reconciled EUIs for use in the SCE and CEC forecasting models.

Overview of the Reconciliation Process

Prior to a detailed review of our results for each building type, we comment on two general features of the reconciliation process. First, we quantify the overall amount of adjustment introduced by the reconciliation process. Second, we describe a modification to the reconciliation algorithm, EDA; this reconciliation was made following review of our initial results.

For a broad perspective on the reconciliation process, we compare the total building electricity EUI (which results from the summing the preliminary end-use EUIs) to the measured total electricity EUI (which results from analysis of the electricity bills of the on-site survey premises). That is, the objective of the reconciliation process is to ensure that these totals match, not only annually, but also for each hour of the year. Differences between the two indicate roughly the amount of adjustment that the reconciliation process would introduce. If the differences were large on a total EUI basis, one could also expect the final end-use EUIs to be quite different from the preliminary estimates produced by NELDIG.

Table VIII-1. Preliminary and Measured Total Electricity EUIs

	Size (ft^2)	Preliminary (kWh/ft^2-yr)	Measured (kWh/ft^2-yr)	Preliminary/ Measured
Small Office	3,800	12.4	16.7	0.75
Large Office	66,147	18.1	25.9	0.70
Small Retail	4,360	10.4	17.7	0.59
Large Retail	67,628	16.3	23.2	0.71
Food Store	5,627	43.1	40.3	1.07
Ref. Ware.	18,980	71.8	23.9	3.00
Non-Ref. Ware.	25,702	6.2	5.0	1.24
Restaurant	3,804	55.1	51.9	1.06

Table VIII-1 compares the preliminary total electricity EUI from the NELDIG/DOE-2 analysis by building type to the measured average electricity bills by building type. These differences indicate the magnitude of discrepancy that was introduced through the use of purely engineering approaches to the development of end-use LSs and EUIs versus measured data.[1] Generally, the differences were within about 30%. The refrigerated warehouse was a notable exception; the preliminary total EUI for this building type was nearly three times the value used for reconciliation (which was the weighted average of the electricity bills). For this building type, we suspected these vast differences were due largely to overestimation of the refrigeration and miscellaneous equipment usage factors. This would logically result in substantial reduction in the preliminary refrigeration and miscellaneous equipment EUIs from the reconciliation process, which was exactly what we found.

The initial reconciliations yielded large discontinuities in the shoulder hours for many end uses. We determined that the cause was mismatches between the start and stop times of the schedules developed for the prototype and the diversified average of these times in the stock; this phenomenon is an inherent limitation of the prototype/simulation approach. Essentially, the prototype must assume a fixed start and stop time before and after which heating, cooling, and ventilation are assumed to account for no energy use. Of course, the average whole-building load shape reflects the diversified demand of many buildings each with a potentially unique starting and stopping time for its HVAC system. Consequently, when the prototype reports no heating, cooling, or ventilation, EDA must allocate energy use to other end uses. As a result, energy use during shoulder hours for these other end uses increases dramatically to account for the absence of HVAC energy use.

To address this problem, we ran EDA iteratively. We first ran EDA to determine the number of shoulder hours over which the discontinuities were most pronounced. We then applied a quadratic smoothing procedure to these hours to extend and ramp up or down HVAC energy use. The smoothed HVAC load shapes were then re-entered into EDA as a new set of initial conditions. The resulting LSs for all end uses became our final LSs, and their integration yielded the final EUIs.

[1] Nevertheless, it is inappropriate to conclude that small differences between preliminary and measured total EUIs indicated good agreement in the constituent end-use LSs and EUIs.

Narrative Descriptions of the Estimation Process, and Final LSs and EUIs

The following pages describe and summarize our analysis separately for each building type. Each discussion consists of a standardized set of results. We first provide comments on interim results and assumptions for the final reconciliations for each building type. Some of these comments identify areas for future study. (Absence of such comments indicates our general satisfication with the results). Next, two tables are presented. The first table shows selected characteristics of the prototype building as developed by NELDIG. The second table compares the preliminary EUIs produced by NELDIG and DOE-2 to the final reconciled values produced by EDA. Comparison of these two values indicates the amount of adjustment introduced by EDA. The HVAC end use EUIs were calculated using the fraction of floor area that was conditioned (from the prototype); the other end uses were calculated based on total floor area. As a result, *summing the individual EUIs will produce an over-estimate total EUI for the building* because the reported total EUI for the entire building was calculated using total floor area.

Finally, two sets of figures are presented. The first set is a summary of the standard and non-standard day load shapes for all end uses averaged over the entire year. Both stacked and unstacked versions of the load shapes for these two day types are presented. The second set of figures presents individual monthly load shapes by end use for standard, non-standard, and peak days. Load shapes for the summer months are represented with solid lines; load shapes for winter months are represented with dashed lines. The reader is cautioned that load shapes cannot be compared across end uses because the axis is scaled separately for each end use (although the same axis is used for each day type for a given end use). For small and large office and retail building types, where sufficient quantities of LRD permitted separate reconciliations for three climate zones, separate HVAC load shapes are presented for each climate zone.[2] For non-HVAC load shapes and for HVAC load shapes for the food store, non-refrigerated and refrigerated warehouses, and restaurant, only those developed for climate zone 2 (BUR) are presented.[3]

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[2] Heating electricity load shapes were not estimated because the LRD regressions were unable to detect heating electricity use and because of subsequent specification of the prototypes to use only natural gas for heating.

[3] Floppies containing the average monthly average standard day, average non-standard day, and peak day load shape for each end use are provided separately.

Small Office

For the small office, we were able to run EDA separately for each of the three climate zones because we had sufficient quantities of LRD in each zone. Prior to running EDA, we adjusted the average electricity bill and, consequently, the whole-building load shape for each climate zone. The adjustments were based on additional DOE-2 simulations of the prototype in each climate zone. The additional simulations resulted in adjustments to the average electricity bill (reported in Table VIII-1) of 0.93, 0.99, and 1.10 for Los Angeles Airport, Hollywood-Burbank, and Norton AFB (San Bernadino), respectively.

Table VIII-2 summarizes major features of the small office prototype. Data from 70 on-site surveys contributed to the development of the prototype.

Table VIII-3 compares the initial EUIs by end use to the reconciled EUIs. Application of EDA produced three separate estimates for each of the non-HVAC EUIs, whose differences were statistically insignificant. We combined them into a single EUI using the relative population of small offices from the 1985 SCE Commercial Sector Mail Survey. Based on the climate mapping reported in Table II-3, the distribution of small offices was 0.28, 0.49, and 0.23 for Los Angeles Airport, Hollywood-Burbank, and Norton AFB (San Bernadino), respectively. HVAC end uses are reported separately for each climate zone.

The preliminary total EUI for the small office (developed using NELDIG and DOE-2) was slightly lower than that of the average electricity bill; accordingly, most of the preliminary EUIs increased in the final reconciliation. Exceptions to this trend were refrigeration, water heating, and cooking. EDA reduced the size of these end uses in the final reconciliation.

Figure VIII-1 presents the standard day, adjusted whole-building load shape developed from the LRD for climate zone 2. The regression analysis of the underlying hourly loads for standard and non-standard days, winter and summer, by climate zone (presented in Appendix G) were used as input to EDA. Figure VIII-2 contains summaries of the resulting reconciled load shapes from EDA for standard and non-standard days for climate zone 2. Figures VIII-3 through VIII-7 present the average monthly reconciled load shapes by end use for standard, non-standard, and peak days.

For premises of this type, the differences between standard and non-standard day operation based on analysis of the LRD were found to be significant. This phenomenon was captured by the final load shapes. Nevertheless, non-standard day miscellaneous equipment loads also appear to be somewhat irregular. This irregularity also exists for electric domestic hot water heating, but energy use for this end use was small. We also observe, but cannot explain at this time, that for the coastal climate zone represented with the LAX weather data (Zone 1), non-standard day cooling loads in the winter exceed those in the summer.

Table VIII-2. Prototype Summary - Small Office

Number of Buildings Averaged:	70
Floor Area (ft^2):	3800
Percent Conditioned:	0.87
Wall Area (ft^2):	3264
Wall R-Value (Btu/ft^2°F):	6.8
Window/Wall Ratio:	0.14
Window U-Value (Btu/ft^2°F):	1.4
Roof Area (ft^2):	2946
Roof R-Value (Btu/ft^2°F):	15.6
Standard Days/Week:	5
Standard Day Start Time:	8
Standard Day Stop Time:	18
Non-Standard Day Start Time:	7
Non-Standard Day Stop Time:	19
Heating Set Point (°F):	68.9
Cooling Set Point (°F):	74.7
Occupancy (ft^2/Person):	233.8
Lighting Intensity (W/sqft):	1.27
Total Equipment Intensity (W/sqft):	0.88
HVAC System Type:	PSZ
Supply Air Flow (CFM/ft^2):	0.96
Minimum Outside Air Fraction:	0.21
Package Cooling COP:	2.2

Table VIII-3. Electricity EUIs (kWh/ft^2-yr) - Small Office

Indoor Lighting	Outdoor Lighting	Misc. Equip.	Refrig.	Cooking	Water Heating	Ventilation[1]	Cooling[1]	Total	
Preliminary									
3.74	0.82	1.96	0.59	0.36	0.17	0.78	3.56	11.42	LAX
						0.99	4.45	12.37	BUR
						1.08	6.08	13.87	NOR
Reconciled									
5.47	1.24	3.59	0.23	0.04	0.15	0.97	2.77	15.52	LAX
						1.38	5.80	16.53	BUR
						1.23	8.92	18.41	NOR

1. calculated using conditioned fraction of total floor area (0.87)

Figure VIII-1. Whole-Building Load Shape for Small Office - Standard Days in Climate Zone 2 (BUR). The load shape is a weighted-average of the hourly electricity use of individual load research buildings, and adjusted so that the annual building energy use derived from the load profile matches the annual bill from the on-site survey data. The plot shows the minimum, 25%-quartile, mean, 75%-quartile, and maximum hourly values; the line represents the mean hourly profile.

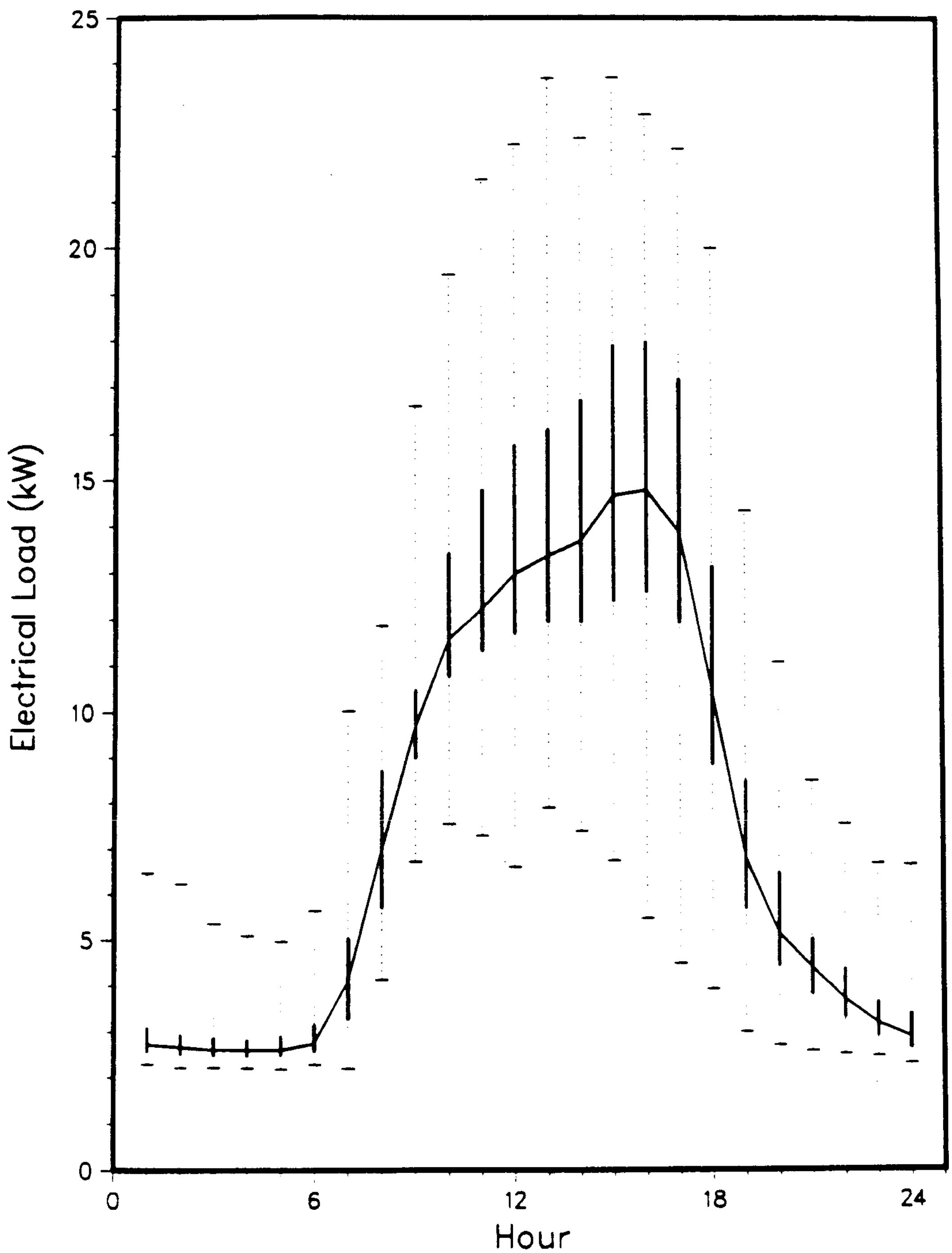


Figure VIII-2. Summary of Reconciled Load Shapes for Small Office in Climate Zone 2 (BUR)

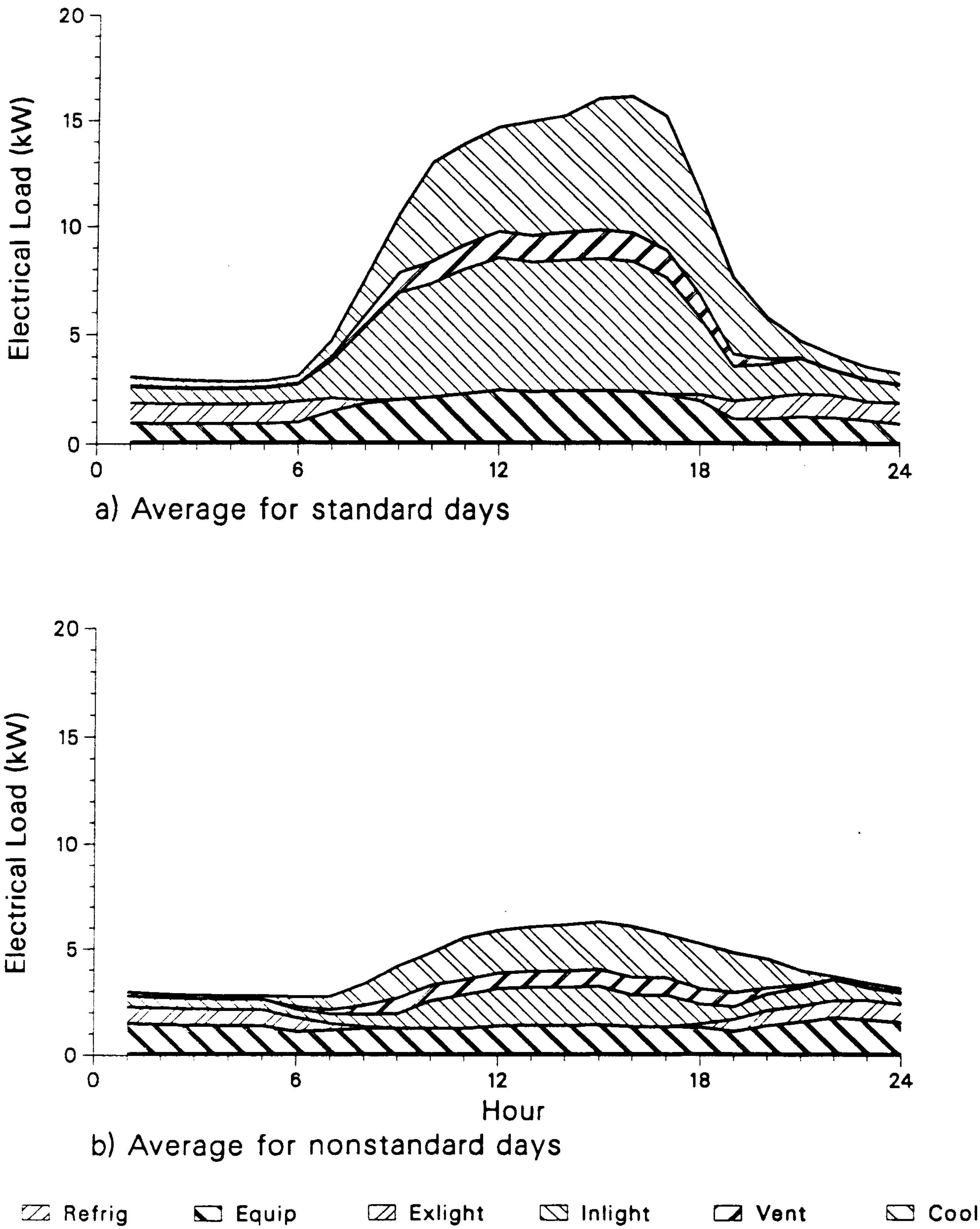


Figure VIII-3. Reconciled Monthly Load Shapes for Small Office - Cooling and Ventilation in Climate Zone 1 (LAX). Solid lines are profiles for months May through October and broken lines are profiles for months November through April.

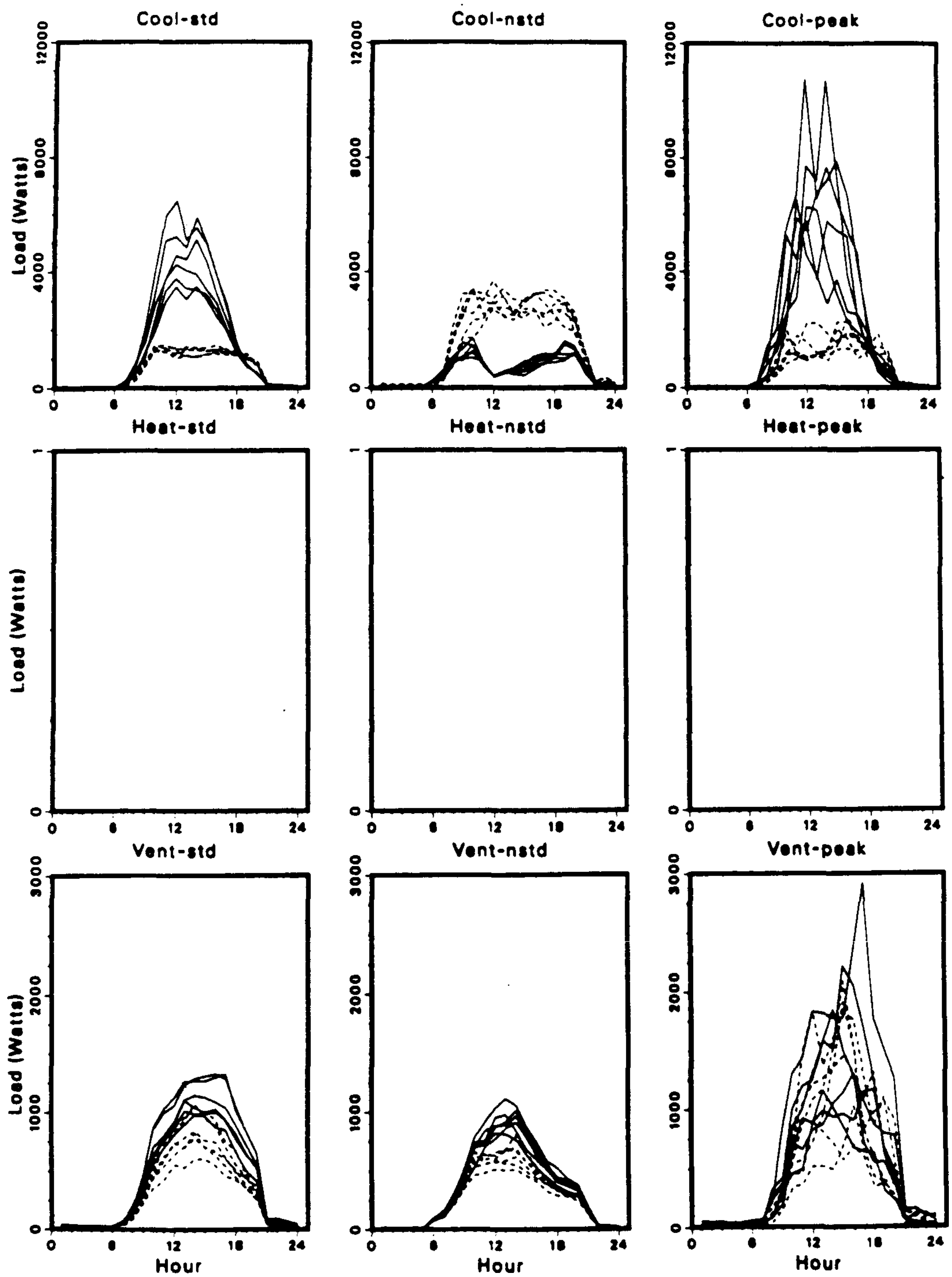


Figure VIII-4. Reconciled Monthly Load Shapes for Small Office - Cooling and Ventilation in Climate Zone 2 (BUR). Solid lines are profiles for months May through October and broken lines are profiles for months November through April.

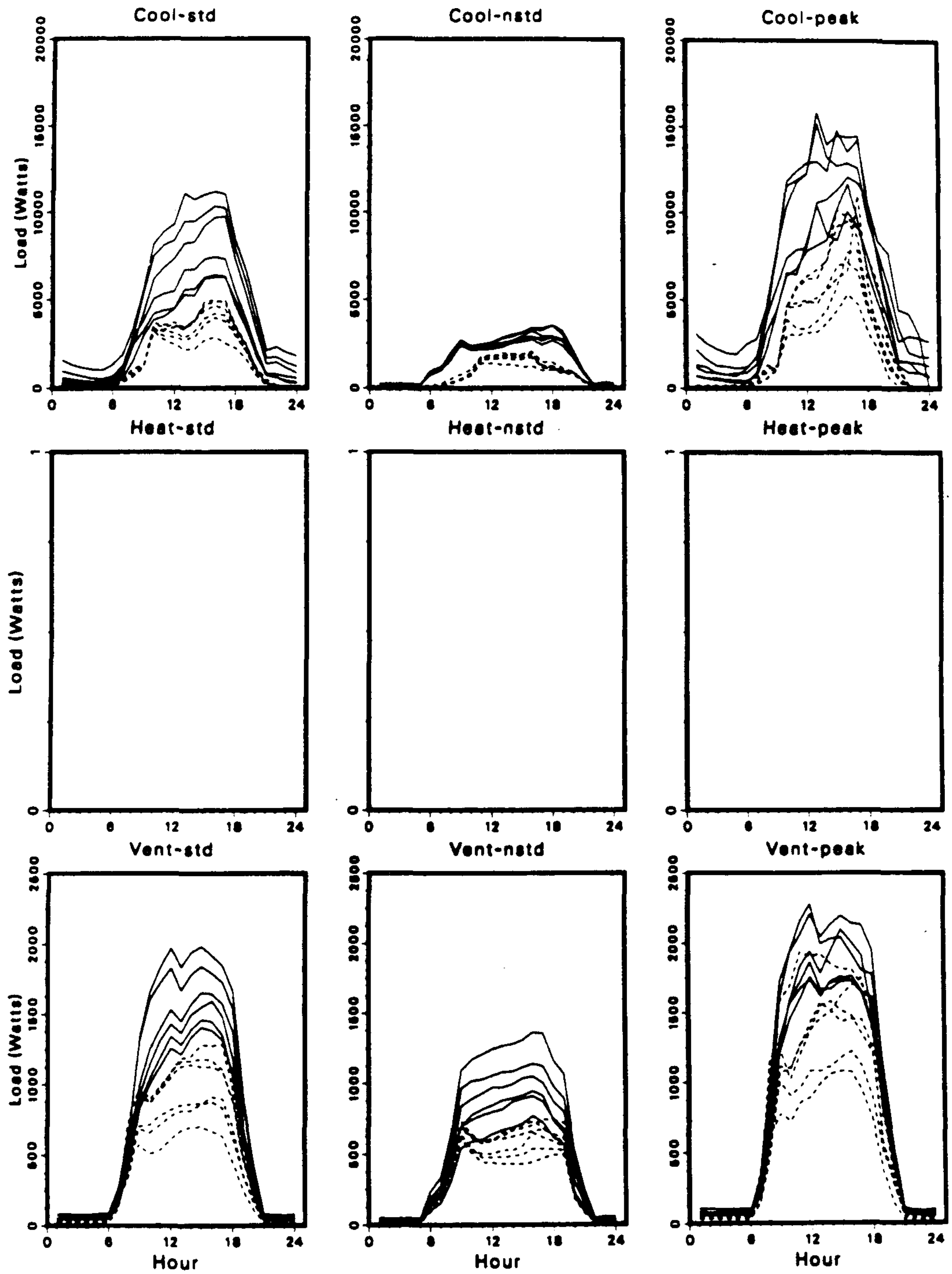


Figure VIII-5. Reconciled Monthly Load Shapes for Small Office - Cooling and Ventilation in Climate Zone 3 (NOR). Solid lines are profiles for months May through October and broken lines are profiles for months November through April.

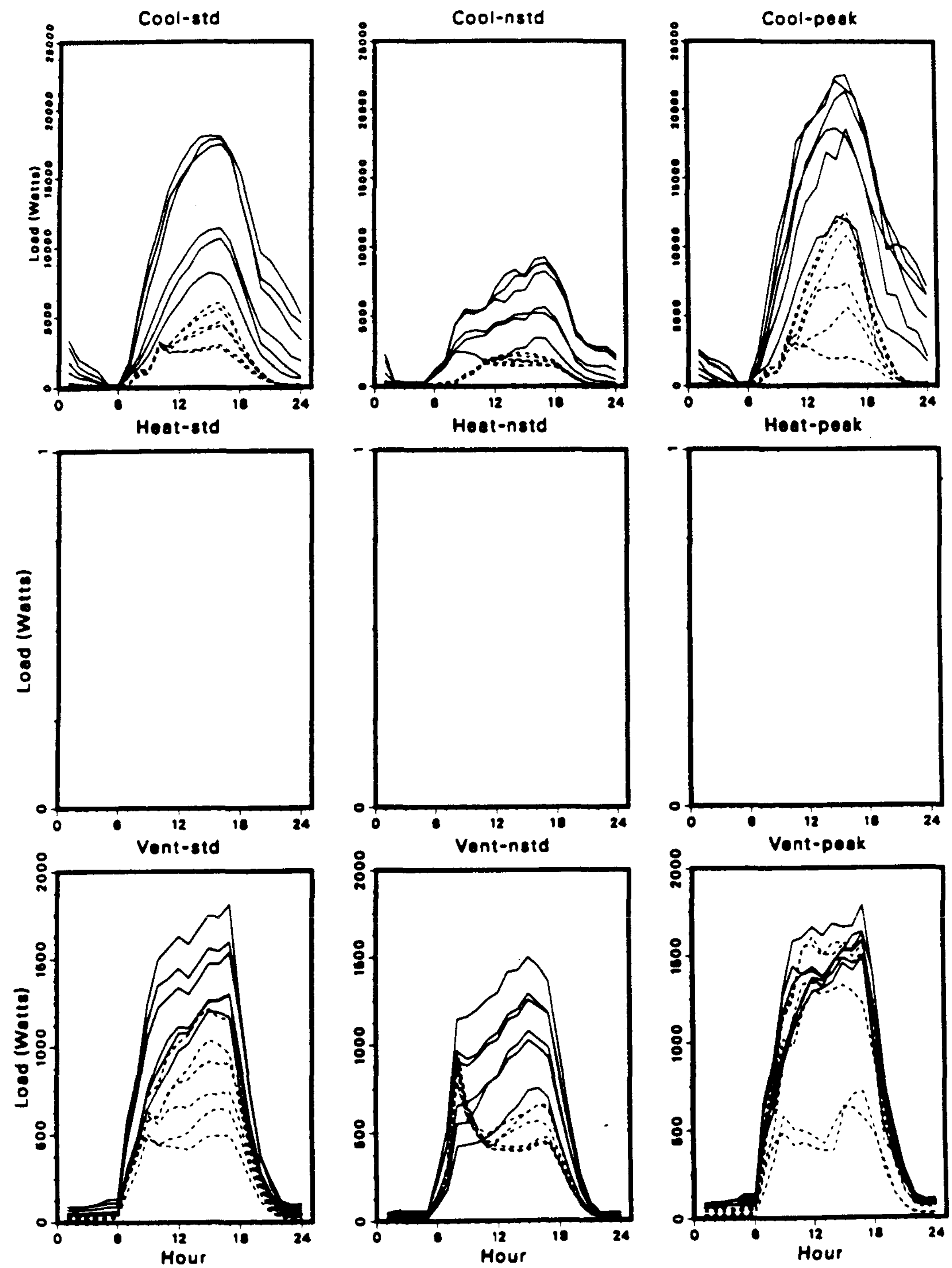


Figure VIII-6. Reconciled Monthly Load Shapes for Small Office - Indoor and Outdoor Lighting, and Misc. Equipment in Climate Zone 2 (BUR). Solid lines are profiles for months May through October and broken lines are profiles for months November through April.

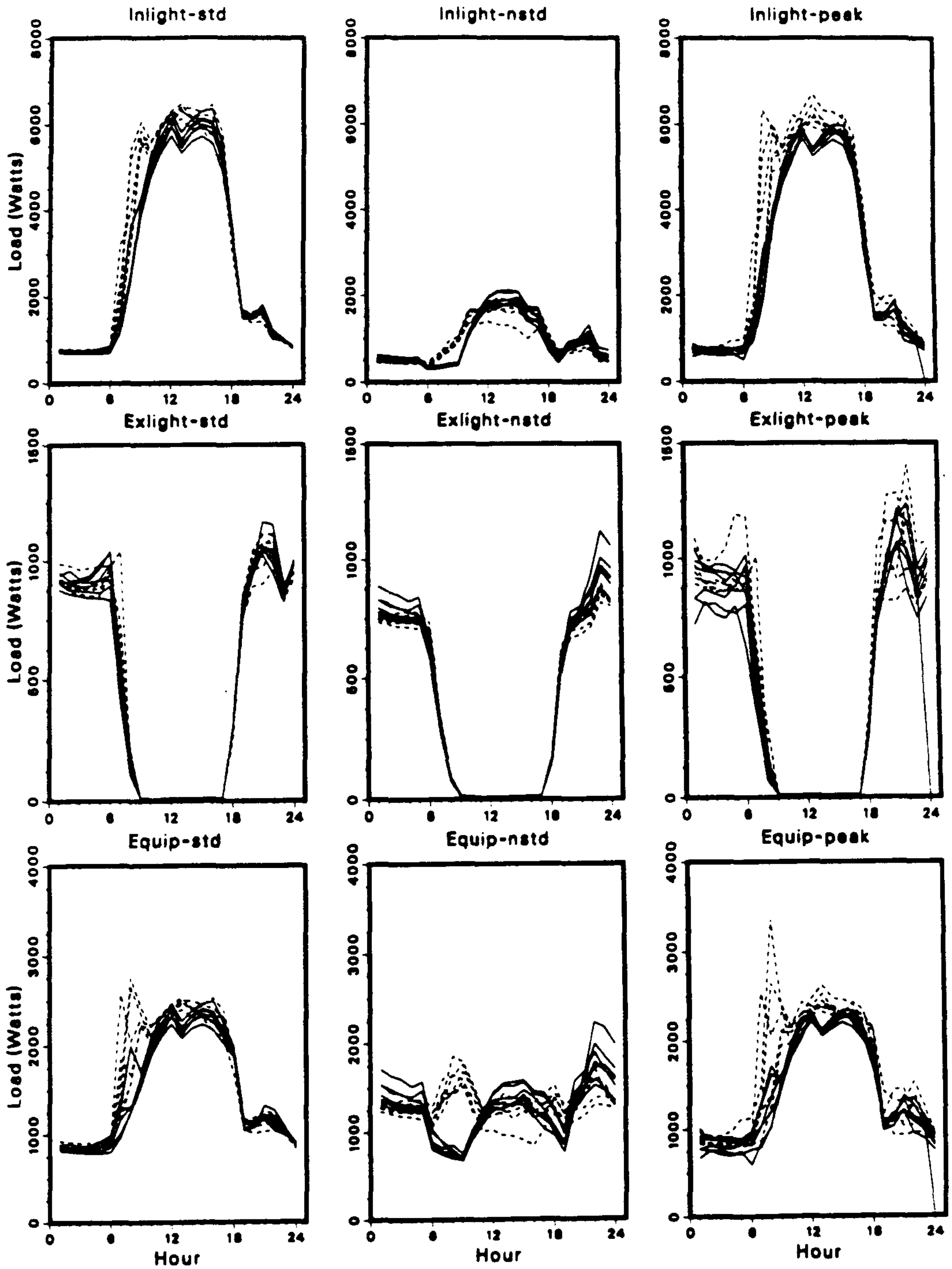
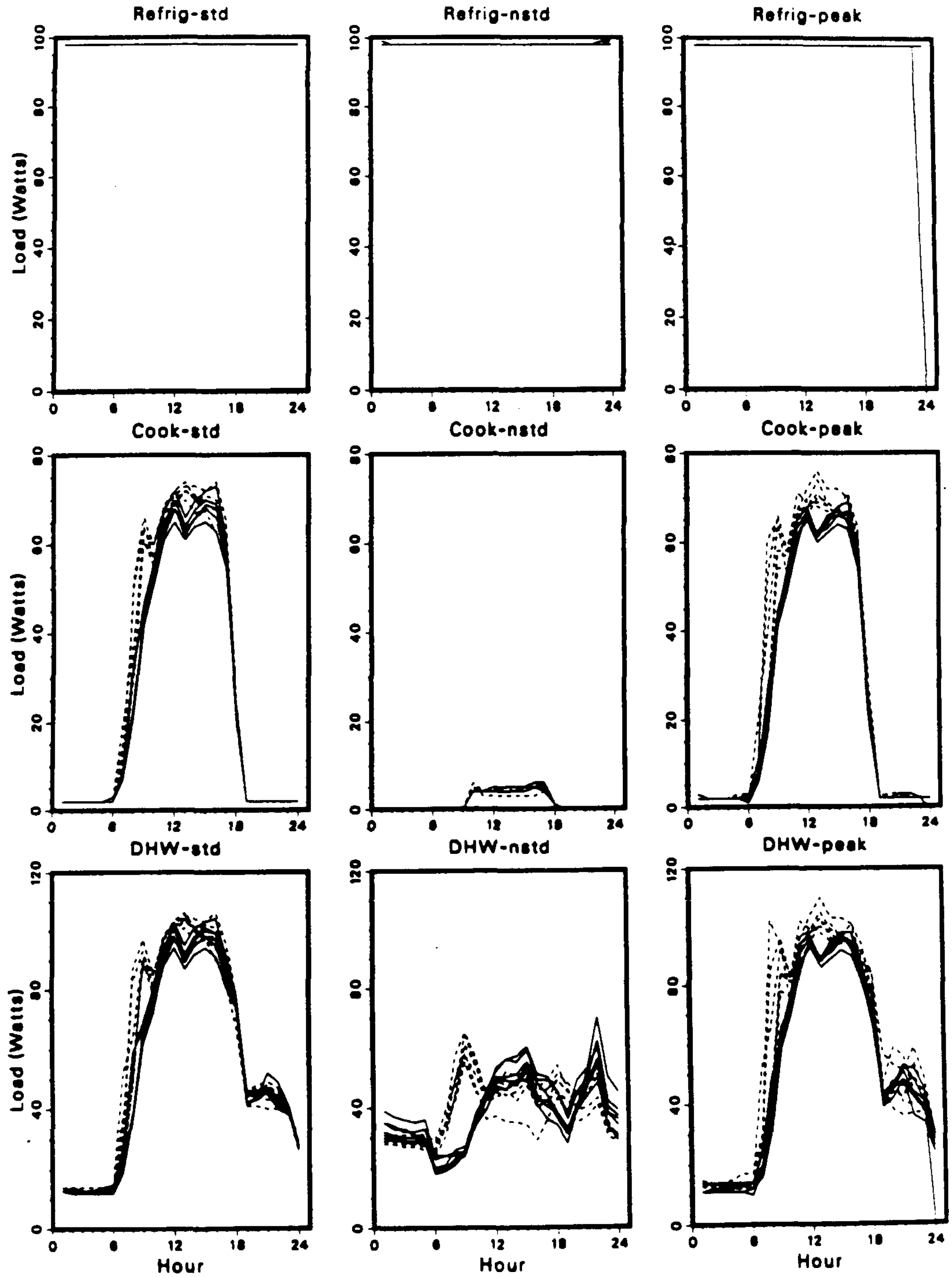


Figure VIII-7. Reconciled Monthly Load Shapes for Small Office - Refrigeration, Cooking, and Hot Water (DHW) in Climate Zone 2 (BUR). Solid lines are profiles for months May through October and broken lines are profiles for months November through April.



Large Office

For the large office, we were able to run EDA separately for each of the three climate zones because there were sufficient quantities of LRD in each zone. Prior to running EDA, we adjusted the average electricity bill and, consequently, the whole-building load shape for each climate zone. The adjustments were based on additional DOE-2 simulations of the prototype in each climate zone. The additional simulations resulted in adjustments to the measured energy use (reported in Table VIII-1) of 0.95, 1.00, and 1.06 for Los Angeles Airport, Hollywood-Burbank, and Norton AFB (San Bernadino), respectively.

Table VIII-4 summarizes major features of the large office prototype. Data from 15 on-site surveys contributed to the development of the prototype. The prevalence of two major types of HVAC systems led to the development of both a central and a packaged HVAC system for the prototype. The results of the simulations using each of these two HVAC systems were weighted together into a single number based on the relative frequency of each system type as reported in the 1985 SCE Commercial Sector Mail Survey. The survey indicated that 51% of large offices had chilled water systems and 49% had rooftop A/C units.

Table VIII-5 compares the initial EUIs by end use to the reconciled EUIs. Application of EDA produced three separate estimates for each of the non-HVAC EUIs, whose differences were statistically insignificant. We combined them into a single EUI using the relative population of large offices from the 1985 SCE Commercial Sector Mail Survey. Based on the climate mapping reported in Table II-3, the distribution of large offices was 0.28, 0.49, and 0.23 for Los Angeles Airport, Hollywood-Burbank, and Norton AFB (San Bernadino), respectively

The preliminary total EUI for the large office was significantly lower than the average electricity bill; accordingly, the final EUIs increased through the application of EDA. We found dramatic increases for the cooling, ventilation, lighting and miscellaneous equipment EUIs.

Figure VIII-8 presents the standard day, adjusted whole-building load shape developed from the LRD for climate zone 2. The regression analysis of the underlying hourly loads for standard and non-standard days, winter and summer, by climate zone (presented in Appendix G) were used as input to EDA. Figure VIII-9 contains summaries of the resulting reconciled load shapes from

EDA for standard and non-standard days for climate zone 2. Figures VIII-10 through VIII-14 present the average monthly reconciled load shapes by end use for standard, non-standard, and peak days.

Despite large increases in annual end-use EUIs, the reconciled load shapes were reasonable. The implied lighting intensity, for example, can be found by inspection to be approximately 2.4 W/ft^2 leading to the conclusion that the large size of the lighting EUI resulted from high levels of baseload lighting, not from the amount of lighting installed.

Non-standard day equipment, DHW and, to a lesser extent, lighting all exhibit unexpected discontinuities in the shoulder hours. We believe that this result stemmed from incorrect specification of hours of HVAC operation in the prototype. In this case, energy that should have been accounted for by an HVAC end use ended up in these non-HVAC end uses. This result was directly related to the reasons given in the overview for the need to introduce smoothing procedures and to use an iterative reconciliation process to compensate for the fixed starting and stopping times assumed in the prototype simulation. In the case of non-standard days, our methods were only partially successful in this compensation; the result was additional energy use for the non-HVAC end uses.

Table VIII-4. Prototype Summary - Large Office

Number of Buildings Averaged:	15
Floor Area (ft^2):	66147
Percent Conditioned:	0.98
Wall Area (ft^2):	17951
Wall R-Value (Btu/ft^2°F):	5.2
Window/Wall Ratio:	0.31
Window U-Value (Btu/ft^2°F):	1.5
Roof Area (ft^2):	32694
Roof R-Value (Btu/ft^2°F):	15.8
Standard Days/Week:	5
Standard Day Start Time:	4
Standard Day Stop Time:	18
Non-Standard Day Start Time:	7
Non-Standard Day Stop Time:	18
Heating Set Point (°F):	72.4
Cooling Set Point (°F):	73.2
Occupancy (ft^2/Person):	255.7
Lighting Intensity (W/sqft):	1.59
Total Equipment Intensity (W/sqft):	0.48
HVAC System Type:	PSZ,SZRH
Supply Air Flow (CFM/ft^2):	0.99
Minimum Outside Air Fraction:	0.14
Package Cooling COP:	2.3
Central Chiller COP:	5.6

Table VIII-5. Electricity EUIs (kWh/ft^2-yr) - Large Office

Indoor Lighting	Outdoor Lighting	Misc. Equip.	Refrig.	Cooking	Water Heating	Ventilation[1]	Cooling[1]	Total	
Preliminary - central HVAC (0.51)[2]									
5.21	0.51	0.95	0.17	0.01	0.29	5.44	2.31	19.32	LAX
						5.79	2.78	20.26	BUR
						6.00	3.26	22.60	NOR
Preliminary - package HVAC (0.49)[2]									
5.21	0.51	0.95	0.17	0.01	0.29	0.80	3.32	14.74	LAX
						0.95	3.89	15.54	BUR
						1.04	4.87	16.21	NOR
Reconciled									
11.93	2.11	4.28	0.10	0.00	0.16	3.09	3.93	24.54	LAX
						3.30	3.91	25.94	BUR
						3.45	5.11	27.58	NOR

1. calculated using conditioned fraction of total floor area (0.98)
2. fraction of stock with this type of HVAC system

Figure VIII-8. Whole-Building Load Shape for Large Office - Standard Days in Climate Zone 2 (BUR). The load shape is a weighted-average of the hourly electricity use of individual load research buildings, and adjusted so that the annual building energy use derived from the load profile matches the annual bill from the on-site survey data. The plot shows the minimum, 25%-quartile, mean, 75%-quartile, and maximum hourly values; the line represents the mean hourly profile.

