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Integrated Estimation of Commercial Sector End-Use Load Shapes and Energy Use Intensities, Phase II, Part 1 of 2

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

Final Report

H. Akbari, L. Rainer, and J. Eto

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DISCLAIMER

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Part 1 of 2

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

Final Report

January 1991

Prepared for

California Energy Commission

and

California Institute for Energy Efficiency

Prepared by

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Abstract

In this study, sponsored by the California Energy Commission (CEC), we used a new end-use load shape estimation technique to develop a database of commercial sector end-use load shapes and energy-use intensities (EUIs) for the CEC's commercial energy and peak load forecasting models. The technique relied on a reconciliation of whole-building hourly electricity load data to energy simulations developed from an analysis of survey data. The technique was applied to four building types (schools, colleges, health, and lodging) and resulted in reconciled hourly electricity load shapes for eight end uses. The end uses included cooling, ventilation, lighting, cooking, refrigeration, water heating, hospital equipment, and miscellaneous equipment. Ventilation and cooling load shapes were estimated separately for four climate regions in southern California. The load shapes were aggregated to produce annual end-use EUIs, and twelve monthly end-use load shapes for three day types (peak, standard, and non-standard). The end-use EUIs were then adjusted to account for observed end-use saturations in the population, the effects of price and technological change, and, most importantly, the impacts of the first generation of California building and appliance standards.

Executive Summary

In 1988, the California Energy Commission (CEC) and the Southern California Edison Company (SCE) funded LBL to apply a new end-use load shape estimation technique to the development of a common data base of commercial sector end-use load shapes (LSs) and energy-use intensities (EUIs) for use by their commercial energy and peak load forecasting models. The technique relies on a unique reconciliation of whole-building hourly electricity load data to energy-use simulations, which are developed from detailed survey data. The outcome of the Phase I project was a set of reconciled LSs for eight end uses in eight building types that were then individually indexed for three building vintage and technology combinations. The hourly LSs were aggregated to produce twelve monthly LSs for three day types (peak, standard, and non-standard) and integrated to produce annual EUIs. The Phase I project is described fully in Akbari, et al. 1989.

The current project, funded only by CEC, supplements the Phase I project by applying the estimation technique to four additional building types (schools, colleges, health, and lodging).[1] **Table EX.1** compares the scope of the Phase II project to that of the Phase I project. The Phase II project relies on the same general approach as the Phase I project. However, the project also faced several new challenges, including the need to develop multiple prototypes for a single building type, the creation of a new end use for hospital equipment, and the comparative scarcity of data to support these activities.

There are four parts to the project: input data, estimation methodology, reconciliation results, and adjustment to the reconciled results for use is forecasting.

1. Input Data

As in the Phase I project, we analyzed and assessed several sources of input data, including load research data, mail surveys, and weather files. However, unlike the Phase I project, detailed survey data of individual SCE premises were not available for the development of prototypes in the Phase II project.[2] Consequently, greater reliance was placed on other sources of data including SCE's 1985 mail survey of commercial premises, detailed survey data collected from premises in the Pacific Gas and Electric Company's service territory, a recently completed LBL analysis of commercial building LSs shapes to assess the market potential for cogeneration (Huang et al. 1990), and other studies of commercial sector energy use.

[1] A separate project, funded by the California Institute for Energy Efficiency and the Southern California Edison Company, will validate the LBL estimation technique using end-use metered data collected by SCE.

[2] In the Phase I project, over 300 detailed, 32-page audits were available for development of prototypes for the eight building types analyzed.

Table EX.1. Phase I and Phase II Project Scopes

	Phase I	Phase II
Building Types:	Large Office Small Office Large Retail Small Retail Restaurant Food Store Ref. Warehouse Non-Ref. Warehouse	Health School Lodging College
End Uses:	Heating Cooling Ventilation Lighting Cooking Refrigeration Water Heating Miscellaneous	Heating Cooling Ventilation Lighting Cooking Refrigeration Water Heating Hospital Equipment Miscellaneous
Load shapes for	12 Months	12 Months
Types of days	Peak Standard Non-Standard	Peak Standard Non-Standard

2. Reconciliation Methodology

We modified and refined the Phase I methodology for Phase II application. The methodology has three major components:

a) Development of prototypical buildings,

b) Simulation of the prototypes using DOE-2 to obtain preliminary estimates of LSs and EUIs, and

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

In the Phase I project, a single prototype was found to be sufficient for use in developing the initial engineering estimates that would later be reconciled against measured hourly electric loads.[3] Due to the heterogeneous composition of the building types analyzed in

[3] An exception was the restaurant, which was represented by two prototypes, a sit-down restaurant and a fast-food restaurant.

the Phase II project, LBL staff developed multiple prototypes, which were aggregated by exogenous statistical weights to develop initial engineering estimates for each building type. Two distinct prototypes were used to represent each of the health, school, and lodging building types, and three prototypes were used to represent the college building type. In addition, within the health building type, LSs for a new end use, called hospital equipment, were estimated.

3. Reconciliation Results

We applied the modified methodology and developed EUIs and LSs for up to nine electricity end uses (electric heating was found to be insignificant in our sample) in four building types. **Table EX-2** summarizes the reconciled EUIs and **Figure EX-1** presents the average annual reconciled LSs for the coastal zone.

4. Adjustments to Reconciled EUIs for Use in Forecasting

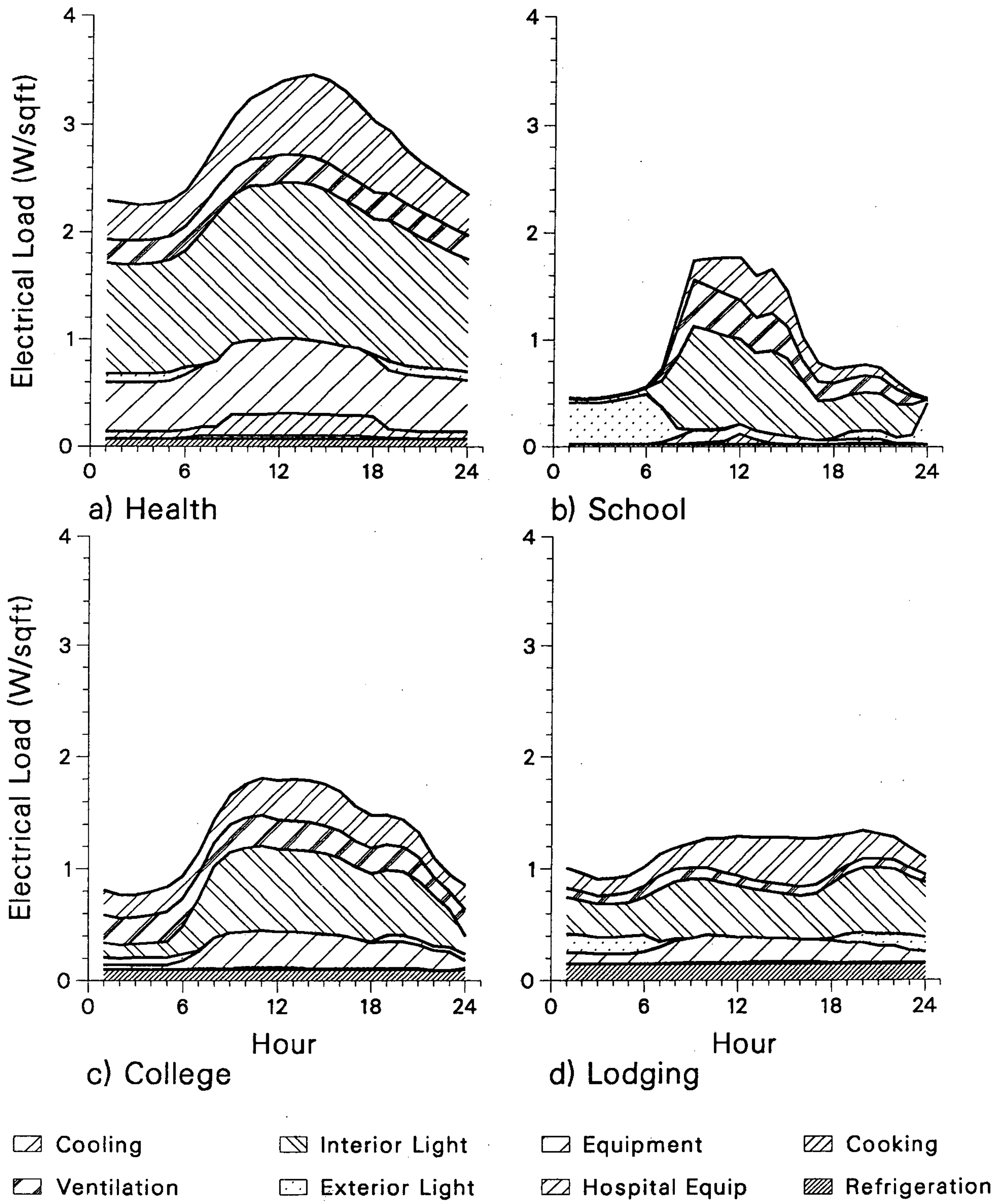
The reconciled EUIs are not directly usable by the SCE and CEC forecasting models because the models require distinct EUIs for individual technologies and vintages that are indexed to building energy use in 1975. The impact of California's building and appliance energy efficiency standards (loosely, 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.

We 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. The adjusted EUIs by vintages are summarized in Chapter VI.