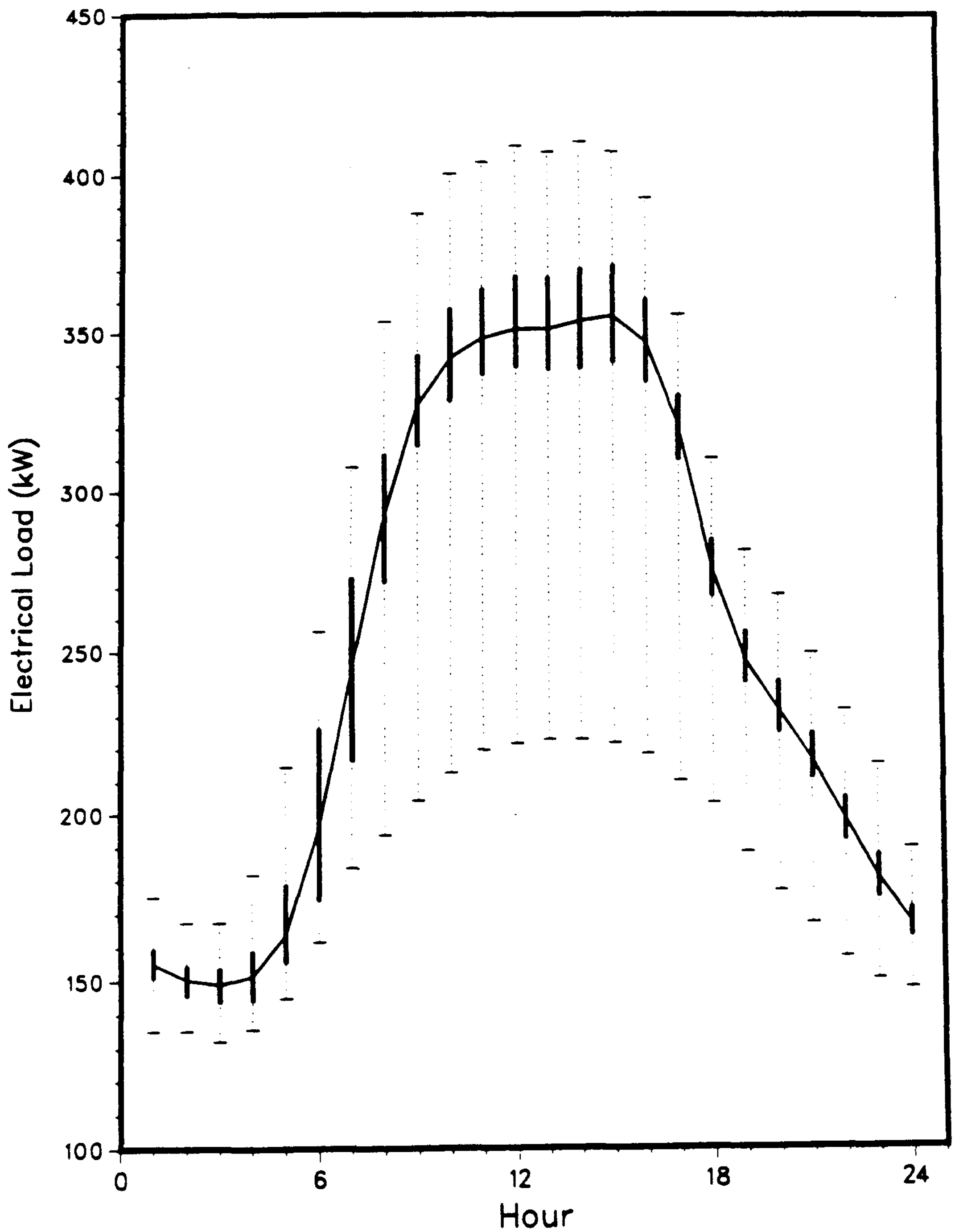


Figure VIII-9. Summary of Reconciled Load Shapes for Large Office in Climate Zone 2 (BUR)

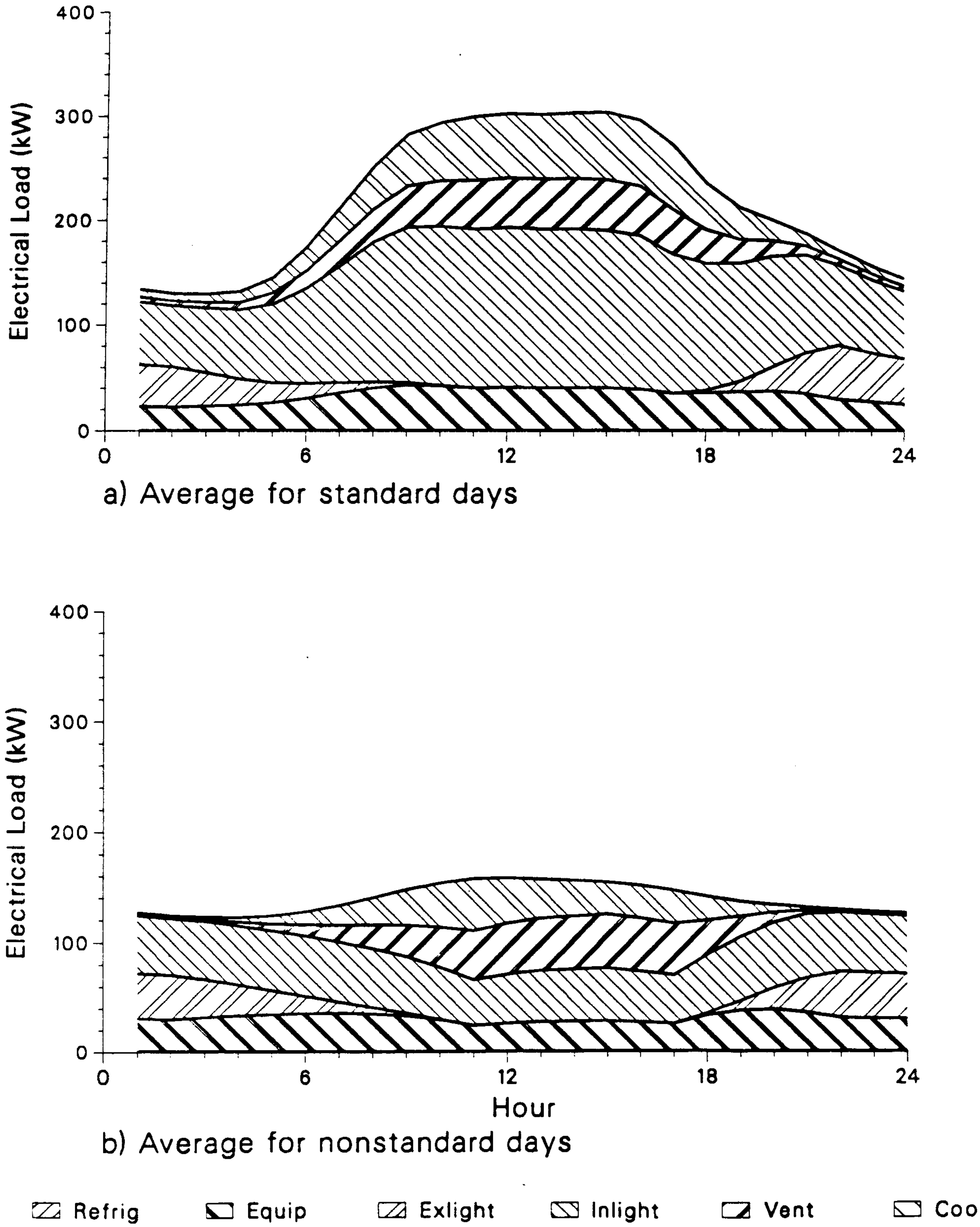


Figure VIII-10. Reconciled Monthly Load Shapes for Large Office - Cooling and Ventilation in Climate Zone 1 (LAX). Solid lines are profiles for months May through October and broken lines are profiles for months November through April.

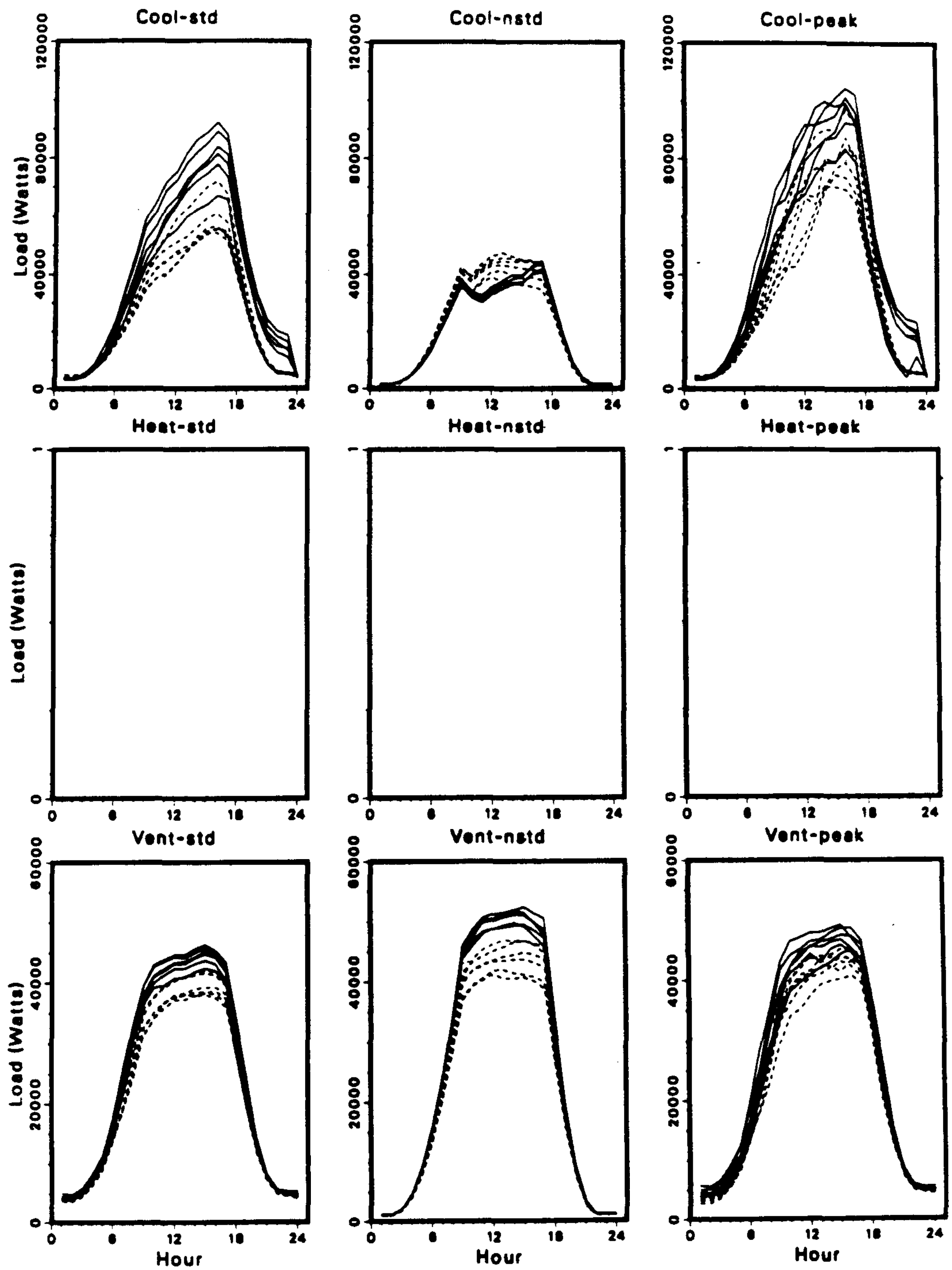


Figure VIII-11. Reconciled Monthly Load Shapes for Large Office - Cooling and Ventilation in Climate Zone 2 (BUR). Solid lines are profiles for months May through October and broken lines are profiles for months November through April.

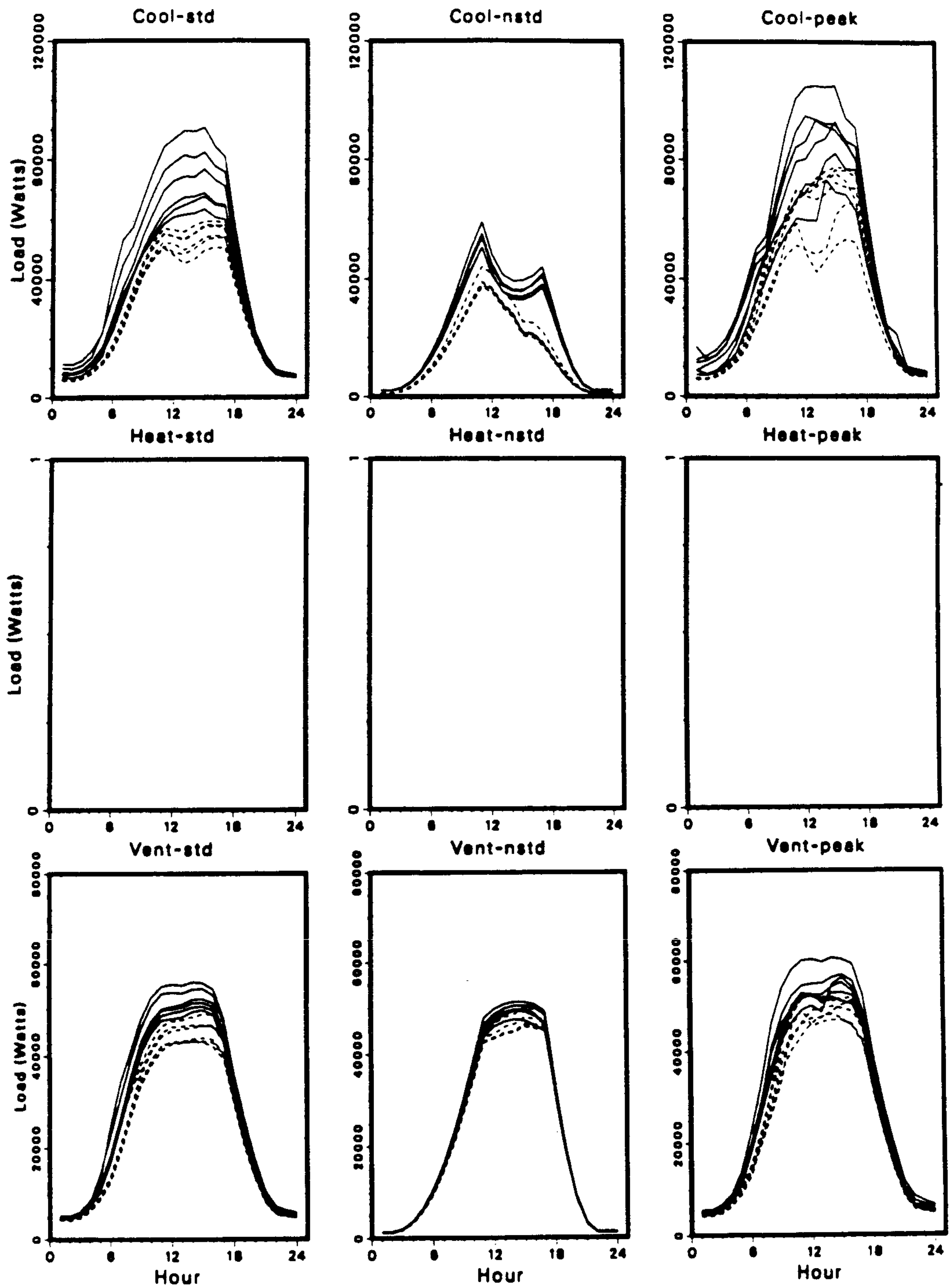


Figure VIII-12. Reconciled Monthly Load Shapes for Large Office - Cooling and Ventilation in Climate Zone 3 (NOR). Solid lines are profiles for months May through October and broken lines are profiles for months November through April.

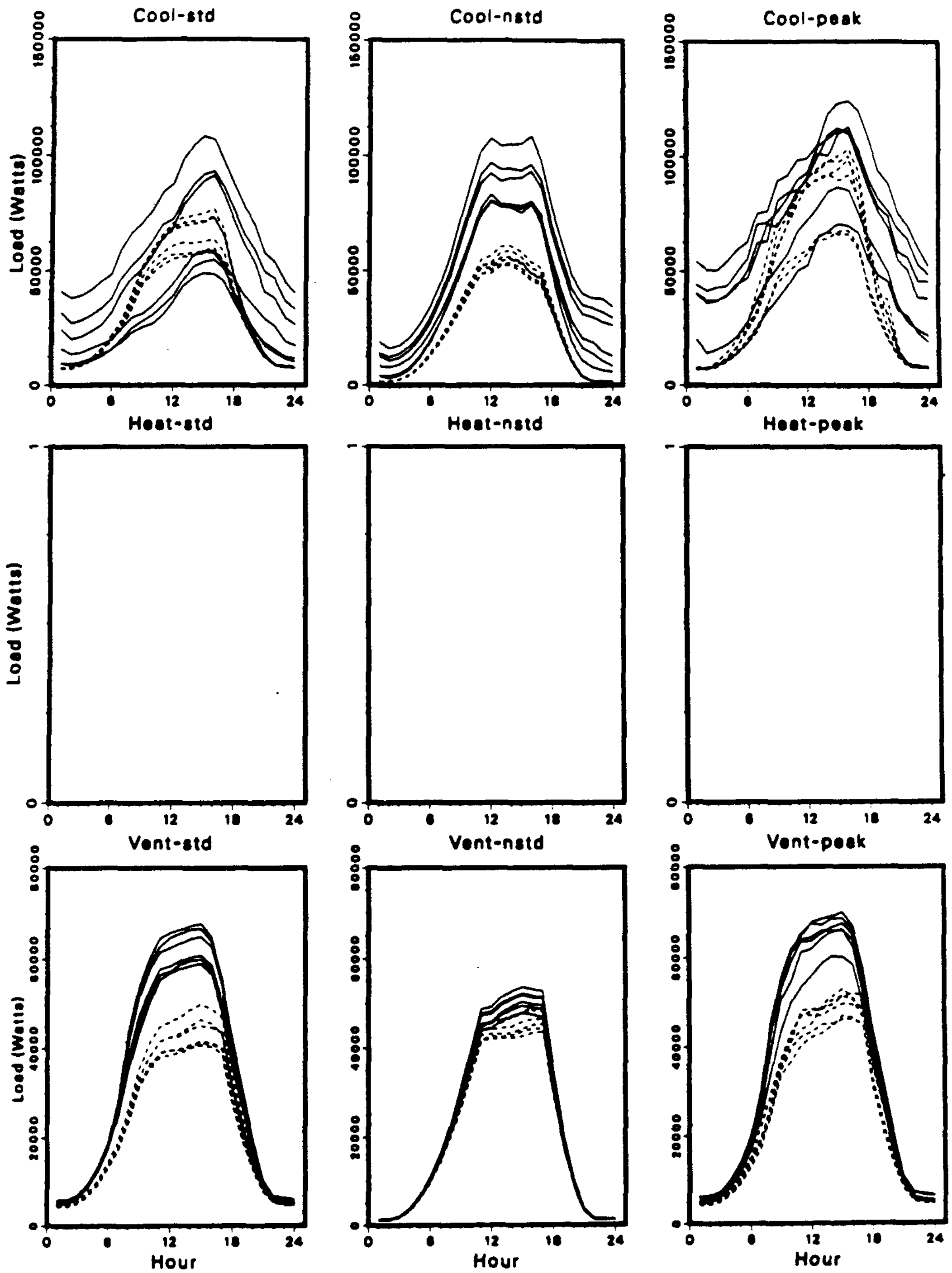


Figure VIII-13. Reconciled Monthly Load Shapes for Large Office - Indoor and Outdoor Lighting, and Misc. Equipment in Climate Zone 2 (BUR). Solid lines are profiles for months May through October and broken lines are profiles for months November through April.

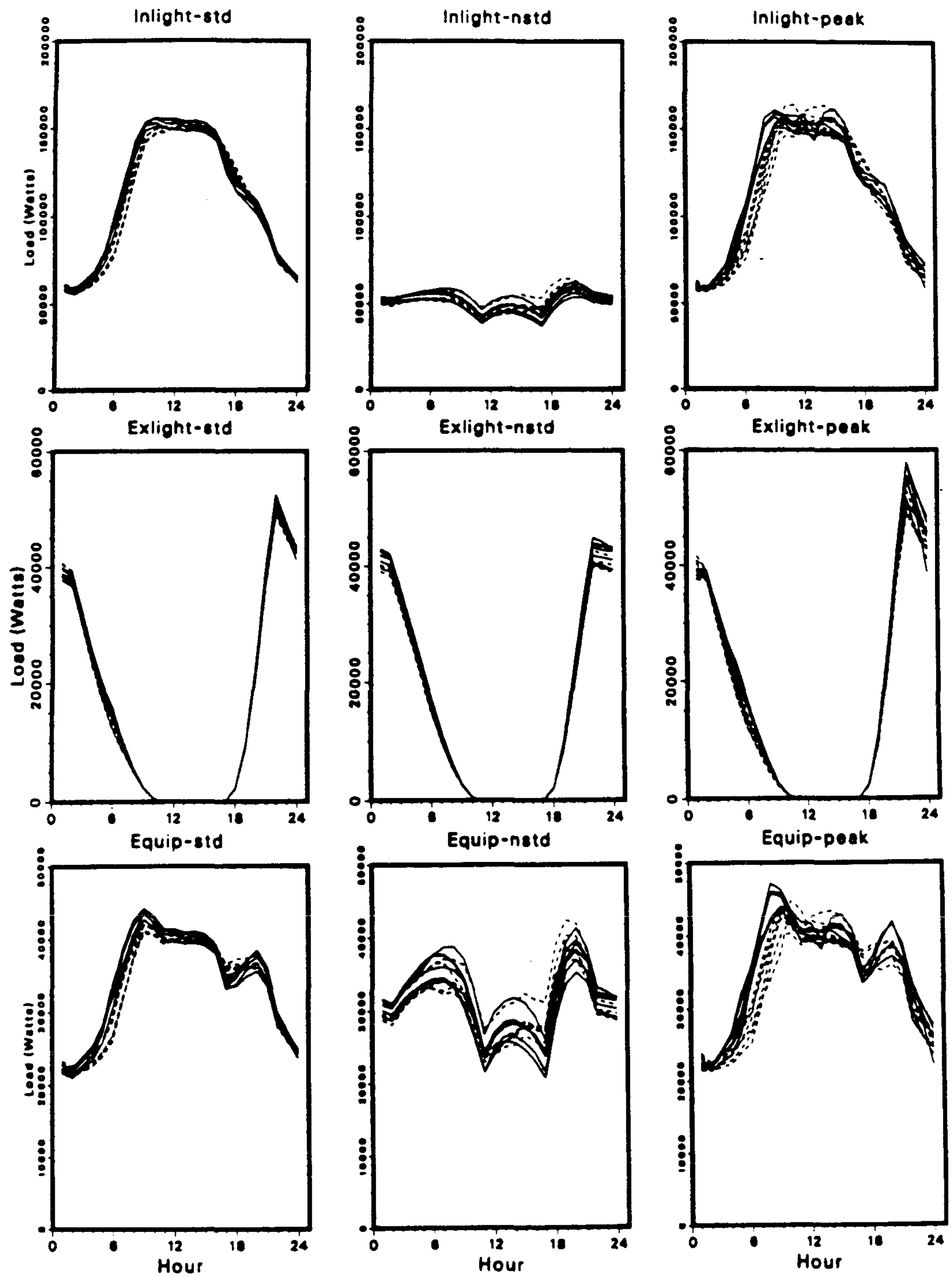
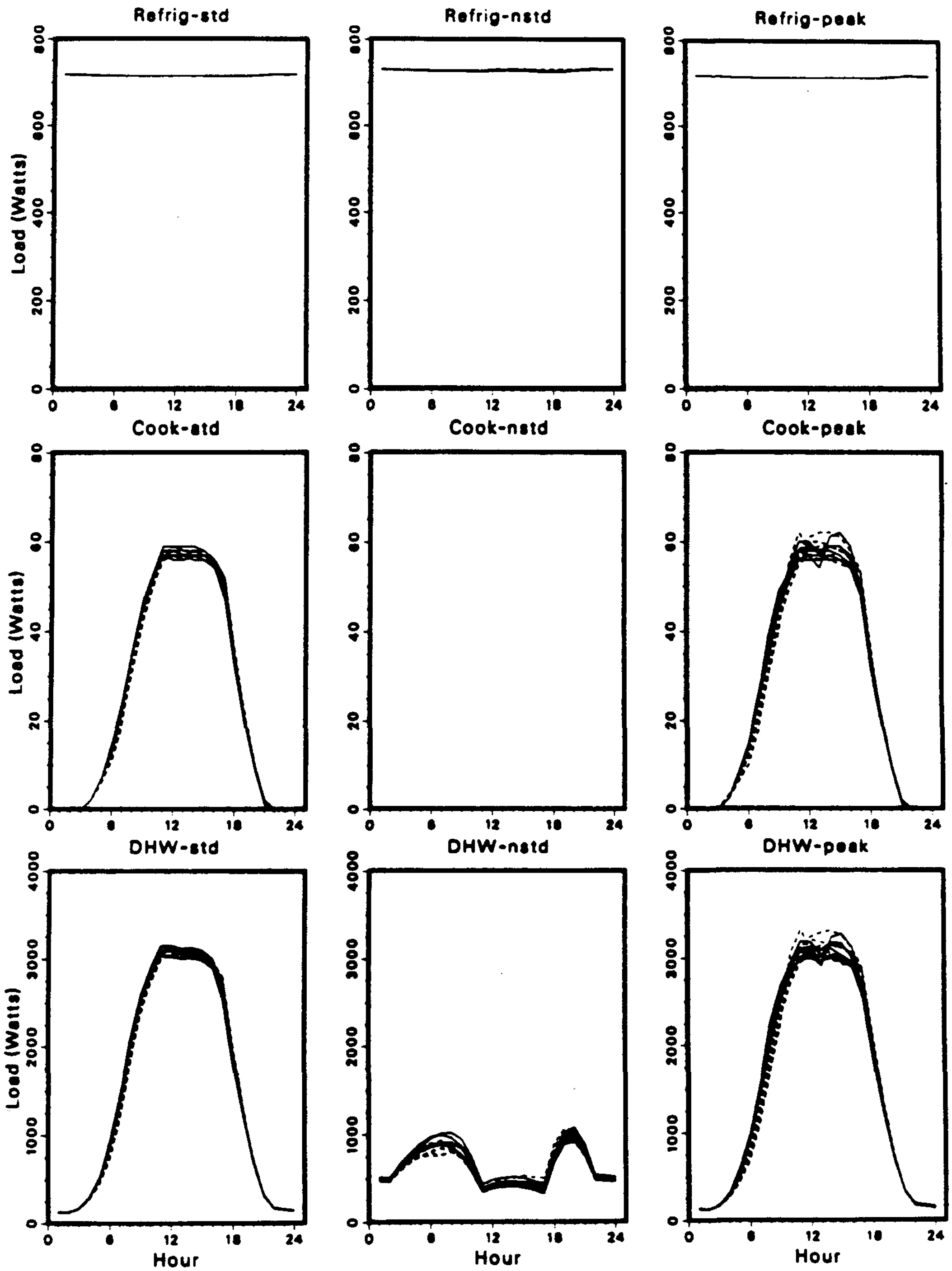


Figure VIII-14. Reconciled Monthly Load Shapes for Large Office - Refrigeration, Cooking, and Hot Water (DHW) in Climate Zone 2 (BUR). Solid lines are profiles for months May through October and broken lines are profiles for months November through April.



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Small Retail

For the small retail, we were able to run EDA separately for each of the three climate zones because there were sufficient quantities of LRD in each zone. Prior to running EDA, we adjusted the weighted average electricity bills and, consequently, the whole-building load shape for each climate zone. The adjustments were based on additional DOE-2 simulations of the prototype in each climate zone. The additional simulations resulted in adjustments to the measured energy use (reported in Table VIII-1) of 0.96, 0.99, and 1.06 for Los Angeles Airport, Hollywood-Burbank, and Norton AFB (San Bernadino), respectively.

Table VIII-6 summarizes major features of the small retail prototype. Data from 65 on-site surveys contributed to the development of the prototype.

Table VIII-7 compares the initial EUIs by end use to the reconciled EUIs. Application of EDA produced three separate estimates for each of the non-HVAC EUIs, whose differences were statistically insignificant. We combined them into a single EUI using the relative population of small offices from the 1985 SCE Commercial Sector Mail Survey. Based on the climate mapping reported in Table II-3, the distribution of small retail was 0.28, 0.44, and 0.28 for Los Angeles Airport, Hollywood-Burbank, and Norton AFB (San Bernadino), respectively

The preliminary total EUI for the small retail was greater than the average electricity bill. As a result, most of the final EUIs were adjusted downward by the reconciliation process. An exception was ventilation and cooling, which increased slightly. Broadly speaking, cooling and ventilation do not necessarily follow the trend implied by the relationship between the preliminary total EUI and the measured total EUI from the electricity bills. The reason is that the cooling LSs (for all premises) were developed using regressions of the LRD against historic weather conditions. LSs for the remaining end uses were generated only after the HVAC end uses were subtracted from the total.

Figure VIII-15 presents the standard day, adjusted whole-building load shape developed from the LRD for climate zone 2. The regression analysis of the underlying hourly loads for standard and non-standard days, winter and summer, by climate zone (presented in Appendix G) were used as input to EDA. Figure VIII-16 contains summaries of the resulting reconciled load shapes from EDA for standard and non-standard days for climate zone 2. Figures VIII-17 through VIII-21 present the average monthly reconciled load shapes by end use for standard, non-standard, and peak days.

Examination of the load shapes indicates two areas of concern. First, climate zone 3 ventilation loads exhibit unrealistic shoulder hour spikes that are related to shortcomings of the smoothing procedures described for previous building types. Second, peak day winter load profiles exhibit spikes that may be be related to bad data for the peak day; several end use winter peak day load shapes are affected.

Table VIII-6. Prototype Summary - Small Retail

Number of Buildings Averaged:	65
Floor Area (ft^2):	4360
Percent Conditioned:	0.66
Wall Area (ft^2):	3372
Wall R-Value (Btu/ft^2°F):	6.9
Window/Wall Ratio:	0.10
Window U-Value (Btu/ft^2°F):	1.4
Roof Area (ft^2):	3791
Roof R-Value (Btu/ft^2°F):	15.1
Standard Days/Week:	6
Standard Day Start Time:	7
Standard Day Stop Time:	16
Non-Standard Day Start Time:	8
Non-Standard Day Stop Time:	19
Heating Set Point (°F):	71.6
Cooling Set Point (°F):	73.1
Occupancy (ft^2/Person):	246.1
Lighting Intensity (W/sqft):	1.61
Total Equipment Intensity (W/sqft):	1.92
HVAC System Type:	PSZ
Supply Air Flow (CFM/ft^2):	1.47
Minimum Outside Air Fraction:	0.24
Package Cooling COP:	2.2

Table VIII-7. Electricity EUIs (kWh/ft^2-yr) - Small Retail

Indoor Lighting	Outdoor Lighting	Misc. Equip.	Refrig.	Cooking	Water Heating	Ventilation[1]	Cooling[1]	Total	
Preliminary									
6.49	1.75	1.20	3.00	0.10	0.12	1.32	5.48	9.86	LAX
						1.52	6.23	10.33	BUR
						1.58	8.56	11.04	NOR
Reconciled									
7.49	1.59	1.48	0.95	0.01	0.04	1.67	5.45	17.21	LAX
						1.82	6.54	17.40	BUR
						2.04	11.15	18.81	NOR

1. calculated using conditioned fraction of total floor area (0.66)

Figure VIII-15. Whole-Building Load Shape for Small Retail - Standard Days in Climate Zone 2 (BUR). The load shape is a weighted-average of the hourly electricity use of individual load research buildings, and adjusted so that the annual building energy use derived from the load profile matches the annual bill from the on-site survey data. The plot shows the minimum, 25%-quartile, mean, 75%-quartile, and maximum hourly values; the line represents the mean hourly profile.

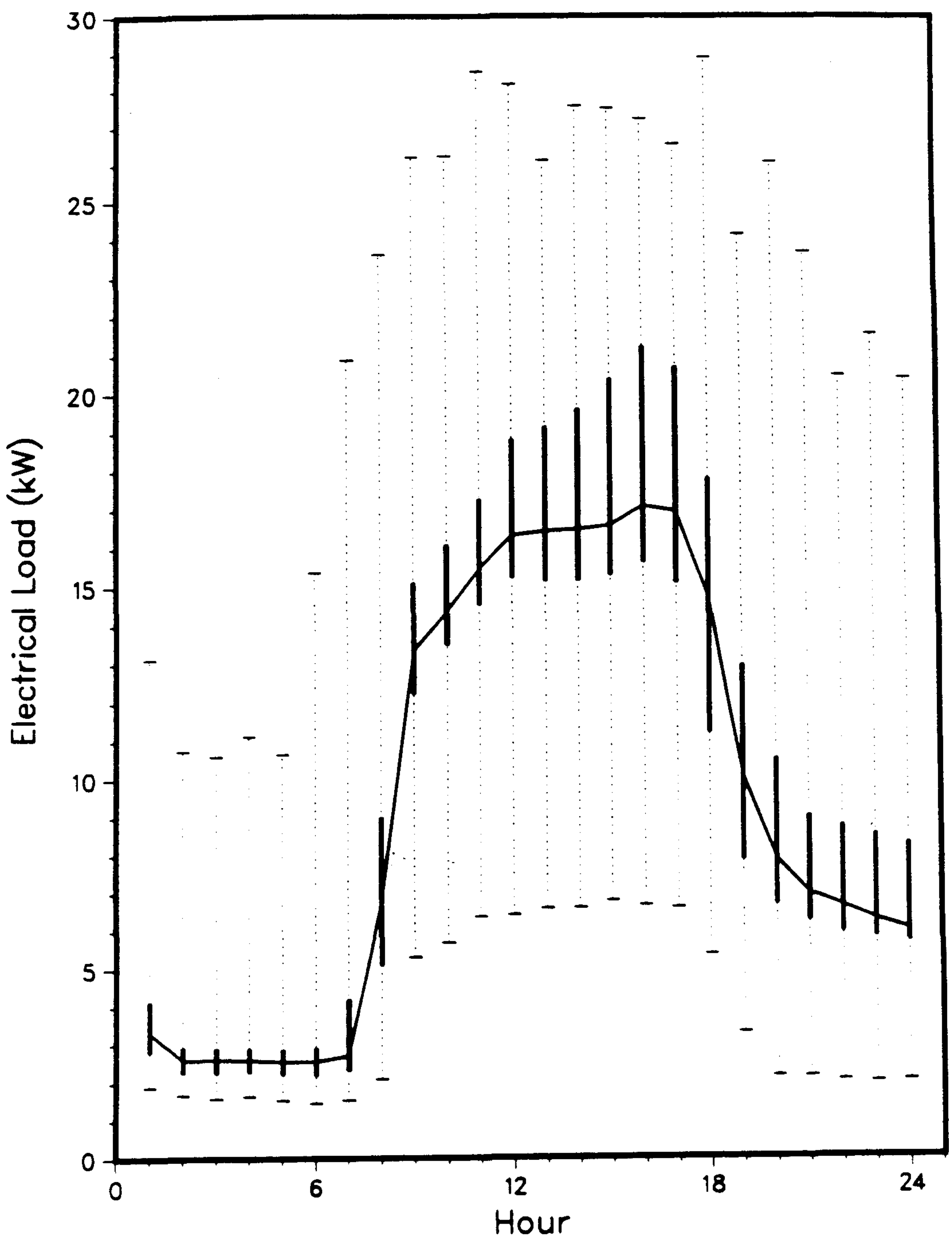
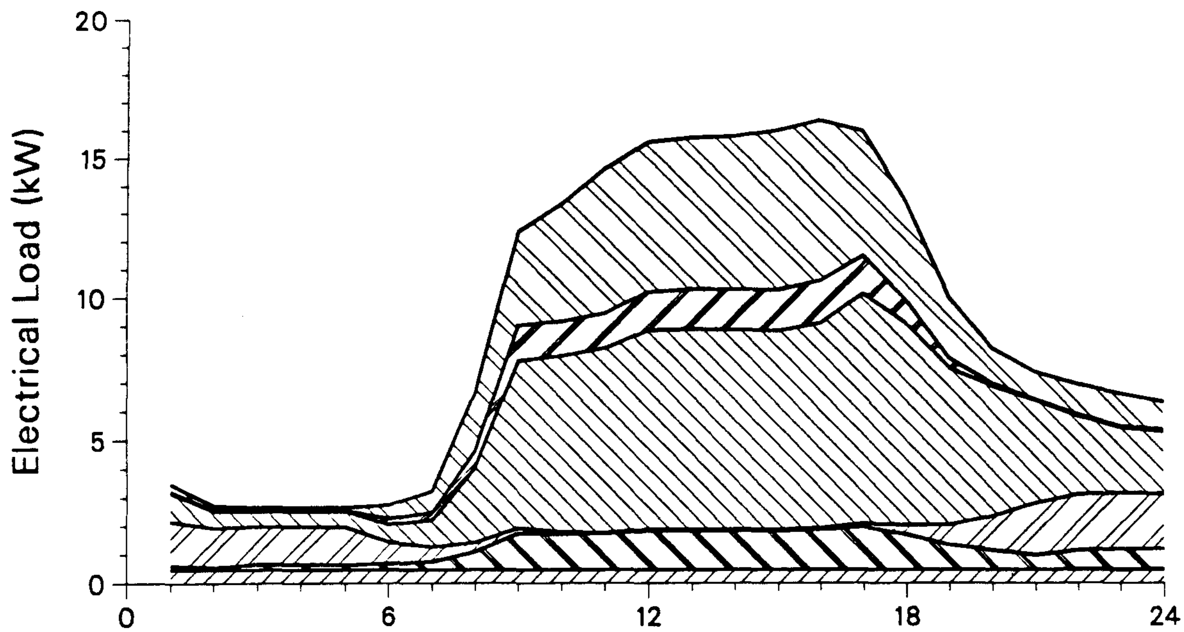
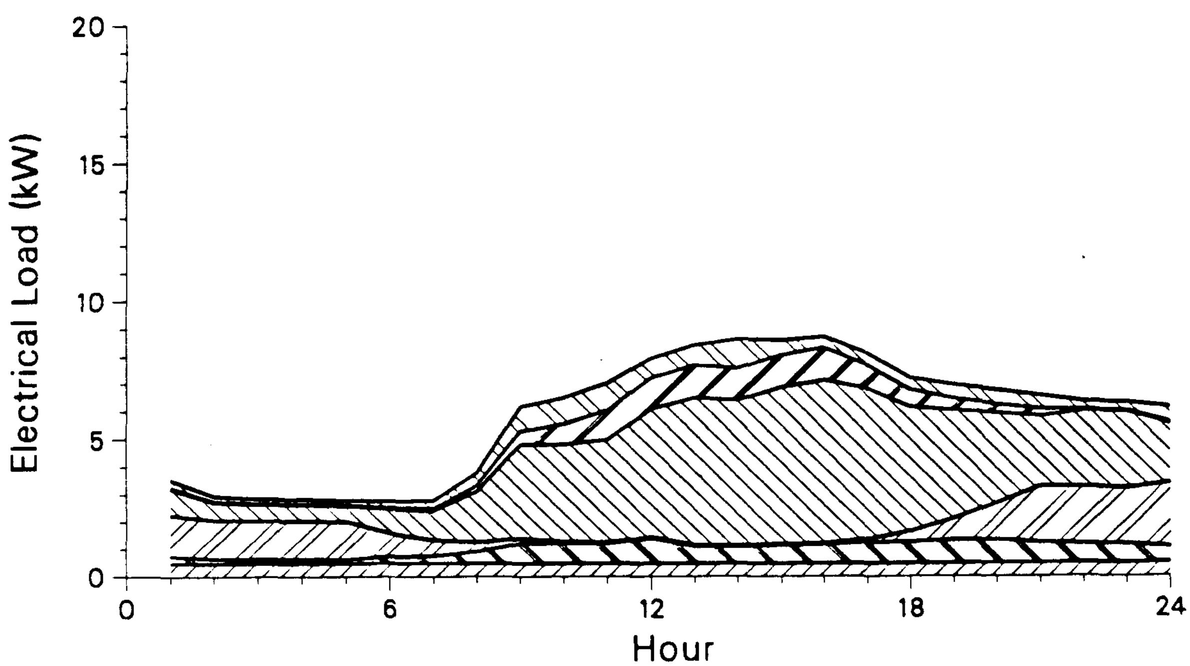


Figure VIII-16. Summary of Reconciled Load Shapes for Small Retail in Climate Zone 2 (BUR)



a) Average for standard days



b) Average for nonstandard days

Figure VIII-17. Reconciled Monthly Load Shapes for Small Retail - Cooling and Ventilation in Climate Zone 1 (LAX). Solid lines are profiles for months May through October and broken lines are profiles for months November through April.