Table EX.2. Initial and Reconciled EUIs for Schools, Healths, Lodgings, and College Campuses (kWh/ft^2.yr)

Location	Cooling	Ventilation	Indoor Lighting	Outdoor Lighting	Miscellaneous Equipment	Hospital Equipment	Cooking	Refrigeration	Total
					Schools				
Initial									
Coastal	1.5	1.7	4.7	0.5	0.5	-	0.1	0.2	9.2
Inland	1.3	1.8							9.1
Desert	1.6	1.8							9.4
Valley	1.7	1.9							9.6
Reconciled									
Coastal	0.7	0.8	3.3	1.2	0.4	-	0.1	0.2	6.5
Inland	0.8	1.0							6.8
Desert	0.9	1.0							6.9
Valley	0.9	1.0							7.0
					Healths				
Initial									
Coastal	4.7	2.3	9.3	0.4	4.3	0.9	0.1	0.6	22.0
Inland	5.7	2.4							23.1
Desert	5.9	3.4							24.2
Valley	5.8	3.3							24.0
Reconciled									
Coastal	4.4	2.1	10.7	0.4	4.9	1.1	0.1	0.6	24.2
Inland	5.3	2.2							25.2
Desert	5.5	2.2							25.4
Valley	5.4	2.1							25.2
					Lodgings				
Initial									
Coastal	2.4	0.8	4.2	0.6	1.6	-	0.1	1.3	11.0
Inland	3.6	0.8							12.1
Desert	4.0	1.4							13.2
Valley	4.8	1.4							13.9
Reconciled									
Coastal	2.2	0.8	4.0	0.6	1.5	-	0.1	1.3	10.6
Inland	2.9	0.8							11.3
Desert	3.2	0.8							11.6
Valley	3.8	0.9							12.2
					College Campuses				
Initial									
Coastal	1.7	3.4	5.3	0.4	2.2	-	0.1	0.9	13.7
Inland	2.0	3.6							14.5
Desert	2.1	3.6							14.6
Valley	2.2	4.0							15.1
Reconciled									
Coastal	1.3	2.2	3.8	0.3	1.6	-	0.1	0.9	10.2
Inland	1.5	2.4							10.6
Desert	1.6	2.4							10.7
Valley	1.7	2.6							11.0

Figure EX-1. Average Annual Reconciled Load Shapes for Coastal Health, School, College, and Lodging.



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Chapter I
Introduction

In 1988, the California Energy Commission (CEC) and the Southern California Edison Company (SCE) funded LBL to apply a new end-use load shape estimation technique to the development of a common data base of commercial sector end-use load shapes (LSs) and energy-use intensities (EUIs) for use by their commercial energy and peak load forecasting models. The technique relied on a unique reconciliation of whole-building hourly electricity load data to energy-use simulations, which were developed from detailed survey data. The outcome of the Phase I project was a set of reconciled LSs for eight end uses in eight building types that were then indexed for three building vintage and technology combinations. The hourly LSs were aggregated to produce twelve monthly LSs for three day types (peak, standard, and non-standard) and integrated to produce annual EUIs. The Phase I project is described fully in Akbari, et al. 1989.

The current project, funded only by CEC, supplements the Phase I project by applying the estimation technique to four additional building types (schools, colleges, health, and lodging).[1] **Table I-1** compares the scope of the Phase II project to that of the Phase I project. While the Phase II project relies on the same general approach as the Phase I project, the building types analyzed presented several new challenges. For example, within the health building type, LSs for a new end use, called hospital equipment, were estimated. More importantly, for the Phase II project, LBL developed multiple prototypes for each building type. This task was complicated by the relative scarcity of data to support the development of these prototypes.

In the Phase I project, a single prototype was found to be sufficient for use in developing the initial engineering estimates that would later be reconciled against measured hourly electric loads.[2] Due to the heterogeneous composition of the building types analyzed in the Phase II project, LBL staff developed multiple prototypes, which were aggregated by exogenous statistical weights to develop initial engineering estimates for each building type. Two distinct prototypes were used to represent each of the health, school, and lodging building types, and three prototypes were used to represent the college building type.

Unlike the Phase I project, detailed survey data of individual SCE premises were not available for the development of prototypes in the Phase II project.[3] Consequently, greater reliance was placed on other sources of data including SCE's 1985 mail survey

[1] A separate project, funded by the California Institute for Energy Efficiency and the Southern California Edison Company, will validate the LBL estimation technique using end-use metered data collected by SCE.

[2] An exception was the restaurant, which was represented by two prototypes, a sit-down restaurant and a fast-food restaurant.

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Table I-1. Phase I and Phase II Project Scopes

	Phase I	Phase II
Building Types:	Large Office Small Office Large Retail Small Retail Restaurant Food Store Ref. Warehouse Non-Ref. Warehouse	Health School Lodging College
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Load shapes for	12 Months	12 Months
Types of days	Peak Standard Non-Standard	Peak Standard Non-Standard

of commercial premises, detailed survey data collected from premises in the Pacific Gas and Electric Company's service territory, a recently completed LBL analysis of commercial building LSs shapes to assess the market potential for cogeneration (Huang et al. 1990), and other studies of commercial sector energy use.

This report presents our findings from the Phase II project. In addition to this introductory chapter, the report consists of four chapters. Chapter II describes modifications to the Phase I methodology to accommodate the unique requirements of and data available for the Phase II project. Chapter III contains descriptions of the prototypical buildings used to develop initial EUIs and LSs for each building type. Chapter IV describes the analysis of SCE's Load Research Data (LRD) for the development of average whole-building hourly electricity use for each building type. Chapter V reviews the reconciliation of the initial EUIs and LSs from Chapter III against the average whole-building hourly loads from Chapter IV. Chapter VI presents the disaggregation and analysis of these reconciled end-use LSs and EUIs to develop inputs to the CEC's commercial sector energy demand forecasting model.

This report also includes additional analyses of three of the building types studied in the Phase I project. The analyses were prompted by a recent re-examination of the whole-building electric EUIs used in the reconciliation process. Based on this re-examination, we re-ran the reconciliation process for the large and small office and retail building types to develop revised LSs and EUIs. These results were submitted to CEC as an interim report. For completeness, we have included these results in Appendix A.

Chapter II
Methodology and Data

The Phase II project is a direct extension of the Phase I project (see Akbari, et al. 1989) to four additional building types, health, school, lodging, and college. The overall methodology and general sources of data are identical. Briefly, the methodology consists of two distinct parts: 1) reconciliation of initial end-use load-shape estimates with measured whole-building load data; and 2) data transfer procedures to develop inputs for the CEC forecasting model. In this chapter, we describe this methodology and the major sources of data used. Since much of the material is documented in Akbari, et al. (1989), we emphasize primarily those aspects of the project that were modified for the Phase II project.

Part 1. Reconciliation Methodology

The heart of our analysis lies with the reconciliation of initial end-use load shape estimates with measured whole-building load shape data. There are three major steps in this process: 1) *initial estimates of end-use load shapes*; 2) *average whole-building load shapes*; and 3) *reconciliation of 1 with 2*. **Figure II-1** illustrates the primary data sources and relationships between these steps.

Initial Estimates of End-Use Load Shapes

In the first step of the reconciliation, we make initial estimates of end-use load shapes for each building type. These estimates are developed using one or more prototypes to represent each building type. For HVAC end uses (heating, cooling, ventilation), the initial estimates result from simulation of the prototype using the DOE-2.1D building energy simulation program (BESG 1990). For non-HVAC end uses (lighting, equipment, cooking, etc.), the estimates result from engineering analysis of data on reported schedules and installed capacities.

In the Phase I project, we were able to rely on over 300 detailed audits of commercial premises in the SCE service territory for information to support the development of these building prototypes. In the Phase II project, these audits were not available for the building types under study. As a result, we combined information from a variety of data sources to develop our prototypes. The sources included SCE's 1985 mail survey of commercial customers (ADM 1986), detailed audits of PG&E commercial premises (ADM 1987), a recent LBL analysis of building prototypes to examine gas cogeneration economics (Huang, et al. 1990), and an analysis of commercial prototypes performed for Northeast Utilities (NU 1986). **Table II-1** lists the primary sources and types of information used to develop our prototypes.

Figure II-1. Phase II Integrated Commercial LS and EUI Estimation Methodology.

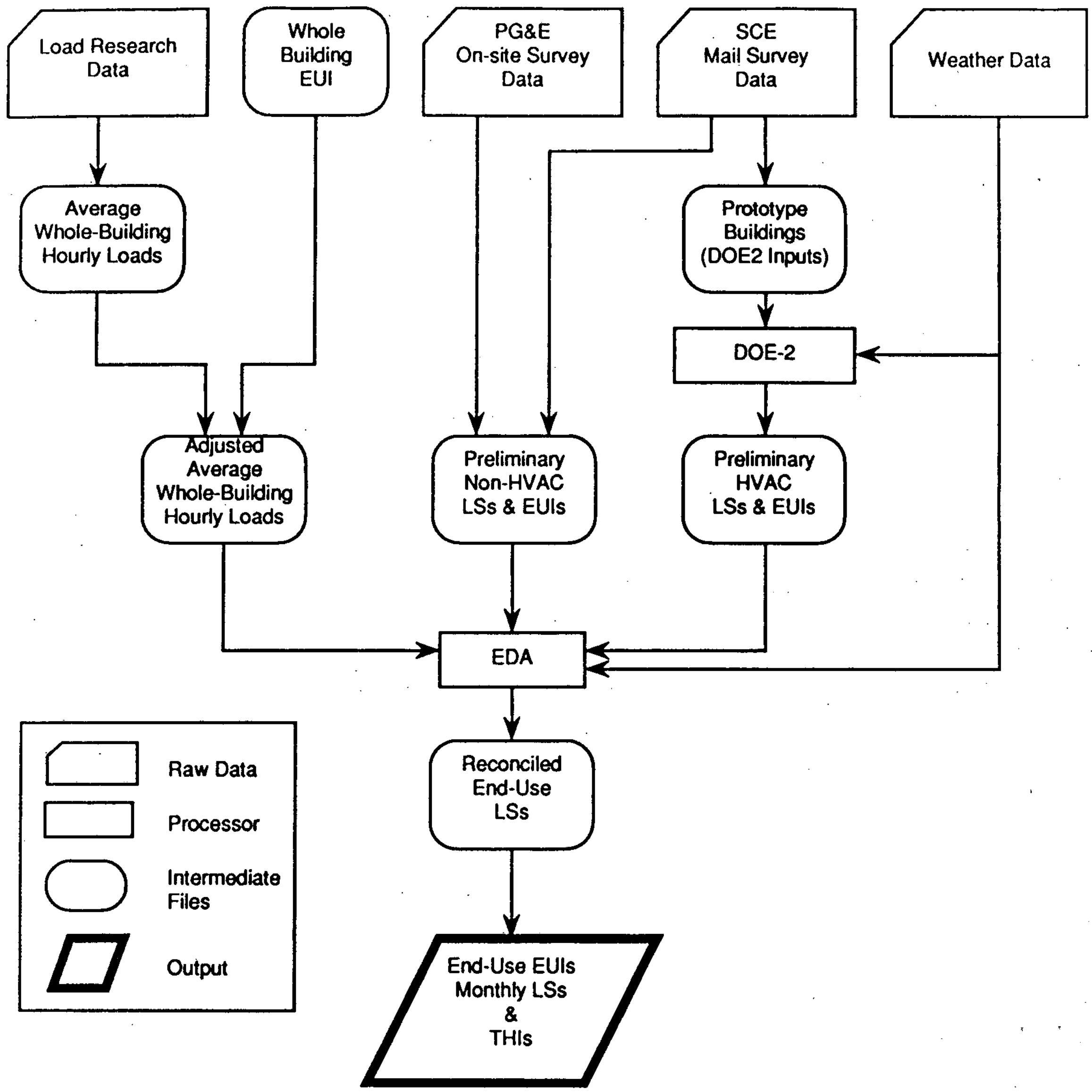


Table II-1. Input Data for Prototype Development

Source	Application	Reference
LBL Cogeneration Study Northeast Utilities	building geometry, zoning	Huang, et al. 1990 NU 1986
SCE 1985 Commercial Mail Survey	floor area, window/wall ratio, number of floors, occupant density	ADM 1986
PG&E On-Site Survey	operating schedules, lighting and equipment inventories, HVAC system types	ADM 1987

Generally speaking, we used the non-SCE-specific prototype studies (i.e., Huang, et al. 1989 and NU 1986) to provide a basic configuration for each prototype. These basic configurations were then extensively modified for conditions found in the SCE service territory by available information from the SCE 1985 mail survey. The design of this survey limited the information we were able to use to floor area, window to wall area ratios, numbers of floors, and occupant densities. Schedules for operation, HVAC system types, and lighting and equipment loads were derived from analysis of the more detailed on-site survey data collected by auditors in the PG&E service territory (ADM 1987).