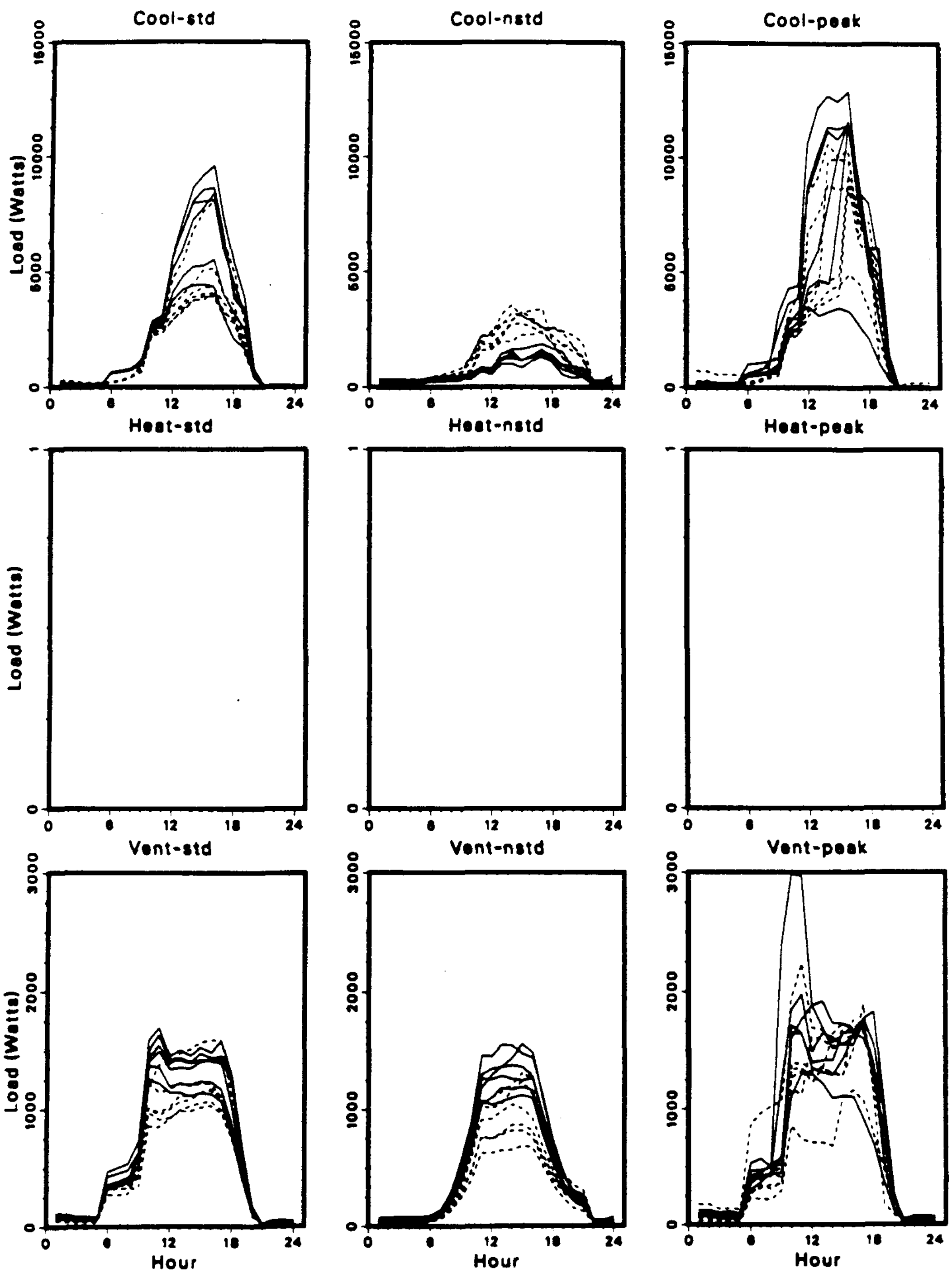


Figure VIII-18. Reconciled Monthly Load Shapes for Small Retail - Cooling and Ventilation in Climate Zone 2 (BUR). Solid lines are profiles for months May through October and broken lines are profiles for months November through April.

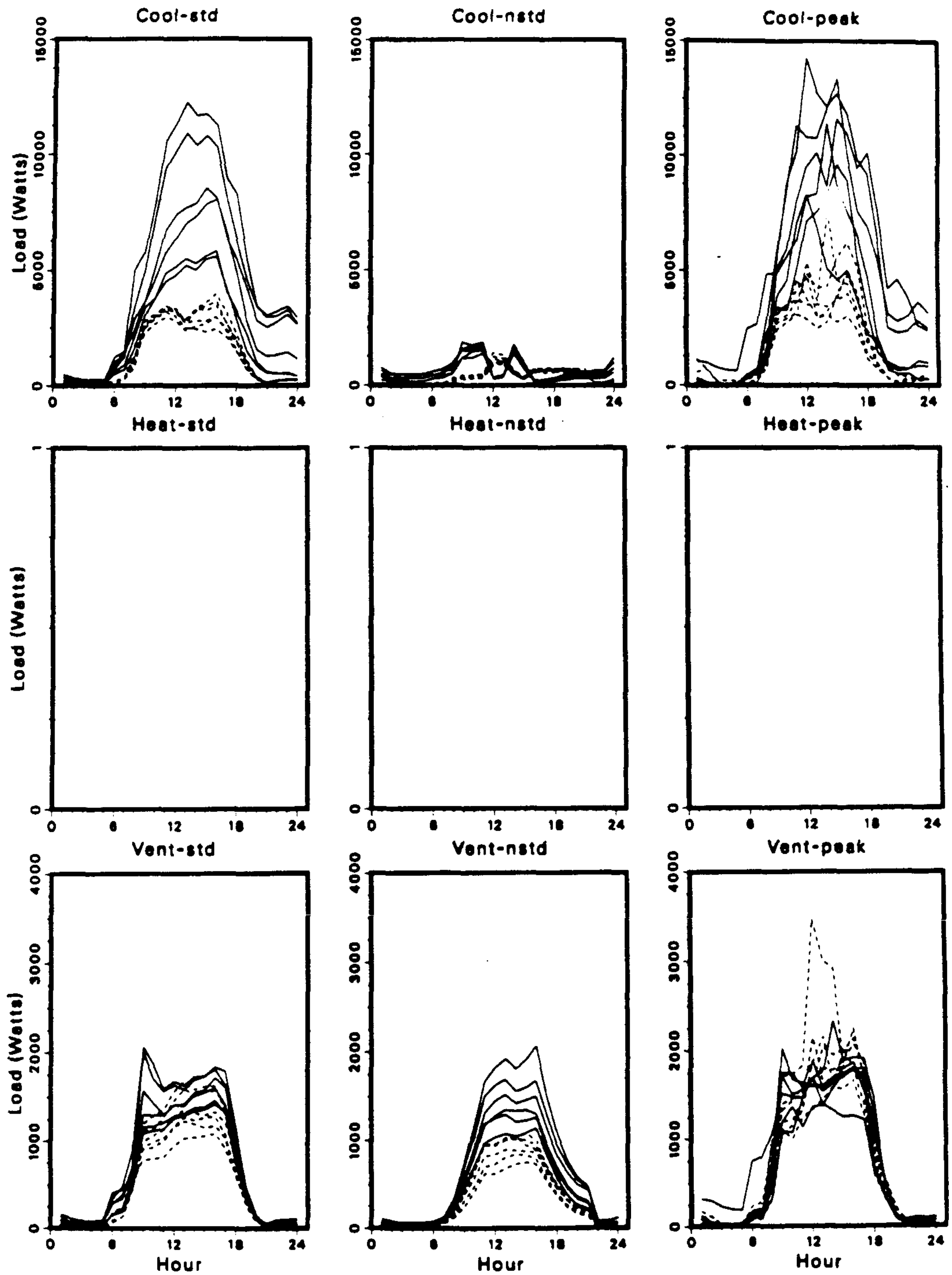


Figure VIII-19. Reconciled Monthly Load Shapes for Small Retail - Cooling and Ventilation in Climate Zone 3 (NOR). Solid lines are profiles for months May through October and broken lines are profiles for months November through April.

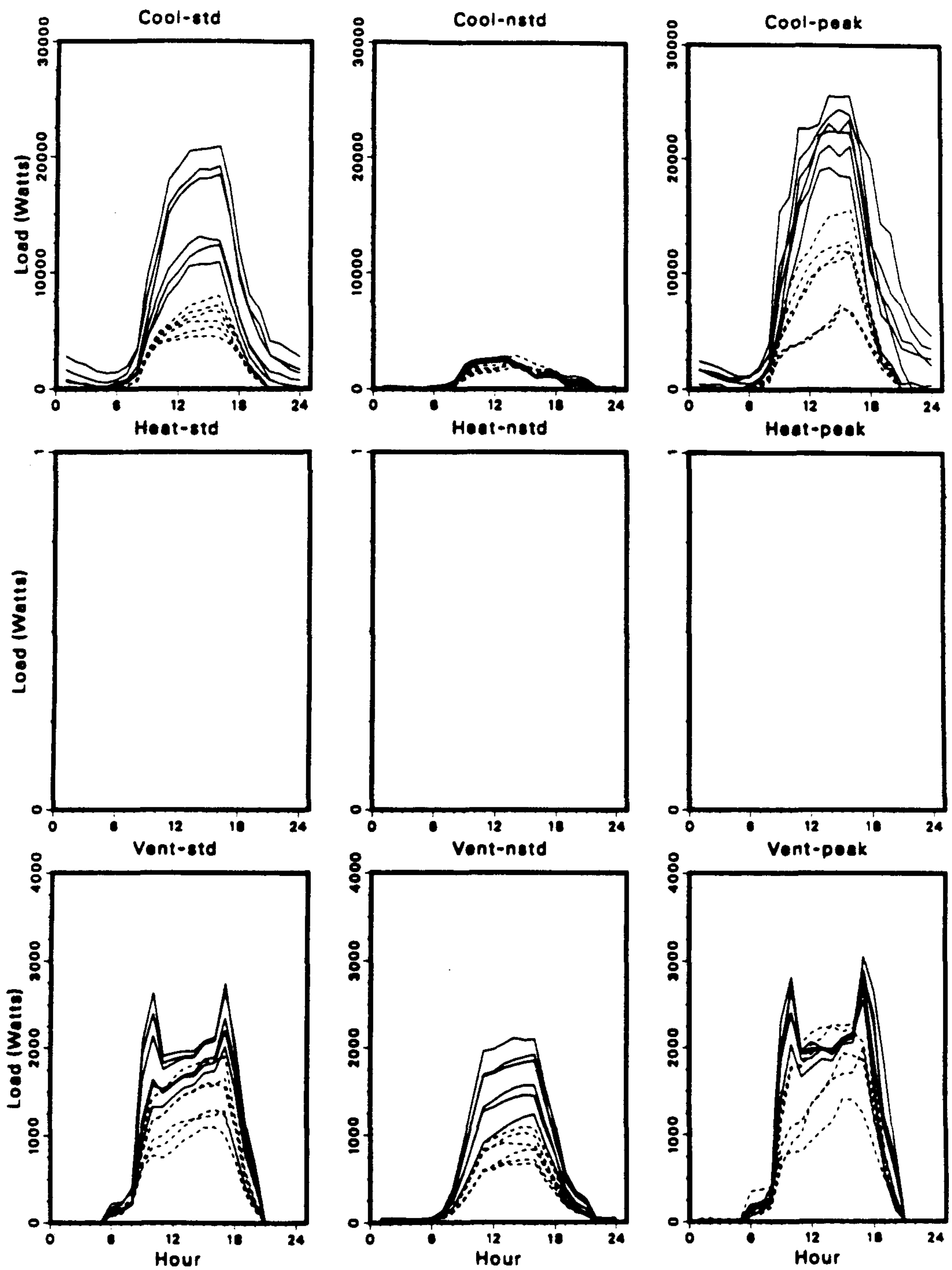


Figure VIII-20. Reconciled Monthly Load Shapes for Small Retail - Indoor and Outdoor Lighting, and Misc. Equipment in Climate Zone 2 (BUR). Solid lines are profiles for months May through October and broken lines are profiles for months November through April.

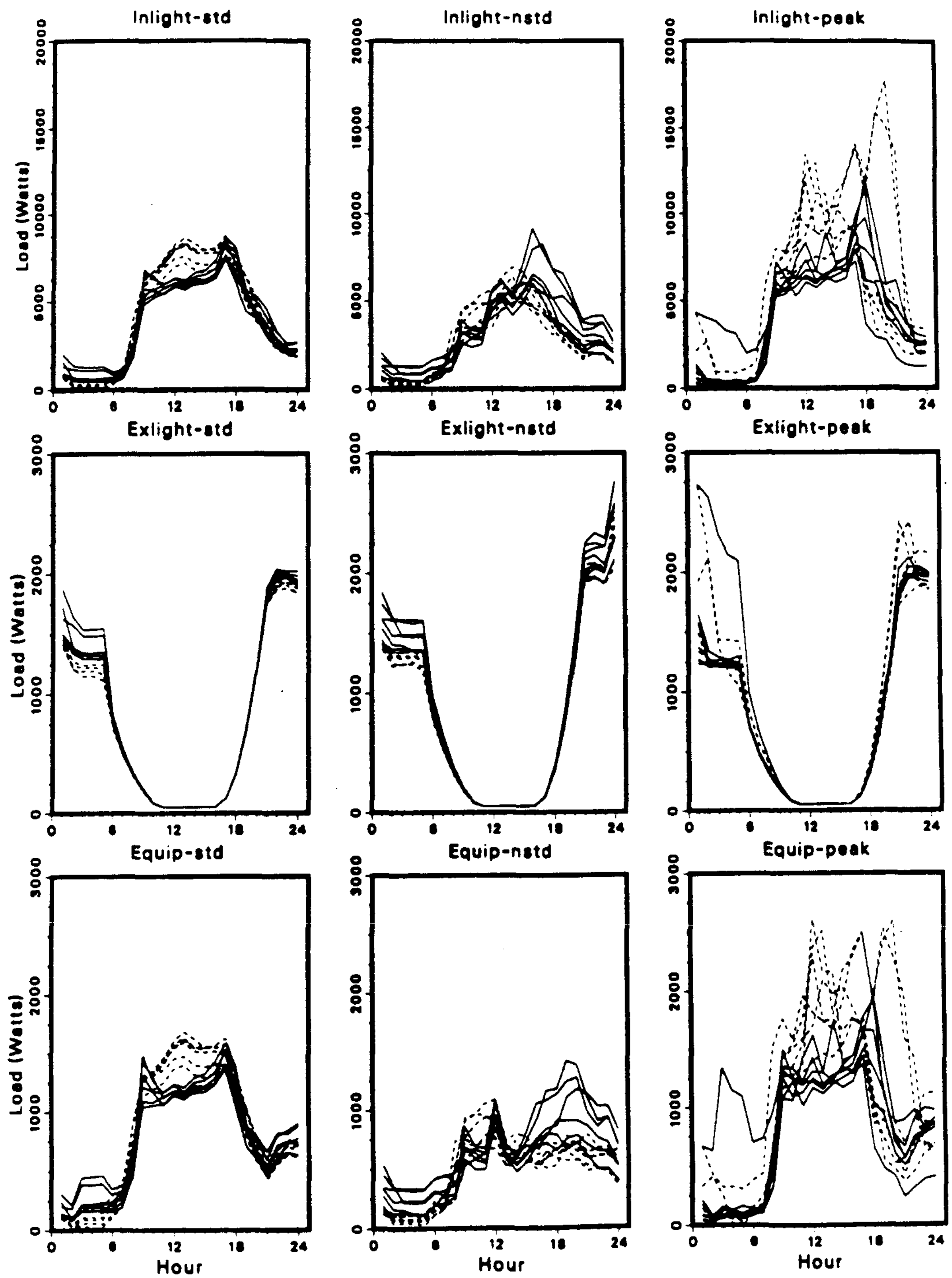
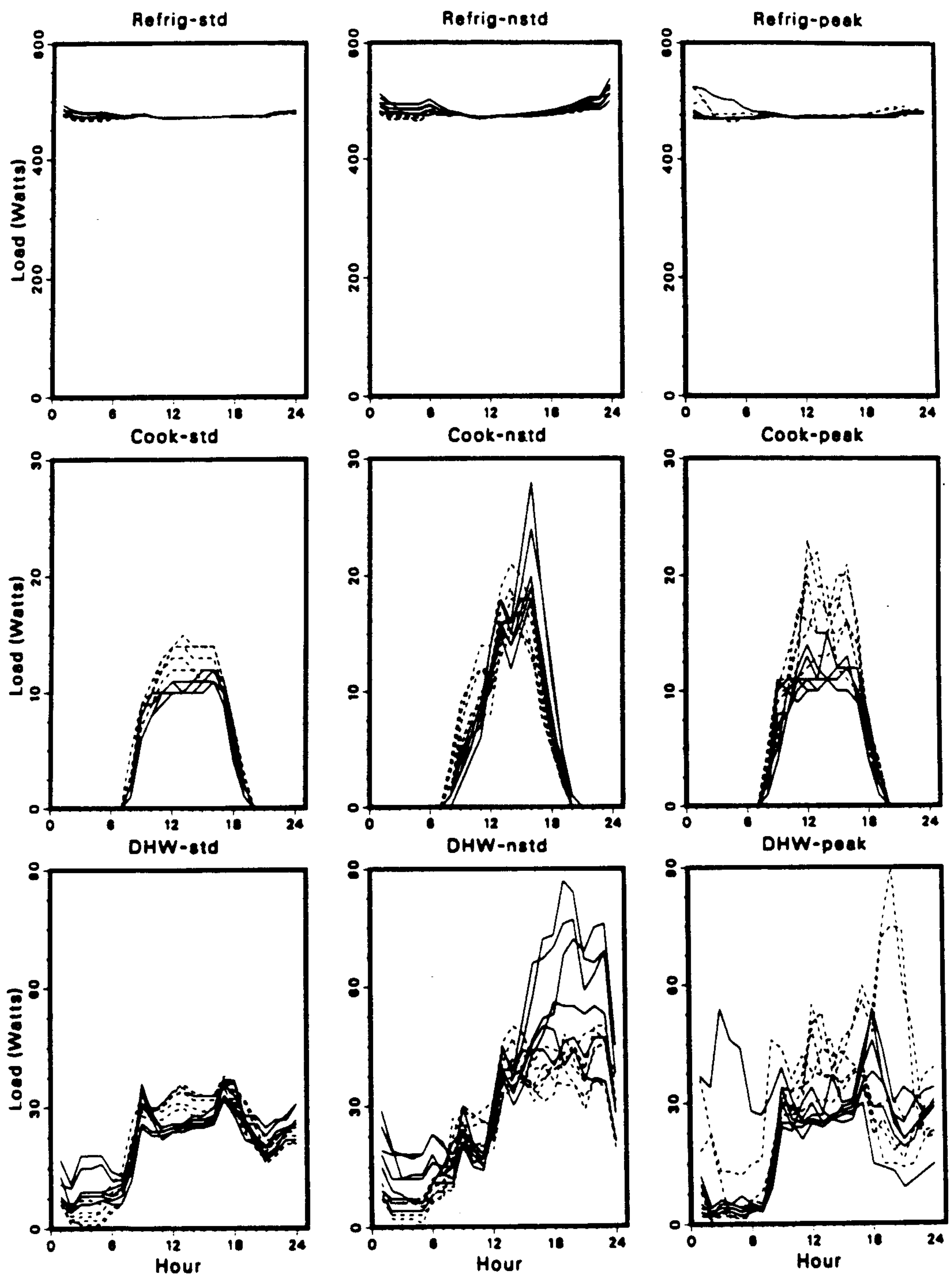


Figure VIII-21. Reconciled Monthly Load Shapes for Small Retail - Refrigeration, Cooking, and Hot Water (DHW) in Climate Zone 2 (BUR). Solid lines are profiles for months May through October and broken lines are profiles for months November through April.



Large Retail

For the large retail, we were able to run EDA separately for each of the three climate zones because there were sufficient quantities of LRD in each zone. Prior to running EDA, we adjusted the average electricity bill and, consequently, the whole-building load shape for each climate zone. The adjustments were based on additional DOE-2 simulations of the prototype in each climate zone. The additional simulations resulted in adjustments to the measured energy use (reported in Table VIII-1) of 0.97, 0.99, and 1.06 for Los Angeles Airport, Hollywood-Burbank, and Norton AFB (San Bernadino), respectively.

Table VIII-8 summarizes major features of the large retail prototype. Data from 13 on-site surveys contributed to the development of the prototype. The prevalence of two major types of HVAC systems led to the development of both a central and a packaged HVAC system for the prototype. The results of the simulations using each of these two HVAC systems were weighted together into a single number based on the relative frequency of each system type from the 1985 SCE Commercial Sector Mail Survey. The survey indicated that 27% had chilled water systems, and 73% had rooftop, package A/C units.

Table VIII-9 compares the initial EUIs by end use to the reconciled EUIs. Application of EDA produced three separate estimates for each of the non-HVAC EUIs, whose differences were statistically insignificant. We have combined them into a single EUI using the relative population of small offices from the 1985 SCE Commercial Sector Mail Survey. Based on the climate mapping reported in Table II-3, the distribution of large retail was 0.28, 0.44, and 0.28 for Los Angeles Airport, Hollywood-Burbank, and Norton AFB (San Bernadino), respectively

The preliminary total EUI for the large retail was lower than that of the average electricity bill. As a result of the regression analysis, some part of the difference was allocated to the cooling and ventilation end use. Nevertheless, a significant portion of the difference was allocated to the indoor and outdoor lighting, and miscellaneous end use. As with the large office, this result stems directly from the large total EUI found for this building type, which was based on an analysis of electricity bills.

Figure VIII-22 presents the standard day, adjusted whole-building load shape developed from the LRD for climate zone 2. The regression analysis of the underlying hourly loads for standard and non-standard days, winter and summer, by climate zone (presented in Appendix G) were used as input to EDA. Figure VIII-23 contains summaries of the resulting reconciled load shapes from EDA for standard and non-standard days for climate zone 2. Figures VIII-24 through VIII-28 present the average monthly reconciled load shapes by end use for standard, non-standard, and peak days.

Unlike large offices, where we found a good deal of the high lighting EUI could be explained by high baseload lighting levels, the large lighting EUI for large retail appears to result from large installed lighting capacities (approximately 3 W/ft^2). Also, summer season standard and peak day ventilation load shapes exhibited late afternoon spikes that we attributed to shortcomings of our shoulder hour smoothing procedure.

Table VIII-8. Prototype Summary - Large Retail

Number of Buildings Averaged:	13
Floor Area (ft^2):	67628
Percent Conditioned:	0.79
Wall Area (ft^2):	13368
Wall R-Value (Btu/ft^2°F):	4.8
Window/Wall Ratio:	0.08
Window U-Value (Btu/ft^2°F):	1.5
Roof Area (ft^2):	59666
Roof R-Value (Btu/ft^2°F):	31.0
Standard Days/Week:	6
Standard Day Start Time:	9
Standard Day Stop Time:	21
Non-Standard Day Start Time:	10
Non-Standard Day Stop Time:	22
Heating Set Point (°F):	71.5
Cooling Set Point (°F):	75.0
Occupancy (ft^2/Person):	465.9
Lighting Intensity (W/sqft):	1.65
Total Equipment Intensity (W/sqft):	0.28
HVAC System Type:	PSZ,SZRH
Supply Air Flow (CFM/ft^2):	1.10
Minimum Outside Air Fraction:	0.17
Package Cooling COP:	2.3
Central Chiller COP:	3.8

Table VIII-9. Electricity EUIs (kWh/ft^2-yr) - Large Retail

Indoor Lighting	Outdoor Lighting	Misc. Equip.	Refrig.	Cooking	Water Heating	Ventilation[1]	Cooling[1]	Total	
Preliminary - central HVAC (0.27)[2]									
6.87	0.74	0.60	2.22	0.48	0.03	6.25	3.36	18.53	LAX
						6.33	3.74	18.90	BUR
						6.39	4.69	19.69	NOR
Preliminary - package HVAC (0.73)[2]									
6.87	0.74	0.60	2.22	0.48	0.03	0.87	3.98	14.77	LAX
						0.98	4.15	14.99	BUR
						1.10	5.85	16.43	NOR
Reconciled									
12.21	1.47	1.12	0.61	0.19	0.02	3.41	5.79	22.50	LAX
						3.71	4.94	22.76	BUR
						3.61	7.65	24.48	NOR

1. calculated using conditioned fraction of total floor area (0.79)
2. fraction of stock with this type of HVAC system

Figure VIII-22. Whole-Building Load Shape for Large Retail - Standard Days in Climate Zone 2 (BUR). The load shape is a weighted-average of the hourly electricity use of individual load research buildings, and adjusted so that the annual building energy use derived from the load profile matches the annual bill from the on-site survey data. The plot shows the minimum, 25%-quartile, mean, 75%-quartile, and maximum hourly values; the line represents the mean hourly profile.

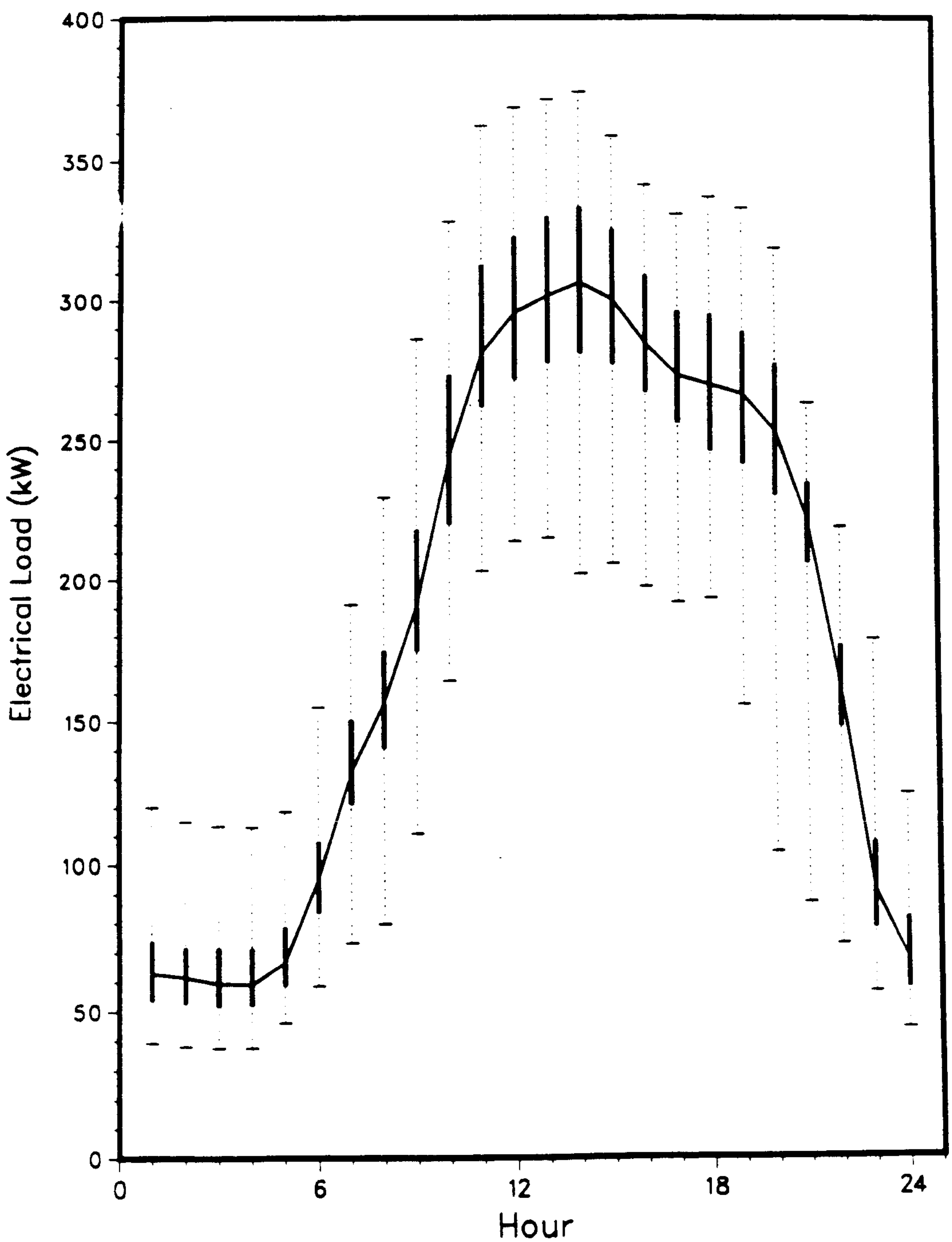


Figure VIII-23. Summary of Reconciled Load Shapes for Large Retail in Climate Zone 2 (BUR)

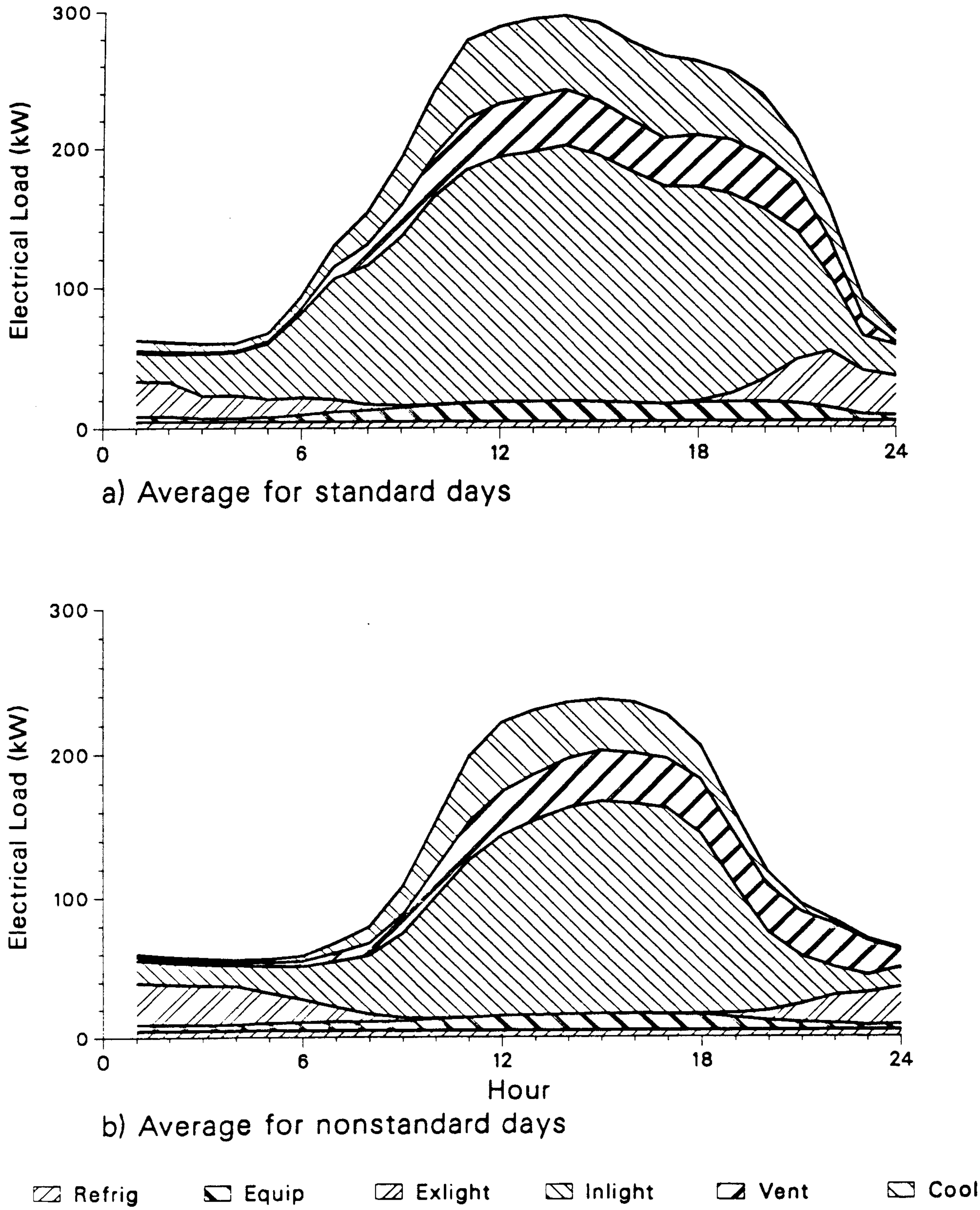


Figure VIII-24. Reconciled Monthly Load Shapes for Large Retail - Cooling and Ventilation in Climate Zone 1 (LAX). Solid lines are profiles for months May through October and broken lines are profiles for months November through April.

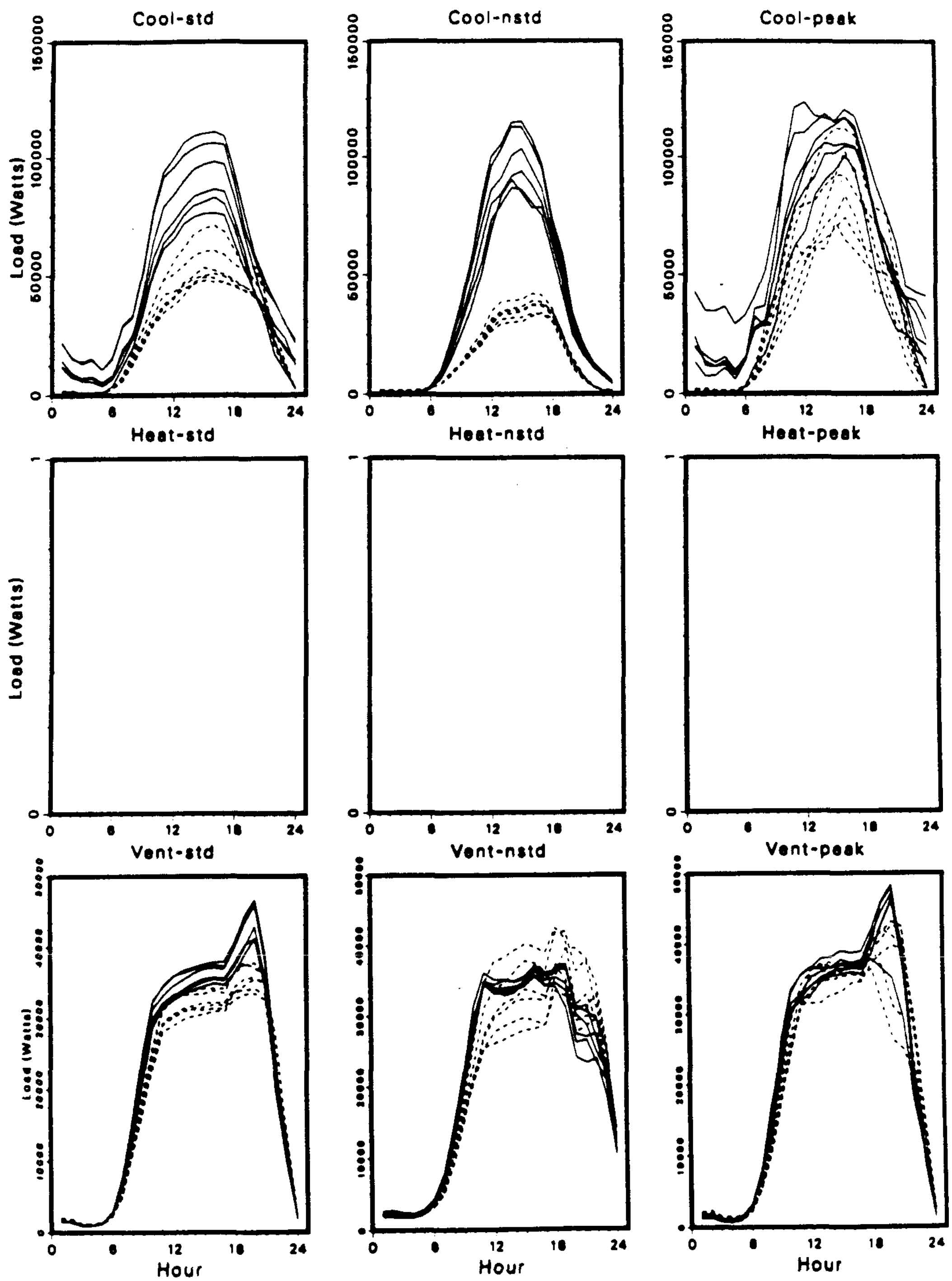


Figure VIII-25. Reconciled Monthly Load Shapes for Large Retail - Cooling and Ventilation in Climate Zone 2 (BUR). Solid lines are profiles for months May through October and broken lines are profiles for months November through April.

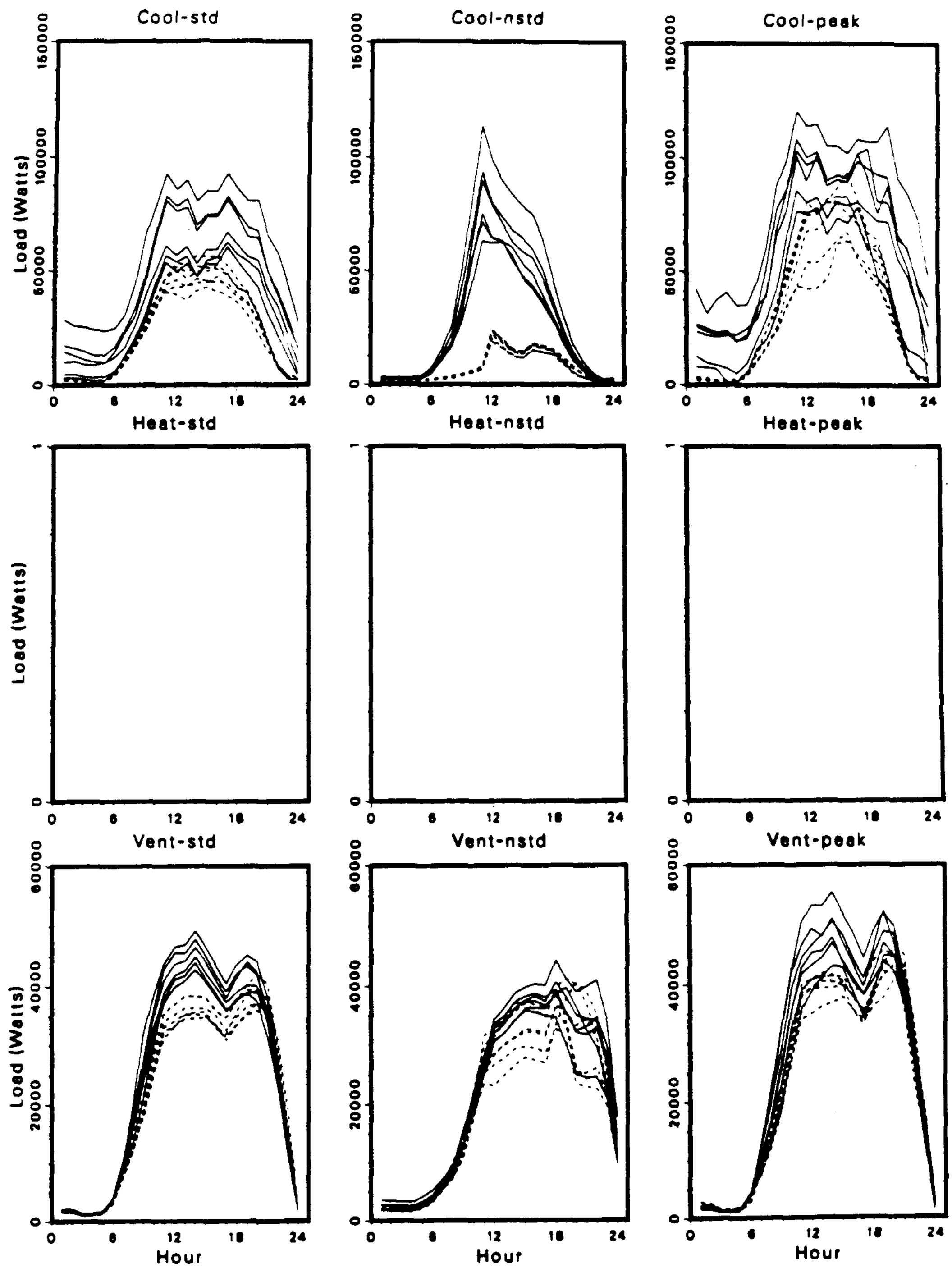


Figure VIII-26. Reconciled Monthly Load Shapes for Large Retail - Cooling and Ventilation in Climate Zone 3 (NOR). Solid lines are profiles for months May through October and broken lines are profiles for months November through April.

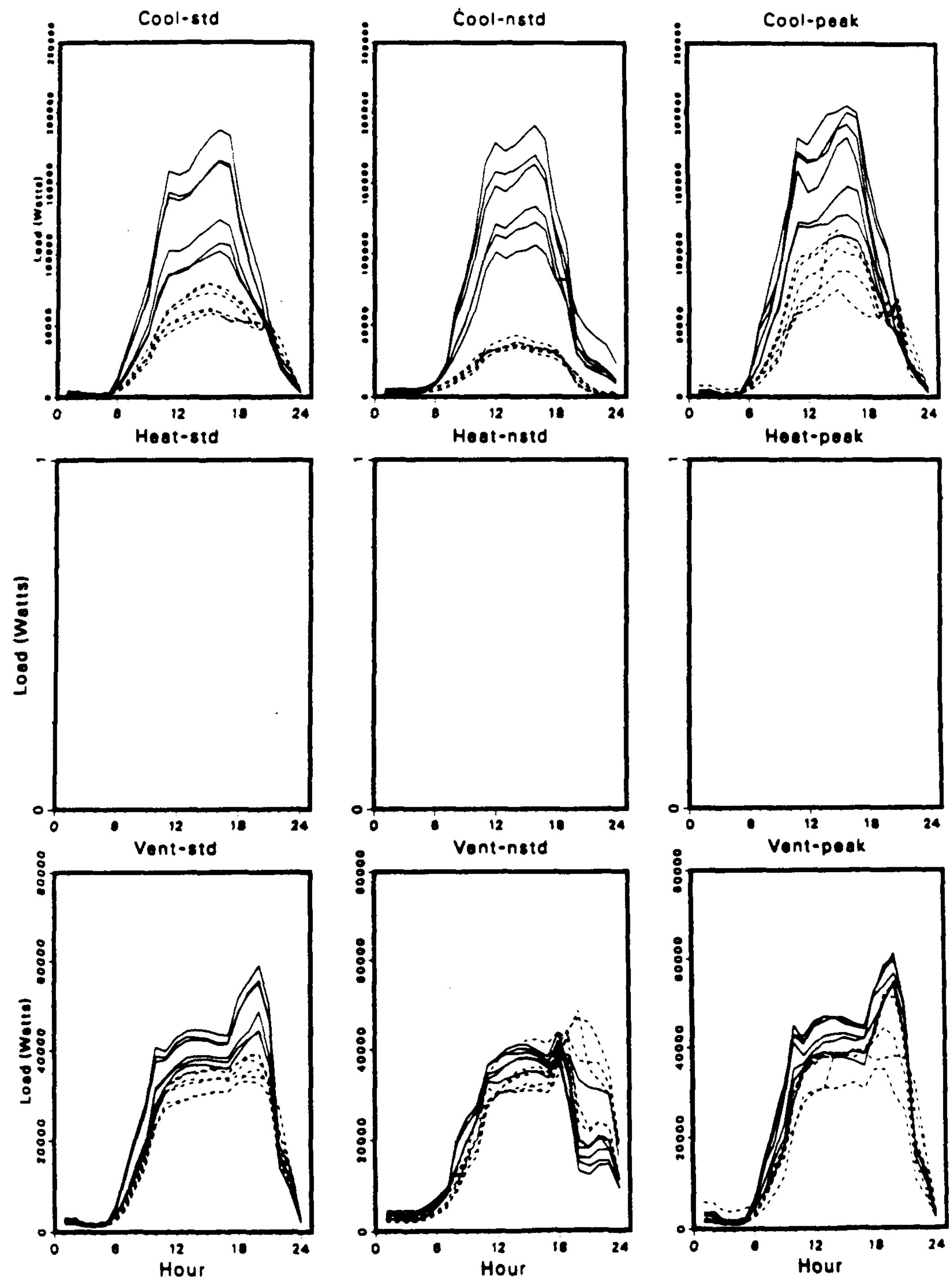


Figure VIII-27. Reconciled Monthly Load Shapes for Large Retail - Indoor and Outdoor Lighting, and Misc. Equipment in Climate Zone 2 (BUR). Solid lines are profiles for months May through October and broken lines are profiles for months November through April.