In the Phase I project, a single prototype was found to be sufficient in developing the initial engineering estimates that would later be reconciled against measured hourly electric loads.[1] Due to the heterogeneous composition of the building types analyzed in the Phase II project, LBL, in close consultation with CEC, developed multiple prototypes to represent each of the four building types studied. **Table II-2** contains information on the SCE 1985 commercial mail survey (ADM 1986) that led to determination of the number and types of prototypes used for each building type. We used two prototypes to represent the health (hospital and nursing home, but not clinic), school (primary and secondary), and lodging (large hotel and small hotel/motel) building types and three prototypes (classroom/office/lab, dormitory, and library, but not trade schools) to represent the college building type. We did not develop a separate prototype for clinics (in health) and trade schools (in college) because they represent very small fractions of the total floor area for each building type. However, for the college building type, we did develop three prototypes to represent the diverse collection of building services contained within this category.

[1] An exception was the restaurant, which was represented by two prototypes, a sit-down restaurant and a fast-food restaurant.

Table II-2. Analysis of the SCE 1985 Commercial Mail Survey

BUILDING TYPE	N *unweighted*	TOTAL *number*	FRACTION *percent*	TOTAL AREA *(1000's ft²)*	FRACTION *percent*
College	21	267	61	21004	92
Trade	7	170	39	1772	8
College/Trade	28	437	100	22776	100
Primary	56	2627	63	24269	21
Secondary	61	1529	37	93777	79
Schools	117	4156	100	118046	100
Hospital	43	447	34	29377	83
Nursing	26	402	31	5152	14
Clinic	8	450	35	1026	3
Health	77	1299	100	35555	100
Large Hotel	18	127	16	21266	69
Small Hotel/Motel	19	689	84	9611	31
Lodging	37	816	100	30877	100

Prior to reconciliation, initial estimates from each prototype were weighted together using information on floor area from the SCE 1985 commercial mail survey (for health, schools, and lodging) and from data on the western region from the Energy Information Agency's Non-Residential Building Energy Consumption Survey (EIA 1988).

Table II-3 lists the prototypes and weights used to combine them by building type. Detailed descriptions of each prototype are presented in Chapter III.

Average Whole-Building Electricity Use Profiles

In the second step of the reconciliation, we constructed average whole-building electricity use profiles (EUPs) for each building type. These profiles provide control totals against which our initial estimates are reconciled. Two sources of data are used: Load research data (LRD) are used to develop their *shape*, while supplementary data on total commercial sector energy use intensity by building type are used to determine their *magnitude* (which is expressed as a total EUI for the building type or kWh/ft^2).

As part of its ongoing rate design efforts, SCE collects 15-minute-interval LRD for all commercial accounts with time-of-use rate schedules (TOU-8) and for a random sample of smaller accounts with GS-1 and GS-2 rate schedules. For our analysis, we reviewed data collected in 1986 (to ensure consistency with the Phase I project) following the procedures developed in the Phase I project (see Akbari et al 1989). These procedures included reviews of graphical summaries and cross-checks between reported SIC codes and building definitions.

Table II-3. Building Prototypes and Floor Area Weighting Factors

Building Type	Prototype	Adjusted Weight (based on Floor Area)
Health	Hospital	0.85
	Nursing Home	0.15
School	Primary	0.21
	Secondary	0.79
Lodging	Large Hotel	0.69
	Small Hotel/Motel	0.31
College	Classroom/Office/Lab	0.75
	Dormitory	0.20
	Library	0.05

Following this review, we developed distinct whole-building electricity use profiles by building type. It is important to note that SCE's sampling methodology for LRD does not rely on building type as a stratification variable; thus, the post-stratification we used to develop whole-building EUPs may introduce biases whose effects we cannot determine, given available data. To some extent, we control these potential biases by relying on LRD to develop only the *shape* of the EUPs. **Table II-4** summarizes the LRD accounts analyzed by building type, climate region and customer rate class. The geographic boundaries used to assign LRD accounts to climate regions are presented in Chapter IV.

Whereas the analysis of LRD provides a load *shape* for use in the reconciliation, a separate analysis of energy use to develop whole-building EUIs is used to set the *magnitude* of the whole-building electricity use profile. Specifically, the whole-building EUI is used to normalize the whole-building load shapes such that integration of the whole-building EUP for the year equals the whole-building EUI. Consequently, the whole-building EUI is an extremely important input to the reconciliation process because it largely determines the magnitude of the reconciled end-use EUIs; that is, the sum of the reconciled EUIs must exactly equal the whole-building EUI.

Whole-building EUIs were developed following extensive discussions with CEC and SCE forecasting staff. The basic data used was an in-house analysis by SCE of their quarterly fuels and electricity report (QFER), which is regularly reported to the CEC. The outcome of these discussions is presented in **Table II-5**.

The resulting average whole-building electricity use profiles used in the reconciliation are presented in Chapter IV.

Table II-4. Summary of LRD by Building Type and Climate Region

Building Type Rate Class	Coastal (1)	Inland (2)	Desert (3)	Valley (4)	Non-Coastal (2+3+4)	Total (1+2+3+4)
Schools						
GS 1&2	12	3	7	1	11	23
TOU	56	25	20	7	52	108
All	68	28	27	8	63	131
Colleges						
GS 1&2	0	0	0	0	0	0
TOU	32	9	9	3	21	53
All	32	9	9	3	21	53
Health						
GS 1&2	2	0	1	1	2	4
TOU	65	22	12	1	35	100
All	67	22	13	2	37	104
Lodging						
GS 1&2	0	1	2	0	3	3
TOU	23	3	9	1	13	36
All	23	4	11	1	16	39

Table II-5. Whole-Building EUIs

Building Type	**EUI** (kWh/ft^2)
Health	24.5
Schools	6.7
Lodging	11.7
College	10.3

Reconciliation of Initial Estimates to Whole-Building Electricity Use Profiles

In the third step of the reconciliation, we applied the End-use Disaggregation Algorithm (EDA) to obtain reconciled end-use LSs. The technical aspects of EDA are documented in Akbari, et al. (1988). Our application followed exactly that of the Phase I project (Akbari, et al. 1989). The corresponding EUIs are simply the integration of the LSs for the entire year.

The results of the reconciliations are presented in Chapter V.

Part 2. Developing CEC Forecasting Model Inputs from Reconciled EUIs

The end-use LSs and EUIs developed through the reconciliation procedures represent a snap-shot of 1986 electricity use by building type and end-use averaged for the entire SCE territory. For each building type, this snap-shot includes energy used by buildings in all four climate zones within the SCE territory. Within these zones, it includes energy use by buildings and equipment subject to various stocks of building construction and equipment selection practices (including the effects of several generations of mandatory building and appliance minimum efficiency standards). Finally, it also includes the effects of differing saturations of fuels and end-use equipment within these end-use categories. Each of the underlying dimensions of total energy use (climate zone, fuel choice, vintage, and equipment saturation) is explicitly represented as a separate element within the CEC commercial sector energy demand forecasting model (which also indexes all energy use to a 1975 base year). In addition, the CEC model also relies on several classes of EUIs that cannot be developed directly through the reconciliation procedure described above including electric space heating (which the reconciliation cannot estimate due to the low saturation of this end use in the LRD), and non-electric space heating, and water heating (since the reconciliation methodology is applicable to only electricity end uses). Fortunately, by further analysis of the reconciled EUIs and their inputs, the more disaggregated data required by the CEC model can be developed, and the EUIs not derived through the reconciliation process can be estimated.

In what follows, we describe the procedures used in these efforts, again referring primarily to the Phase I report for the bulk of the documentation of procedures and here emphasizing only what has changed for the Phase II report. The supporting analysis and final results of our efforts are reported in Chapter VI.

Climatic Impacts on Space-Conditioning EUIs

Space-conditioning EUIs (cooling, ventilation, and heating) are influenced by climate. Within the SCE service territory, the CEC forecasts energy use separately for four distinct climatic regions (coastal, inland, valley, and desert). Generally speaking, different premises of the same building type would experience different heating, cooling, and ventilation loads (and, therefore, EUIs) depending on which of these regions they were located.

In principle, these differences could be estimated directly with separate reconciliations. That is, one could develop unique initial estimates of end-use EUIs and LSs for each region and reconcile them separately for each region. This approach could not be used in the Phase II project because sufficient quantities of LRD were not always available to support the development of unique average whole-building electricity use profiles for each region (refer to Table II-4).

Instead, a hybrid approach was taken. A separate reconciliation was made for the coastal region where sufficient data were available (using weather data from Long Beach to represent the region[2]). For the other regions (inland, valley, and desert), a single reconciliation was made for a combined, non-coastal region (using Burbank weather data). When compared, we observed that the separate reconciliations produced small differences in the non-HVAC end uses, which in principle should be identical across regions; accordingly, we averaged them to a single value.

For the combined, non-coastal region, a separate set of DOE-2 simulations were run for the prototype using weather data from each region. The ratios of simulated energy use for cooling, ventilation, and heating from these simulations were then used to adjust the reconciled HVAC EUIs to produce a unique value for each region.