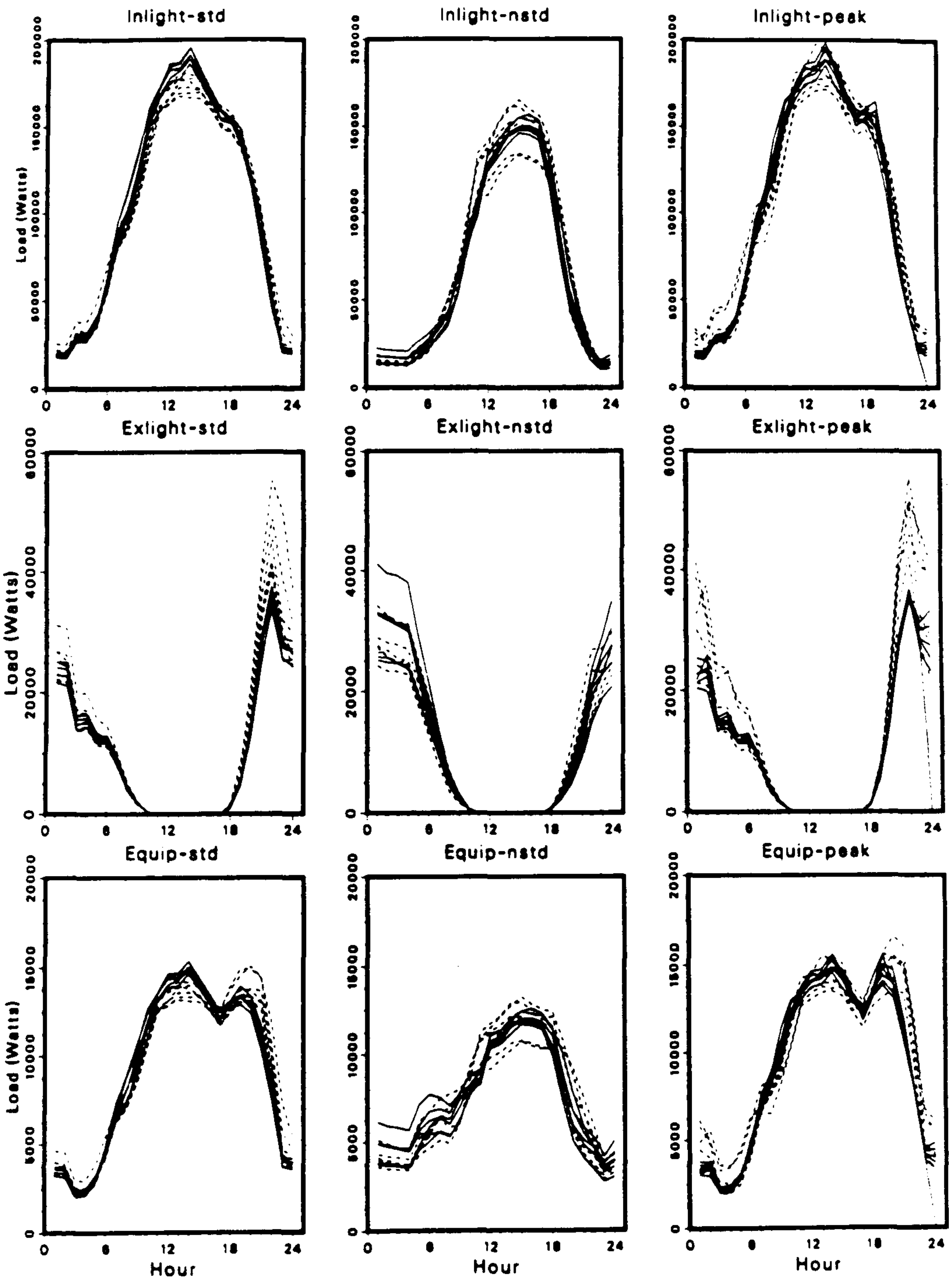
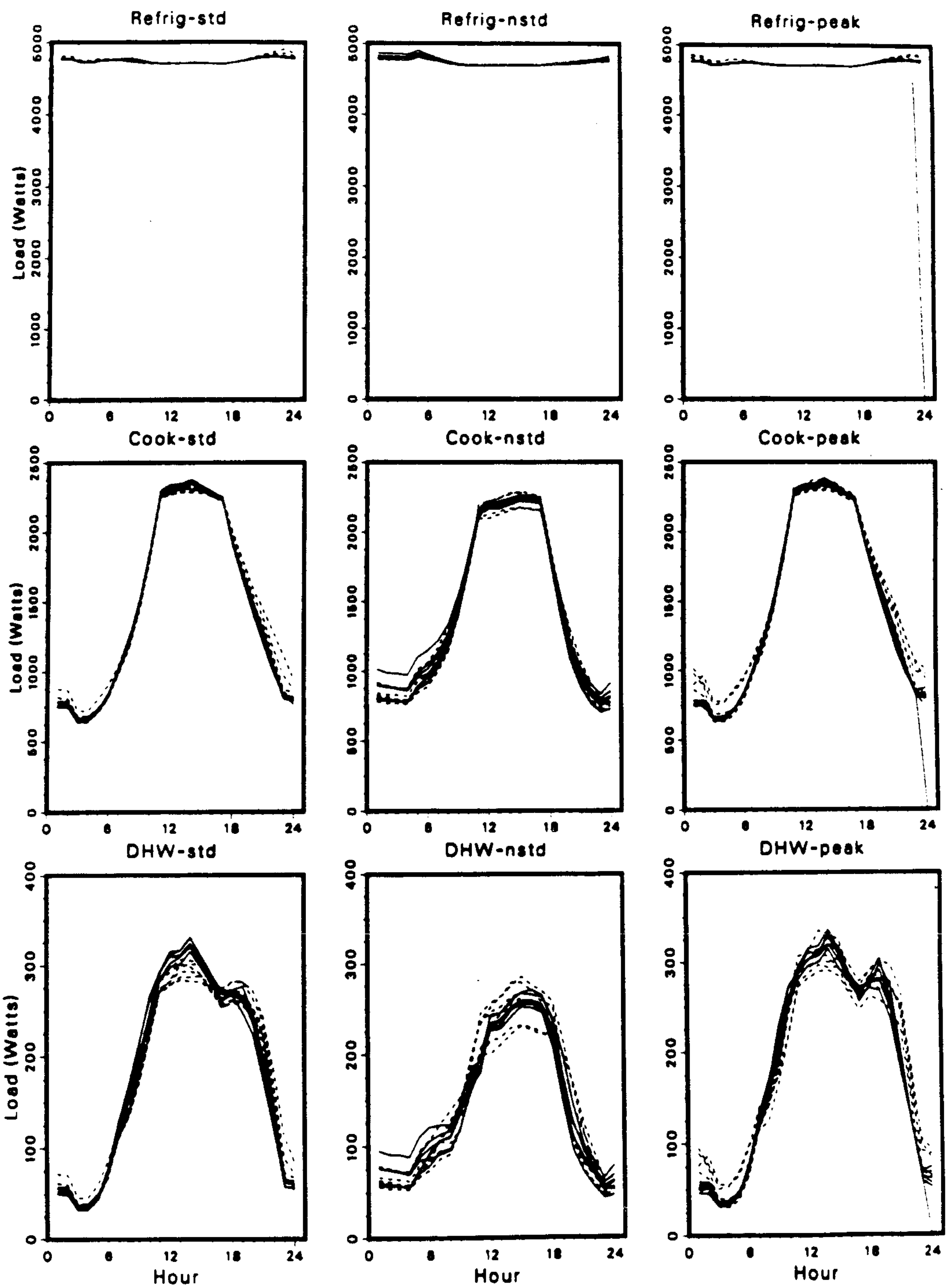


Figure VIII-28. Reconciled Monthly Load Shapes for Large Retail - Refrigeration, Cooking, and Hot Water (DHW) in Climate Zone 2 (BUR). Solid lines are profiles for months May through October and broken lines are profiles for months November through April.



Food Store

For the food store, we ran EDA for a single climate zone. For this building type, we had sufficient quantities of LRD to run EDA separately for each of the three climate zones, but the simulations of the prototype showed in no significant cooling energy in any zone. As a result, we used only a single climate zone, Hollywood-Burbank, in the weather regressions.

The reasons for insignificant cooling loads from the prototype simulation are complex but once again are related to the use of single prototype to represent a heterogeneous population of premises. The physical dimensions of our prototype represent a small building, but the refrigeration load developed from the on-site survey data appears to represent loads of larger food stores. When simulated using DOE-2, the refrigeration equipment essentially carries the entire cooling load. In our reconciliations, consequently, we allocated all weather sensitivity to the refrigeration end use. In reality, refrigeration equipment and conventional cooling equipment share the cooling load. Unfortunately, our methodology and sources of data could not make this distinction meaningfully.

Table VIII-10 summarizes major features of the food store prototype. Data from 79 on-site surveys contributed to the development of the prototype. Seven-day operation appears typical; neither the prototype (based on on-site survey data) nor the LRD indicated significant differences between standard and non-standard days. Load shapes were only developed for standard and peak days.

Table VIII-11 compares the initial EUIs by end use to the reconciled EUIs. For this building type, refrigeration energy use dominates total energy use. As discussed, we found that refrigeration equipment acted as a surrogate for conventional cooling equipment. Nevertheless, the initial estimate for refrigeration energy use was adjusted downward by EDA, and ventilation and lighting increased slightly.

Figure VIII-29 presents the standard day, adjusted whole-building load shape developed from the LRD for climate zone 2. The regression analysis of the underlying hourly loads for standard and non-standard days, winter and summer, by climate zone (presented in Appendix G) were used as input to EDA.

Inspection of this figure reveals a mismatch between the prototype and the LRD. Most on-site surveys were conducted at a time when food stores operated with fixed start and stop schedules. The LRD appear to represent a more recent practice in which food stores operate 24 hours per day. This mismatch was partially addressed with the smoothing procedures described earlier.[4]

Figure VIII-30 contains summaries of the resulting reconciled load shapes from EDA for standard and non-standard days for climate zone 2. Figures VIII-31 through VIII-33 present the average monthly reconciled load shapes by end use for standard, non-standard, and peak days.

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4 We believe our efforts were only partially successful because ventilation still roughly follows the schedule from the prototype, rather than a 24-hour schedule.

Table VIII-10. Prototype Summary - Food Store

Number of Buildings Averaged:	79
Floor Area (ft^2):	5627
Percent Conditioned:	0.51
Wall Area (ft^2):	3421
Wall R-Value (Btu/ft^2°F):	5.8
Window/Wall Ratio:	0.08
Window U-Value (Btu/ft^2°F):	1.5
Roof Area (ft^2):	4926
Roof R-Value (Btu/ft^2°F):	14.2
Standard Days/Week:	7
Standard Day Start Time:	8
Standard Day Stop Time:	17
Non-Standard Day Start Time:	0
Non-Standard Day Stop Time:	0
Heating Set Point (°F):	72.7
Cooling Set Point (°F):	74.2
Occupancy (ft^2/Person):	177.2
Lighting Intensity (W/sqft):	1.59
Total Equipment Intensity (W/sqft):	1.91
HVAC System Type:	PSZ
Supply Air Flow (CFM/ft^2):	2.22
Minimum Outside Air Fraction:	0.19
Package Cooling COP:	2.3

Table VIII-11. Electricity EUIs (kWh/ft^2-yr) - Food Store

	Indoor Lighting	Outdoor Lighting	Misc. Equip.	Refrig.	Cooking	Water Heating	Ventilation[1]	Cooling[1]	Total
Preliminary	8.14	0.63	1.09	31.19	0.97	0.16	1.61	0.19	43.10
Reconciled	11.96	2.01	1.77	23.17	0.24	0.03	2.14	0.00	40.27

1. calculated using conditioned fraction of total floor area (0.51)

Figure VIII-29. Whole-Building Load Shape for Food Store - Standard Days in Climate Zone 2 (BUR). The load shape is a weighted-average of the hourly electricity use of individual load research buildings, and adjusted so that the annual building energy use derived from the load profile matches the annual bill from the on-site survey data. The plot shows the minimum, 25%-quartile, mean, 75%-quartile, and maximum hourly values; the line represents the mean hourly profile.

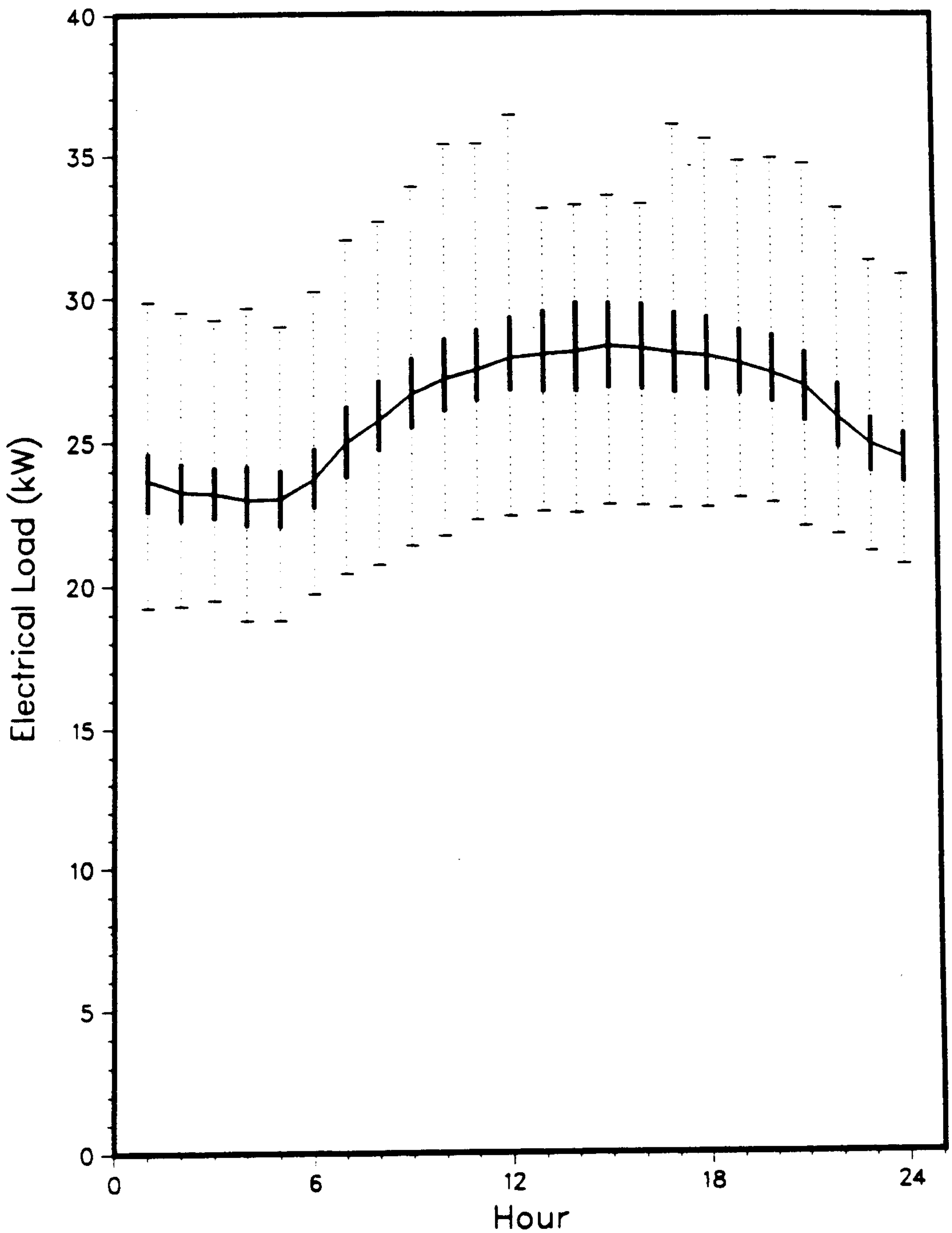
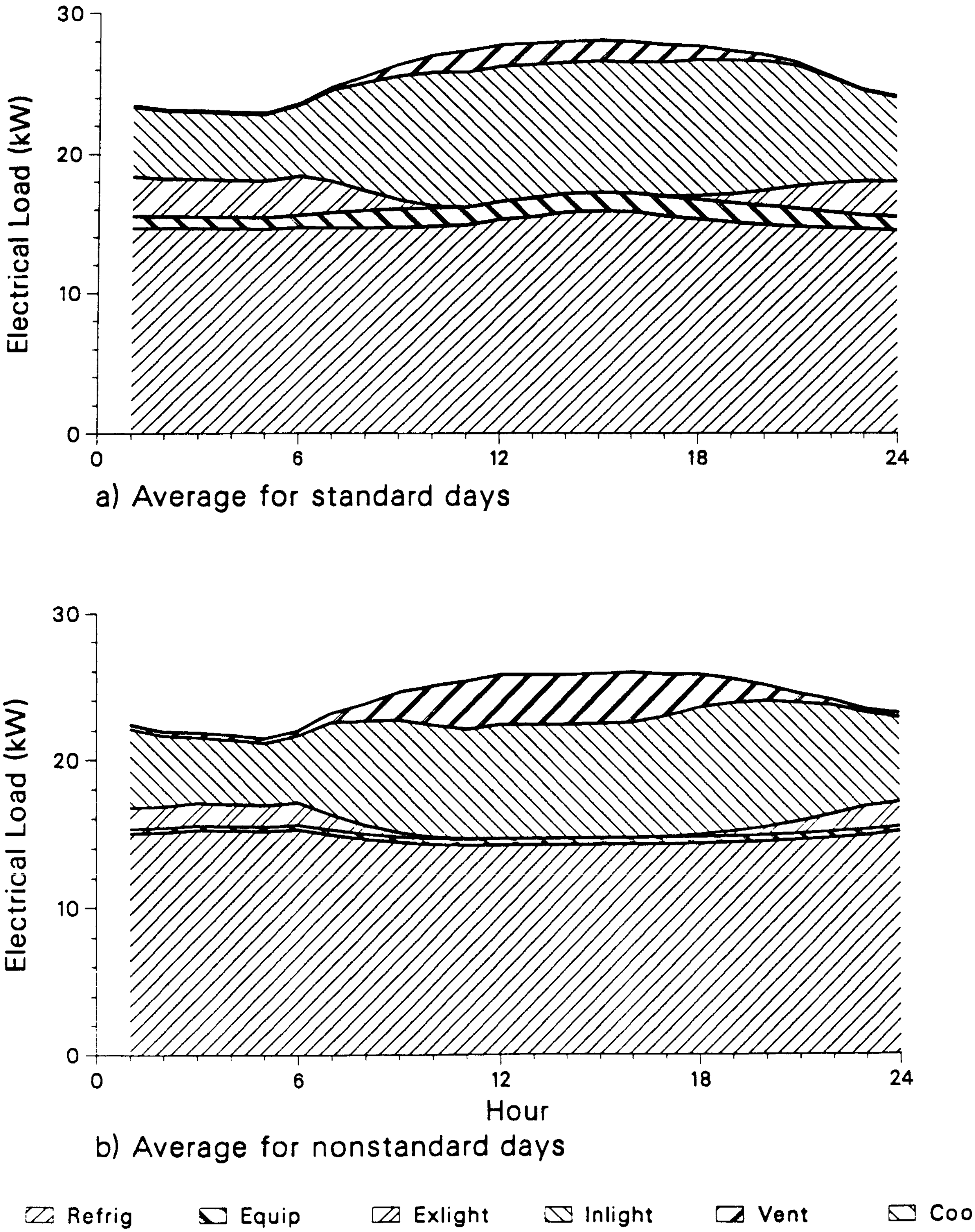


Figure VIII-30. Summary of Reconciled Load Shapes for Food Store in Climate Zone 2 (BUR)



food2

Figure VIII-31. Reconciled Monthly Load Shapes for Food Store - Cooling and Ventilation in Climate Zone 2 (BUR). Solid lines are profiles for months May through October and broken lines are profiles for months November through April.

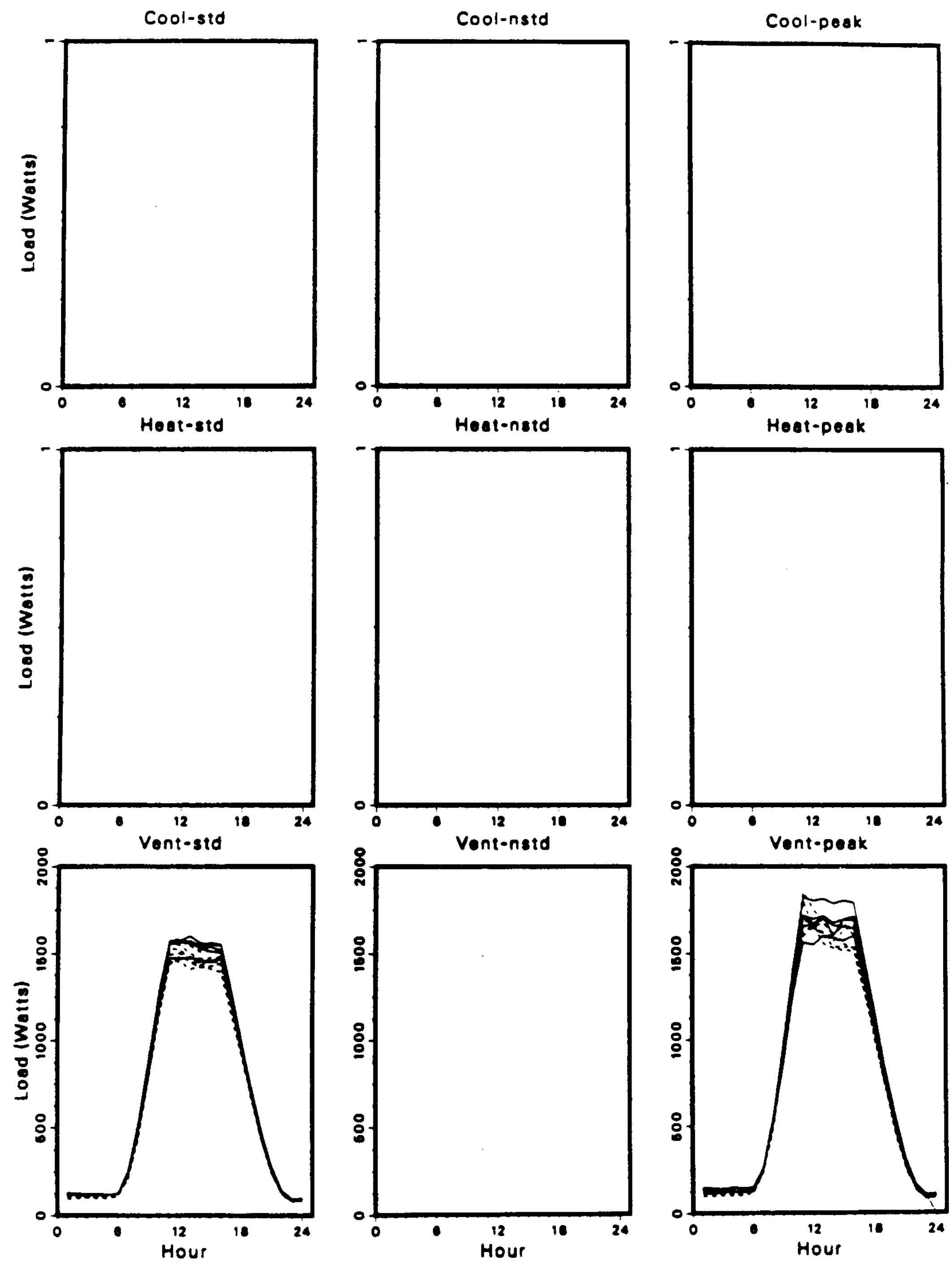


Figure VIII-32. Reconciled Monthly Load Shapes for Food Store - Indoor and Outdoor Lighting, and Misc. Equipment in Climate Zone 2 (BUR). Solid lines are profiles for months May through October and broken lines are profiles for months November through April.

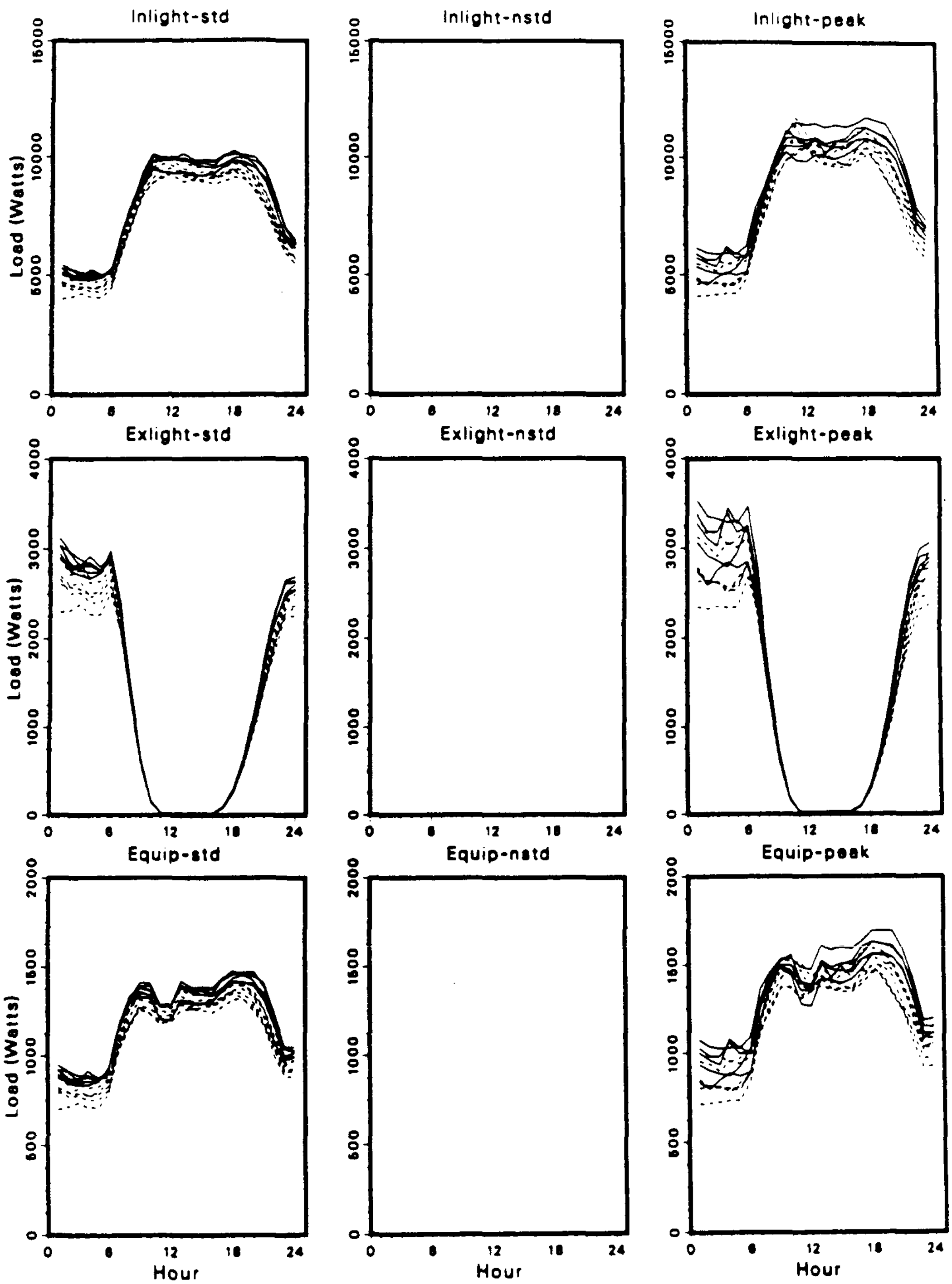
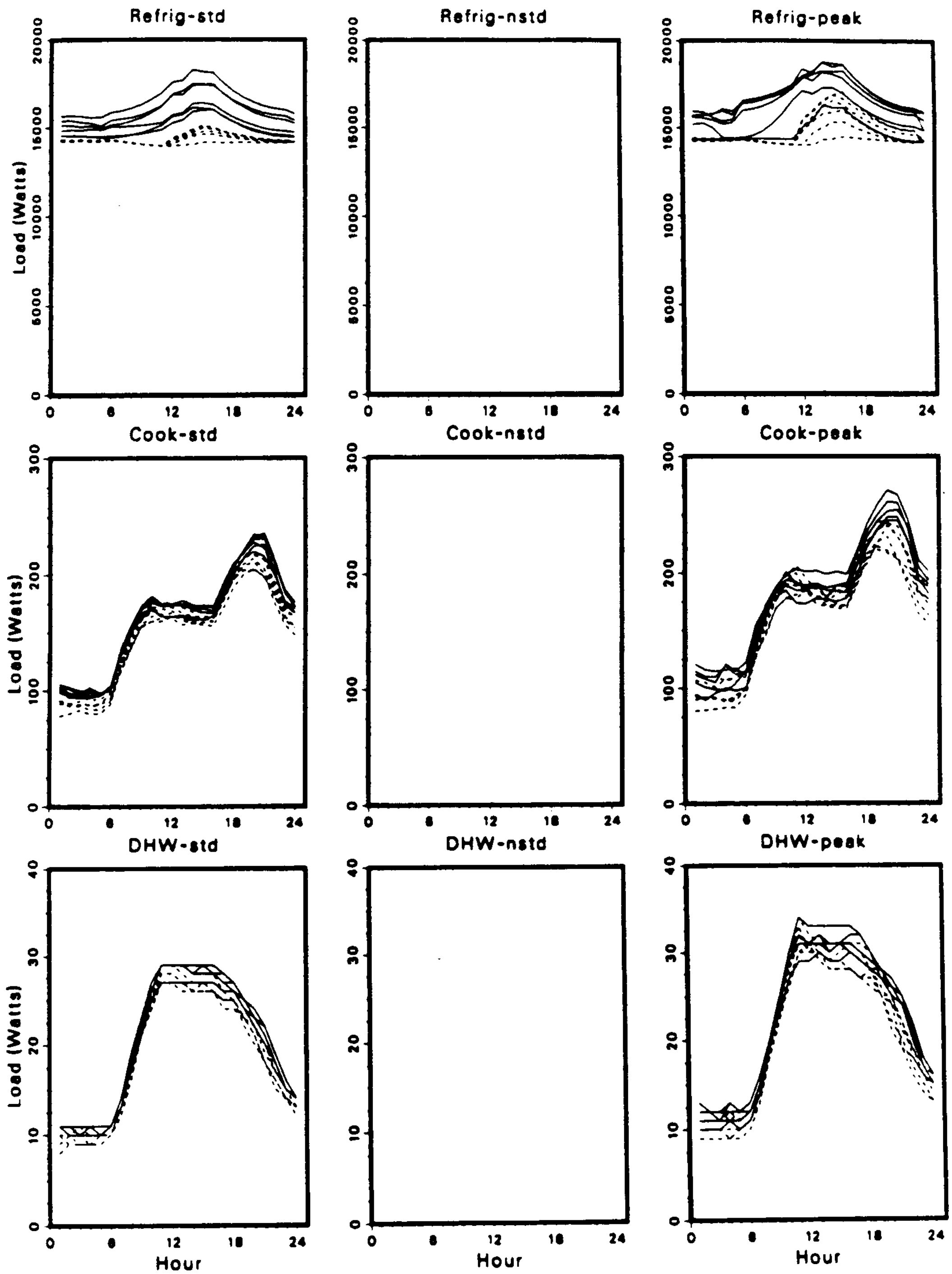


Figure VIII-33. Reconciled Monthly Load Shapes for Food Store - Refrigeration, Cooking, and Hot Water (DHW) in Climate Zone 2 (BUR). Solid lines are profiles for months May through October and broken lines are profiles for months November through April.



Refrigerated Warehouse

For the refrigerated warehouse, we ran EDA for a single climate zone, Hollywood-Burbank. Our analysis for this building type was especially limited by the absence of data. Only five on-site surveys were available for prototype development, and only 20 LRD accounts were used in whole-building load shape development.

Table VIII-12 summarizes major features of the refrigerated warehouse prototype. Development of the prototype for premises of this type assumed limited interaction between the areas conditioned by conventional HVAC equipment and those conditioned by refrigeration equipment (in contrast to food stores where we assumed open casework tightly coupled the two types of systems). As a result we found small but significant cooling energy use (for the conventional HVAC system) and were able to develop reconciled cooling EUIs.

Table VIII-13 compares the initial EUIs by end use to the reconciled EUIs. As described in the overview, the preliminary total EUI was significantly larger than the average electricity bill. As a result, the preliminary EUIs were adjusted downward by the reconciliation process.

Figure VIII-34 presents the standard day, adjusted whole-building load shape developed from the LRD for climate zone 2. The regression analysis of the underlying hourly loads for standard and non-standard days, winter and summer, by climate zone (presented in Appendix G) were used as input to EDA. Figure VIII-35 contains summaries of the resulting reconciled load shapes from EDA for standard and non-standard days for climate zone 2. Although our prototype analysis suggested two separate day types of operation, the whole-building loads were quite similar for the two day types. As with the food store, this result was not surprising given the dominating influence of the equipment and refrigeration loads.

Figures VIII-36 through VIII-38 present the average monthly reconciled load shapes by end use for standard, non-standard, and peak days. Inspection of the winter standard day cooling and ventilation load shapes indicates a tight link between these two end uses. Cooling loads appear to dip early in the day, while ventilation loads appear to increase. This observation reinforces the degree to which distinctions between these two end uses can in some cases be somewhat arbitrary as both are jointly providing the same energy service.

For this building type, we were unable to fully resolve discontinuities between operating and non-operating hour energy use for miscellaneous equipment. Off-hour levels tended to exceed on-hour levels. The source of this discontinuity is probably related to the very unrealistic non-standard day hot water heating load shape.

Table VIII-12. Prototype Summary - Refrigerated Warehouse

Number of Buildings Averaged:	5
Floor Area (ft^2):	18980
Percent Conditioned:	0.60
Wall Area (ft^2):	6461
Wall R-Value (Btu/ft^2°F):	4.2
Window/Wall Ratio:	0.02
Window U-Value (Btu/ft^2°F):	1.5
Roof Area (ft^2):	17581
Roof R-Value (Btu/ft^2°F):	8.1
Standard Days/Week:	5
Standard Day Start Time:	5
Standard Day Stop Time:	17
Non-Standard Day Start Time:	6
Non-Standard Day Stop Time:	13
Heating Set Point (°F):	66.1
Cooling Set Point (°F):	70.8
Occupancy (ft^2/Person):	320.8
Lighting Intensity (W/sqft):	1.04
Total Equipment Intensity (W/sqft):	6.18
HVAC System Type:	PSZ
Supply Air Flow (CFM/ft^2):	3.07
Minimum Outside Air Fraction:	0.02
Package Cooling COP:	2.2

Table VIII-13. Electricity EUIs (kWh/ft^2-yr) - Refrigerated Warehouse

	Indoor Lighting	Outdoor Lighting	Misc. Equip.	Refrig.	Cooking	Water Heating	Ventilation[1]	Cooling[1]	Total
Preliminary	4.08	0.57	23.02	34.06	0.12	0.58	3.37	12.30	71.83
Reconciled	3.02	0.55	6.24	11.34	0.01	0.17	1.50	2.82	23.91

1. calculated using conditioned fraction of total floor area (0.18)

Figure VIII-34. Whole-Building Load Shape for Refrigerated Warehouse - Standard Days in Climate Zone 2 (BUR). The load shape is a weighted-average of the hourly electricity use of individual load research buildings, and adjusted so that the annual building energy use derived from the load profile matches the annual bill from the on-site survey data. The plot shows the minimum, 25%-quartile, mean, 75%-quartile, and maximum hourly values; the line represents the mean hourly profile.

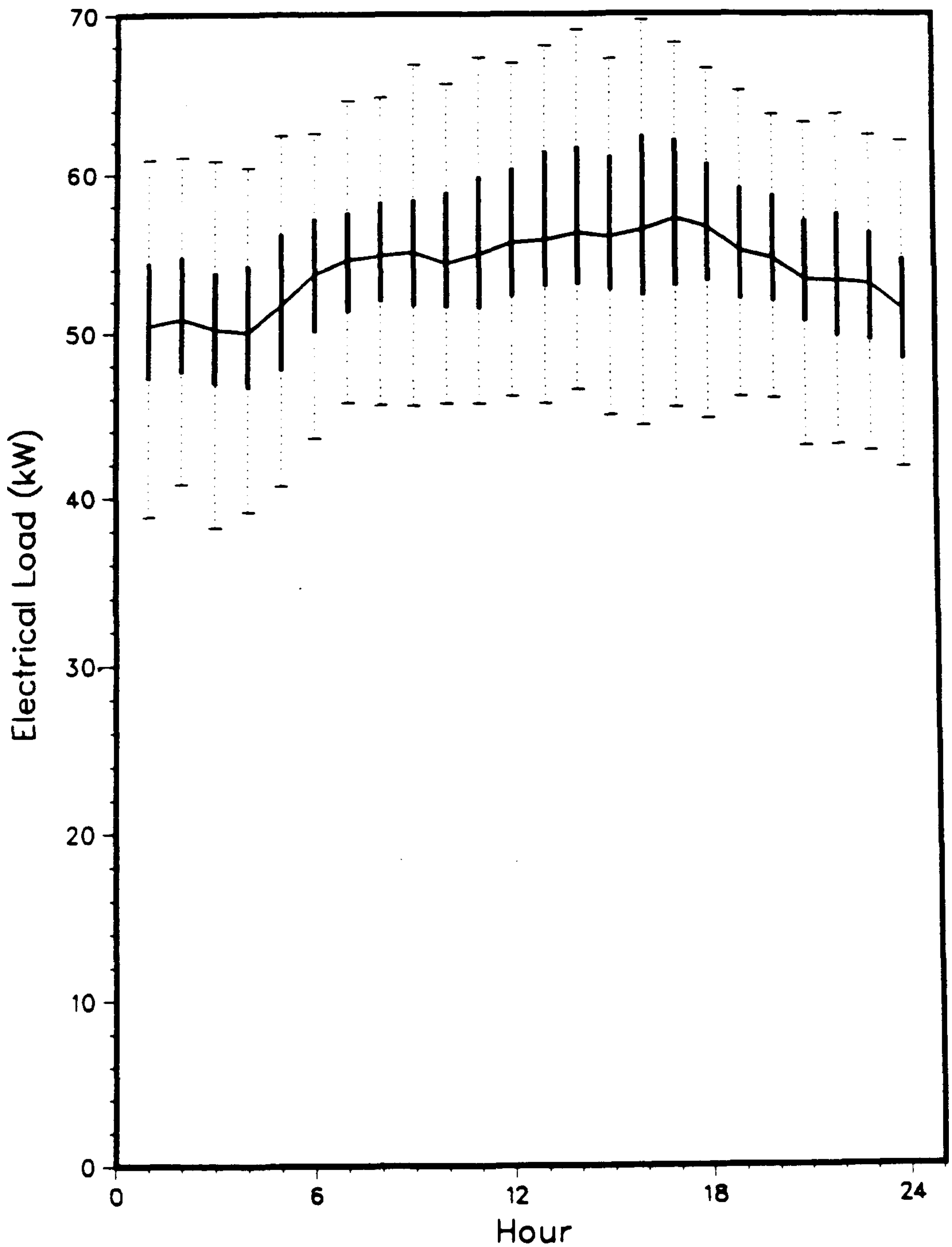
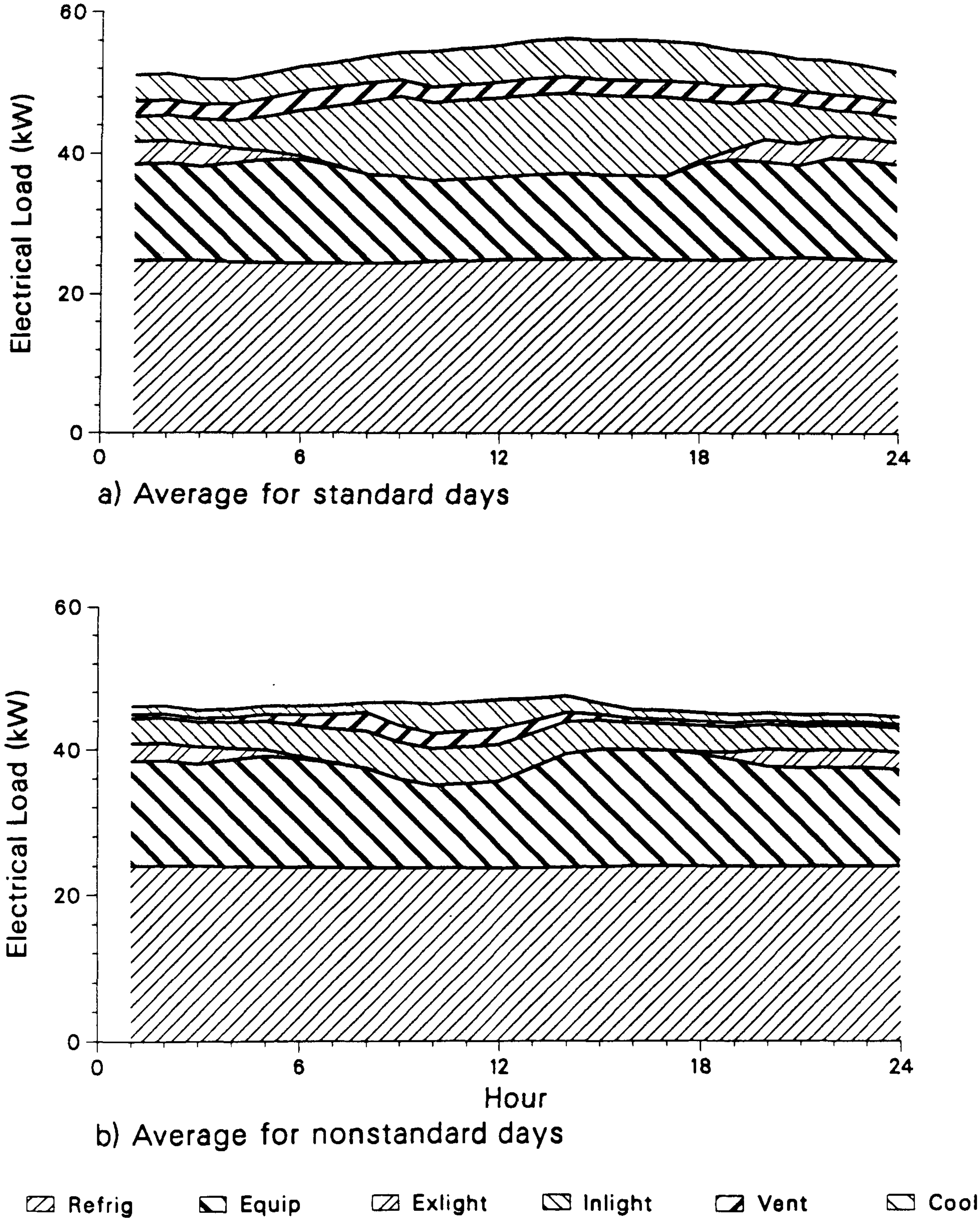


Figure VIII-35. Summary of Reconciled Load Shapes for Refrigerated Warehouse in Climate Zone 2 (BUR)



refware2

Figure VIII-36. Reconciled Monthly Load Shapes for Refrigerated Warehouse - Cooling and Ventilation in Climate Zone 2 (BUR). Solid lines are profiles for months May through October and broken lines are profiles for months November through April.