Table II-6 presents the locations of the weather stations used to represent each climate region.

Table II-6. Weather Stations

Climate Region	Weather Stations
Coastal	Long Beach Airport
Inland	Burbank Airport
Desert	Norton Air Force Base
Valley	Fresno Airport

Accounting for Fuel Saturation Effects

The control total used in the reconciliation process reflects the aggregate impact of the various saturations of electricity end uses in the SCE service territory in 1986. Since the CEC forecasting model accounts for fuel saturations separately by end use, the effects of the observed aggregate saturations embedded in the reconciled EUIs must be removed. In principle, one would use data on the aggregate saturation of electricity for each end use for this process. For our analysis, however, we relied on CEC's electricity saturations for the 1965-1978 era (to be more fully described in the following subsection). These saturations are presented on **Table II-7** for cooling, ventilation, cooking, and refrigeration. The electricity saturations for the other end uses are either 100% (for indoor lighting, other, office equipment, and outdoor lighting) or are not relevant to this process since reconciled electricity EUIs were not estimated (for heating and water heating).

[2] See the Phase I report for additional information on the weather data used in the Phase I and II projects. Note also that, in the Phase I project, Los Angeles International Airport was used to represent the coastal region.

Disaggregating Reconciled EUIs by Building and Equipment Vintage

The CEC commercial sector energy demand forecasting model separately tracks energy use by several different vintages for a given building type. These vintages are intended to reflect different eras of building construction practices and equipment choice. Importantly, CEC has defined vintages that correspond to the enactment of mandatory building and appliance minimum efficiency standards by the state of California. **Table II-8** illustrates the relationship between these two eras.

Table II-7. Electricity Saturations by End Use*

	Cool	Vent	Cook	Refr
School	40.5	99.6	16.2	95.9
College	50.7	100.0	20.1	81.6
Health	72.4	100.0	30.2	98.4
Lodging	72.4	100.0	30.2	98.4

* Supporting data used to develop this Table are presented in Chapter VI.

Table II-8. Building and Equipment Vintages

	Equipment Vintage	
Building Vintage	**before 1979**	**after 1979**
before 1979	A	B
after 1979	n/a	C

The approach taken is fully documented in the Phase I report (Akbari, et al. 1989). The basic idea is to rely on additional DOE-2 simulations to provide ratios that then modify the reconciled EUIs. In this case, the prototypes themselves are modified to reflect conditions unique to each vintage. The challenge for implementing this procedure in the Phase II project was the absence of high quality data to support the development of unique prototypes corresponding to each vintage.

In the Phase I project, we were able to rely on much more detailed survey data to develop our prototypes. For the present project, less SCE-specific data were available. We relied principally on the actual California standards (Titles 24 and 20) and on ASHRAE standards 90/75 and 90.2P. Notably, some aspects of the California standards do not apply to several of the building prototypes examined including nursing homes, both primary and secondary schools, hotels and motels, and colleges.

The resulting modifications are summarized in Chapter III following the presentation of the basic (i.e., un-vintaged) prototypes used in the reconciliation.

Developing EUIs for Electric Heating, and Non-Electric End Uses

There are several classes of EUIs that cannot be estimated using the LBL reconciliation procedure. They include electric space heating and water heating, and non-electric space heating, water heating, cooking, and miscellaneous end uses. Electric space heating and water heating have very low saturations in the SCE service territory; we could not, for example, detect the presence of electric space heating in our analysis of the LRD. Accordingly, we could not extract profiles for these end uses using our reconciliation procedures. Non-electric space heating, water heating, cooking, and miscellaneous energy use cannot be estimated directly because they do not affect electric loads. Our analysis of all of these end uses can, however, benefit from the analyses supporting the reconciliation procedures.

For example, simulation of our prototypes yields estimates for space heating energy use, which could be supplied with either electricity or another fuel. Although ideally these estimates should be reconciled against measured data, in the absence of such data, they remain as reasonable engineering estimates of EUIs for the heating end uses. This same general approach is also taken to develop electric and non-electric water heating EUIs.

Our analysis in support of prototype development did not, however, uncover very much information on non-electric cooking and miscellaneous EUIs. While we use estimates for total non-electric energy use in our prototypes (which would include water heating, cooking and miscellaneous), we can only extract reliable information on water heating. We have chosen not to provide an estimate for non-electric cooking and miscellaneous.

Expressing Reconciled EUIs Relative to a 1975 Base Year

The final data development activity involves expressing the EUIs we developed from an observation of energy use in 1986 (the year all of our measured data were recorded) in the base year used by the CEC forecasting model, which is 1975. The primary adjustment accounts for the effect of energy price on energy use. We used a time series of SCE electricity prices and the CEC's estimate of the price elasticity of demand to develop an adjustment factor of 7%. A second adjustment accounts for technological change and applies only to the miscellaneous electric EUI. This adjustment has the effect of reducing the miscellaneous electric EUI by 19.5% (see Table VIII-28 in Akbari, et al. 1989).

Chapter III

Prototypical Building Descriptions and DOE-2 Simulation Results

The prototypical building DOE-2 input files are based on a combination of existing prototypes from other studies, statistical data from the Southern California Edison (SCE) mail surveys, the PG&E on-site survey data, and engineering judgement, as discussed in Chapter II. In this chapter we discuss the main features of each prototype, including pre- and post-1978 vintage characteristics, and the results of the initial DOE-2 simulations. Initial LSs and EUIs for prototypes within a building category are aggregated, using the weighting factors discussed in Chapter II, to develop initial LSs and EUIs for that building category. In Chapter V, we will reconcile the initial LSs and EUIs developed in this chapter against the whole-building load shapes developed in Chapter IV.

Health

The Health classification is made up of acute care hospitals, skilled nursing homes/residential care, and clinics/labs. Some studies also place medical offices in this category while others place medical offices in with conventional offices. The only difference between medical office and conventional office should be the equipment intensities and possibly some added ventilation.

Analysis of the SCE mail survey shows that although hospitals make up only 34% of the buildings in the health category, they account for 83% of the floor area and an even greater fraction of the energy use. Therefore, the choice of weighting factors play a very strong part in the eventual load shapes developed for this category. As we discussed in Chapter II, we have developed prototypes for a Hospital and a Nursing Home, but not a Clinic, in the Health category.

Hospital

The hospital prototype is a 250,000 ft^2, seven-floor building modeled with five zones. The zones are clinic, core/public, perimeter, kitchen, and hallway; conditioned with dual-duct, VAV, four pipe fan coil, single zone reheat, and VAV systems respectively. Hot water and heating is provided by gas boilers and cooling is provided by centrifugal chillers. Major characteristics of the prototypical building and its operational schedule are summarized in **Table III-1**. The vintage and technology options are summarized in **Table III-2**.

Table III-1. Building Descriptions for Hospital Prototype

Shell	
Floor Area (1000 ft^2)	250
Number of Floors	7
Ceiling Insulation R-value	7.3
Wall Insulation R-value	1.0
Window shading coefficient	0.4
Window/wall ratio	0.18
Occupancy (ft^2/person)	310
Lights (W/ft^2)	2.1
Equipment (W/ft^2)	0.9
Hot Water (Btu/ft^2)	6.8
System	
System Type	Dual duct in Clinic, VAV in Core and Hallway, four pipe fan coil in Perimeter, single zone reheat in Kitchen.
Heat Setpoint	72°F
Cool Setpoint	76°F
Plant	
Heating	Gas boiler
Cooling	Hermetic centrifugal chiller
Hot Water	Gas boiler

Table III-2. Hospital Vintage

Vintage/ Technology	Pre 1978	Post 1978
Shell characteristics:		
Ceiling Insulation R-value	7.3	9.0
Wall Insulation R-value	1.0	4.0
Window glass	1-pane	1-pane
Lights W/ft^2	~2.1	~1.5
System Type	Same system as the prototype for clinic, perimeter, kitchen, and hallway.	
Lobby/core equipment	Constant volume	Variable-air-volume

Nursing Home

The nursing home prototype is a 30,000 ft^2, single-story building with 96 beds. It consists of 48,400 ft^2 rooms, a 2,000 ft^2 kitchen and an 8,000 ft^2 multipurpose room. The rooms have packaged terminal air conditioners with gas heaters. The kitchen and multipurpose room are supplied by packed single zone units. Major characteristics of the prototypical building and its operational schedule are summarized in **Table III-3**. The vintage and technology options are summarized in **Table III-4**.

Table III-3. Building Descriptions for Nursing Home Prototype

Shell	
Floor Area (1000 ft^2)	29
Number of Floors	1
Ceiling Insulation R-value	8.0
Wall Insulation R-value	1.0
Window shading coefficient	0.4
Window/wall ratio	0.18
Occupancy (ft^2/person)	200
Lights (W/ft^2)	1.5
Equipment (W/ft^2)	0.6
Hot Water (Btu/ft^2)	3.7
System	
System Type	Packaged single-zone system in multipurpose room and kitchen, packaged terminal air conditioner with gas furnace in rooms.
Heat Setpoint	70°F
Cool Setpoint	76°F
Plant	
Heating	Gas furnace
Cooling	Direct expansion
Hot Water	Gas boiler

Table III-4. Nursing Home Vintage

Vintage/ Technology	Pre 1978	Post 1978
Shell characteristics:		
Ceiling Insulation R-value	8.0	9.0
Wall Insulation R-value	1.0	4.0
Window glass	1-pane	1-pane
Lights W/ft^2:		
Rooms	1.0	1.0
Multipurpose	1.5	1.5
Kitchen	1.7	1.7
System Type	packaged single-zone system in multipurpose/kitchen; packaged terminal air conditioners in rooms.	packaged VAV system in multipurpose/kitchen; high efficiency A/C in rooms.

DOE-2 Simulation and Initial LSs and EUIs

The prototype buildings are simulated using DOE-2 building energy simulation program. **Table III-5** shows the simulation summary for Hospital and Nursing Home, and health category. The resultant EUIs and LSs are combined, using the Mail Survey weighting factors, to obtain initial EUIs and LSs for Health category. The DOE-2 inputs for the prototypical Hospital and Nursing Home are presented in the Appendix B.

Table III-5. Simulated EUI Summary of Health Prototypes

Climate Region	Electricity (kWh/ft²/yr) Cooling	Fan	Light	Misc	Total	Gas (kBtu/ft²/yr) Heating	DHW	Misc	Total
Hospital (weight = 0.85)									
Coast	5.4	3.4	12.6	5.2	28.4	6.7	44.1	8.1	58.9
Inland	6.5	3.8	12.6	5.2	29.9	6.3	44.1	8.1	58.5
Valley	6.6	3.8	12.6	7.0	30.0	6.7	44.1	8.1	58.9
Desert	6.3	3.7	12.6	7.0	29.6	15.6	44.1	8.1	67.8
Nursing (weight = 0.15)									
Coast	0.6	1.1	4.5	1.5	7.6	16.2	16.6	0.0	32.8
Inland	1.2	1.2	4.5	1.5	8.4	14.1	16.6	0.0	30.7
Valley	1.6	1.2	4.5	1.5	8.8	18.4	16.6	0.0	35.0
Desert	2.5	1.3	4.5	1.5	9.7	27.8	16.6	0.0	44.4
Weighted Average									
Coast	4.7	3.0	11.3	4.6	25.3	8.1	40.0	6.9	55.0
Inland	5.7	3.4	11.3	4.6	26.7	7.5	40.0	6.9	54.3
Valley	5.9	3.4	11.3	6.2	26.8	8.4	40.0	6.9	55.3
Desert	5.8	3.3	11.3	6.2	26.6	17.4	40.0	6.9	64.3

School

The school category consists of primary schools (grades K through 6) and secondary schools (junior and senior highs). We have chosen not to include day care/preschools in this category.

Primary

The primary school prototype is a 27,000 ft^2, single-story building consisting of fifteen 1,800 ft^2 classrooms, a 6,000 ft^2 library/multipurpose room, and a 2,000 ft^2 kitchen. The HVAC system is packaged multi-zone system with a packaged single-zone system for the kitchen. Weekday operating hours are 8 a.m. until 3 p.m. with partial operation from 3 p.m. until 6 p.m. The systems are shut down for vacation periods from June 1 until September 1 and from Dec 20 until Dec 31. Major characteristics of the prototypical building and its operational schedule are summarized in **Table III-6**. The vintage and technology options are summarized in **Table III-7**.

Table III-6. Building Description for Primary School Prototype

Shell	
Floor Area (1000 ft^2)	35
Number of Floors	1
Ceiling Insulation R-value	4.9
Wall Insulation R-value	1.0
Window shading coefficient	0.8
Window/wall ratio	0.25
Occupancy (ft^2/person)	100
Lights (W/ft^2)	2.1
Equipment (W/ft^2)	0.5
Hot Water (Btu/ft^2)	1.0
System	
System Type	Packaged multi-zone system with gas furnace.
Heat Setpoint (day/night)	75/65°F
Cool Setpoint (day/night)	78/85°F
Plant	
Heating	Gas furnace
Cooling	Direct expansion
Hot Water	Gas boiler

Table III-7. Primary School Vintage

Vintage/ Technology	Pre 1978	Post 1978
Shell characteristics:		
Ceiling Insulation R-value	4.9	9.0
Wall Insulation R-value	1.0	4.0
Window glass	1-pane	1-pane
Lights W/ft^2:		
Library	1.5	1.5
Class Rooms	2.2	2.2
Kitchen	1.7	1.7
System Type	Packaged Multi-zone	Packaged Single-zone

Secondary

The secondary school is a three-story, 242,000 ft^2 building consisting of six zones: classrooms, library, gymnasium, auditorium, kitchen, and dinning room. The HVAC system is packaged multi-zone system supplied by a gas boiler and a centrifugal chiller. The classrooms are occupied from 7 a.m. until 3 p.m. on weekdays with partial occupancy in the evenings and on Saturdays. The gym, auditorium, kitchen, and dining rooms are occupied only during weekdays. The systems are shut down for vacation periods from June 1 until September 1 and from Dec 20 until Dec 31. Major characteristics of the prototypical building and its operational schedule are summarized in **Table III-8**. The vintage and technology options are summarized in **Table III-9**.

Table III-8. Building Descriptions for Secondary School Prototype

Shell	
Floor Area (1000 ft^2)	242
Number of Floors	3
Ceiling Insulation R-value	4.9
Wall Insulation R-value	1.0
Window shading coefficient	0.85
Window/wall ratio	0.29
Occupancy (ft^2/person)	150
Lights (W/ft^2)	2.0
Equipment (W/ft^2)	0.5
Hot Water (Btu/ft^2)	2.1
System	
System Type	Packaged multi-zone with gas furnace.
Heat Setpoint (day/night)	75/65°F
Cool Setpoint (day/night)	78/85°F
Plant	
Heating	Gas furnace
Cooling	Direct expansion
Hot Water	Gas boiler

Table III-9. Secondary School Vintage

Vintage/ Technology	Pre 1978	Post 1978
Shell characteristics:		
Ceiling Insulation R-value	4.9	9.0
Wall Insulation R-value	1.0	4.0
Window glass	1-pane	1-pane
Lights W/ft^2:		
Music, Lib	1.5	1.5
Class Rooms	2.2	2.2
Gym	0.65	0.65
Auditorium	0.8	0.8
Kitchen	1.7	1.7
Dining Area	1.7	1.7
System Type	Packaged Multi-zone	Packaged Single-zone

DOE-2 Simulation and Initial LSs and EUIs

The prototype buildings are simulated using DOE-2 building energy simulation program. **Table III-10** shows the simulation summary for Primary, Secondary School, and School category. The resultant EUIs and LSs are combined, using the Mail Survey weighting factors, to obtain initial EUIs and LSs for School category. The DOE-2 inputs for the prototypical Primary and Secondary School are presented in the Appendix B.

Table III-10. Simulated EUI Summary of School Prototypes

Climate Region	Electricity (kWh/ft²/yr) Cooling	Fan	Light	Misc	Total	Gas (kBtu/ft²/yr) Heating	DHW	Misc	Total
Primary (weight = 0.21)									
Coast	3.1	3.4	4.3	2.2	13.0	27.5	7.9	0.0	35.4
Inland	2.7	3.7	4.3	2.2	12.9	25.7	7.9	0.0	33.6
Valley	3.3	3.5	4.3	2.2	13.3	23.5	7.9	0.0	31.4
Desert	3.3	3.7	4.3	2.2	13.5	40.7	7.9	0.0	48.6
Secondary (weight = 0.79)									
Coast	1.1	1.2	4.5	1.4	8.2	9.5	3.7	0.0	13.2
Inland	1.0	1.3	4.5	1.4	8.2	9.0	3.7	0.0	12.7
Valley	1.2	1.3	4.5	1.4	8.4	8.8	3.7	0.0	12.4
Desert	1.2	1.4	4.5	1.4	8.6	15.2	3.7	0.0	18.9
Weighted Average									
Coast	1.5	1.7	4.5	1.6	9.2	13.3	4.6	0.0	17.9
Inland	1.3	1.8	4.5	1.6	9.2	12.5	4.6	0.0	17.1
Valley	1.6	1.8	4.5	1.6	9.4	11.9	4.6	0.0	16.4
Desert	1.7	1.9	4.5	1.6	9.6	20.6	4.6	0.0	25.1

Lodging

The Lodging category consists of large hotels and small hotels/motels as described below.

Large Hotel

The large hotel is a seven-story, 207,000 ft^2 building modeled using three zones: three hundred sixty 400 ft^2 guest rooms, 50,000 ft^2 of lobby/conference rooms, and 10,000 ft^2 of kitchen/laundry. Guest rooms are heated and cooled with four pipe fan coils supplied by gas boilers and centrifugal chillers. The other zones are conditioned by packaged single zone systems. Major characteristics of the prototypical building and its operational schedule are summarized in **Table III-11**. The vintage and technology options are summarized in **Table III-12**.

Table III-11. Building Descriptions for Large Hotel Prototype

Shell	
Floor Area (1000 ft^2)	207
Number of Floors	10
Ceiling Insulation R-value	5.8
Wall Insulation R-value	2.6
Window shading coefficient	0.4
Window/wall ratio	0.27
Occupancy (ft^2/person)	200
Lights (W/ft^2)	1.2
Equipment (W/ft^2)	0.6
Hot Water (Btu/ft^2)	5.0
System	
System Type	Single-zone reheat system for kitchen, VAV for lobby and conference, four pipe fan-coil for rooms.
Heat Setpoint (day/night)	70/65°F
Cool Setpoint	78°F
Plant	
Heating	Gas boiler
Cooling	Hermetic centrifugal chiller
Hot Water	Gas boiler

Table III-12. Hotel Vintage

Vintage/ Technology	Pre 1978	Post 1978
Shell characteristics:		
Ceiling Insulation R-value	5.8	9.0
Wall Insulation R-value	2.6	4.0
Window glass	1-pane	1-pane
Lights W/ft^2	1.2	1.2
System Type	four pipe fan-coil in rooms, single-zone reheat system in kitchen and lobby/conference.	four pipe fan-coil in rooms, VAV in lobby/conference, single-zone reheat system in kitchen.

Small Hotel/Motel

The small hotel/motel is a two-story, 27,000 ft^2 building modeled with three zones: one hundred twenty 200 ft^2 guest rooms, a 1,300 ft^2 lobby, and a 1,300 ft^2 laundry. The guest rooms are cooled with packaged terminal air conditioning units and heated with gas furnaces. The lobby and laundry are heated and cooled with single-zone packaged units. Major characteristics of the prototypical building and its operational schedule are summarized in **Table III-13**. The vintage and technology options are summarized in **Table III-14**.

Table III-13. Building Descriptions for Small Hotel Prototype

Shell	
Floor Area (1000 ft^2)	27
Number of Floors	2
Ceiling Insulation R-value	8.0
Wall Insulation R-value	1.0
Window shading coefficient	0.4
Window/wall ratio	0.23
Occupancy (ft^2/person)	150
Lights (W/ft^2)	1.5
Equipment (W/ft^2)	0.5
Hot Water (Btu/ft^2)	3.2
System	
System Type	Packaged single-zone system in lobby and laundry, packaged terminal air conditioner with gas furnace in rooms.
Heat Setpoint	72°F
Cool Setpoint	76°F
Plant	
Heating	Gas furnace
Cooling	Direct Expansion
Hot Water	Gas boiler

Table III-14. Small Hotel/Motel Vintage

Vintage/ Technology	Pre 1978	Post 1978
Shell characteristics:		
Ceiling Insulation R-value	8.0	9.0
Wall Insulation R-value	1.0	4.0
Window glass	1-pane	1-pane
Lights W/ft^2:		
Guest Rooms	1.0	1.0
Lobby/Conf. Rooms	1.5	1.5
Kitchen/Laundry	2.0	2.0
System Type	packaged single-zone system in laundry/lobby; gas furnace and window-AC in rooms.	packaged VAV system in laundry/lobby; high efficiency AC in rooms.