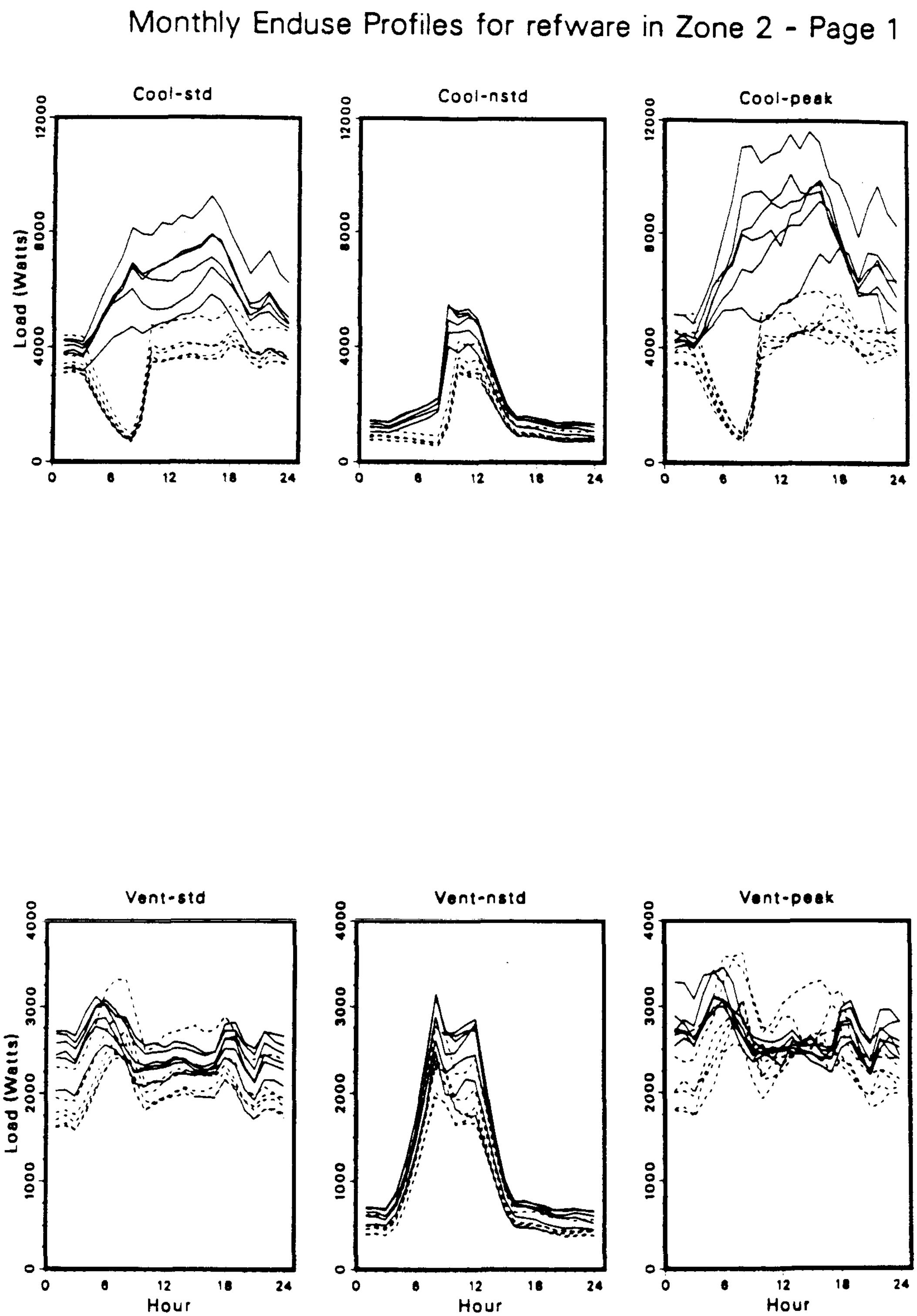


Figure VIII-37. Reconciled Monthly Load Shapes for Refrigerated Warehouse - Indoor and Outdoor Lighting, and Misc. Equipment in Climate Zone 2 (BUR). Solid lines are profiles for months May through October and broken lines are profiles for months November through April.

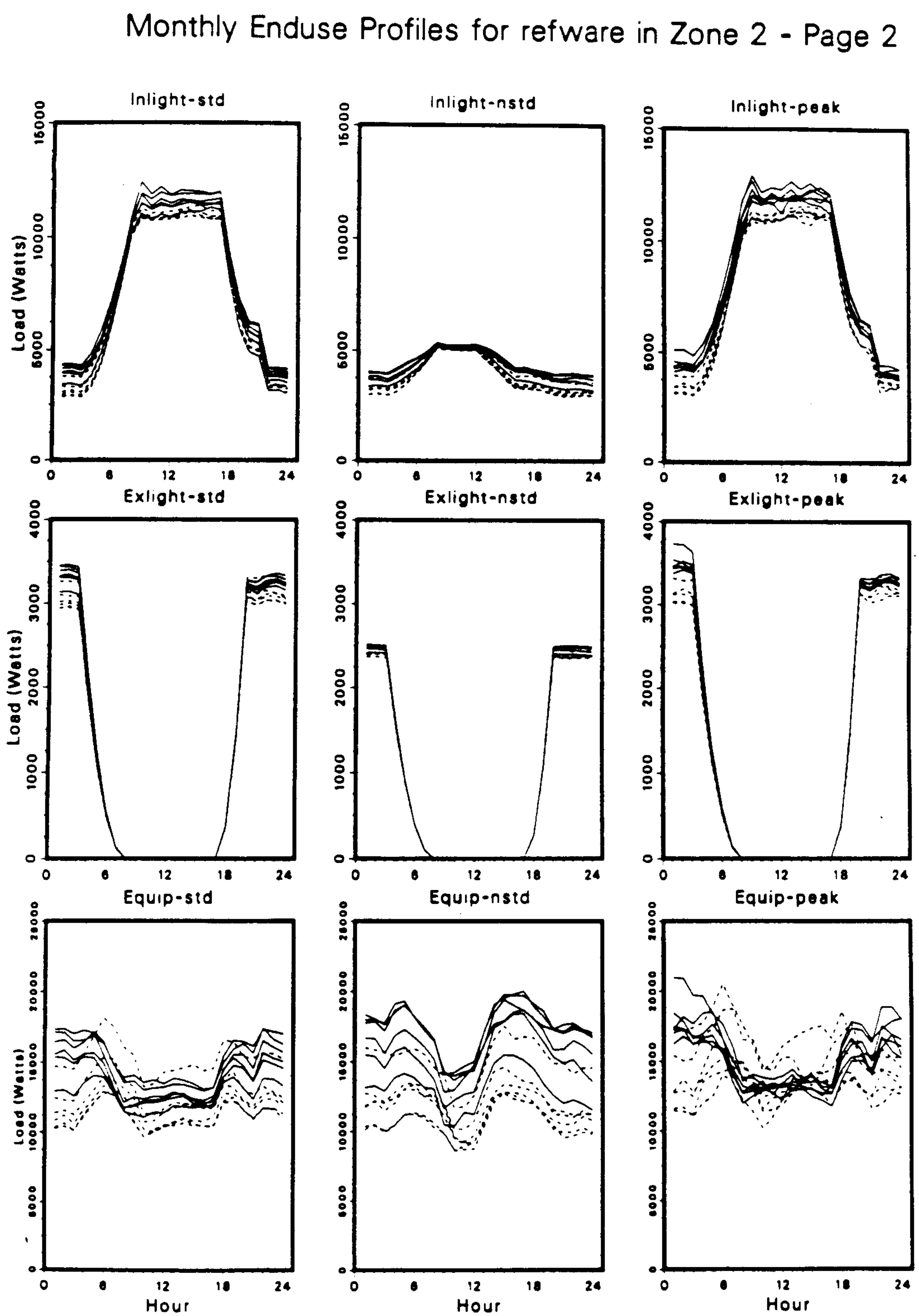
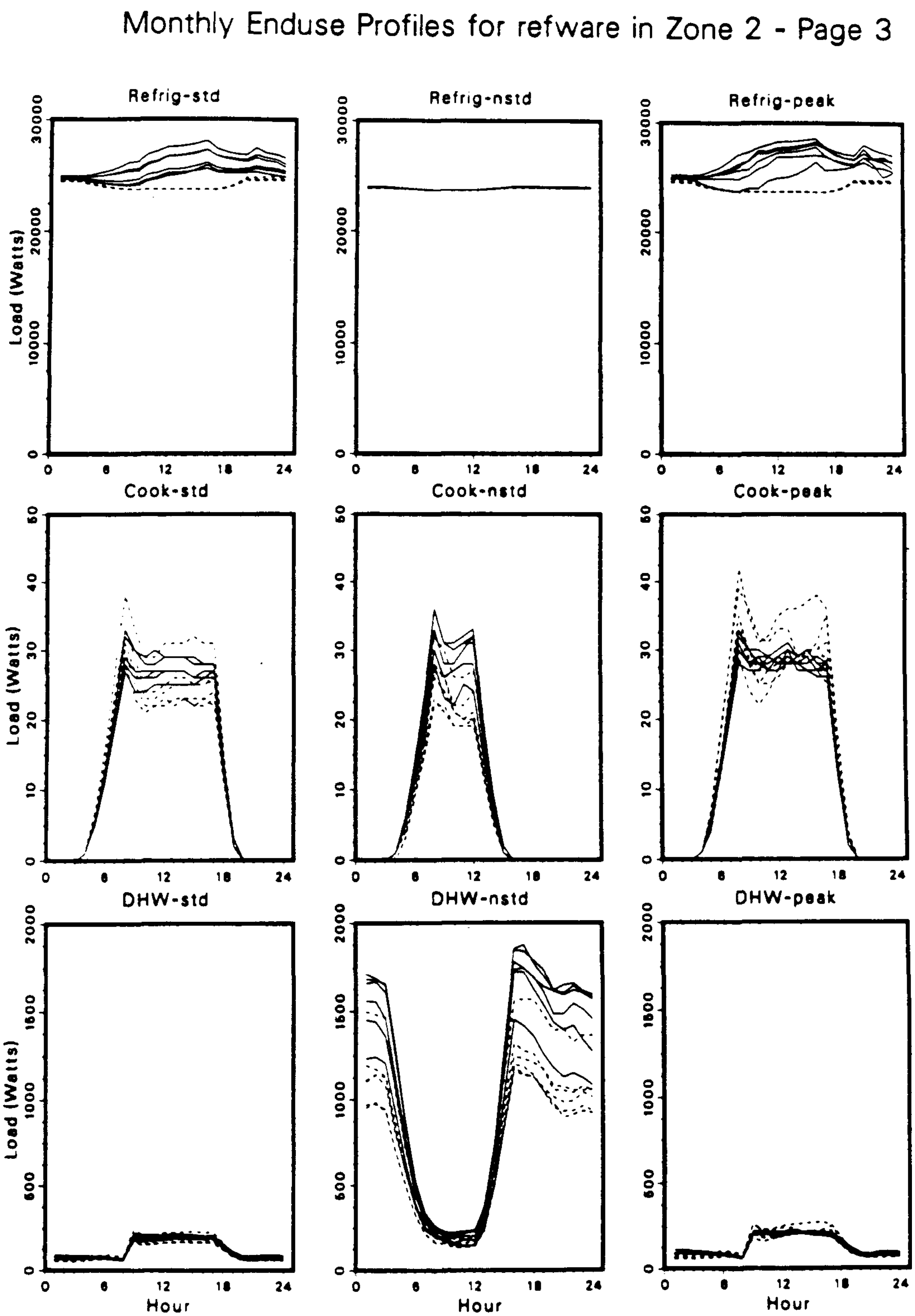


Figure VIII-38. Reconciled Monthly Load Shapes for Refrigerated Warehouse - Refrigeration, Cooking, and Hot Water (DHW) in Climate Zone 2 (BUR). Solid lines are profiles for months May through October and broken lines are profiles for months November through April.



Non-Refrigerated Warehouse

For the non-refrigerated warehouse we ran EDA for a single climate zone, Hollywood-Burbank because insufficient quantities of LRD precluded separate analysis for individual climate zones.

Table VIII-14 summarizes major features of the non-refrigerated warehouse prototype. Data from 14 on-site surveys contributed to the development of the prototype.

Table VIII-15 compares the initial EUIs by end use to the reconciled EUIs. The preliminary total EUI was greater than the average electricity bill, so the trend from the reconciliation was downward. An exception was lighting.

Figure VIII-38 presents the standard day, adjusted whole-building load shape developed from the LRD for climate zone 2. The regression analysis of the underlying hourly loads for standard and non-standard days, winter and summer, by climate zone (presented in Appendix G) were used as input to EDA. Figure VIII-39 contains summaries of the resulting reconciled load shapes from EDA for standard and non-standard days for climate zone 2. Figures VIII-40 through VIII-43 present the average monthly reconciled load shapes by end use for standard, non-standard, and peak days.

The load shapes for these premises revealed the non-refrigerated warehouse to be the most well-scheduled of types of premises. Well-defined lunch hours and reduced operating levels on non-standard days were easily identified in the LRD. Although lunch-time reductions were evident in the reconciled load shapes for cooling in summer, they were less identifiable for winter cooling loads.

The cooking load shape is so small that our results are not significantly different from zero. As an EUI, the value is smaller than the minimum used in our presentations (i.e., 0.01 $kWh/ft^2.yr$) and, as a load shape, it is at the limits of the resolution of our graphing capabilities, 1 W for the whole building.

Table VIII-14. Prototype Summary - Non-Refrigerated Warehouse

Number of Buildings Averaged:	14
Floor Area (ft^2):	25702
Percent Conditioned:	0.18
Wall Area (ft^2):	6530
Wall R-Value (Btu/ft^2°F):	6.5
Window/Wall Ratio:	0.09
Window U-Value (Btu/ft^2°F):	1.5
Roof Area (ft^2):	13340
Roof R-Value (Btu/ft^2°F):	10.1
Standard Days/Week:	6
Standard Day Start Time:	7
Standard Day Stop Time:	18
Non-Standard Day Start Time:	0
Non-Standard Day Stop Time:	24
Heating Set Point (°F):	71.4
Cooling Set Point (°F):	74.0
Occupancy (ft^2/Person):	1371.4
Lighting Intensity (W/sqft):	0.64
Total Equipment Intensity (W/sqft):	0.24
HVAC System Type:	PSZ
Supply Air Flow (CFM/ft^2):	1.88
Minimum Outside Air Fraction:	0.10
Package Cooling COP:	2.3

Table VIII-15. Electricity EUIs (kWh/ft^2-yr) - Non-Refrigerated Warehouse

Indoor Lighting	Outdoor Lighting	Misc. Equip.	Refrig.	Cooking	Water Heating	Ventilation[1]	Cooling[1]	Total
Preliminary								
3.01	0.15	0.66	0.83	1.07	0.03	0.53	2.18	6.24
Reconciled								
3.38	0.17	0.70	0.41	0.00	0.03	0.62	1.16	5.02

1. calculated using conditioned fraction of total floor area (0.60)

Figure VIII-39. Whole-Building Load Shape for Non-Refrigerated Warehouse - Standard Days in Climate Zone 2 (BUR). The load shape is a weighted-average of the hourly electricity use of individual load research buildings, and adjusted so that the annual building energy use derived from the load profile matches the annual bill from the on-site survey data. The plot shows the minimum, 25%-quartile, mean, 75%-quartile, and maximum hourly values; the line represents the mean hourly profile.

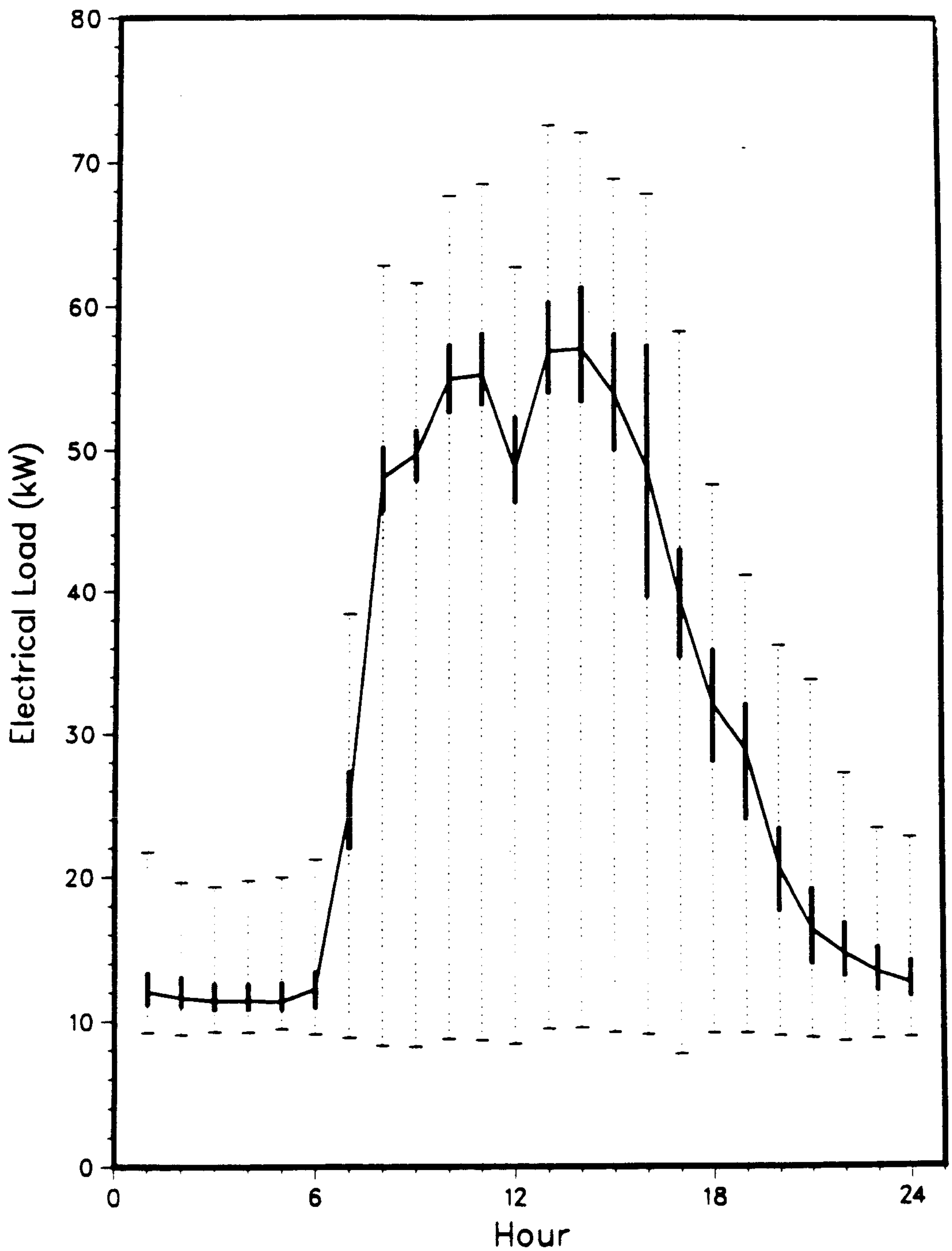
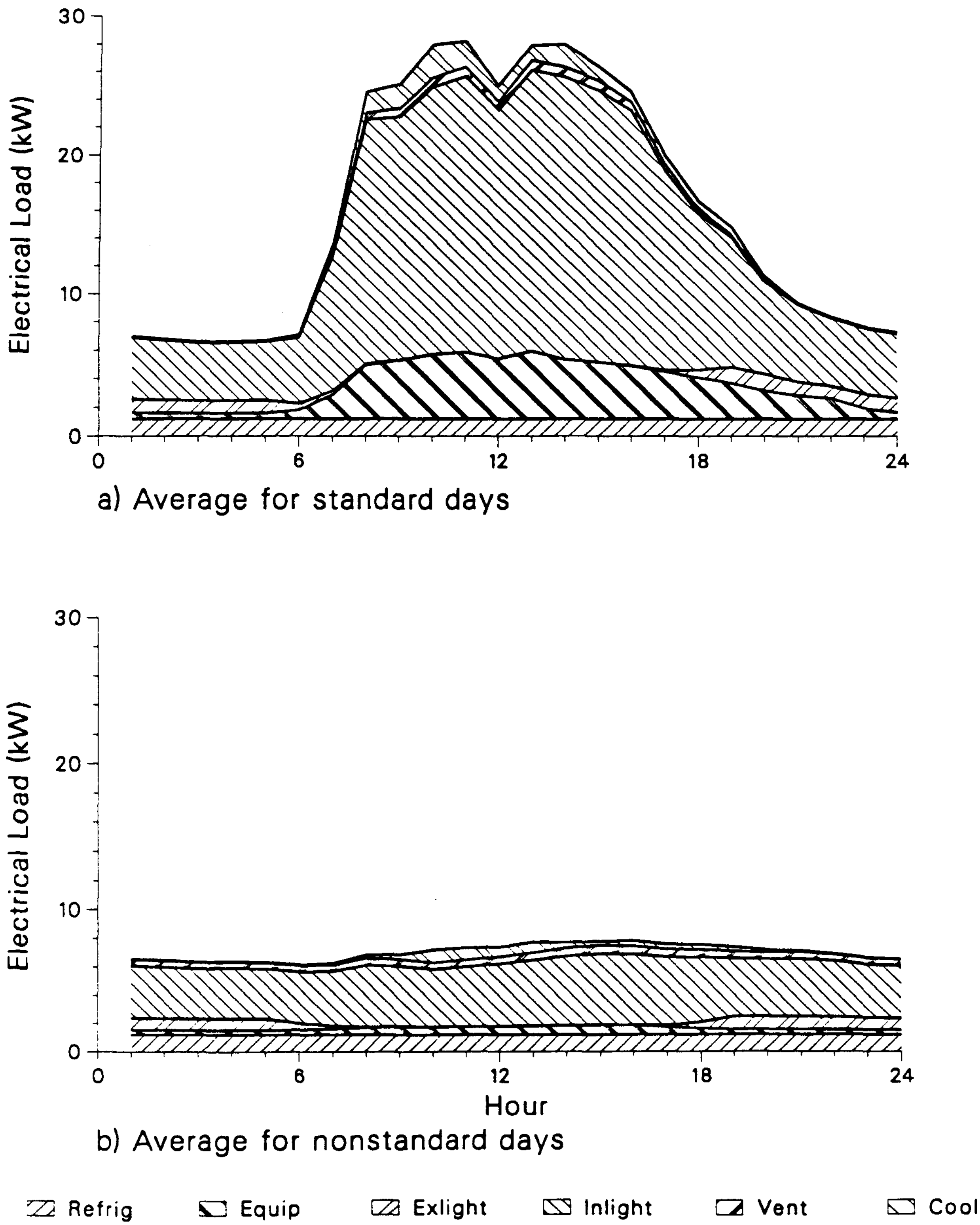


Figure VIII-40. Summary of Reconciled Load Shapes for Non-Refrigerated Warehouse in Climate Zone 2 (BUR)



nonrefware2

Figure VIII-41. Reconciled Monthly Load Shapes for Non-Refrigerated Warehouse - Cooling and Ventilation in Climate Zone 2 (BUR). Solid lines are profiles for months May through October and broken lines are profiles for months November through April.

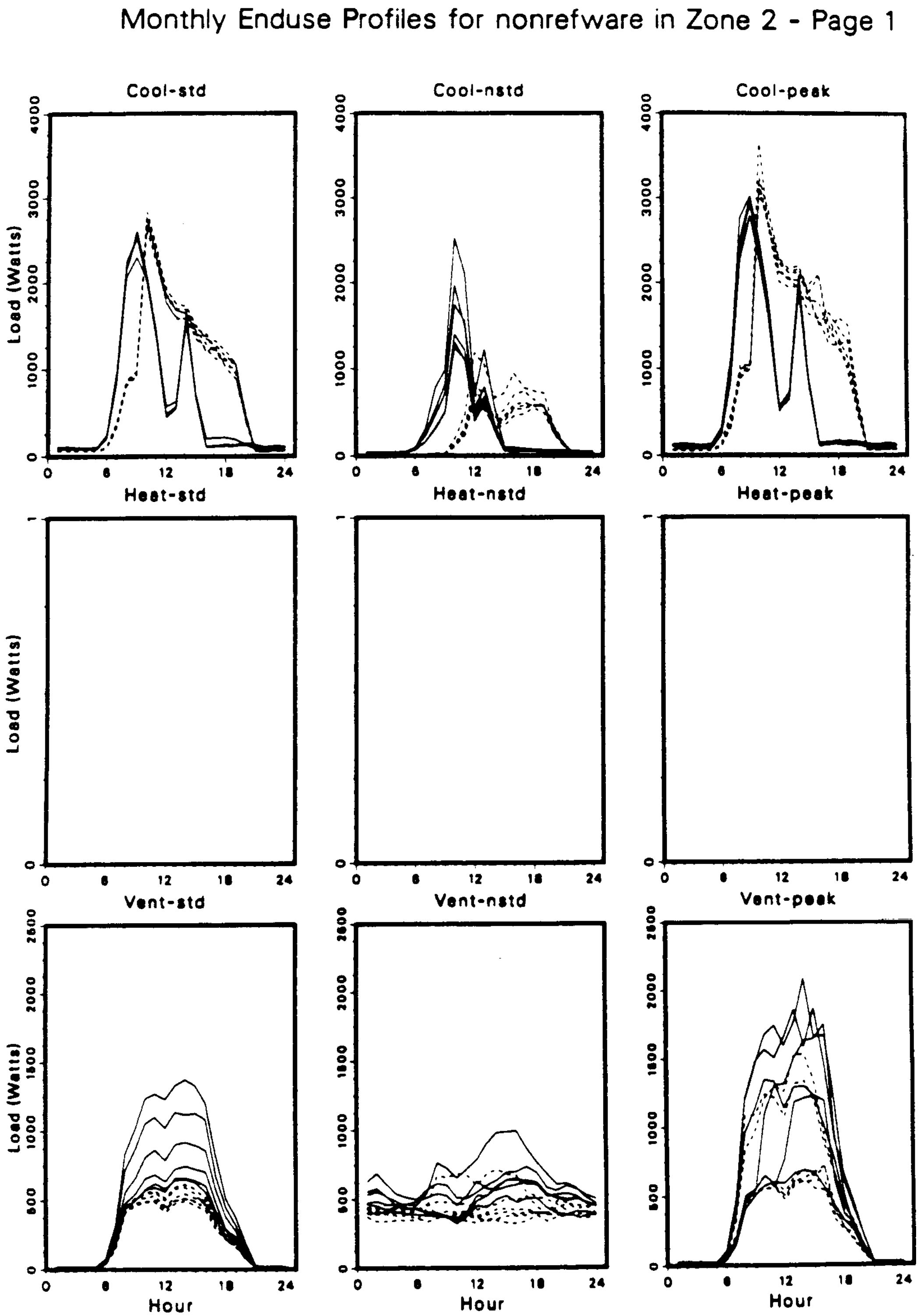


Figure VIII-42. Reconciled Monthly Load Shapes for Non-Refrigerated Warehouse - Indoor and Outdoor Lighting, and Misc. Equipment in Climate Zone 2 (BUR). Solid lines are profiles for months May through October and broken lines are profiles for months November through April.

Monthly Enduse Profiles for nonrefware in Zone 2 - Page 2

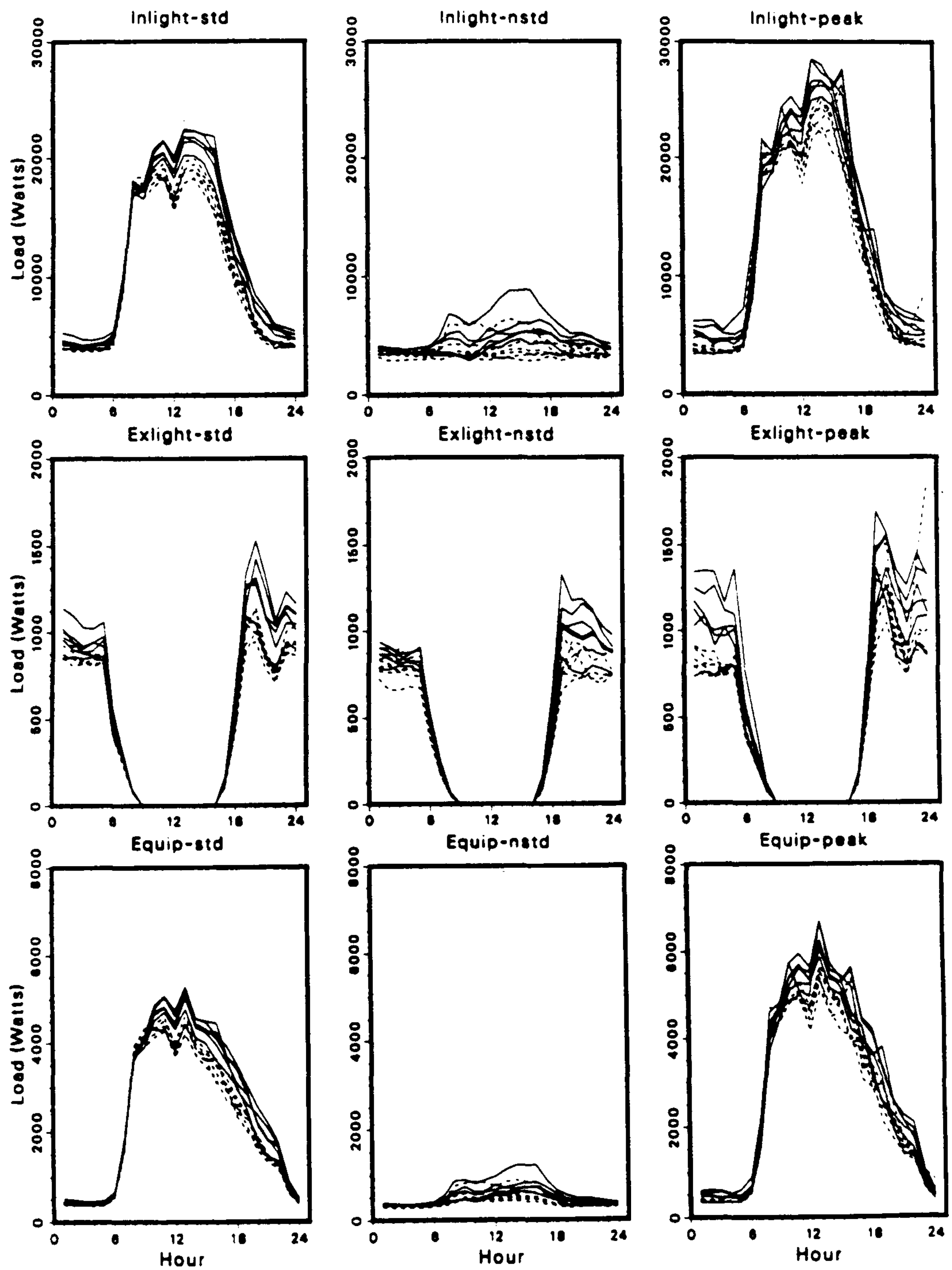
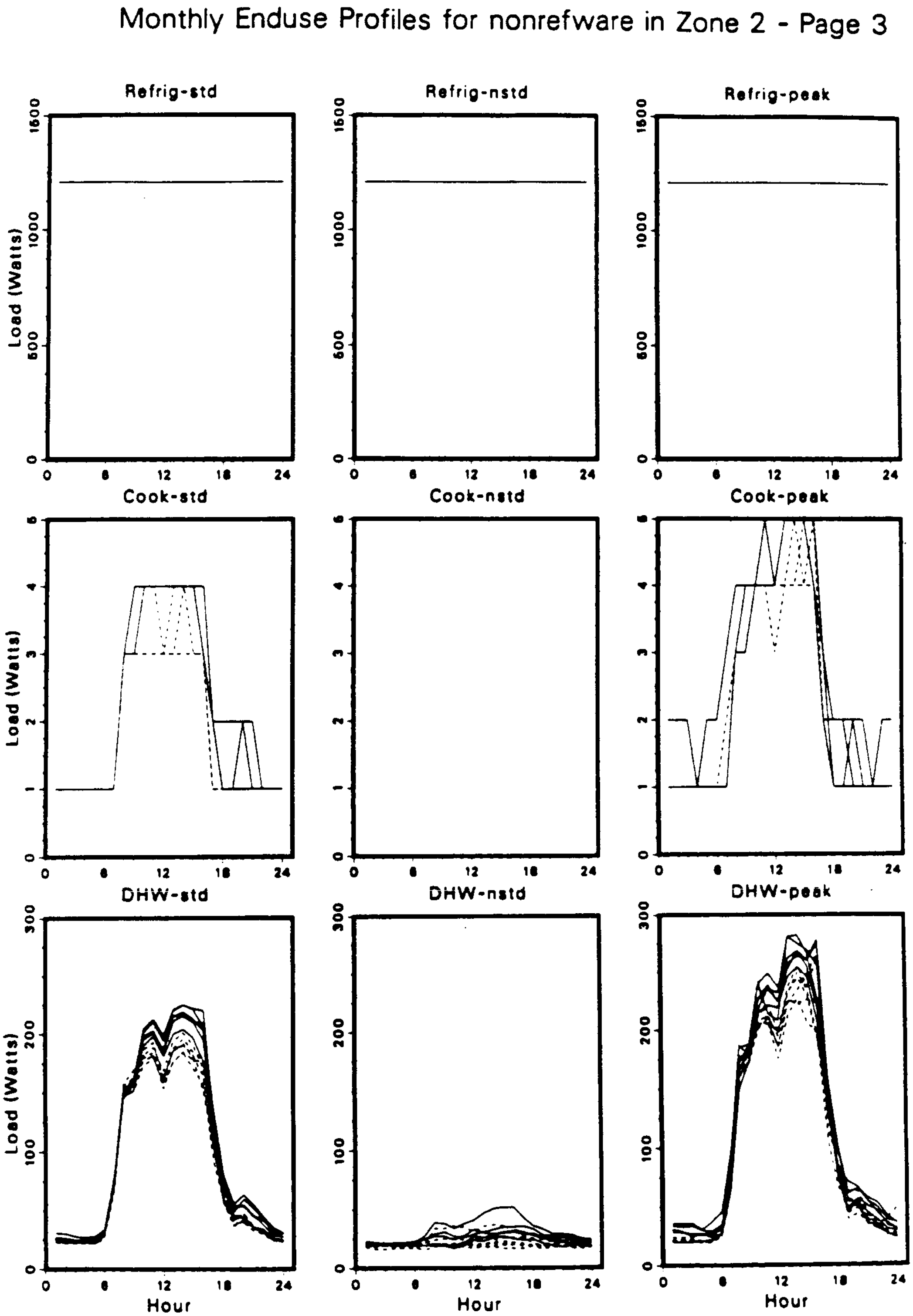


Figure VIII-43. Reconciled Monthly Load Shapes for Non-Refrigerated Warehouse - Refrigeration, Cooking, and Hot Water (DHW) in Climate Zone 2 (BUR). Solid lines are profiles for months May through October and broken lines are profiles for months November through April.



Restaurant

For the restaurant, we ran EDA for a single climate zone for a hybrid set of initial conditions (preliminary LSs and weighted average electricity bills). The LRD sample for restaurants was the smallest of all building types examined (seven total, see Task I). Within that sample, we were unable to distinguish sitdown from fastfood restaurants. As a result, we combined our preliminary LSs and the weighted average electricity bills for these two building types into a single set of LSs and a single measured total EUI for use as input to EDA. The aggregation of sitdown and fastfood relied on the 1985 SCE Commercial Sector Mail Survey to determine the relative population of the two types of restaurants (63% sitdown and 37% fastfood).[1] As a result of this weighting process, the total and conditioned floor area of the newly created hybrid became 3,804 ft^2 total floor area, of which 76% is conditioned. The weather regressions were performed using data from the Hollywood-Burbank Airport.

Tables VIII-16 and VIII-17 summarize major features of the sitdown and fastfood restaurant prototypes. Data from 64 and 22 on-site surveys contributed to the development of these prototype, respectively.

Table VIII-18 compares the initial EUIs by end use to the reconciled EUIs. Lighting, miscellaneous equipment, and ventilation increased through the reconciliation process, while refrigeration, cooking, water heating, and cooling decreased. Again, cooling and ventilation are probably better thought of as a single end use from the standpoint of reconciliation, in which case the reconciled totals are close to the preliminary total.

Figure VIII-44 presents the standard day, adjusted whole-building load shape developed from the LRD for climate zone 2. The regression analysis of the underlying hourly loads for standard and non-standard days, winter and summer, by climate zone (presented in Appendix G) were used as input to EDA. Figure VIII-45 contains summaries of the resulting reconciled load shapes from EDA for standard and non-standard days for climate zone 2. Figures VIII-46 through VIII-48 present the average monthly reconciled load shapes by end use for standard, non-standard, and peak days.

Time constraints precluded application of the smoothing procedure. As a result, load shapes for several end uses exhibit anomalous spikes. We also have not adjusted the cooling schedules to match the ventilation schedule. The result is that in the late evening hours, when cooling goes to zero, indoor lighting and miscellaneous equipment, and to a lesser extent, cooking and hot water heating energy use increase so that the reconciled total equals the whole-building load shape.

Table VIII-16. Prototype Summary - Sitdown Restaurant

Number of Buildings Averaged:	64
Floor Area (ft^2):	5252
Percent Dining Area (ft^2):	0.78
Wall Area (ft^2):	4336
Wall R-Value (Btu/ft^2°F):	6.6
Window/Wall Ratio:	0.12
Window U-Value (Btu/ft^2°F):	1.4
Roof Area (ft^2):	4643
Roof R-Value (Btu/ft^2°F):	12.8
Standard Days/Week:	6
Standard Day Start Time:	8
Standard Day Stop Time:	21
Non-Standard Day Start Time:	10
Non-Standard Day Stop Time:	1
Heating Set Point (°F):	71.7
Cooling Set Point (°F):	74.5
Occupancy (ft^2/Person):	69.3
Lighting Intensity (W/sqft):	1.09
Total Equipment Intensity (W/sqft):	5.35
HVAC System Type:	PSZ
Supply Air Flow (CFM/ft^2):	1.45
Minimum Outside Air Fraction:	0.40
Package Cooling COP:	2.2

Table VIII-17. Prototype Summary - Fastfood Restaurant

Number of Buildings Averaged:	22
Floor Area (ft^2):	1391
Percent Dining Area (ft^2):	0.66
Wall Area (ft^2):	2698
Wall R-Value (Btu/ft^2°F):	5.6
Window/Wall Ratio:	0.08
Window U-Value (Btu/ft^2°F):	1.4
Roof Area (ft^2):	1331
Roof R-Value (Btu/ft^2°F):	9.1
Standard Days/Week:	6
Standard Day Start Time:	9
Standard Day Stop Time:	20
Non-Standard Day Start Time:	11
Non-Standard Day Stop Time:	1
Heating Set Point (°F):	68.0
Cooling Set Point (°F):	73.5
Occupancy (ft^2/Person):	81.5
Lighting Intensity (W/sqft):	1.38
Total Equipment Intensity (W/sqft):	5.11
HVAC System Type:	PSZ
Supply Air Flow (CFM/ft^2):	1.93
Minimum Outside Air Fraction:	0.31
Package Cooling COP:	2.2

Table VIII-18. Electricity EUIs (kWh/ft^2-yr) - Restaurant

Indoor Lighting	Outdoor Lighting	Misc. Equip.	Refrig.	Cooking	Water Heating	Ventilation[1]	Cooling[1]	Total
Preliminary - Sitdown (0.63)[2]								
5.25	1.66	2.87	12.44	4.38	2.82	4.16	15.76	44.96
Preliminary - Fastfood (0.27)[2]								
7.41	3.55	4.10	21.35	17.24	1.38	4.56	17.85	72.06
Reconciled								
7.94	4.09	4.89	10.78	4.46	0.03	7.49	12.25	51.91

1. calculated using conditioned fraction of total floor area (sitdown - 0.78; fastfood - 0.66; reconciled - 0.76)
2. fraction of stock premises of this type

Figure VIII-44. Whole-Building Load Shape for Restaurant - Standard Days in Climate Zone 2 (BUR). The load shape is a weighted-average of the hourly electricity use of individual load research buildings, and adjusted so that the annual building energy use derived from the load profile matches the annual bill from the on-site survey data. The plot shows the minimum, 25%-quartile, mean, 75%-quartile, and maximum hourly values; the line represents the mean hourly profile.