DOE-2 Simulation and Initial LSs and EUIs

The prototype buildings are simulated using DOE-2 building energy simulation program. **Table III-15** shows the simulation summary for Large Hotel, Small Hotel/Motel, and Lodging. The resultant EUIs and LSs are combined, using the Mail Survey weighting factors, to obtain initial EUIs and LSs for Lodging category. The DOE-2 inputs for the prototypical Large Hotel and Small Hotel/Motel are presented in the Appendix B.

Table III-15. Simulated EUI Summary of Lodging Prototypes

Climate Region	Electricity (kWh/ft²/yr) Cooling	Fan	Light	Misc	Total	Gas (kBtu/ft²/yr) Heating	DHW	Misc	Total
Hotel (weight = 0.69)									
Coast	2.3	1.5	6.9	2.2	13.6	21.9	9.7	4.7	36.2
Inland	3.2	1.7	6.9	2.2	14.7	16.6	9.7	4.7	31.0
Valley	3.4	1.7	6.9	3.0	14.9	21.3	9.7	4.7	35.6
Desert	3.8	1.7	6.9	3.0	15.3	31.5	9.7	4.7	45.8
Motel (weight = 0.31)									
Coast	2.7	0.6	3.7	2.1	9.1	38.9	19.3	5.5	63.6
Inland	4.5	0.7	3.7	2.1	10.9	31.8	19.3	5.5	56.5
Valley	5.5	0.7	3.7	2.1	12.0	42.3	19.3	5.5	67.0
Desert	7.1	0.7	3.7	2.1	13.6	57.1	19.3	5.5	81.8
Weighted Average									
Coast	2.4	1.2	5.9	2.1	12.2	27.1	12.6	4.9	44.7
Inland	3.6	1.4	5.9	2.1	13.6	21.3	12.6	4.9	38.9
Valley	4.0	1.4	5.9	2.7	14.0	27.8	12.6	4.9	45.3
Desert	4.8	1.4	5.9	2.7	14.8	39.4	12.6	4.9	57.0

College Prototypical Building

The college building category is made up of college campuses and vocational/trade schools. We have analyzed the SCE mail survey data to determine the fraction of these building categories by both number of buildings and floor area (presented in Table II-2). The SCE mail survey samples 28 buildings in the college category representing 437 buildings and over 22 million ft^2 of floor area. Trade schools constitute approximately 40% of the total buildings in the college category. However, only 8% of the total floor area in the college category are trade schools. Given that the overall energy use per ft^2 in the trade schools and colleges are comparable and given the statistical accuracy of our method, we argue that the LSs and EUIs for college building category is mainly determined by colleges. Hence, we have focused on developing prototypes for colleges but not trade schools.

Also, CEC models the college prototype with both dormitory and library buildings. The mail survey data does not provide any information of the fraction of college campuses that are dormitories and libraries. We have reviewed available sources of information such as NBECS (EIA 1979) for this data. The rather scarce data sources suggest that about 20 percent of college-campus floor area consists of dormitories and 5 percent consists of libraries. The remaining 75 percent is made up of class rooms, labs and offices.

Class Rooms/Offices

The Class Rooms/Offices are modeled as a four story concrete building with 128,000 ft^2 of floor area. The exterior walls are 20% glass. The bottom floor consists of class rooms and lecture halls served by a single zone reheat system. The upper floors contain individual offices served by a VAV system. Both systems are supplied with heating and cooling by a central gas boiler and a hermetic chiller with cooling tower. Major characteristics of the prototypical building and its operational schedule are summarized in **Table III-16**. The vintage and technology options are summarized in **Table III-17**.

Table III-16. Building Descriptions for Class Room/Office Prototype

Shell	
Floor Area (1000 ft^2)	128
Number of Floors	4
Ceiling Insulation R-value	5.8
Wall Insulation R-value	2.6
Window shading coefficient	0.4
Window/wall ratio	0.20
Occupancy (ft^2/person)	165
Lights (W/ft^2)	1.3
Equipment (W/ft^2)	0.7
Hot Water (Btu/ft^2)	2.2
System	
System Type	Single-zone reheat system in classrooms, Reheat fan in offices.
Heat Setpoint (day/night)	72/65°F
Cool Setpoint	76°F
Plant	
Heating	Gas boiler
Cooling	Hermetic centrifugal chiller
Hot Water	Gas boiler

Table III-17. Class Room/Office Vintage

Vintage/ Technology	Pre 1978	Post 1978
Shell characteristics:		
Ceiling Insulation R-value	5.8	9.0
Wall Insulation R-value	2.6	4.0
Window glass	1-pane	1-pane
Lights W/ft^2:		
Offices	1.0	1.0
Class Rooms	2.0	2.0
System Type	Constant volume	Variable air volume

Dormitory

The dormitory building is modeled as a five story concrete building with 52,000 ft^2 of floor area. The exterior walls are 20% glass. The bottom floor consists of kitchen, and dinning area, and is conditioned with a single zone reheat system. The rooms are on the upper floors with common bath room and shower facilities and are only heated with a two-pipe fan coil system. Both heating and hot water energy source is a gas boiler. Cooling is supplied by a hermetic centrifugal chiller. Major characteristics of the prototypical building and its operational schedule are summarized in **Table III-18**. The vintage and technology options are summarized in **Table III-19**.

Table III-18. Building Descriptions for Dormitory Prototype

Shell	
Floor Area (1000 ft^2)	52
Number of Floors	5
Ceiling Insulation R-value	5.8
Wall Insulation R-value	2.6
Window shading coefficient	0.6
Window/wall ratio	0.2
Occupancy (ft^2/person)	125
Lights (W/ft^2)	1.5
Equipment (W/ft^2)	1.6
Hot Water (Btu/ft^2)	5.4
System	
System Type	Single-zone reheat system in kitchen and dinning, two pipe fan coil system in corridors and rooms.
Heat Setpoint (day/night)	72/65°F
Cool Setpoint (day/night)	78/85°F
Plant	
Heating	Gas boiler
Cooling	Hermetic centrifugal chiller
Hot Water	Gas boiler

Table III-19. Dormitory Vintage

Vintage/ Technology	Pre 1978	Post 1978
Shell characteristics:		
Ceiling Insulation R-value	5.8	9.0
Wall Insulation R-value	2.6	4.0
Window glass	1-pane	1-pane
Lights W/ft^2:		
Offices	1.0	1.0
Class Rooms	2.0	2.0
System Type	single-zone reheat system in kitchen/dinning; two pipe fan coil system in rooms/corridors	single-zone reheat system in kitchen/dinning; variable air volume system in rooms/corridors

Library

The library building is modeled as a single story concrete building with 40,000 ft^2 of floor area. The exterior walls are 60% glass. The building is heated and cooled with a single zone reheat system. Heating energy source is gas boiler and cooling energy source is hermetic centrifugal chiller. Major characteristics of the prototypical building and its operational schedule are summarized in **Table III-20**. The vintage and technology options are summarized in **Table III-21**.

Table III-20. Building Descriptions for Library Prototype

Shell	
Floor Area (1000 ft^2)	40
Number of Floors	1
Ceiling Insulation R-value	4.9
Wall Insulation R-value	1.0
Window shading coefficient	0.6
Window/wall ratio	0.1
Occupancy (ft^2/person)	333
Lights (W/ft^2)	1.7
Equipment (W/ft^2)	0.5
Hot Water (Btu/ft^2)	-
System	
System Type	Reheat fan
Heat Setpoint (day/night)	72/65°F
Cool Setpoint (day/night)	78/85°F
Plant	
Heating	Gas boiler
Cooling	Hermetic centrifugal chiller
Hot Water	-

Table III-21. Library Vintage

Vintage/ Technology	Pre 1978	Post 1978
Shell characteristics:		
Ceiling Insulation R-value	5.8	9.0
Wall Insulation R-value	2.6	4.0
Window glass	1-pane	1-pane
Lights W/ft^2:		
Offices	1.0	1.0
Class Rooms	2.0	2.0
System Type	Reheat fan	Variable air volume

DOE-2 Simulation and Initial LSs and EUIs

The prototype buildings are simulated using DOE-2 building energy simulation program. **Table III-22** shows the simulation summary for Class/Office, Dormitory, Library, and the combined College category. The resultant EUIs and LSs are combined, using the weighting factors given in the table, to obtain initial EUIs and LSs for College category. The DOE-2 inputs for the prototypical Class/Office, Library, and Dormitory are presented in the Appendix B.

Table III-22. Simulated EUI Summary of College Prototypes

Climate Region	Electricity ($kWh/ft^2/yr$) Cooling	Fan	Light	Misc	Total	Gas ($kBtu/ft^2/yr$) Heating	DHW	Misc	Total
Classroom (weight = 0.75)									
Coast	2.1	3.5	5.4	2.4	13.5	1.7	10.8	0.0	12.5
Inland	2.4	3.7	5.4	2.4	13.9	1.8	10.8	0.0	12.6
Valley	2.5	3.6	5.4	2.4	14.0	2.4	10.8	0.0	13.2
Desert	2.6	4.0	5.4	2.4	14.5	5.1	10.8	0.0	15.9
Dormitory (weight = 0.20)									
Coast	0.0	1.1	3.9	5.0	10.0	17.7	40.1	15.2	73.0
Inland	0.0	1.1	3.9	5.0	10.0	14.6	40.1	15.2	69.9
Valley	0.0	1.1	3.9	5.0	10.0	18.7	40.1	15.2	74.0
Desert	0.0	1.1	3.9	5.0	10.0	27.4	40.1	15.2	82.6
Library (weight = 0.05)									
Coast	3.0	10.2	9.1	0.0	22.2	24.2	0.0	0.0	24.3
Inland	4.6	13.6	9.1	0.0	27.3	26.6	0.0	0.0	26.6
Valley	4.3	12.8	9.1	0.0	26.2	29.4	0.0	0.0	29.4
Desert	5.5	15.1	9.1	0.0	29.6	37.3	0.0	0.0	37.3
Weighted Average									
Coast	1.7	3.4	5.3	2.8	13.2	6.1	16.1	3.0	25.2
Inland	2.0	3.6	5.3	2.8	13.8	5.6	16.1	3.0	24.8
Valley	2.1	3.6	5.3	2.8	13.8	7.0	16.1	3.0	26.2
Desert	2.2	4.0	5.3	2.8	14.3	11.2	16.1	3.0	30.3

Chapter IV

Whole-Building Load Shapes

Whole-building electricity-use profiles (EUPs) provide an hourly control total against which the initial LS and EUI estimates (developed using the prototypes described in Chapter III) are reconciled with (in Chapter V). In this Chapter, we describe the development of these EUPs.

Whole-building EUPs are developed in a three step process. First, load research data (LRD) routinely collected by SCE for ratemaking purposes are sorted by building type and SCE district numbers. Then, they are averaged using statistical weights to produce whole-building hourly load shapes by building type and region. Third, these hourly load shapes are normalized by whole-building EUIs (expressed in kWh/ft^2) to produce whole-building EUPs for the reconciliation process (to be described in Chapter V). The whole-building EUIs were presented in Chapter II.

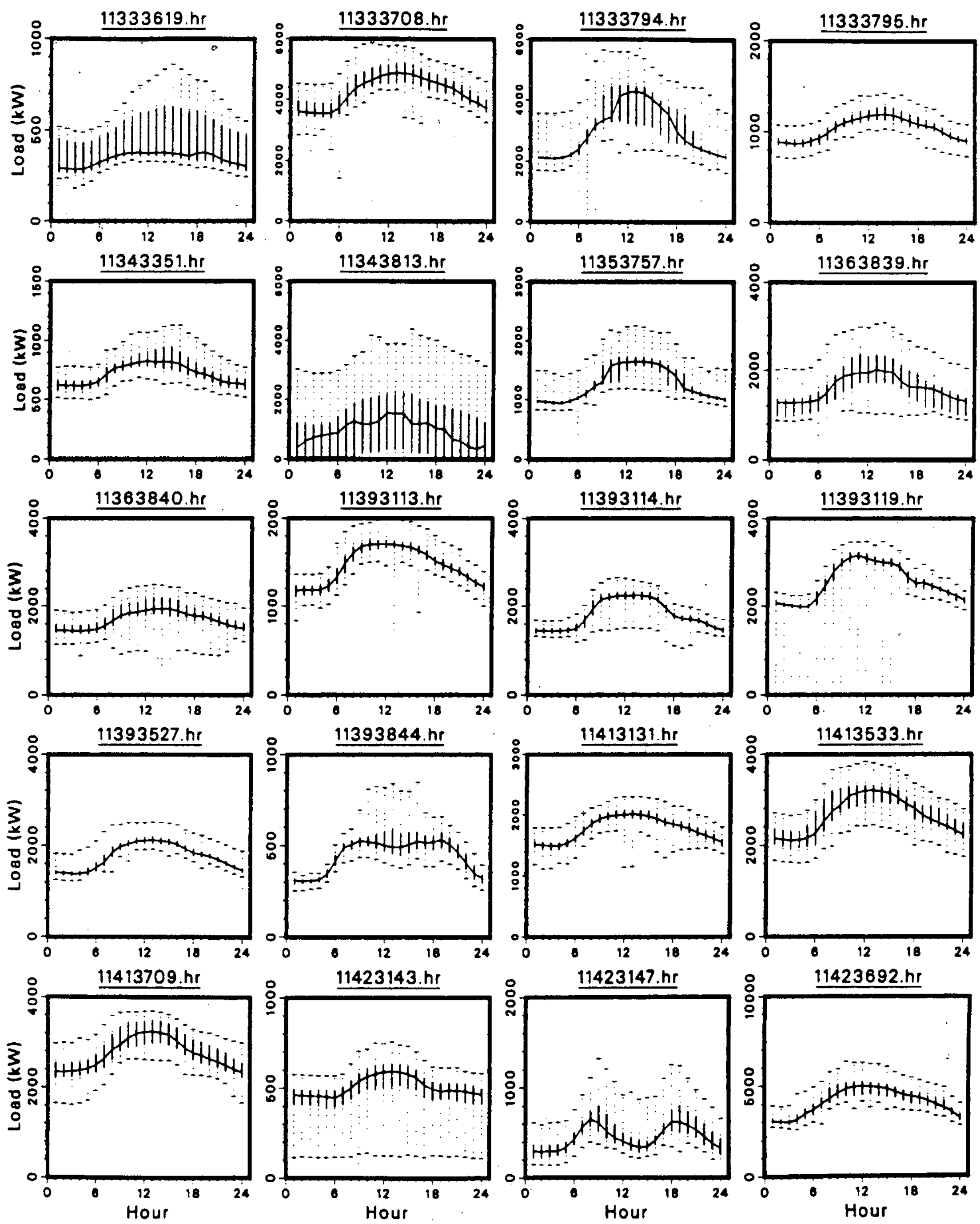
In this chapter, we describe our analysis of the LRD and the final whole-building EUPs. Our analysis proceeds in four steps:

1. review of the raw load research data;
2. integration of the load research data by building type and climate region;
3. creation of whole-building EUPs by normalizing the integrated LRD using whole-building EUIs; and
4. hourly regressions of load against temperature to determine the weather-responsiveness of the EUPs.

Raw Load Research Data

The LRD were reviewed for completeness and erroneous or questionable data were excluded from the averaging process. **Figure IV-1** shows an overview of the LRD for a sample of hospital accounts. For each graph, the central line shows the median, the heavy bars denote the quartile range and the dotted lines show the minimum and maximum for each hour. All of the accounts show the high nighttime load (relative to daytime peaks) that one would expect in hospitals. Building 11343813 was removed after closer examination which revealed 167 zero load days. Buildings 11393844 and 11423147 have a different load shape than most of the other accounts but this was explained by their SIC code which was for residential care. Since this building category is included in health, these two accounts where retained. An overview of all the LRD is included in Appendix C.

Figure IV-1. Representative Summary of Load Research Data for Health. The central line in each graph is the median; the heavy bars denote the quartile range, and the dotted lines show the minimum and maximum for each hour. Summaries for all LRD accounts are presented in Appendix C.



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 weighting factors derived from analysis of billing data in SCE service territory. Table II-4 shows the number of LRD files by building type and climate region. Note that there is very little data for the valley region (4) for all building types. There is also a shortage of data for lodging in the inland region (2).

The weighting factors used to aggregate individual LRD to average whole-building load shapes were developed using the billing account information provided by SCE. All TOU-8 accounts have LRD, so the weighting factor for each account is 1.[1] However, GS-1 and GS-2 LRD accounts are random samples from the population of all GS-1 and GS-2 accounts. The SCE billing account information was stratified by annual average demand and building type. To develop the GS-1 and GS-2 weighting factors, the total number of accounts in each stratum was divided by the number of LRD files in that stratum. These data are shown in **Table IV-1**.

The primary challenge of 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 four climate regions used in the reconciliation process. Our analysis was based on reviews of SCE district mapping, CEC climate zone ZIP code mapping, Southern California maps, and discussions with SCE and CEC personnel. **Table IV-2** reports the assignments of SCE district numbers to these climate regions.

Since the number of accounts in the interior zones where not sufficient to develop whole-building load shapes for each zone, we combined the LRD for "inland", "valley", and "desert" climate zones into a single "non-coastal" zone. Later, with the help of additional DOE-2 simulations, we have developed end-use EUIs for each individual non-coastal climate zone. We selected Burbank weather data to represent the entire non-coastal climate zone for this initial stage of the analysis.

Once aggregated, the average whole-building load shapes were normalized so that the integral under the load shapes was set equal to the whole-building EUIs presented in Table II-5.

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[1] TOU-8, GS-1, and GS-2 are billing account codes used by SCE.

Table IV-1. 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 Commercial Accounts										
School	2061	15	153	358	1171	790	396	557	1012	85
College	786	14	99	132	254	94	31	67	90	50
Hospital	1604	36	181	282	517	259	134	188	366	102
Lodging	2171	10	235	470	853	345	124	164	508	57
Distribution of GS-1 and GS-2 Load Research Data										
School	0	0	1	0	13	5	1	0	3	0
College	0	0	0	0	0	0	0	0	0	0
Health	0	0	2	0	0	0	1	0	1	0
Lodging	0	0	0	0	0	1	0	0	2	0
Sample Weights										
School	----	----	153	----	90	158	396	----	337	----
College	----	----	----	----	----	----	----	----	----	----
Health	----	----	91	----	----	----	134	----	366	----
Lodging	----	----	----	----	----	345	----	----	254	----

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

Weighted Average Whole-Building Load Shapes

Figures IV-2 to **IV-5(i-ii)** show the average whole-building LSs-shapes for School, College, Health, and Lodging (for the coastal and non-coastal climate regions).

The prototypical whole-building loads were also analyzed by day of the week to determine the number of standard and non-standard days. **Figures IV-6** to **IV-9** show the variation in the prototypical whole-building loads by day of the week for Health, Schools, College, and Lodging, respectively. **Table IV-3** shows the final assignment of day types for each building type.