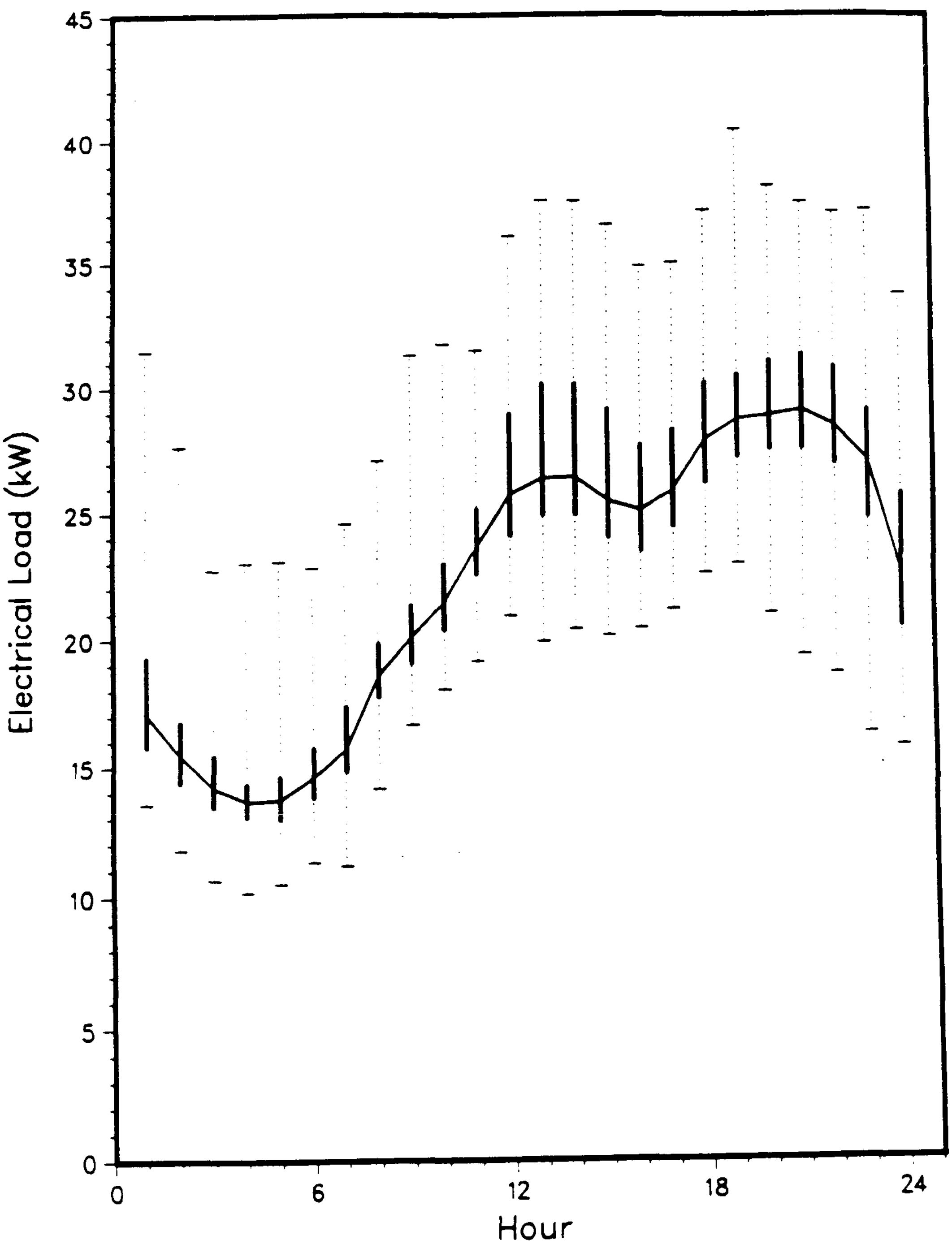


Figure VIII-45. Summary of Reconciled Load Shapes for Restaurant in Climate Zone 2 (BUR)

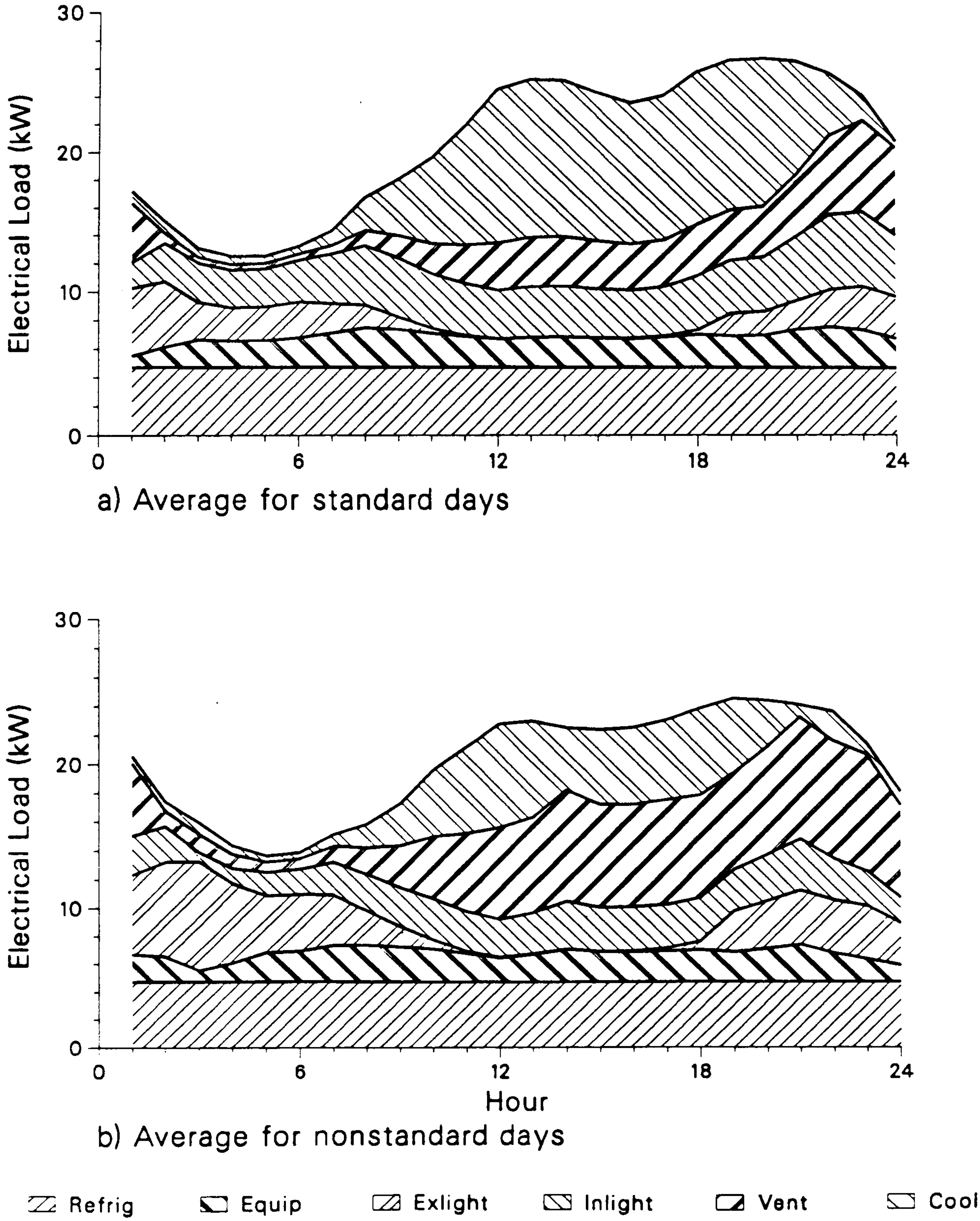


Figure VIII-46. Reconciled Monthly Load Shapes for Restaurant - Cooling and Ventilation in Climate Zone 2 (BUR). Solid lines are profiles for months May through October and broken lines are profiles for months November through April.

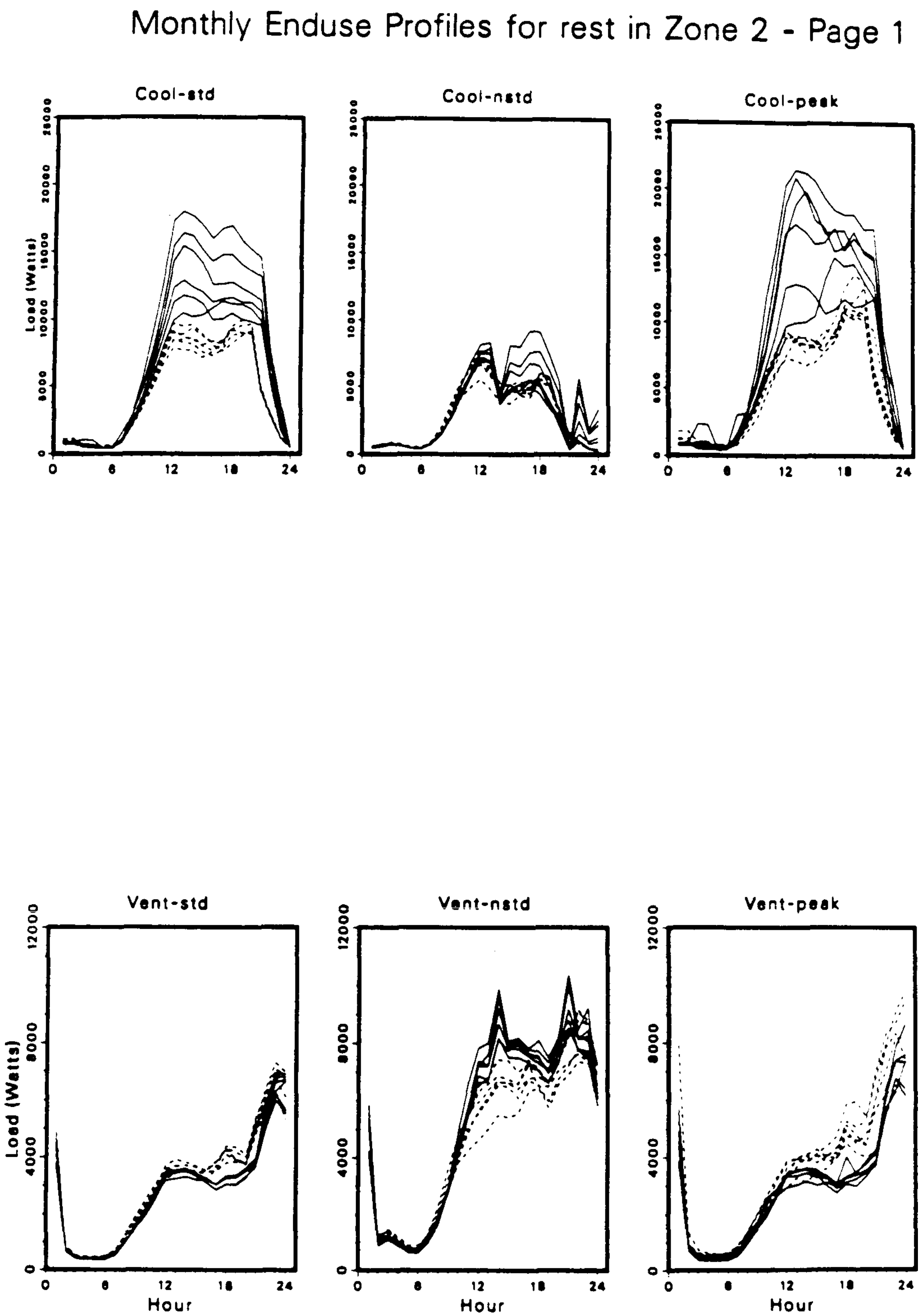


Figure VIII-47. Reconciled Monthly Load Shapes for Restaurant - Indoor and Outdoor Lighting, and Misc. Equipment in Climate Zone 2 (BUR). Solid lines are profiles for months May through October and broken lines are profiles for months November through April.

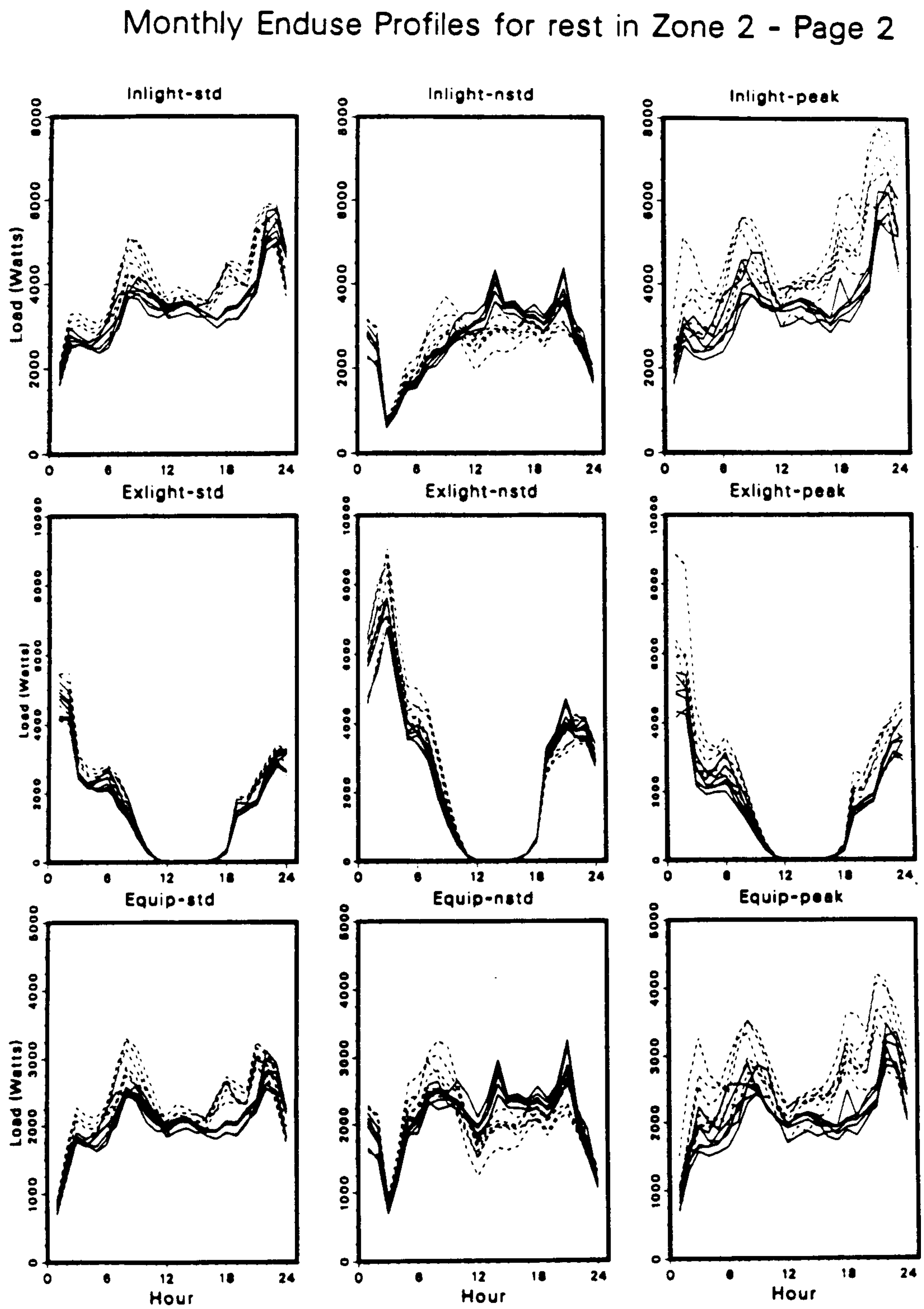
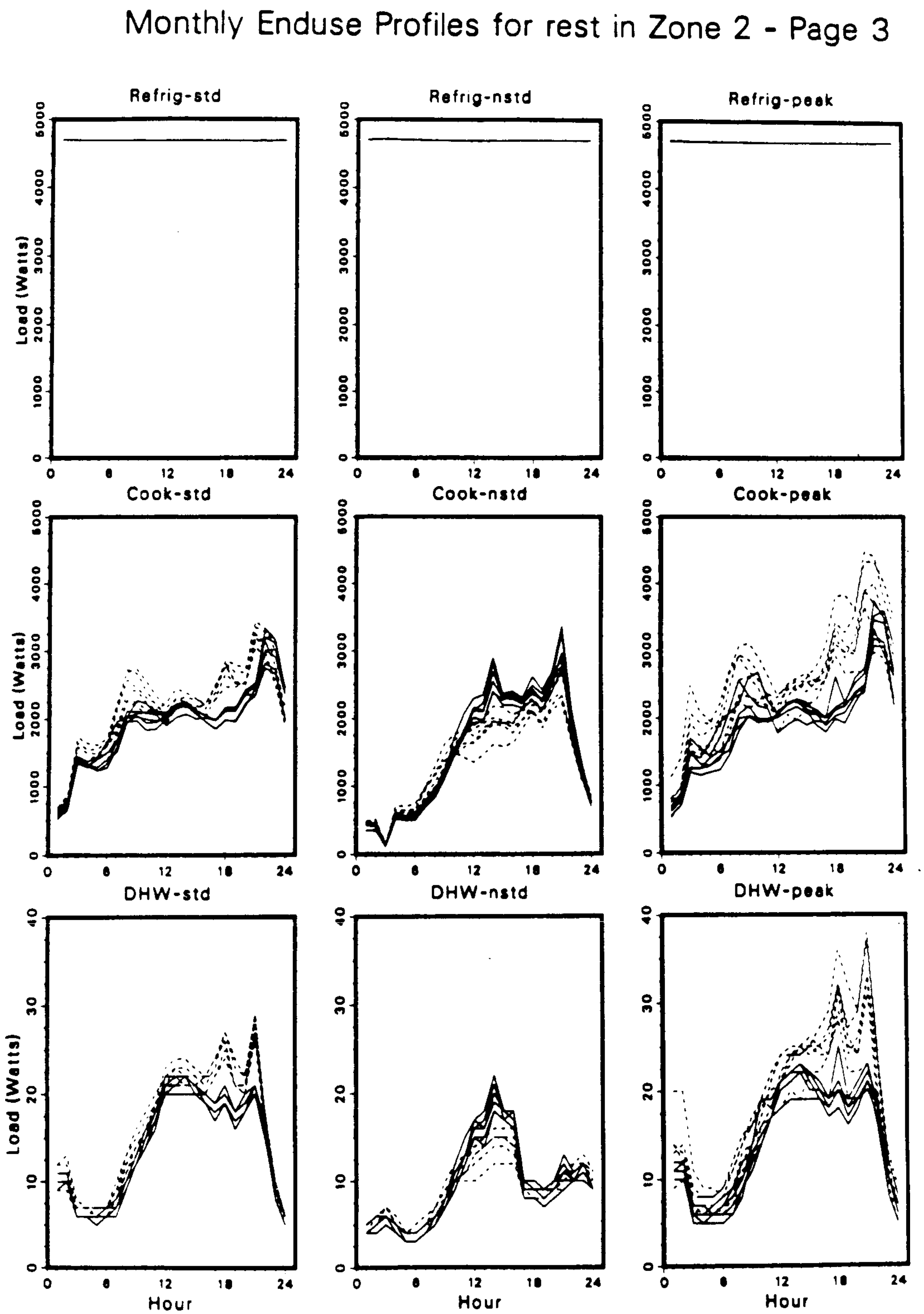


Figure VIII-48. Reconciled Monthly Load Shapes for Restaurant - Refrigeration, Cooking, and Hot Water (DHW) in Climate Zone 2 (BUR). Solid lines are profiles for months May through October and broken lines are profiles for months November through April.



Comparison with Previous EUIs and LSs

EUI Comparison

Table VIII-19 summarizes the reconciled electric EUIs. Figures VIII-49 through VIII-60 compare these EUIs to those found in earlier studies. These figures are reproductions of Figures III-1 through III-11 (from Task III), on which we have indicated the final EUIs from the current study, with a horizontal line drawn across the vertical bars used to represent EUI values from the previous study.

Table VIII-19. Reconciled Electricity EUIs (kWh/ft^2-yr) fo Climate Zone 1 (LAX), Zone 2 (BUR) and Zone 3 (NOR)

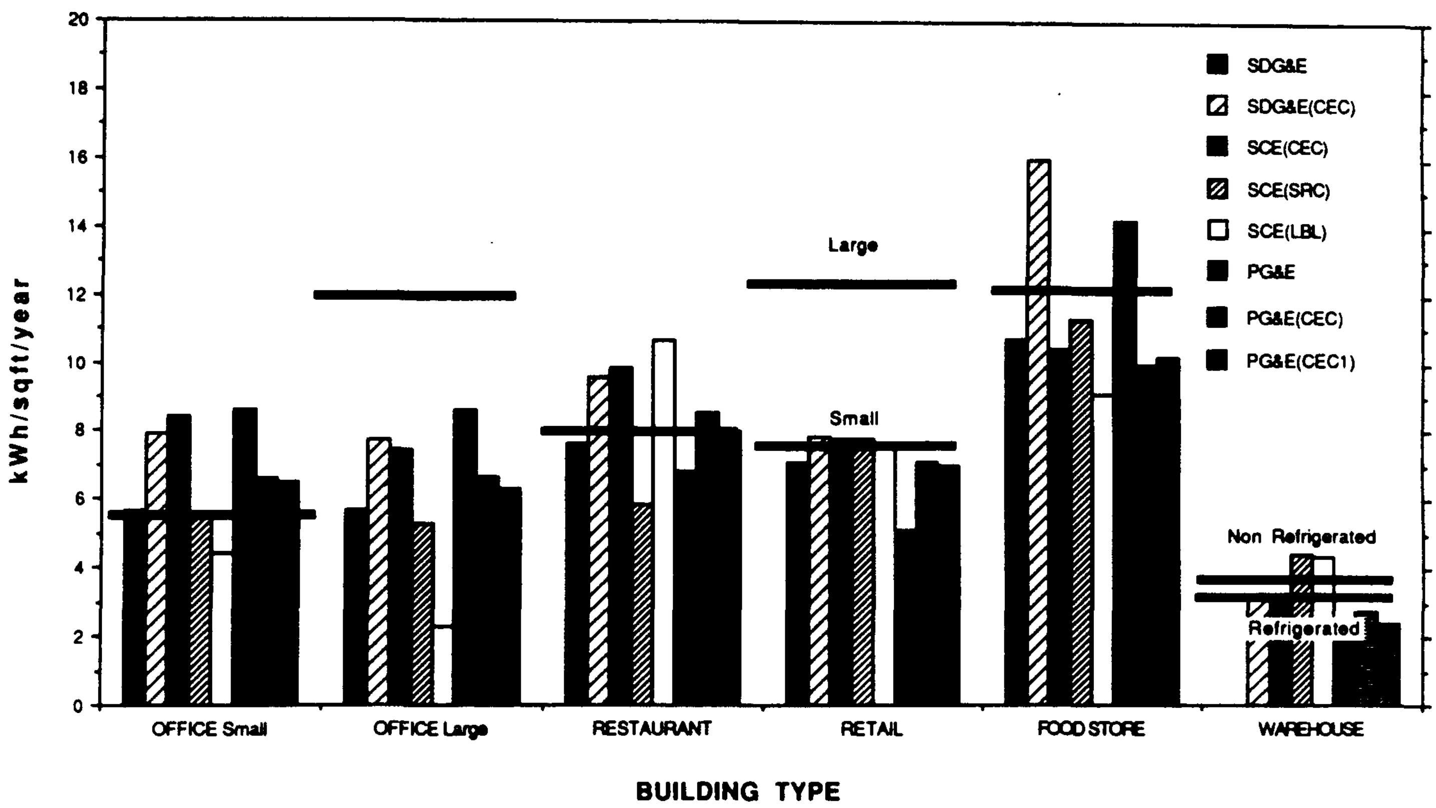
	Indoor Lighting	Outdoor Lighting	Misc. Equip.	Refrig.	Cooking	Water Heating	Ventilation[1]	Cooling[1]	Total	
Small Office	5.47	1.24	3.59	0.23	0.04	0.15	0.97	2.77	15.52	LAX
							1.38	5.80	16.53	BUR
							1.23	8.92	18.41	NOR
Large Office	11.93	2.11	4.28	0.10	0.00	0.16	3.09	3.93	24.54	LAX
							3.30	3.91	25.94	BUR
							3.45	5.11	27.58	NOR
Small Retail	7.49	1.59	1.48	0.95	0.01	0.04	1.67	5.45	17.21	LAX
							1.82	6.54	17.40	BUR
							2.04	11.15	18.81	NOR
Large Retail	12.21	1.47	1.12	0.61	0.19	0.02	3.41	5.79	22.50	LAX
							3.71	4.94	22.76	BUR
							3.61	7.65	24.48	NOR
Food Store	11.96	2.01	1.77	23.17	0.24	0.03	2.14	0.00	40.27	
Ref Warehse	3.02	0.55	6.24	11.34	0.01	0.17	1.50	2.82	23.91	
NonRef Warehse	3.38	0.17	0.70	0.41	0.00	0.03	0.62	1.16	5.02	
Restaurant	7.94	4.09	4.89	10.78	4.46	0.03	7.49	12.25	51.91	

1. Cooling and ventilation EUIs were estimated separately for the Coastal region (represented by Los Angeles Airport weather), the Inland region (represented by Hollywood-Burbank Airport weather), and the Desert region (represented by Norton Air Force Base weather), in descending order.

For lighting, we find reasonable agreement with previous studies for all business types except large office and large retail (see Figure VIII-49). For these two building types, the reconciled EUIs are significantly greater than those found in previous studies. These high EUIs can be traced to the weighted average electricity bill used in the reconciliation process.

With EDA, differences between the preliminary total EUI and the measured total are allocated (with the exception of cooling and ventilation) roughly in proportion to the initial size of a given end use. Accordingly, lighting accounts for much of this difference. This phenomenon, moreover, will also be reflected in other end uses, notably miscellaneous equipment. In the following section, during our review of sources of uncertainty, we will discuss some of the reasons underlying differences in total EUI between small and large office and retail.

FIGURE VIII-49 LIGHTING EUIs COMPARISON



Electric miscellaneous EUIs are compared to those from previous studies in Figure VIII-50. The large office EUI is greater than those found in previous studies. For this end use, we also find larger EUIs for small office, restaurant, and refrigerated warehouses, and, to a lesser extent, small retail.

For the restaurant, comparison is complicated by uncertainty over the treatment of kitchen ventilation. The reconciled EUI developed in the current project includes kitchen ventilation in the miscellaneous EUI, but we are unsure about its treatment in other studies. To the extent that these studies treat kitchen ventilation separately, our estimates should be higher. Similarly, warehouse EUIs from previous studies do not distinguish between refrigerated and non-refrigerated warehouses.

FIGURE VIII-50 ELECTRIC MISCELLANEOUS EUIs COMPARISON

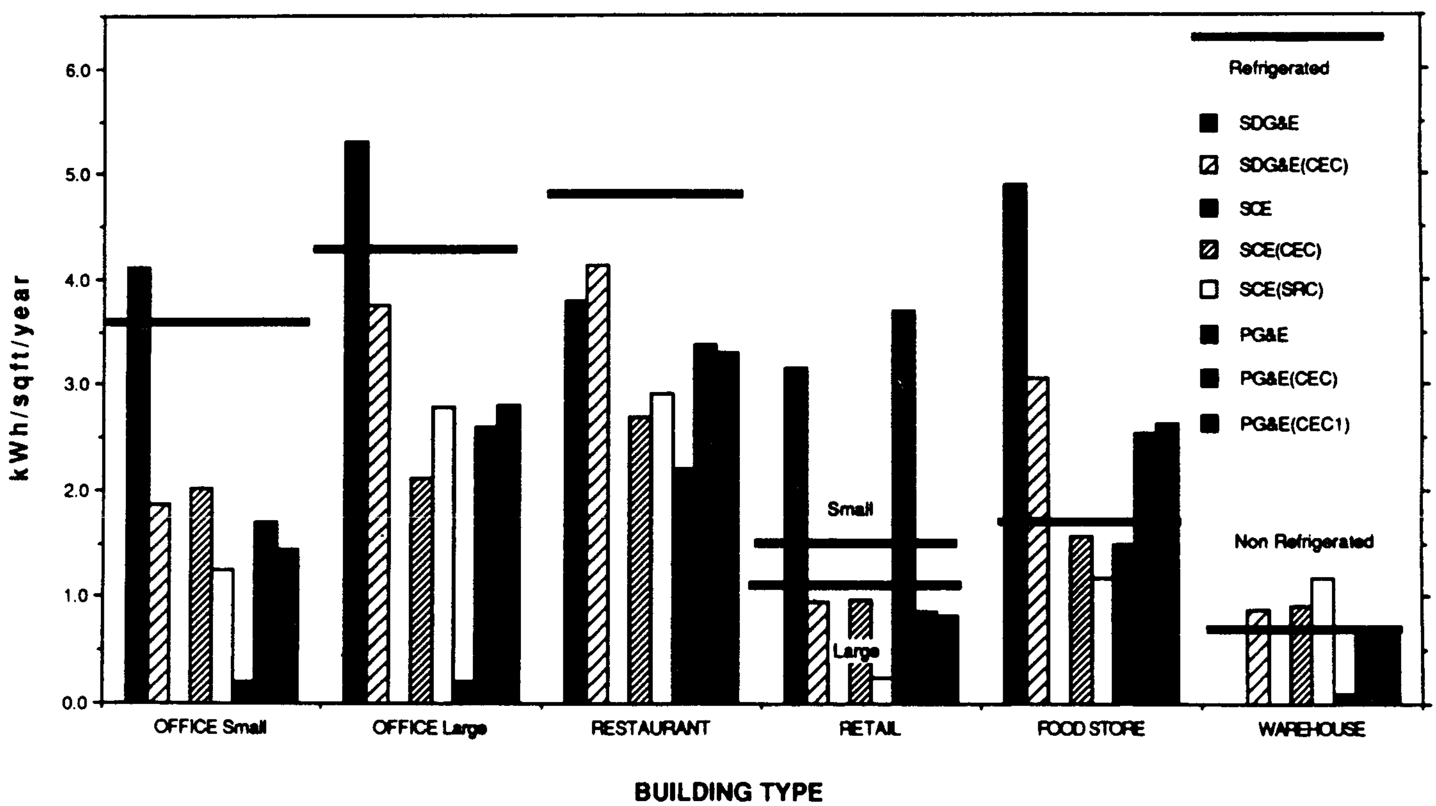


Figure VIII-51 compares refrigeration EUIs. Fairly good agreement was found for refrigeration in the food store and restaurant (although previous studies show significant disagreement about this EUI in restaurants). As stated before, previous studies did not distinguish refrigerated from non-refrigerated warehouses and so comparisons were not particularly meaningful. For the remaining types of premises, EUIs were quite small, both in our study and in previous studies.

FIGURE VIII-51 REFRIGERATION EUIs COMPARISON

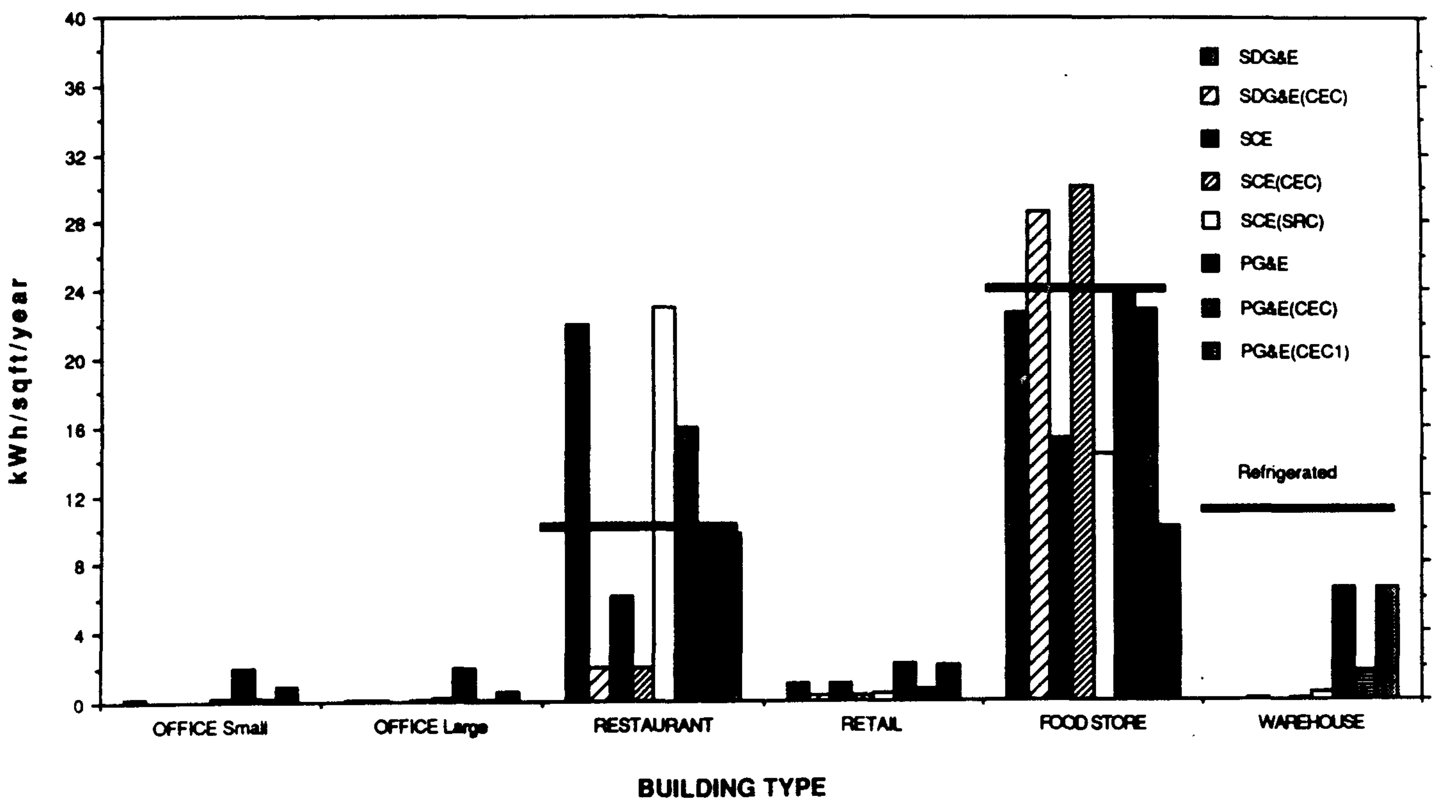
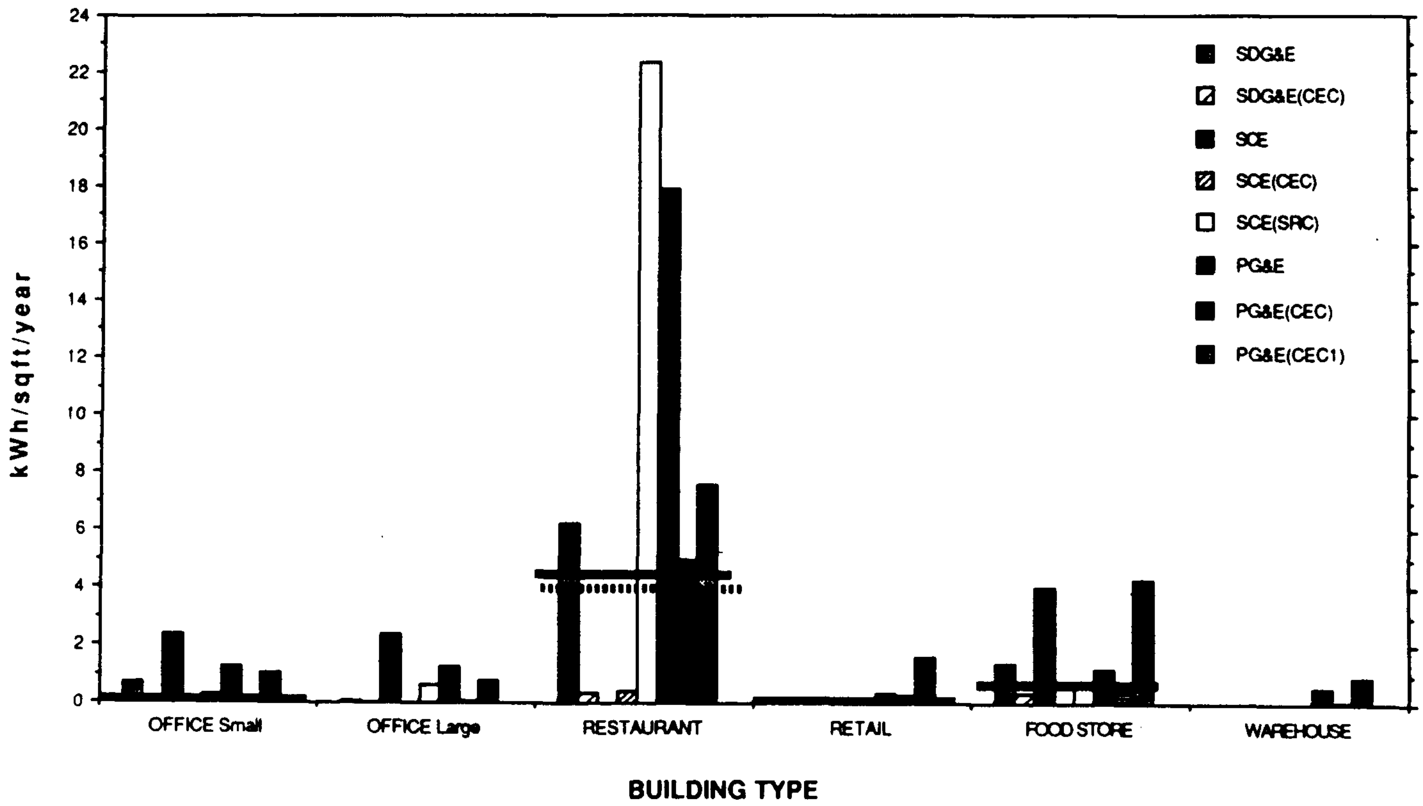


Figure VIII-52 compares cooking EUIs. Direct comparisons are complicated because of uncertainty about the treatment of saturation. The EUIs estimated in the current study reflect the saturation of electric cooking, refrigeration, and domestic hot water found in the on-site surveys. The EUIs developed in previous studies typically treat saturation effects separately. We have attempted to address the issue by reporting both the original reconciled EUI and one in which the saturation effect has been removed (resulting in a higher EUI).[1] Unfortunately, in either case, the EUIs for this end use are small, so visual comparison is difficult.

Direct comparisons can, however, be made for restaurants, retail, and food stores. For these building types, our reconciled cooking EUIs are all slightly higher than the highest values found previously. As noted in Task III, there was significant lack of consensus on cooking EUIs for restaurants from previous studies.

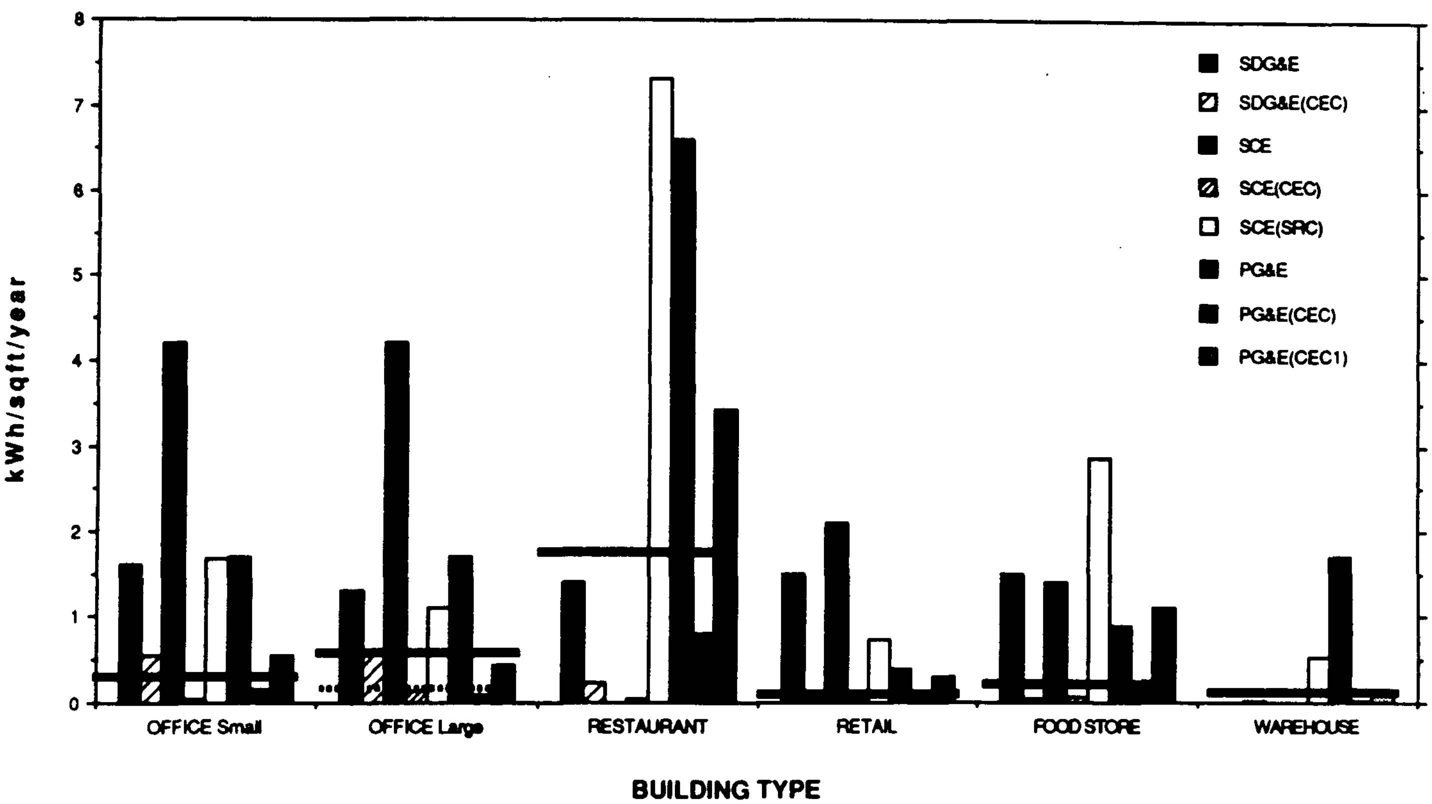
FIGURE VIII-52 COOKING EUIs COMPARISON



[1] These saturations are presented in the final section of this chapter during the discussion of adjustments for the SCE and CEC forecasting models.

Figure VIII-53 compares water heating EUIs. As with cooking, we present both the reconciled EUI and the EUI corrected for the saturation effects.[2] Once adjusted, we found that the small and large office, and refrigerated and non-refrigerated warehouse EUIs were larger than those found previously. For the restaurant and food store, our EUIs were near the lower end of values found in previous studies.

FIGURE VIII-53 WATER HEATING EUIs COMPARISON



[2] These saturations are presented in the final section of this chapter during the discussion of adjustments for the SCE and CEC forecasting models.

Figure VIII-54 compares ventilation EUIs. The ventilation EUIs found in our study were generally higher than those found in previous studies for the restaurant and large retail building types. The ventilation EUIs for the remaining building types fell within the ranges found in previous studies.

FIGURE VIII-54 VENTILATION EUIs COMPARISON

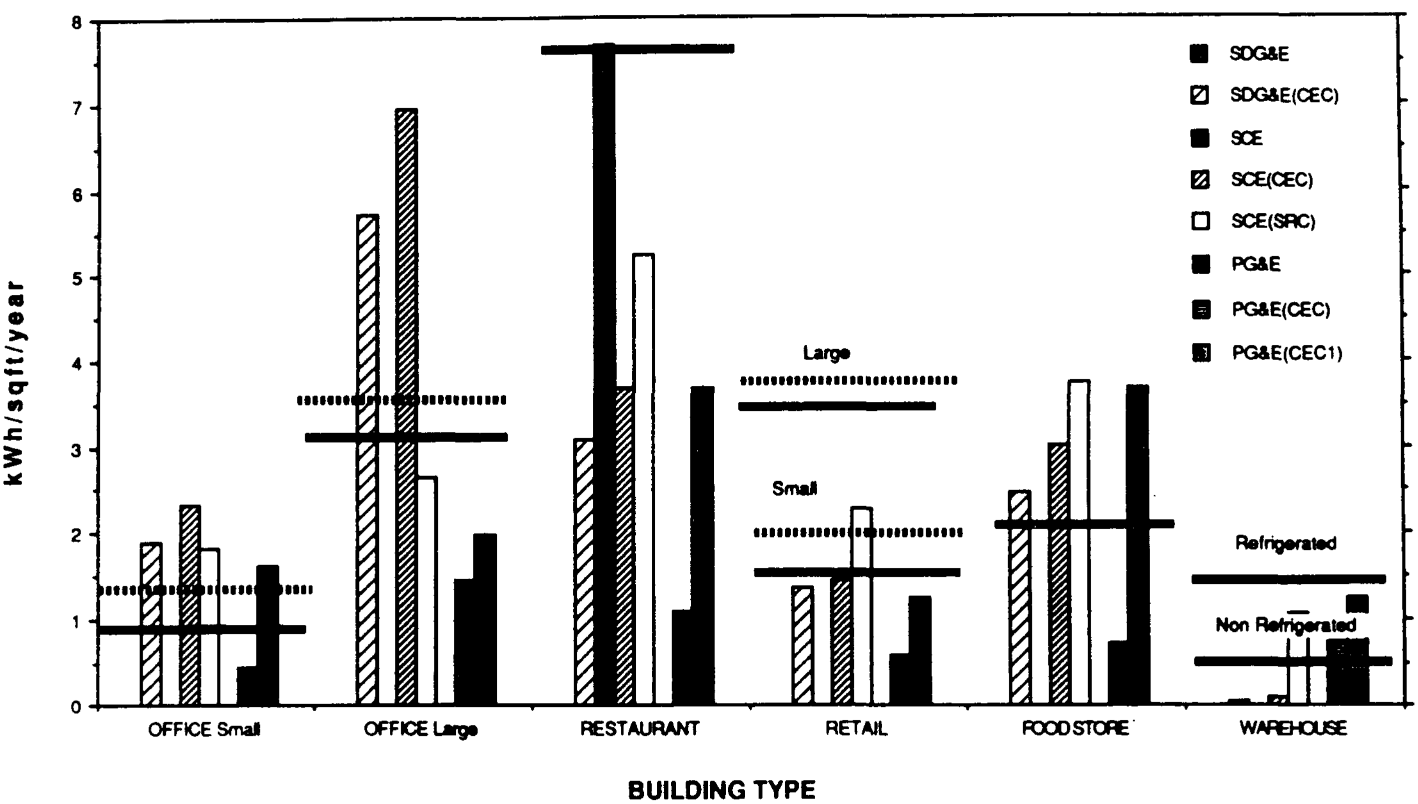
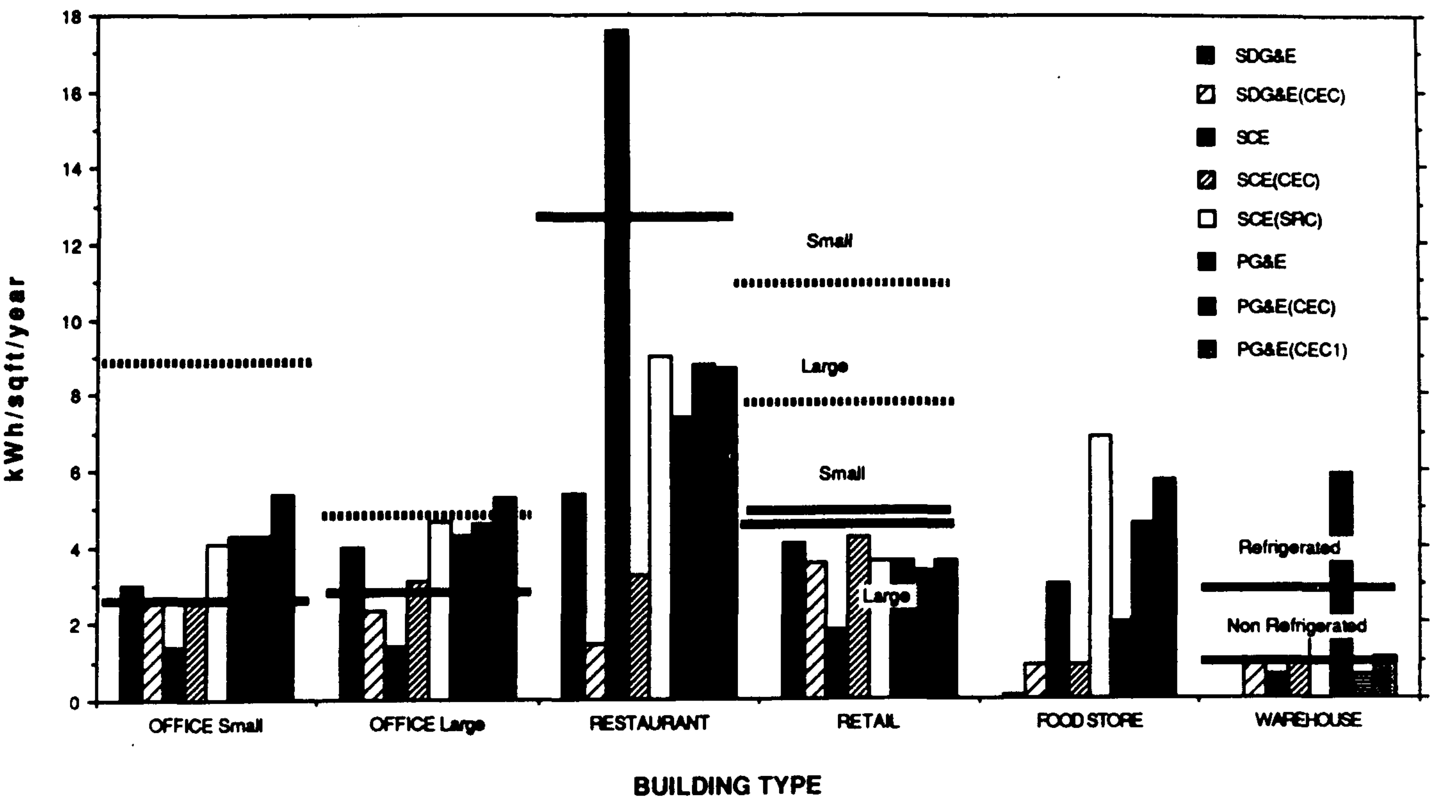


Figure VIII-55 compares cooling EUIs. The cooling EUIs found in our study exceeded those in previous studies for the restaurant and retail premises. As described earlier, we allocated the cooling EUI for food stores to the refrigeration EUI.

FIGURE VIII-55 COOLING EUIs COMPARISON



For completeness, we also report gas EUIs in Table VIII-20. Note that the gas EUIs were developed using NELDIG and DOE-2 and were not reconciled to measured data. Figures VIII-56 through VIII-59 compare these EUIs to those found in previous studies.

Table VIII-20. Gas EUIs (kBtu/ft^2.yr)

	Miscellaneous Equipment	Cooking	Water Heating	Space Heating
Small Office	0.00	6.36	2.39	2.11 LAX
				2.11 BUR
				2.11 NOR
Large Office	0.00	0.34	1.47	0.74 LAX
				0.72 BUR
				0.88 NOR
Small Retail	13.99	0.00	0.51	2.42 LAX
				2.42 BUR
				2.42 NOR
Large Retail	0.00	0.67	0.85	0.19 LAX
				0.20 BUR
				0.20 NOR
Food Store	0.00	6.75	1.28	2.44
Ref Ware	2.82	0.00	0.31	0.00
NonRef Ware	0.00	0.00	1.21	1.48
Restaurant	17.81	120.15	18.42	5.47

Our gas cooking and gas water heating EUIs for sitdown and fastfood restaurants compared favorably to the middle of the range found in previous studies (see Figures VIII-56 and VIII-57). For most types of premises, these EUIs were quite small both in our study and in previous studies, precluding meaningful comparison.

FIGURE VIII-56 GAS COOKING EUIs COMPARISON

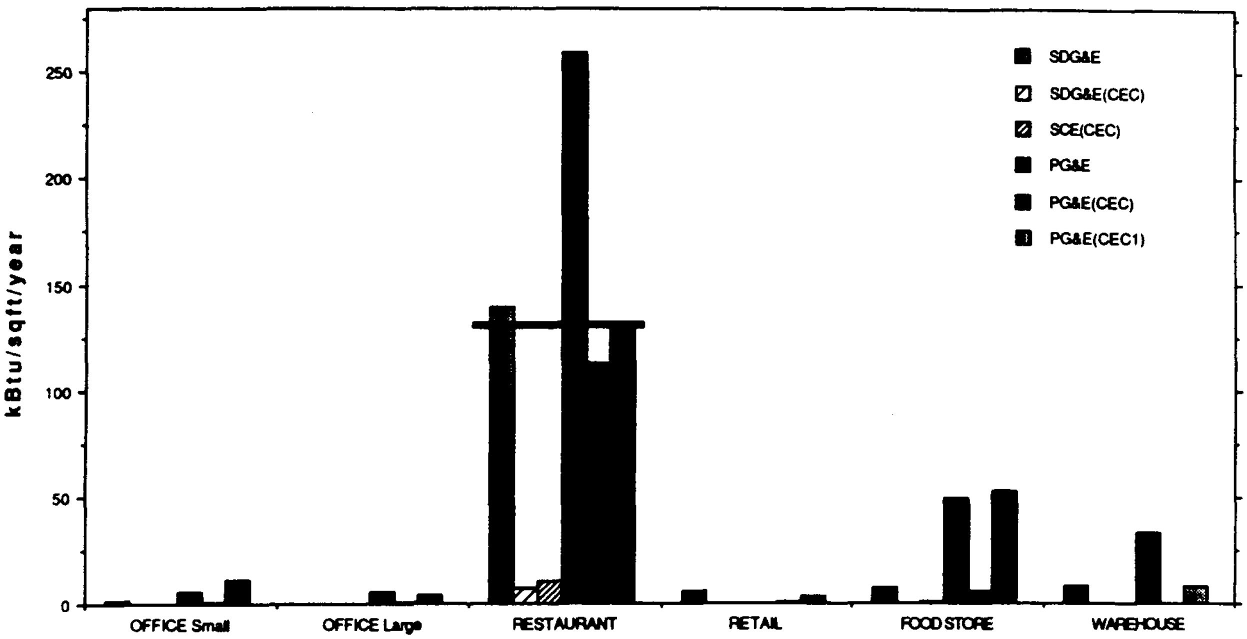
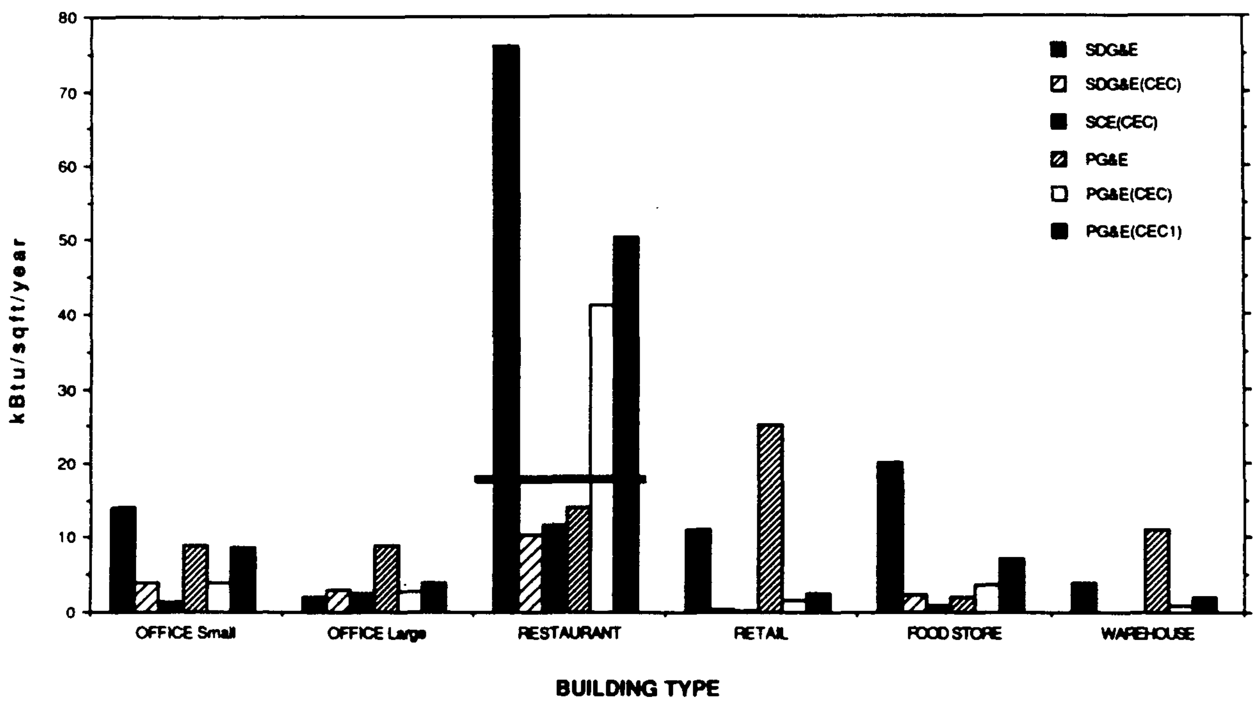


FIGURE VIII-57 GAS WATER HEATING EUIs COMPARISON



The gas space heating EUIs from the DOE-2 simulations were quite low compared to the EUIs found in previous studies (see Figure VIII-58). Only food stores and restaurants showed significant heating energy use. For the food store, our estimate was in excess of the values from previous studies. For the restaurant our EUIs were lower than the values from previous studies.

We found insignificant quantities of miscellaneous gas equipment in all building types; accordingly our EUI estimates were quite low relative to those in previous studies (see Figure VIII-59).

FIGURE VIII-58 GAS SPACE HEATING EUIs COMPARISON

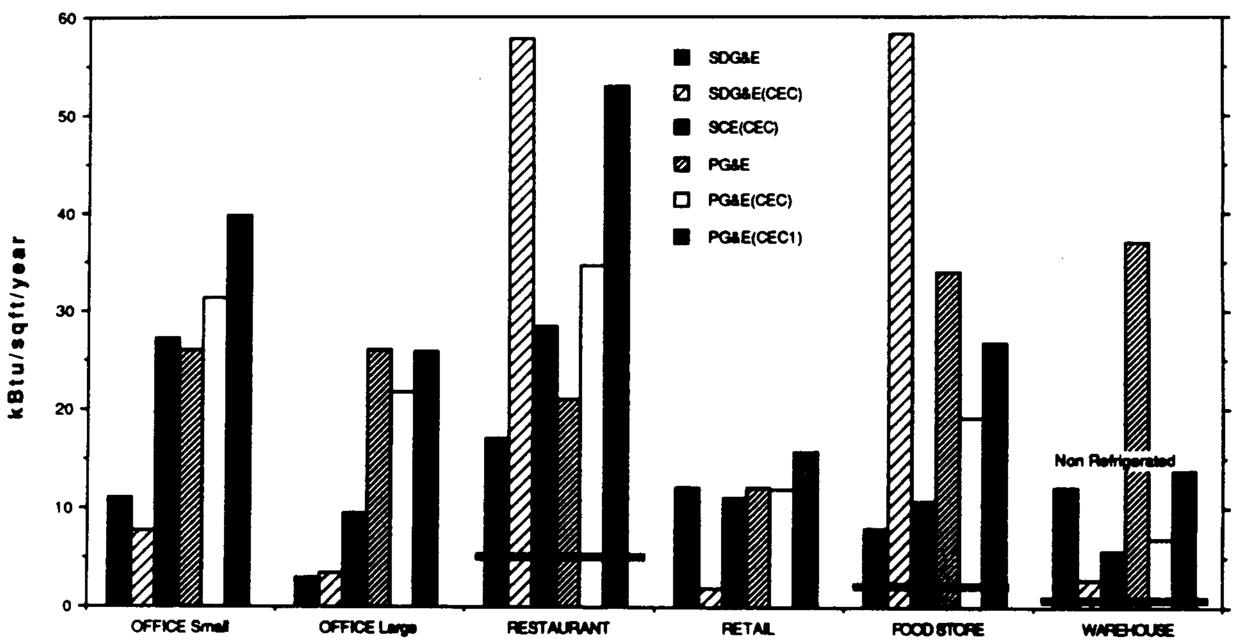
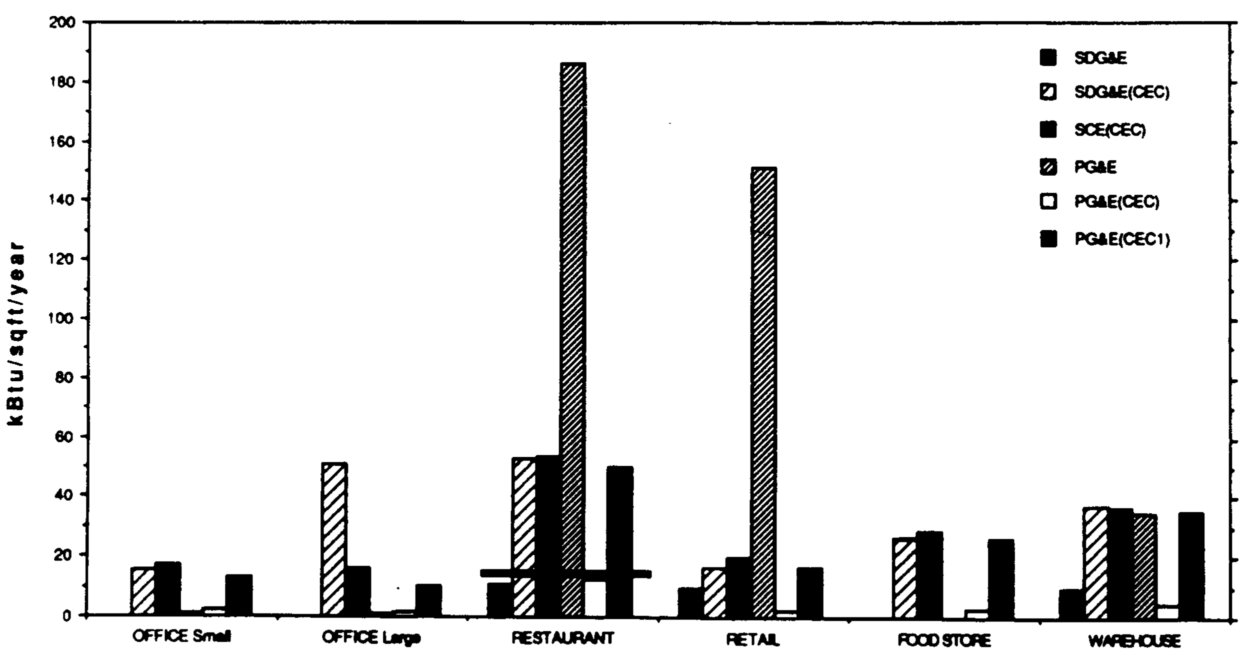


FIGURE VIII-59 GAS MISCELLANEOUS EUIs COMPARISON



LS Comparison

The comparison of load shapes is qualitative in nature because, on a sectoral basis, the magnitude of these loads is a function of the energy forecast.

First, the reconciled load shapes, as one might suspect, show much smoother transitions between day and night hours than do load shapes developed using pure simulation approaches. Prototypes are fundamentally limited in their ability to capture the diversity of starting and stopping times found in the stock of commercial premises. This limitation is a major argument in favor of using the reconciliation methods developed in this project, rather than using only simulations to estimate LSs and EUIs.

Second, perhaps the most important influence introduced by EDA on the preliminary EUIs was that of exact reconciliation to the whole-building average load. For this reason, we found that seasonal influences could be very important for many non-HVAC end uses. We also found considerable differences between non-standard day and standard day profiles, for several types of premises.

Third, we are concerned by the dependence of the lighting and miscellaneous LS (and EUI) on the initial estimates from the analysis of the on-site survey data. For both the large office and retail, the lighting and equipment levels found in the prototype and the large total electricity EUI for the whole building combined to produce very high EUIs for these end uses. Large total electricity use aside, in the office the high EUI was related to high load factors; for the large retail, the installed capacities were the primary cause of the high EUIs. Given the very different load shapes and total electricity use considerations underlying high EUIs for these end uses, it is difficult to identify one or the other as the primary cause for high EUIs. Of course, analysis of measured end-use hourly load data (from SCE and others) would provide the best possible source of information for resolution to this issue.

Adjustments to Reconciled EUIs for Use in Forecasting

The reconciled EUIs are not directly usable by the SCE and CEC forecasting models because the models require distinct EUIs for individual technologies and vintages that are indexed to building energy use in 1975. The impact of California's building and appliance energy efficiency standards (loosely, Titles 24 and 20) is of particular interest because a major challenge for the adjustment procedure is to "remove" the impacts of these standards from our reconciled EUIs. The issues for development of these adjustment factors are:

A. the LRD could not be disaggregated by technology or vintage;

B. the on-site survey data were not representative of construction after the standards; and

C. in any case, the LRD and on-site survey data were both observations made in 1986, not 1975 energy use and characteristics of premises.

Five commercial sector end uses were directly affected by the standards: heating, cooling, ventilation, lighting and water heating. Independent of the influence of standards, all end uses can be expected to exhibit different levels of consumption as a function of time because of the effects of prices and technological change. Thus, one can also expect that all EUIs will differ from their reconciled values when indexed to a different base year.

Both CEC and SCE use end-use forecasting models that rely on estimates of energy use for buildings and equipment built to meet standards. The estimates used by CEC and SCE were developed using a combination of survey data, engineering judgment, and heat load simulations of prototypical buildings. The changes in energy use resulting from standards are expressed, for a given end use, as fractions relative to a base year of 1975 (prior to the enactment of either standard).

For the HVAC end uses, the use of a heat load simulation program to estimate energy use for prototypical buildings makes explicit what is meant by compliance with a standard because use of simulations requires precise specification of building characteristics and operation. Two simulations are typically required to estimate the impacts of standards on HVAC energy use. First, a reference building prototype is defined that corresponds to a set of base case conditions. Second, the effects of other vintages and technologies are then estimated deterministically by direct modifications to the prototype, resimulation, and, finally, scaling to the original result. The modifications are incremental in nature; building size, geometry, hours of operation, occupancy, miscellaneous equipment energy use, etc., are assumed to remain constant between the base case and the modified case.

In this section, we describe a hybrid method for adjusting the reconciled EUIs to reflect the impacts of standards, changing energy prices, and changing technologies. The focus of our discussion is on HVAC end uses because they are the end uses most affected by standards and because they interact strongly with the non-HVAC end uses. A final set of tables summarizes application of the procedure for each building type and end use.

Approach for HVAC EUIs. Our method for adjusting reconciled HVAC EUIs is based on the development of scaling factors. It follows historic practice of incrementally modifying the prototype descriptions to model the building and energy use practices of different vintages. It differs from historic practice in that the ratios of simulated performance are used to adjust *reconciled* EUIs, rather than simply using *simulated* EUIs.

In the SCE and CEC forecasting models, the heating and cooling EUIs are based on a weighted average energy conversion efficiency by fuel type times a heating or cooling load:

$$\mathbf{EUI} = \frac{\mathbf{Load}}{\sum_{i=1}^{n} \mathbf{Frac}_i \times \mathbf{Eff}_i} \qquad [1]$$

where

EUI	= EUI for heating or cooling
Load	= HVAC loads (not energy) for heating or cooling
$Frac_i$	= Fraction of stock with equipment type i
Eff_i	= Energy conversion efficiency of equipment type i

Tables VIII-21 to VIII-23 summarize the components of and final weighted average energy conversion efficiencies currently used by CEC. Table VIII-21 reports energy conversion efficiency assumptions for individual heating and cooling technologies for electricity and natural gas. Table VIII-22 reports the saturations of these technologies for a given energy source and building type. These saturations report only relative shares of technologies for a given energy source; they do not report fuel saturations of electricity, natural gas, and ''other'' relative to each other. Table VIII-23 reports the weighted average energy conversion efficiencies that result from application of the saturations in Table VIII-22 to the energy conversion efficiencies in Table VIII-21 (the category "other" is assumed to have the same energy conversion efficiencies as natural gas in Table VIII-21).

Table VIII-21. CEC Energy Conversion Efficiency by Vintage and Energy Source

	Heating Equipment				Cooling Equipment			
	Boiler (η)	Furnace (η)	Heat Pump (COP)	Other (η)	Chiller (COP)	Pkg. Mult (COP)	Pkg. Term (COP)	Heat Pump (COP)
Electricity								
Vintage 65-78	0.95	0.95	1.9	1	4.2	2.04	1.76	1.76
Vintage 79-83	0.95	0.95	2.4	1	4.25	2.34	2.41	2.43
Natural Gas								
Vintage 65-78	0.66	0.66	3	0.66	0.59	0.36	0.2	0.2
Vintage 79-83	0.75	0.75	3	0.66	0.75	0.65	0.2	0.2

Table VIII-22. CEC Equipment Saturations (%) by Fuel Type

	Heating Equipment				Cooling Equipment			
	Boiler	Furnace	Heat Pump	Other	Chiller	Pkg. Mult	Pkg. Term	Heat Pump
OFFICE								
Electricity	9.8	38	37.1	15.1	58.3	26.9	6.3	8.6
Natural Gas	45.6	41.3	0	13.1	11.3	89.1	0	0
Other	84	5.8	0.5	9.6	100	0	0	0
RESTAURANT								
Electricity	0.7	60	12.6	26.7	72.4	24.1	1.6	1.8
Natural Gas	8.8	89	0	2.2	60.2	39.8	0	0
Other	85.6	14.4	0	0	100	0	0	0
RETAIL								
Electricity	12.1	21.9	19.3	46.7	56.4	34.6	3.8	5.2
Natural Gas	11.2	58.1	0	30.7	44.8	55.2	0	0
Other	80	11.4	0	8.6	100	0	0	0
FOOD STORE								
Electricity	0	32	64.9	31.3	82.5	7	4.3	6.1
Natural Gas	15	82.4	0	2.6	100	0	0	0
Other	0	100	0	0	100	0	0	0
WAREHOUSE								
Electricity	0	17.7	3.7	78.6	41.8	37.5	7.9	12.8
Natural Gas	9	45.1	0	46	40.3	59.7	0	0
Other	100	0	0	0	100	0	0	0

Table VIII-23. CEC Weighted Average Energy Conversion Efficiencies by Fuel and Vintage

	Heating	Cooling
OFFICE 65-78		
Electricity	1.310	3.260
Natural Gas	0.660	0.387
Other	0.671	0.590
OFFICE 79-83		
Electricity	1.496	3.468
Natural Gas	0.738	0.664
Other	0.752	0.750
RESTAURANT 65-78		
Electricity	1.083	3.592
Natural Gas	0.660	0.498
Other	0.660	0.590
RESTAURANT 79-83		
Electricity	1.146	3.723
Natural Gas	0.748	0.710
Other	0.750	0.750
RETAIL 65-78		
Electricity	1.157	3.233
Natural Gas	0.660	0.463
Other	0.660	0.590
RETAIL 79-83		
Electricity	1.253	3.425
Natural Gas	0.722	0.695
Other	0.742	0.750
FOOD 65-78		
Electricity	1.850	3.791
Natural Gas	0.660	0.590
Other	0.660	0.590
FOOD 79-83		
Electricity	2.175	3.922
Natural Gas	0.748	0.750
Other	0.750	0.750
WAREHOUSE 65-78		
Electricity	1.024	2.885
Natural Gas	0.661	0.453
Other	0.660	0.590
WAREHOUSE 79-83		
Electricity	1.043	3.155
Natural Gas	0.709	0.690
Other	0.750	0.750

The prototypical premises developed for use in this project were based on the use of a single type of energy conversion equipment. That is, $Frac_i$ was assumed to be 1.0 and Eff_i was that derived from the analysis of the on-site survey data.[1]

Our approach was to use information from the DOE-2 simulations of both the NELDIG prototype and a modified version of this prototype to determine the annual average energy conversion efficiency of the HVAC equipment; then we used this relationship to estimate a heating and cooling load from the reconciled heating and cooling EUIs. This load is next adjusted to the load for the 1975 vintage using the ratios of HVAC loads from additional simulations. These simulations rely on new versions of the NELDIG prototypes that have modified to reflect 1975 building and energy use practices. Finally, we convert the HVAC loads to back to EUIs using CEC's weighted average energy conversion efficiency (from Table VIII-23):

$$\mathbf{EUI_{reconciled-1975} = EUI_{reconciled} \times \frac{Load_{protoype}}{EUI_{prototype}} \times \frac{Load_{1975}}{Load_{prototype}} \times \sum_{i=1}^{n} Frac_i \times Eff_i} \qquad [2]$$

or

$$\mathbf{EUI_{reconciled-1975} = EUI_{reconciled} \times \frac{Load_{1975}}{EUI_{prototype}} \times \sum_{i=1}^{n} Frac_i \times Eff_i} \qquad [3]$$

The EUIs for 1980 were calculated relative to the EUIs for 1975 and do not include the effects of HVAC equipment efficiency. Consequently, they were calculated using the ratio of vintage 1975 and vintage 1980 loads from DOE-2 simulation of modified versions of the NELDIG prototypes.

$$\mathbf{EUI_{reconciled-1980} = EUI_{reconciled-1975} \times \frac{Load_{1980}}{Load_{1975}}} \qquad [4]$$

[1] Exceptions to this assumption were the large retail and office in which two HVAC systems were modeled and, to a lesser extent, the restaurant in which the fastfood and sitdown premises were combined for reconciliation to the load research data.

Prototype Modifications to Determine **$Load_{1975}$** *and* **$Load_{1980}$**. Our approach for modifying the prototypes to reflect different vintage/technologies relied on three guiding principles:

1. Continue historic practice of changing prototype descriptions incrementally. In other words, we kept the size, geometry, hours of operation, temperatures, occupancy profiles, miscellaneous equipment energy use, etc. of the prototypes fixed. Changes only affected building thermal integrity, lighting levels, and HVAC equipment and operating strategies.
2. Use the on-site survey data to the extent possible and the 1985 mail survey, where applicable. Where required, engineering judgment was kept to a minimum.
3. Attempt only to ensure that the minimum levels required by the prescriptive standards are met. That is, we used the prescriptive standards only to provide a lower bound constraint on the data, not as a fixed target to be met exactly.

The specific assumptions we used to modify each building type are presented in Tables VIII-24 through VIII-27, for building envelope, lighting level, and HVAC equipment, respectively. The building envelope, lighting level, and HVAC equipment of the 1975 vintage prototype were all unaffected by the influence of standards. Our general approach was to rely on the on-site survey data for pre-1979 buildings to the extent possible because the majority of our data are from buildings that were built prior to 1979. The 1980 vintage is a building in which the building envelope, lighting level, and HVAC equipment are all affected by standards. As previously noted, it is also the vintage for which we had the smallest number of data.

Building Envelope. For vintage 1975, we developed wall, roof, and window U-values, and window shading coefficients using only data from pre-1979 premises. This procedure was based on an assumption that commercial building envelopes have not been retrofitted since construction.[2]

For the 1980 vintage, our approach was to rely on the standards merely as constraints on values reported from our NELDIG prototypes. Vintage 1980 envelope values were developed by using the prescriptive standards to constrain values from the NELDIG prototypes. We calculated maximum U-values for walls and roofs (a heating criterion) and maximum overall thermal transfer

[2] This assumption was borne out by examination of envelope conservation measures reported in the on-site survey.

values of walls (a cooling criterion) for each prototype, and we determined whether the values from prototypes exceeded the levels called for by the standard.[3]

The constraints were introduced sequentially. Because the on-site survey does not report window U-values (requiring us to assign them separately for single- and double-pane windows), we used the maximum U-value calculation for heating to constrain the wall U-value. Having fixed the wall U-value, we used the overall thermal transfer calculation to constrain window shading coefficients. Roof U-values could be constrained directly by the maximum U-value calculation for heating. Based on discussions with CEC staff, we also ensured that wall and roof thermal integrities were at least R-11 and R-19, respectively.

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[3] "Building Energy Efficiency Standards, 1987 Edition," California Energy Commission, December, 1987, P400-88-001, pgs. 60-71.

Table VIII-24. Prototype Envelope Modifications

Premise	NELDIG Prototype	Vintage 1975	Vintage 1980
Wall Conductivity (Btu/ft^2.°F.ft.hr)			
Fastfood Rest.	0.15	0.16	0.11*
Food Store	0.14	0.14	0.11*
Large Office	0.16	0.16	0.11*
Large Retail	0.17	0.19	0.11*
Non-Ref. Warehse.	0.13	0.12	0.11*
Ref. Warehse.	0.20	0.24	0.11*
Sitdown Rest.	0.13	0.15	0.11*
Small Office	0.12	0.13	0.11*
Small Retail	0.12	0.13	0.11*
Roof Conductivity (Btu/ft^2.°F.ft.hr)			
Fastfood Rest.	0.11	0.13	0.05*
Food Store	0.07	0.08	0.05*
Large Office	0.06	0.06	0.05*
Large Retail	0.03	0.11	0.03
Non-Ref. Warehse.	0.10	0.12	0.05*
Ref. Warehse.	0.12	0.15	0.05*
Sitdown Rest.	0.08	0.09	0.05*
Small Office	0.06	0.07	0.05*
Small Retail	0.07	0.07	0.05*
Window U-Value (Btu/ft^2.°F.hr)			
Fastfood Rest.	1.41	1.44	1.41
Food Store	1.46	1.46	1.46
Large Office	1.47	1.47	1.47
Large Retail	1.47	1.47	1.47
Non-Ref. Warehse.	1.46	1.47	1.46
Ref. Warehse.	1.47	1.47	1.47
Sitdown Rest.	1.38	1.41	1.38
Small Office	1.42	1.45	1.42
Small Retail	1.41	1.41	1.41
Window Shading Coefficient			
Fastfood Rest.	0.80	0.83	0.80
Food Store	0.88	0.88	0.88
Large Office	0.63	0.63	0.50*
Large Retail	0.82	0.84	0.82
Non-Ref. Warehse.	0.72	0.83	0.72
Ref. Warehse.	0.73	0.69	0.73
Sitdown Rest.	0.78	0.79	0.78
Small Office	0.71	0.74	0.71
Small Retail	0.82	0.83	0.82

0

* Constrained by Title-24

Lighting and Equipment Intensities. Meaningful estimation of the impacts of standards on HVAC energy use requires modifying internal loads that result from lighting and equipment, so these loads will be consistent with the vintages examined. Our approach was to use CEC data on the short-run price elasticity of demand for electricity, recent SCE prices, and information CEC has gathered on increases in miscellaneous equipment energy use to develop indexing factors for lighting and equipment. The resulting levels are reported in Tables VIII-25 and TVIII-26.

Table VIII-25. Prototype Lighting Modifications (W/ft^2)

Premise	NELDIG Prototype	Vintage 1975	Vintage 1980
Fastfood Rest.	1.38	1.38	1.45
Food Store	1.59	1.78	1.72
Large Office	1.59	1.71	1.70
Large Retail	1.65	1.93	1.77
Non-Ref. Warehse.	0.64	0.69	0.67
Ref. Warehse.	1.04	0.88	1.08
Sitdown Rest.	1.09	1.21	1.11
Small Office	1.27	1.52	1.36
Small Retail	1.61	1.68	1.72

Table VIII-26. Prototype Equipment Modifications (W/ft^2)

Premise	NELDIG Prototype	Vintage 1975	Vintage 1980
Fastfood Rest.	6.08	4.89	5.40
Food Store	1.91	1.54	1.70
Large Office	0.48	0.31	0.36
Large Retail	0.28	0.23	0.25
Non-Ref. Warehse.	0.24	0.19	0.21
Ref. Warehse.	6.18	4.97	5.49
Sitdown Rest.	6.27	5.04	5.56
Small Office	0.88	0.57	0.67
Small Retail	1.92	1.54	1.70

HVAC Equipment and Operation. Specifying HVAC equipment and operation included defining HVAC system types, outside air quantities and economizer cycles, equipment sizes and efficiencies, and thermostat control strategies. There were few definitive data, so much engineering judgment was required.

HVAC system types were selected using the 1985 mail survey to determine whether package or central systems were more common for a building type. Beyond this, relatively simple system types were selected (primarily, package single zone systems). System types were not varied by vintage with the exception of the large office in which dual-duct and multi-zone systems were specified for vintage 1975 and a variable air volume system was specified for vintage 1980 (dual-duct and multi-zone systems are prohibited by the standards).

Outside air quantities for vintage 1975 were taken from reported values for pre-1979 premises. For vintage 1980, we used the recommended values for outside air quantities per person and the design occupancies from ASHRAE Standard 62-1973. Application of the ASHRAE procedures, which are based on building population, often produced very low estimates of outside air flow, which we suspect were related to our low estimates of building occupants (see Task IV).

Cooling plant efficiencies for vintage 1975 were taken from reported values for pre-1979 premises. For vintage 1980, these values were the most efficient of those from the NELDIG prototype or those called for by the standard. With one exception, the minimum levels called for by the standard constrained the cooling plant efficiencies to have a COP of 2.5.

Control strategies are not reported in Table VIII-27 because they were relatively uniform for all types of premises. For vintage 1980, economizers and resetting thermostats were specified; for vintages 1975, they were omitted.

Table VIII-27. Prototype HVAC Modifications

Premise	NELDIG Prototype	Vintage 1975	Vintage 1980
HVAC System Type[1]			
Fastfood Rest.	PSZ	PSZ	PSZ
Food Store	PSZ	PSZ	PSZ
Large Office	PSZ,SZRH	PMZS,DDS	PSZ,VAVS
Large Retail	PSZ,SZRH	PSZ,SZRH	PSZ,SZRH
Non-Ref. Warehse.	PSZ	PSZ	PSZ
Ref. Warehse.	PSZ	PSZ	PSZ
Sitdown Rest.	PSZ	PSZ	PSZ
Small Office	PSZ	PSZ	PSZ
Small Retail	PSZ	PSZ	PSZ
Outside Air (Min OA CFM/Total CFM)			
Fastfood Rest	0.20	0.23	1.00
Food Store	0.19	0.22	0.02
Large Office	0.14	0.14	0.15
Large Retail	0.17	0.17	0.13
NonRef Warehse	0.10	0.10	0.02
Ref Warehse	0.02	0.15	0.01
Sitdown Rest	0.31	0.30	0.47
Small Office	0.21	0.18	0.16
Small Retail	0.24	0.29	0.10
Cooling Efficiency (COP); Direct Expansion (Chiller)			
Fastfood Rest.	2.17	2.08	2.50
Food Store	2.27	2.22	2.50
Large Office	2.33 (5.56)	2.33 (5.56)	2.50 (5.56)
Large Retail	2.33 (3.85)	2.33 (3.85)	2.50 (4.00)
Non-Ref. Warehse.	2.27	2.27	2.50
Ref. Warehse.	2.17	1.85	2.50
Sitdown Rest.	2.22	2.13	2.50
Small Office	2.22	2.22	2.50
Small Retail	2.22	2.17	2.50

Note 1:

PSZ - Package, Single-Zone
SZRH - Single-Zone Reheat System
DDS - Dual Duct System
VAVS - Variable Air Volume System

Approach for non-HVAC EUIs. For non-HVAC end uses, adjustments to the reconciled EUIs sought only to capture the price impacts on energy use and remove the effects of the saturation of equipment found in the on-site survey premises. For miscellaneous equipment, the effects of technological change were also taken into account.

Table VIII-28 summarizes the price effects for the 1975 vintage and, for miscellaneous equipment, the combined effects of technological change and price. The changes were based on the CEC's short-run price elasticity of demand and SCE historic price series for all end uses except miscellaneous. For miscellaneous, they were based on both a price effect and a technological growth factor developed by the CEC.

Table VIII-28. Price Effects on Non-HVAC EUI from 1986 to 1975

End Use	Adjustment
All (except misc. elec.)	+ 7%
Misc. Elec. (except office)	- 19.5%
Misc. Elec. (office)	- 35.9%

Table VIII-29 summarizes the saturations of equipment found in the on-site survey premises.

Table VIII-29. Weighted Saturation Data from the On-Site Survey

		Cooking		Water Heating	
	Refrigeration	Electric	Gas	Electric	Gas
Restaurant	1.000	0.899	0.069	0.017	0.839
Food Store	1.000	0.268	0.031	0.131	0.640
Large Office	0.808	0.433	0.000	0.283	0.717
Large Retail	0.993	0.557	0.000	0.138	0.553
NonRef Ware	0.829	0.004	0.000	0.756	0.062
Ref Ware	1.000	0.656	0.000	0.725	0.275
Small Office	0.765	0.159	0.026	0.421	0.238
Small Retail	0.790	0.099	0.000	0.262	0.566

Adjusted EUIs for Use in CEC and SCE Forecasting Models. The resulting EUIs for cooling, heating, and ventilation are presented on Tables VIII-30, VIII-31, and VIII-32, respectively. Climate variations were reintroduced to the reconciled EUIs for the non-refrigerated warehouse, the refrigerated warehouse, and the restaurant. The adjustments were made using the ratios of the initial DOE-2 simulations from each region to the weighted average of these ratios used to develop the preliminary total EUI estimates that were the initial conditions to the EDA (see Table VIII-1). Table VIII-33 and VIII-34 summarize the adjusted non-HVAC EUIs.

Table VIII-30. Cooling EUIs for 1975 and 1980 Vintages (kWh/ft^{2}yr)

	Recon EUI	$Load_{Proto}$/ EUI_{Proto} [1]	$Load_{1975}$/ $Load_{Proto}$ [2]	Fuel Type	1975 EUI [3,4]	$Load_{1980}$/ $Load_{1975}$ [5]
Sm Off LAX	2.77	2.48	0.94	Elec.	1.98	0.91
				Gas	16.71	
				Other	10.96	
Sm Off BUR	5.80	2.36	0.98	Elec.	4.11	0.84
				Gas	34.63	
				Other	22.71	
Sm Off NOR	8.92	2.19	0.97	Elec.	5.82	0.92
				Gas	49.05	
				Other	32.17	
Lg Off LAX	3.93	3.48	1.98	Elec.	8.34	0.38
				Gas	70.24	
				Other	46.07	
Lg Off BUR	3.93	3.41	1.82	Elec.	7.45	0.40
				Gas	62.76	
				Other	41.17	
Lg Off NOR	5.11	3.22	1.72	Elec.	8.67	0.47
				Gas	73.01	
				Other	47.89	
Sm Ret LAX	5.45	2.51	0.92	Elec.	3.92	0.97
				Gas	27.34	
				Other	21.46	
Sm Ret BUR	6.54	2.38	0.94	Elec.	4.54	0.87
				Gas	31.68	
				Other	24.86	
Sm Ret NOR	11.15	2.21	0.95	Elec.	7.25	0.90
				Gas	50.62	
				Other	39.73	
Lg Ret LAX	5.79	2.80	1.17	Elec.	5.89	0.75
				Gas	41.14	
				Other	32.29	
Lg Ret BUR	4.94	2.72	1.18	Elec.	4.90	0.72
				Gas	34.21	
				Other	26.85	
Lg Ret NOR	7.65	2.59	1.13	Elec.	6.88	0.84
				Gas	48.07	
				Other	37.73	

Table VIII-30. Cooling EUIs cont.[6]

	Recon EUI	$Load_{Proto}$/ EUI_{Proto}[1]	$Load_{1975}$/ $Load_{Proto}$[2]	Fuel Type	1975 EUI[3,4]	$Load_{1980}$/ $Load_{1975}$[5]
NonRef Ware	1.16	2.56	0.85			
LAX			0.96[5]	Elec.	0.84	0.82
				Gas	5.33	
				Other	4.09	
BUR			1.01	Elec.	0.89	0.80
				Gas	5.64	
				Other	4.33	
NOR			1.04	Elec.	0.90	0.67
				Gas	5.76	
				Other	4.42	
Ref Ware	2.82	2.27	0.97			
LAX			0.79	Elec.	1.69	0.73
				Gas	10.76	
				Other	8.26	
BUR			0.85	Elec.	1.83	0.80
				Gas	11.65	
				Other	8.94	
NOR			1.19	Elec.	2.56	0.72
				Gas	16.31	
				Other	12.52	
Restaurant	12.25	2.55	0.88			
LAX			0.94	Elec.	7.20	0.96
				Gas	51.88	
				Other	43.83	
BUR			0.94	Elec.	7.20	0.93
				Gas	51.88	
				Other	43.83	
NOR			1.15	Elec.	8.80	1.04
				Gas	63.40	
				Other	53.57	

Notes for Table VIII-30

1. Developed from DOE-2 simulations of the NELDIG prototype.
2. Developed using an additional simulation of the prototype modified for the 1975 vintage.
3. Calculated using CEC weighted average energy conversion efficiencies by fuel type: electricity, gas, and other.
4. To convert to $kBtu/ft^2yr$ multiply by 3.412
5. Because reconciliation was not performed separately for each climate region, climate variation is introduced by multiplying the 1975 EUI (one column to the right and above) by this ratio, which was developed using additional DOE-2 simulations of the prototype in each climate region.
6. Food stores showed no cooling load in the simulations of the NELDIG prototype; consequently, all temperature-sensitive load was assigned to refrigeration, and the cooling EUI was set to zero.

Table VIII-31. Heating EUIs for 1975 and 1980 Vintages (kBtu/ft^{2}yr)

	NELDIG EUI	$Load_{Proto}/EUI_{Proto}$	$Load_{1975}/Load_{Proto}$ [1]	Fuel Type	1975 EUI	$Load_{1980}/Load_{1975}$ [3]
Small Office LAX	2.11	0.74	0.87	Elec.	1.03	1.00
				Gas	2.05	
				Other	2.01	
Small Office BUR	2.11	0.74	0.71	Elec.	0.85	1.00
				Gas	1.69	
				Other	1.66	
Small Office NOR	2.11	0.74	0.67	Elec.	0.80	1.00
				Gas	1.58	
				Other	1.55	
Large Office LAX	0.74	0.74	38.21	Elec.	15.99	0.04
				Gas	31.74	
				Other	31.22	
Large Office BUR	0.72	0.74	38.39	Elec.	15.74	0.04
				Gas	31.24	
				Other	30.72	
Large Office NOR	0.88	0.74	33.56	Elec.	16.76	0.05
				Gas	33.26	
				Other	32.71	
Small Retail LAX	2.42	0.74	0.95	Elec.	2.09	1.00
				Gas	3.67	
				Other	3.67	
Small Retail BUR	2.42	0.74	1.03	Elec.	1.60	1.00
				Gas	2.81	
				Other	2.81	
Small Retail NOR	2.42	0.74	0.94	Elec.	1.45	1.00
				Gas	2.54	
				Other	2.54	
Large Retail LAX	0.19	0.74	0.76	Elec.	0.09	0.98
				Gas	0.16	
				Other	0.16	
Large Retail BUR	0.20	0.74	0.82	Elec.	0.11	0.96
				Gas	0.19	
				Other	0.19	
Large Retail NOR	0.20	0.74	0.76	Elec.	0.10	0.94
				Gas	0.17	
				Other	0.17	

Table VIII-31. Heating EUIs cont.[5]

	NELDIG EUI	$Load_{Proto}$/ EUI_{Proto}	$Load_{1975}$/ $Load_{Proto}$ [1]	Fuel Type	1975 EUI	$Load_{1980}$/ $Load_{1975}$ [3]
Food Store	2.44	0.74	1.17			
LAX[4]			1.00	Elec.	3.90	1.00
				Gas	1.39	
				Other	1.39	
BUR			1.00	Elec.	3.90	1.00
				Gas	1.39	
				Other	1.39	
NOR			1.00	Elec.	3.90	1.00
				Gas	1.39	
				Other	1.39	
NonRef Ware	1.48	0.74	0.91			
LAX			1.00	Elec.	1.02	1.00
				Gas	0.66	
				Other	0.66	
BUR			1.00	Elec.	1.02	1.00
				Gas	0.66	
				Other	0.66	
NOR			1.00	Elec.	1.02	1.00
				Gas	0.66	
				Other	0.66	
Restaurant	5.47	0.74	1.58			
LAX			0.99	Elec.	6.92	1.02
				Gas	4.22	
				Other	4.22	
BUR			1.00	Elec.	6.94	1.08
				Gas	4.23	
				Other	4.23	
NOR			1.01	Elec.	6.98	1.05
				Gas	4.25	
				Other	4.25	

Notes for Table VIII-31.

1. Developed using an additional simulation of the prototype modified for the 1975 vintage.
2. Calculated using CEC weighted average energy conversion efficiencies by fuel type; the descending order of entries is electricity, gas, and other.
3. Developed using additional simulations of the prototype modified for the 1975 and 1980 vintages -- does not include effects of higher equipment efficiencies or changes in saturations.
4. Climate variation is introduced by multiplying the 1975 EUI (one column to the right and above) by this ratio, which was developed using DOE-2 simulations of the prototype in each climate region.
5. Refrigerated warehouses showed no heating load in the simulation of the NELDIG prototypes and so are not included in this analysis.

Table VIII-32. Ventilation EUIs for 1975 and 1980 Vintages (kWh/ft^{2}yr)

	Reconciled EUI	1975/[1] Prototype	1975 EUI (kWh/ft^{2}yr)	1975 EUI (kBtu/ft^{2}yr)	1980/[2] 1975
Small Office LAX	0.97	0.93	0.90	3.08	1.02
Small Office BUR	1.38	0.97	1.34	4.58	0.97
Small Office NOR	1.23	0.98	1.20	4.09	0.98
Large Office LAX	3.09	1.52	4.69	16.00	0.36
Large Office BUR	3.29	1.49	4.91	16.76	0.37
Large Office NOR	3.45	1.47	5.06	17.28	0.38
Small Retail LAX	1.67	0.92	1.53	5.23	1.04
Small Retail BUR	1.82	0.94	1.71	5.84	1.01
Small Retail NOR	2.04	0.95	1.94	6.61	1.02
Large Retail LAX	3.41	1.05	3.58	12.20	0.97
Large Retail BUR	3.71	1.05	3.89	13.28	0.96
Large Retail NOR	3.61	1.05	3.79	12.92	0.96

1. Based on DOE-2 simulations of the NELDIG prototype and a prototype modified for the 1975 vintage.
2. Based on DOE-2 simulations of the 1975 vintage prototype and a prototype modified for the 1980 vintage.

Table VIII-32. Ventilation EUIs cont.

	Reconciled EUI	1975/ Prototype[1]	Climate Adjustment[2]	1975 EUI (kWh/ft^{2}yr)	1975 EUI (kBtu/ft^{2}yr)	1980/ 1975[3]
Food	2.14	1.05		2.24		
LAX			0.98	2.20	7.49	0.96
BUR			0.98	2.20	7.49	0.95
NOR			1.03	2.31	7.87	0.95
NonRef Ware	0.62	0.96		0.60		
LAX			0.95	0.57	1.93	1.03
BUR			1.02	0.61	2.08	1.01
NOR			1.04	0.62	2.11	1.02
Ref Ware	1.50	0.85		1.27		
LAX			0.85	1.09	3.70	0.83
BUR			0.98	1.24	4.24	0.96
NOR			1.09	1.39	4.73	0.90
Restaurant	7.49	0.91		6.82		
LAX			0.96	6.53	22.28	1.08
BUR			1.01	6.88	23.46	1.05
NOR			1.03	7.04	24.01	1.05

1. Based on DOE-2 simulations of the NELDIG prototype and a prototype modified for the 1975 vintage.
2. Because reconciliation was not performed separately for each climate region, climate variation is introduced by multiplying the 1975 EUI (one column to the right and above) by this ratio, which was developed using additional DOE-2 simulations of the prototype in each climate region.
3. Based on DOE-2 simulations of the 1975 vintage prototype and a prototype modified for the 1980 vintage.

Table VIII-33. Electric Non-HVAC EUIs for 1975 Vintage (kWh/ft^2 yr)

	In Light	Ex Light	Misc Eq	Refrig	Cook	Water Ht
Reconciled EUIs (kWh/ft^2)						
Small Office	5.47	1.24	3.59	0.23	0.04	0.12
Large Office	11.93	2.11	4.28	0.10	0.00	0.16
Small Retail	7.49	1.59	1.48	0.95	0.01	0.04
Large Retail	12.21	1.47	1.12	0.61	0.19	0.02
Food Store	11.96	2.01	1.77	23.17	0.24	0.03
Ref Ware	3.02	0.55	6.24	11.34	0.01	0.17
NonRef Ware	3.38	0.17	0.70	0.41	0.00	0.03
Restaurant	7.94	4.09	4.89	10.78	4.46	0.03
Saturation from on-site survey and sampling weights (%)[1]						
Small Office	1.00	1.00	1.00	0.77	0.16	0.42
Large Office	1.00	1.00	1.00	0.81	0.43	0.28
Small Retail	1.00	1.00	1.00	0.79	0.10	0.26
Large Retail	1.00	1.00	1.00	0.99	0.56	0.14
Food Store	1.00	1.00	1.00	1.00	0.27	0.13
Ref Ware	1.00	1.00	1.00	1.00	0.66	0.73
NonRef Ware	1.00	1.00	1.00	0.83	0.00	0.76
Restaurant	1.00	1.00	1.00	1.00	0.90	0.02
1975 EUIs (kBtu/ft^2)[2]						
Small Office	19.95	4.51	7.84	1.10	1.03	1.05
Large Office	43.55	7.69	9.37	0.43	0.00	2.09
Small Retail	27.33	5.80	4.06	4.40	0.37	0.62
Large Retail	44.57	5.38	3.09	2.24	1.25	0.53
Food Store	43.66	7.34	4.86	84.59	3.27	0.84
Ref Ware	11.03	2.01	17.14	41.40	0.06	0.86
NonRef Ware	12.34	0.62	1.92	1.81	0.00	0.14
Restaurant	28.99	14.93	13.43	39.36	18.11	6.44

1. Developed on a total floor area basis using the on-site survey and the same weighting factors used for prototype development.
2. Developed using CEC short-run price elasticities and SCE historic prices and, for miscellaneous equipment only, a CEC technology growth adjustment factor. For all end uses but miscellaneous equipment, the price effect increases the reconciled EUIs by 7%. For office miscellaneous equipment, the combined effect reduces the miscellaneous equipment EUI by 36%; for all other building types, the combined effect reduces the miscellaneous equipment EUI by 19%.

Table VIII-34. Gas Non-HVAC EUIs for 1975 Vintage (kBtu/ft^2 yr)

	Gas Equipment	Gas Cooking	Gas Water Heat
NELDIG Gas EUIs (kBtu/ft^2)[1]			
Small Office	0.00	6.36	2.39
Large Office	0.00	0.34	1.47
Small Retail	13.99	0.00	0.51
Large Retail	0.00	0.67	0.85
Food Store	0.00	6.75	1.28
Ref Ware	2.82	0.00	0.31
NonRef Ware	0.00	0.00	1.21
Restaurant	17.81	120.15	18.42
1975 EUIs (kBtu/ft^2)[2]			
Small Office	0.00	6.81	2.56
Large Office	0.00	0.36	1.57
Small Retail	14.97	0.00	0.55
Large Retail	0.00	0.72	0.91
Food Store	0.00	7.22	1.37
Ref Ware	3.02	0.00	0.33
NonRef Ware	0.00	0.00	1.29
Restaurant	19.06	128.56	19.71

1. Developed on a total floor area basis using the on-site survey and the same weighting factors used for prototype development.
2. Developed using CEC short-run price elasticities and SCE historic prices. For all end uses, the price effect increases the EUIs by 7%.

Task IX. Assessment of Uncertainties

The available data and the methods used to develop preliminary and reconciled LSs and EUIs from these data were both subject to statistical fluctuations and biases and, therefore, introduced uncertainty to our results. There were many sources of uncertainty, including statistical random variation and errors in the input data (which is unavoidable); errors introduced by the analyses in this project, such as disaggregation of the whole-building load into end uses (a factor that we have tried to minimize it); and errors and biases introduced because of the format required for the output data, including averaging of daily load shapes into monthly load shapes. A thorough analysis of all these uncertainties was not within the scope of this project. However, we have tried to identify and qualitatively assess the impact of errors in the input data, the estimation methods and reconciliation procedures, and data formatting on the final LSs and EUIs. In a final section, we provide a preliminary quantitative estimate of the level of uncertainty in our EUIs based on an analysis of total electricity EUIs from the billing data.

Sources of Uncertainty

Review of the major steps of our project (see Figures IV-1) provides the basis for an outline of our discussion. From this review, we identify three major categories of uncertainty:

- *Input Data*
  - building data used to develop prototypes (on-site and mail surveys)
  - on-site survey electricity billing data
  - load research data
  - weather data

- *Estimation Method*
  - aggregation of the characteristics from individual premises into a prototype
  - aggregation of individual electricity bills into an average electricity bill
  - aggregation of LRD by building type to obtain average whole-building load shapes
  - adjustment of whole-building load shapes by the average electricity bill
  - development and use of statistical weighting factors
  - DOE-2 building energy analysis program
  - regression of average whole-building load shape against weather data
  - estimation of whole-building load from electricity bills and simulations for three regions
  - reconciliation of preliminary LSs to the average whole-building loads using EDA

- *Post-Processing of EDA Results*
  - averaging hourly end use data into load shapes for three day types per month
  - estimation of the final EUIs and LSs
  - application of factors to adjust final EUIs and LSs for use in SCE and CEC forecasting models

Input Data

Building Data. The on-site survey data were by far the most important sources of error in the analysis. The errors at this level were of two types: those associated with the process of collecting the building data and those associated with the process of coding data into electronic files. As noted in Task I, we spent a considerable amount of time analyzing and cleaning the on-site survey data. Errors such as improperly coded building type, floor area, equipment capacities, etc., were frequent and generally easy to identify and correct. Correcting for errors that affected the calculation of EUIs required additional analysis. Nevertheless, the analysis of EUIs for each of the individual premises (which corresponded to the calculation of preliminary EUIs, prior to reconciliation, for the prototype) still showed large variations in the EUIs found for a given building type. Some variations were unavoidable and could be attributed to the natural statistical variations among buildings, but some variations were due to errors in the auditor's reporting or the subsequent coding of data.

Table IX-1 summarizes the results of our analyses of non-HVAC EUIs by type of premises. For each end use, the mean, minimum, and maximum values are reported along with the standard deviations. For most types of premises and end uses, the standard deviation of the data was comparable to mean EUIs. For some types of premises, the average of the auditor's estimate was not significantly different from that of the average of the electricity bills, the indicated variations were probably a result of statistical variation among the premises themselves. If this were the case and the sample of premises was large, then we can expect our data to characterize well the EUIs of the stock. For a normally distributed sample, the standard error of the mean EUI can be estimated by the standard error of the sample divided by the square root of the sample size. As an example, the standard error of the unweighted population mean for interior lighting in the small office is $\frac{\mathbf{2.79}}{\sqrt{\mathbf{61}}} = \mathbf{0.36}$, and the 95% confidence level of average lighting EUI as estimated by the auditor is ~ **4.77±0.72**.

Table IX-1. Average Electric and Gas EUIs by End Use and Building Type - Unweighted

	Electric (kWh/ft^2.yr)							Gas (kBtu/ft.yr)		
	Indoor Lighting	Outdoor Lighting	Misc.	Refrig.	Cooking	Heating	Water Vent.	Misc.	Cooking	Water Heating
Low-Rise Office										
Mean	4.66	0.63	1.76	0.49	0.16	0.25	1.48	0.00	2.67	1.99
Max.	13.02	1.76	7.86	8.11	0.77	3.53	5.75	0.00	8.02	5.16
Min.	0.46	0.08	0.05	0.02	0.01	0.02	0.11	0.00	0.04	0.23
Std. Dev.	2.92	0.49	1.68	1.27	0.21	0.64	1.21	0.00	3.53	1.52
N	69	49	68	50	18	29	68	0	5	24
High-Rise Office										
Mean	3.47	0.14	0.92	0.07	0.04	0.08	12.70	0.00	0.00	1.08
Max.	4.74	0.32	1.23	0.10	0.06	0.08	4.03	0.00	0.00	1.58
Min.	2.39	0.02	0.42	0.04	0.01	0.00	0.04	0.00	0.00	0.57
Std. Dev.	1.19	0.16	0.44	0.04	0.04	.	0.35	0.00	0.00	0.71
N	3	3	3	2	2	1	3	0	0	2
Small Office										
Mean	4.77	0.67	1.76	0.55	0.19	0.26	1.50	0.00	4.41	2.15
Max.	13.02	1.76	7.86	8.11	0.77	3.53	5.75	0.00	8.02	5.16
Min.	0.91	0.08	0.10	0.02	0.01	0.02	0.11	0.00	0.66	0.29
Std. Dev.	2.79	0.50	1.64	1.34	0.22	0.66	1.21	0.00	3.68	1.42
N	61	43	60	44	15	27	60	0	3	18
Large Office										
Mean	3.71	0.24	1.53	0.05	0.02	0.14	1.27	0.00	0.05	1.39
Max.	12.75	0.71	5.19	0.10	0.06	0.28	4.03	0.00	0.06	5.13
Min.	0.46	0.02	0.05	0.02	0.01	0.05	0.04	0.00	0.04	0.23
Std. Dev.	3.30	0.22	1.79	0.03	0.02	0.13	1.12	0.00	0.01	1.60
N	11	9	11	8	5	3	11	0	2	8
Small Retail										
Mean	7.46	2.20	1.77	1.73	0.08	0.16	1.47	10.21	0.00	0.65
Max.	19.39	27.63	22.06	11.82	0.13	0.90	7.57	11.89	0.00	4.16
Min.	0.91	0.02	0.01	0.01	0.02	0.03	0.11	8.53	0.00	0.09
Std. Dev.	4.45	5.06	3.82	2.95	0.08	0.19	1.42	2.38	0.00	0.84
N	61	49	60	46	2	21	56	2	0	25
Large Retail										
Mean	5.51	0.58	0.46	0.41	0.35	0.04	1.72	0.00	0.62	0.71
Max.	14.21	2.00	0.98	2.08	0.94	0.07	5.15	0.00	1.14	1.53
Min.	1.66	0.08	0.07	0.01	0.08	0.01	0.13	0.00	0.28	0.18
Std. Dev.	3.15	0.60	0.38	0.66	0.35	0.03	1.42	0.00	0.46	0.52
N	13	10	12	12	5	4	13	0	3	5

Table IX-1. cont. Average Electric and Gas EUIs by End Use and Building Type - Unweighted

	Electric ($kWh/ft^2.yr$)							Gas (kBtu/ft.yr)		
	Indoor Lighting	Outdoor Lighting	Misc.	Refrig.	Cooking	Heating	Water Vent.	Misc.	Cooking	Water Heating
Food Store										
Mean	10.38	1.29	1.96	31.27	1.29	0.22	2.07	0.00	7.32	1.77
Max.	24.85	24.37	35.73	103.54	15.51	0.96	8.14	0.00	21.83	10.16
Min.	1.10	0.02	0.06	0.41	0.04	0.04	0.05	0.00	0.13	0.12
Std. Dev.	5.10	2.88	4.40	19.28	2.92	0.24	1.60	0.00	8.48	2.15
N	76	75	76	77	27	13	70	0	12	59
Refrigerated Warehouse										
Mean	6.99	0.63	24.61	5.87	0.21	4.05	9.07	2.68	0.00	0.27
Max.	12.31	1.01	67.11	14.64	0.31	7.97	17.99	3.52	0.00	0.41
Min.	1.63	0.33	0.18	1.25	0.10	0.14	0.14	1.83	0.00	0.13
Std. Dev.	4.75	0.31	30.52	6.18	0.15	5.53	12.62	1.20	0.00	0.20
N	4	4	4	4	2	2	2	2	0	2
Nonrefrigerated Warehouse										
Mean	2.70	0.20	2.21	2.19	0.89	0.12	0.73	0.00	0.00	6.10
Max.	5.15	0.55	11.48	9.40	1.67	0.20	5.59	0.00	0.00	23.90
Min.	1.30	0.02	0.15	0.01	0.10	0.03	0.06	0.00	0.00	0.06
Std. Dev.	1.10	0.16	3.35	3.65	1.11	0.06	1.54	0.00	0.00	11.87
N	13	11	12	11	2	7	12	0	0	4
Health										
Mean	6.02	0.38	1.56	1.21	0.43	0.00	2.91	17.04	10.50	8.63
Max.	10.73	0.99	3.87	2.46	0.89	0.00	11.48	33.20	17.95	23.28
Min.	1.32	0.09	0.25	0.39	0.11	0.00	0.81	0.88	2.34	1.14
Std. Dev.	3.21	0.26	1.20	0.70	0.31	0.00	3.19	22.85	6.05	8.00
N	11	9	10	11	7	0	10	2	6	8
Sit Down Restaurant										
Mean	5.66	2.20	2.28	11.74	6.25	1.80	3.12	28.27	98.04	22.92
Max.	24.14	10.95	13.21	54.02	106.01	3.05	9.21	30.47	839.76	113.70
Min.	0.19	0.06	0.01	0.69	0.10	0.24	0.28	26.07	0.30	0.30
Std. Dev.	4.60	2.54	2.97	10.21	14.53	1.43	2.36	3.11	128.50	22.97
N	58	54	61	63	54	3	57	2	57	56
Fast Food Restaurant										
Mean	9.09	4.19	3.10	18.84	16.46	1.73	4.24	0.00	159.19	20.89
Max.	18.51	15.68	12.55	67.96	86.74	2.10	13.16	0.00	833.11	60.43
Min.	0.42	1.27	0.38	4.24	0.23	1.35	0.81	0.00	4.69	0.82
Std. Dev.	5.12	3.20	2.78	15.03	22.37	0.53	3.85	0.00	221.28	19.65
N	22	22	22	22	18	2	20	0	14	20

This estimate of error does not include the auditor's biases and unresolved significant discrepancies between the on-site audit and the electricity bills (correspondence between the bill and the audited premises). For example, the differences between the average electricity bills and simulated total EUI by type of premises (reported in Table VIII-1) introduced significant bias to the EUIs, which can not be addressed by conventional statistical procedures. For the refrigerated warehouse, the difference was a factor of four; for the large office, the difference was almost a factor of two. The only way to remove these biases would be by obtaining a larger and more representative sample of buildings and analyzing the data more closely by, for example, revisiting the premises after an initial reconciliation of the audit and electricity bills.

On-site Survey Electricity Billing Data. The billing data were probably among the most statistically robust data used in our LS and EUI analysis. Although these data were accurate when they were measured, sources of inaccuracies included length of the billing period, (month to month comparison can easily vary by 20%), varying operation in some premises (e.g. seasonal variations in occupancy and schedules), and missing data.

We have minimized variations in the electricity bills by aggregating the monthly data to annual energy use and imputing missing values. However, in most cases, identifying extended unoccupied periods and other variations in occupancy was not possible and hence no corrections were made to the data.

In general, we judged typical uncertainties in annual electricity consumption to be less than 5%. Thus, when this uncertainty is combined with that of the floor area, the variation in the measured whole-building EUI is predominantly defined by the uncertainties in the floor area.

Load Research Data. To a certain extent, the uncertainties in the LRD were of the same nature as those of the electricity bills. Other than periods of missing data, LRD provided information that was not only accurate for monthly or yearly energy calculation, but also at the hourly level for the whole-building load shape. A quick comparison of the LRD whole-building loads with those estimated through simulations revealed: 1) for a majority of the buildings, the time-average end-use load shapes for a building gradually increase and decrease during shoulder hours; and 2) the energy use by large equipment is usually not as large as was indicated by the auditor, according to estimates by NELDIG.

The time-average hourly loads of the whole-building load shape after being corrected for weather were very robust and exhibited only small variation. For instance, typical variations in the large office whole-building load for standard weekdays (10 am to 4 pm) and during late night hours were usually around 5%. The same level of variation was observed in most other building types. The variation in shoulder hours was much larger than 5%.

After removing bad data, we used the LRD without any correction or imputation. The general criteria for identifying bad data were 1) the presence of missing data; and 2) misclassification of the building type based on visual review of the load shapes (see Task I).

Weather Data. Weather data for the project were obtained from the National Oceanic and Atmospheric Administration (NOAA). The data were collected at airports and included hourly dry-bulb, wet-bulb and dew-point temperature; wind speed; and wind direction.

In our analysis, we assumed that the weather at the airports and at the building sites was not significantly different. However, we know that the observed dry-bulb and wet-bulb temperature and the wind data can change significantly between the airports and building sites.[1] The uncertainties in the weather data affected primarily building HVAC loads; these effects can be as high as 30% of the HVAC load in smaller shell-dependent buildings. In this project, we did not study uncertainties introduced by the variation of weather data.

[1] The probability of significant changes usually, but not always, increases with distance from the airport. For this project, weather data from the Norton AFB was used to analyze data from sites as disparate as Bakersfield, Bishop, and Palm Springs.

Estimation Method

Many factors in the LS and EUI estimation method introduced uncertainties in the final results. The major factors were integration of the data into *prototype buildings*, *average electricity bills*, *average whole-building load shapes*, *adjusted average whole-building load shapes*, as well as the use of *weighting factor*, and the *final EDA disaggregation*.

Prototypical Buildings. In Task VI, we examined some of the uncertainties introduced by averaging the on-site survey building characteristics into prototypical buildings. In general, the process was deterministic and did not introduce significant uncertainties into the final results.[2] However, this stage inherited the uncertainties associated with the sample and the auditor's biases and errors. One major point of caution here was the use of weighting factors for developing prototypical buildings. The sample for some building types was very small. In addition to the statistical problems introduced by small sample sizes, the problem may have been aggravated when the weighted mean of the sample was estimated.

We did not detect significant differences in the sample population by geographical regions, so we generated one set of prototypes for all climates. A larger and more detailed sample may show significant differences between premises of the same type located in different climate regions.

Average Electricity Bills. For analysis of premises' loads by geographic regions, average electricity bills for each region were needed. However, the sample size was not large enough to provide this information. For our analysis, we aggregated the electricity bills of all climate regions by building type and then adjusted the average electricity bills using adjustment factors developed from DOE-2 simulations of the prototypes in each location. This process implicitly assumes that the non-HVAC end uses did not vary among climate regions (a rather reasonable assumption in the absence of better data).

[2] An exception was estimation of HVAC energy use, which showed large differences between the prototype approach and the individual premises approach.

Table IX-2 shows the variation in the mean annual electricity bills. Significant variation in the estimate of the population mean can be observed for the small retail, refrigerated warehouse, fast-food restaurant, and small office.

Table IX-2. Distribution of Total Electricity EUIs from the On-Site Survey (kWh/ft^2.yr)

	Large Office	Small Office	Large Retail	Small Retail	Food	NonRef Ref Ware	Ware	Fastfood	Sitdown
Min	4.20	0.96	6.83	3.77	7.36	8.94	0.18	7.53	1.40
Max	58.78	315.71	30.05	1479.74	224.26	112.39	9.81	151.20	186.33
Mean	21.06	29.47	19.31	48.37	59.09	35.00	5.36	80.49	53.93
Sample σ	16.16	51.53	7.07	176.94	28.11	38.85	2.55	37.30	33.73
N	15	72	13	68	79	5	14	22	64
Pop. Mean σ	4.17	6.07	1.96	21.46	3.16	17.37	0.68	7.95	4.22

Average Whole-Building Load Shapes. The LRD sample of billing accounts was different from the sample of on-site survey premises; the intersection of these data sets was fewer than 50 premises. In our analysis, we used the LRD only to provide the whole-building load shape for either one all-inclusive or three separate climate regions. In doing so, we assumed that, although the LRD and on-site survey samples were different, they were drawn from the same population, so, on the average, they should have the same characteristics. The assumption is fairly good for larger sample sizes (>30), plausible for medium sample sizes (>5 and <30) and questionable for small sample sizes (<5). Table II-5 summarizes the sample number for each climate region by type of premises. When the sample size by climate region was small, the LRD for all climates were aggregated and analyzed as one group in order to partially overcome the uncertainties associated with the small sample size. We performed separate analyses for each of the three climate regions for only large office, small office, large retail, and small retail. The LRD data for all the other building types were grouped together. This aggregation meant that, in the our final evaluation for these buildings, we would not find differences among the load shapes of the three climate regions.

At this time, we do not have a quantitative feeling for the accuracy of the averaging involved in this step. However, it can be rigorously proved that for larger sample sizes (e.g., large office, large retail, and non-refrigerated warehouse LRD), this averaging would not introduce significant errors in the final results.

We have learned that SCE and CEC assign districts to climate zones differently from the assignments presented in Table II-4. The alternative assignments are presented in Table IX-3 and the resulting number of LRD accounts in each climate region for those building types that were evaluated separately by region is presented in Table IX-4. The new assignments would move many of the LRD accounts to the coastal regions and would not leave statistically adequate data in the remaining climate regions. We considered the impact of new assignments on the final LSs and EUIs and determined that, in general, they would not change the LSs and EUIs significantly. The primary reason is that the total energy under the load shapes is determined by the measured electricity bills adjusted by additional DOE-2 simulations (see below). Significant changes would result only if large changes in the whole-building load shape resulted from the new assignments.

Adjusting Whole-Building Load Shapes Using Average Electricity Bills As mentioned previously, we assumed only that the overall whole-building load shapes of the buildings could be defined by the LRD. That is, since the LRD did not report floor area, we could not use the average whole-building load directly from the LRD. Instead, we normalized the whole-building load shape from the LRD using an average of the electricity bills from the on-site survey. One drawback of this assumption is that it scales up the day and night load shapes of LRD with the same adjusting factor and, in effect, shifts some energy use to different hours. Again, we expect that this normalization procedure is defensible for large building samples. For smaller samples, the magnitude of energy use shifted between day and night hours may be significant.[3]

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[3] One way of reducing this level of uncertainty in the future may be to use both the kWh and kW data to adjust the LRD load shapes.

Table IX-3. SCE and CEC Assignments of Districts to Climate Regions

Climate Regions			
Coastal Los Angeles Airport	Inland Hollywood-Burbank	Desert Norton (San Bernadino)	Central Valley
Santa Monica (42)	Monrovia (27)	Arrowhead (40)	Kernville (53)
Ventura (39)	San Fernando (59)	Hemet (78)	Big Creek (50)
Long Beach (46)	Lancaster (36)	Victorville (73)	Ridgecrest (86)
Santa Barbara (49)	Covina (26)	Redlands (31)	San Joaquin Valley (51)
Redondo Beach (44)	Bishop (85)	Barstow (72)	
Santa Ana (29)		Palm Springs (79)	
Compton (32)		29 Palms (84)	
Huntington Beach (33)		San Bernadino (30)	
Catalina (61)		Perris (77)	
Montebello (22)		Blythe (87)	
Thousand Oaks (35)			
El Toro (43)			
Ontario (34)			
Inglewood (41)			
Fullerton (48)			
Whittier (47)			

Table IX-4. SCE's Alternative Geographic Distribution of Load Research Data

	Climate Regions			
Premise	Coastal Los Angeles Airport	Inland Hollywood-Burbank	Desert Norton (San Bernadino)	Central Valley
Large Office	286	18	10	3
Small Office	16	6	6	2
Large Retail	162	32	17	1
Small Retail	11	1	6	3

Weighting Factors. Weighting factors were an essential part of our estimation analysis. We developed weighting factors using data provided by SCE on the distributions of electricity use by premises. We assumed that each of the premises or accounts in our on-site survey and LRD data bases represented information for a random draw from the SCE universe of billing accounts. We don't know how valid this assumption is. We acknowledge that a better source of weighting factors would result from a more rigorous and well-documented sampling procedure for the on-site survey data.

One effect of the weighting factors was that their use led to the development of smaller prototypes than those historically used by SCE and CEC. Again, it is difficult to assess the effect of smaller prototypes on the resulting EUIs and LSs because they are normalized by floor area.

A more dramatic effect of the weighting factors was that they led to large differences between the total initial estimate and total measured EUI for large and small offices, and retail buildings. Because these totals were the basis for reconciliation, these large differences were not fully corrected in EDA, so they produced significant differences in end-use EUIs.

DOE-2 Building Energy Analysis Program. We used DOE-2 to calculate of heating, cooling, and ventilation loads for our prototypes. The potential errors introduced at this step include errors in calculation of the HVAC loads, and errors introduced by assuming that simulation of prototypes will produce the same result as that from the simulation of individual buildings. The DOE-2 algorithms have been extensively validated, and the potential errors in the annual energy use have been estimated to be less than 10%. The errors in the hourly loads have not been examined and may be larger.

The second source of error is actually traceable to the use of prototypes, as discussed in Task VI. We found that the errors introduced by the use of prototypes could be as much as 30%. In our analysis, whenever feasible, we used the measured load temperature dependencies of the LRD to estimate HVAC loads. This greatly reduced the size of potential errors that DOE-2 simulation could introduce to our final LSs and EUIs.

Regression of Average Whole-Building Load Shape Against Weather Data. Our methodology for estimating cooling loads relied on regressions of the average whole-building load against selected weather parameters. The parameters examined included dry-bulb, wet-bulb, and dew-point temperatures, and humidity ratios, but we found out that the hourly loads were best regressed with dry-bulb and dew-point temperatures (see Task II). For the majority of climate regions and types of premises, the regressions yielded relatively high $\mathbf{R}^2$s, and typical standard errors of estimates were less than 20%.

Estimation of Whole-Building Load from Electricity Bills and Simulations for Three Regions. The electricity bills from the on-site surveys, when broken down into the three climate regions were usually a very small sample and hence statistically non-representative. To overcome this problem, we first estimated the average electricity bill for the entire service area and then adjusted the figure to specific regions, using DOE-2 simulations. This approach worked well to generate initial conditions for EDA. However, for some premises, we found that the reconciled EUIs for non-HVAC end uses exhibited 10-20% variations across the climate regions. This variation was a methodological error. We have addressed it by aggregating the non-HVAC EUIs across regions into a single value.[4]

Reconciliation of the Estimated Whole-Building Load and Initial Conditions Using EDA. The basic ideas used in EDA were fairly straightforward and simple. For a given hour, having the total building load, outside weather conditions, and a preliminary estimate of end uses (the initial conditions), EDA reconciles the differences between the initial estimate and measured data. The EDA results were generally plausible for the midday and midnight hours. However, because of the mismatch of the observed schedules and those of the prototypes, the initial end-use profiles during the shoulder-hour were unrealistic. We were required to use an iterative approach to resolve this problem. After the first EDA reconciliation, we smoothed the shoulder-hour profiles, using a quadratic interpolation, and used the smoothed profiles as initial conditions to a second EDA run. The resulting load shapes were presented as our deliverable.

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[4] One way to correct for this error in the future may be to estimate the electricity bills from the first EDA iteration and perform a second EDA with this new initial condition.

The overall errors introduced by the EDA for HVAC end uses were probably smaller than those of the non-HVAC end uses. EDA can not, *a priori*, distinguish differences among end uses, so, our results were very dependent on the initial conditions. Of course, when highly unrealistic results were obtained, we constrained the degree of adjustment permitted.

The major emphasis in this project was on standard and peak day hourly load profiles. For this reason, some of the non-standard days profiles were questionable, and some end uses may have as much as a 50% error at the hourly level.

Post Processing of EDA Results

Averaging Hourly End-Use LSs into Monthly Average LSs. We developed monthly load shapes for peak, standard, and non-standard days. We processed the hourly profiles from EDA to obtain the required load shapes. The statistical variation of the final results was fairly small for non-HVAC end uses (usually 10-20%) and was slightly higher for HVAC end uses.

Developing EUIs from LSs. The hourly load profiles were integrated to calculate the final EUIs. We estimate these EUIs to be accurate within 20% for the HVAC end uses. We also expect the same level of overall error for the summation of all non-HVAC end uses. For individual non-HVAC end uses, however, the errors are probably at about the same level as those contained in the original auditor's estimate. The major sources of error are in the equipment and lighting end uses.

As discussed in Chapter VII, end-use data are essential for the refinement and further development of the EDA. The major advantage of the EDA, with its current capabilities, is to obtain cooling energy load from the measured whole-building data. The superiority of the EDA in this regard was demonstrated by the example given in Chapter VII. Measured end-use data are needed in order to refine EDA to recognize characteristic differences among non-weather dependent end uses.

EUI Adjustments for SCE and CEC Forecasting Models. We adjusted our reconciled EUIs for use in the SCE and CEC forecasting models. The adjustment procedure for HVAC end uses relied on additional DOE-2 simulations of modified versions of the prototypes. Although the adjustments were developed from simulations, they were applied as scaling factors to the reconciled EUIs. Without question, these procedures introduced unique biases to the EUIs. At this time, however, we are unable to assess them separately from the overall assessment of uncertainty presented next, in our final section.

An Overall Estimate of Uncertainty in the Reconciled EUIs

A detailed analysis of the contributing uncertainties to the overall end-use EUIs and LSs is a major effort and was beyond the scope of the current project. However, we have attempted to estimate the uncertainties associated with the end-use EUIs using analysis of average total building EUIs calculated from on-site survey electricity bills. In these calculations, we made the following assumptions:

1. all end uses were independent and normally distributed;[5] and
2. the standard deviation of each end use is proportional to its mean value.[6]

Using the above assumptions, we calculated the standard deviation for each end use from the whole-building EUI statistics, calculated from electricity bills. Table IX-5 shows the resulting standard error of estimates on the final end-use EUIs. In order to make these calculations, we analyzed the electricity bills for outliers and removed them from the data base.

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[5] For independent and normally distributed variables, $\sigma_{total}^2 = \sum_i^{All} \sigma_i^2$

[6] This assumption allows us to estimate σ_i from σ_{total} such that $\frac{\sigma_i}{\sigma_{total}} = \frac{EUI_i}{\sqrt{\sum_i^{All} EUI_i^2}}$.

Table IX-5. Estimated whole-building and end-use electric EUIs and their standard errors [kWh/ft^2 yr]

Standard errors are estimated from the utility bills and are corrected for outliers. Large standard errors for Refrigerated warehouses are because of the small sample size. Note that the cooling and ventilation EUIs are based on the total floor area and are different from those presented in Chapter VIII.

Type of Permises	N	InLight	ExLight	Equip.	Refr	Cook	DHW	Vent	Cool	Total
Small Off.	66	4.76 (0.98)	1.08 (0.22)	3.13 (0.64)	0.2 (0.04)	0.03 (0.01)	0.11 (0.02)	1.22 (0.25)	5.63 (1.15)	16.16 (1.67)
Large Off.	15	11.93 (4.42)	2.11 (0.77)	4.28 (1.59)	0.1 (0.04)	0 (0.00)	0.16 (0.06)	3.21 (1.19)	4.11 (1.51)	25.9 (5.13)
Small Ret.	62	8.59 (1.56)	1.82 (0.33)	1.7 (0.31)	1.09 (0.20)	0.01 (0.00)	0.05 (0.01)	1.05 (0.19)	4.3 (0.78)	18.61 (1.82)
Large Ret.	13	12.21 (2.12)	1.47 (0.26)	1.12 (0.19)	0.61 (0.11)	0.19 (0.03)	0.02 (0.00)	2.84 (0.49)	4.69 (0.81)	23.16 (2.35)
Food Store	73	11.96 (0.70)	2.01 (0.12)	1.77 (0.10)	23.17 (1.35)	0.24 (0.01)	0.03 (0.00)	1.09 (0.06)	0 (0.00)	40.27 (1.53)
Ref WareH	5	3.02 (2.49)	.55 (0.45)	6.24 (5.14)	11.34 (9.34)	0.01 (0.01)	0.17 (0.14)	0.27 (0.22)	0.51 (0.42)	22.11 (10.97)
NonRef WareH	14	3.38 (0.69)	0.17 (0.03)	0.7 (0.14)	0.41 (0.09)	0 (0.00)	0.03 (0.01)	0.37 (0.08)	0.7 (0.14)	5.76 (0.73)
Restaurant	80	7.94 (1.35)	4.09 (0.69)	4.89 (0.83)	10.78 (1.83)	4.46 (0.76)	0.03 (0.01)	5.72 (0.97)	9.35 (1.59)	47.26 (3.22)