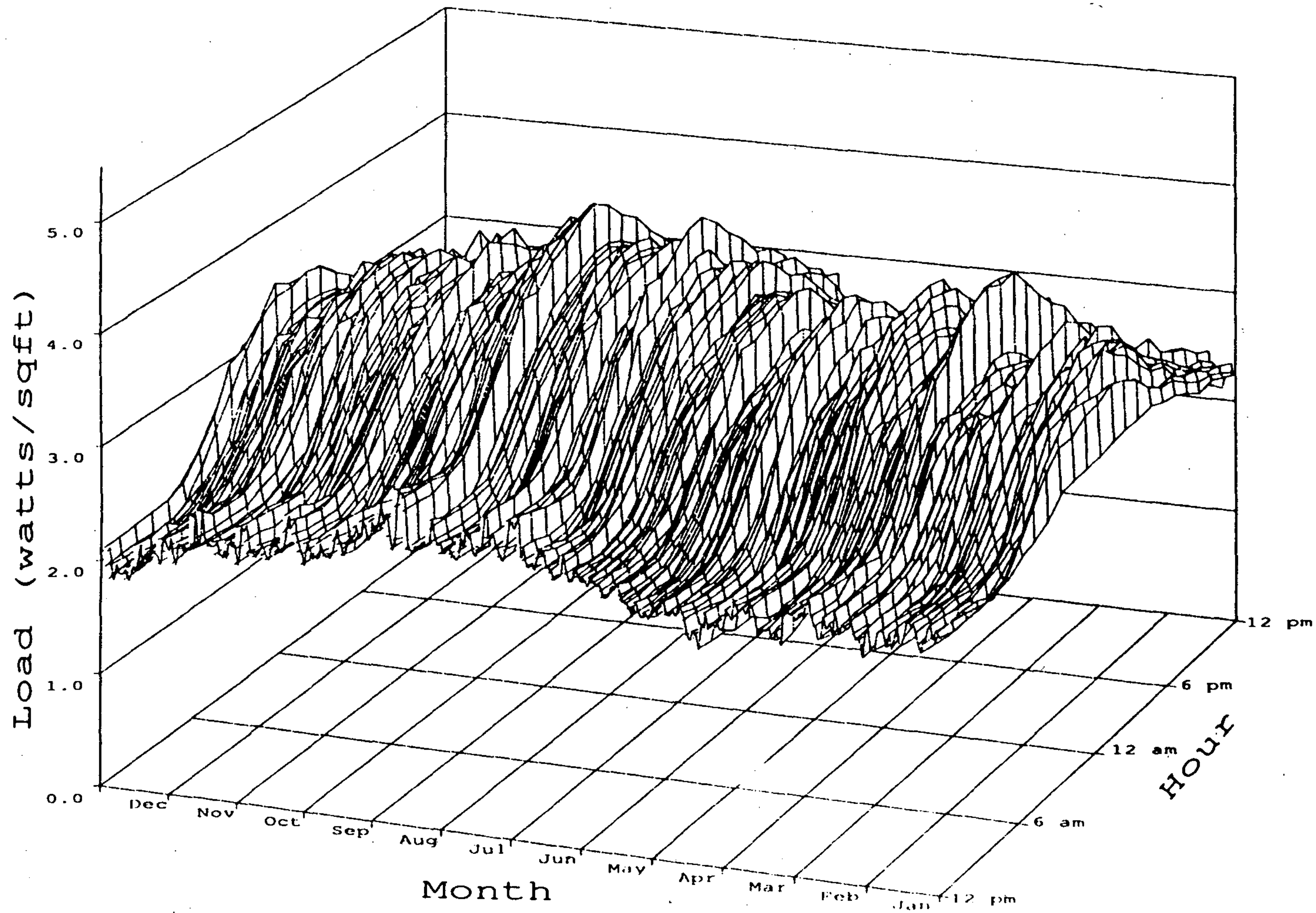
Table IV-2. Assignment of SCE Districts to Climate Regions

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

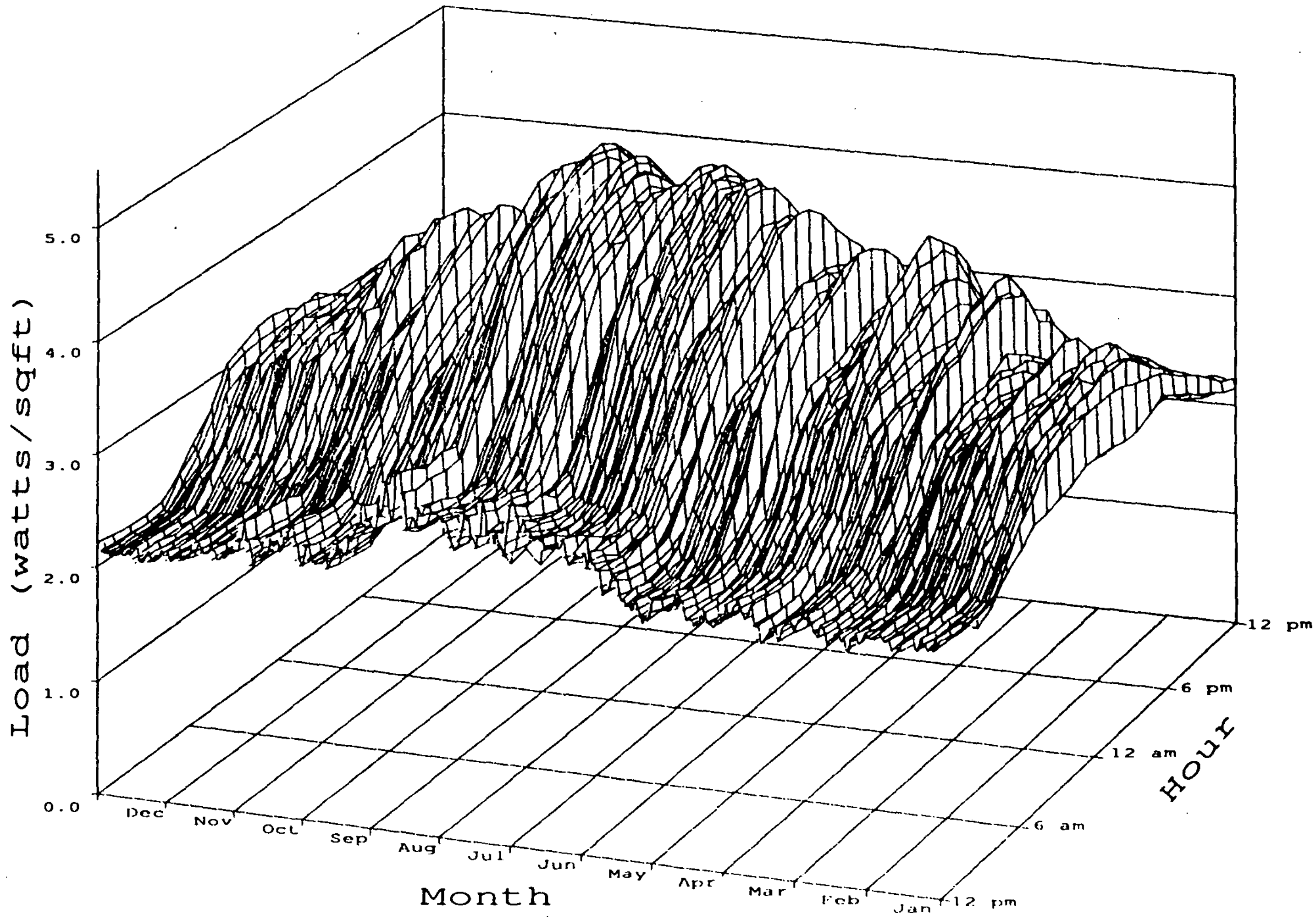
Table IV-3. Assignment of Day Types by Building Type

Building Type	Standard Days	Non-Standard Days
School	M-F	Sat,Sun,Hol,June 1 - Sep 1
College	M-F	Sat,Sun,Hol
Health	M-F	Sat,Sun,Hol
Lodging	All	none

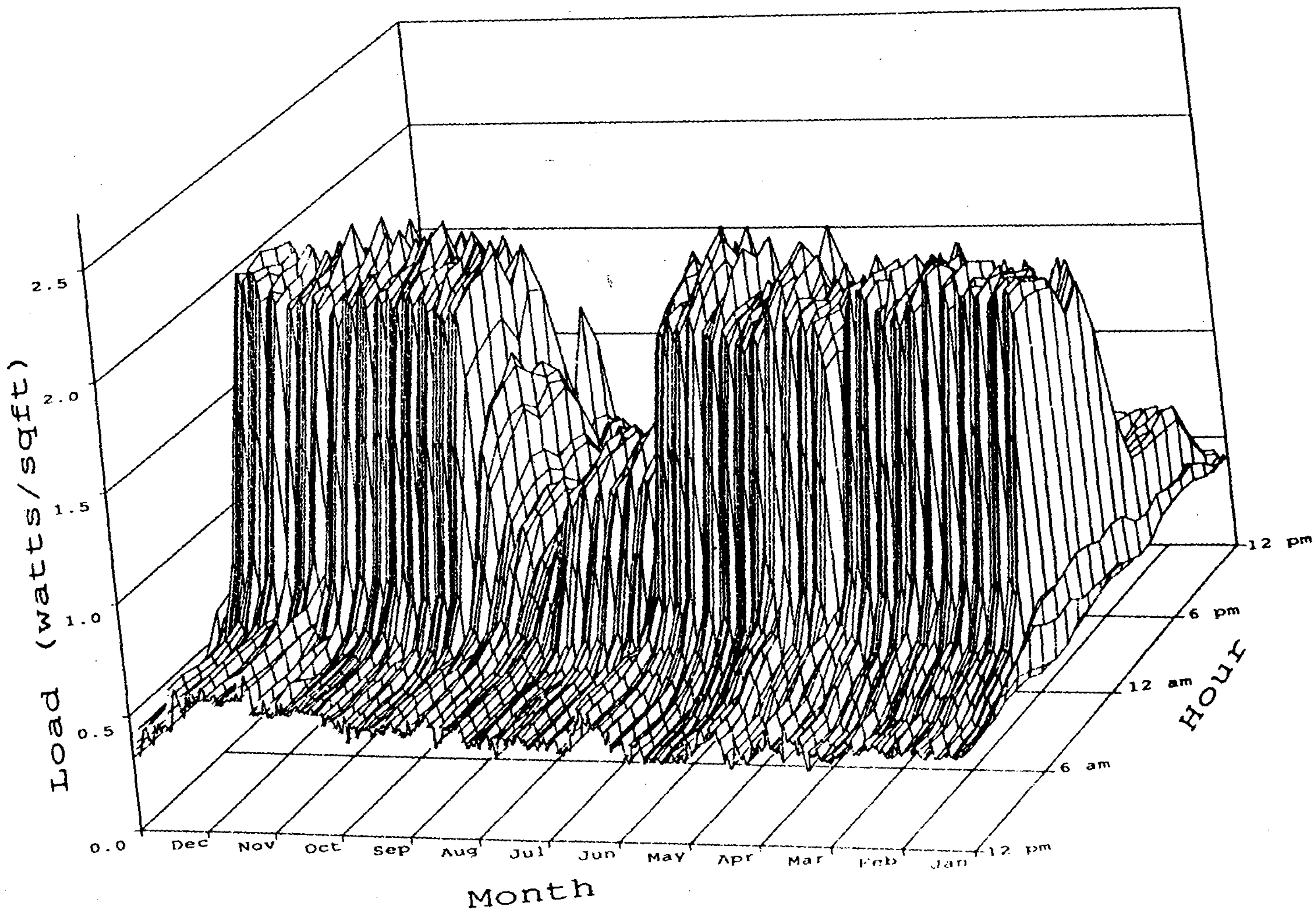
Figures IV-2i. Average Whole-Building Load Shapes for Health - Coastal Region.



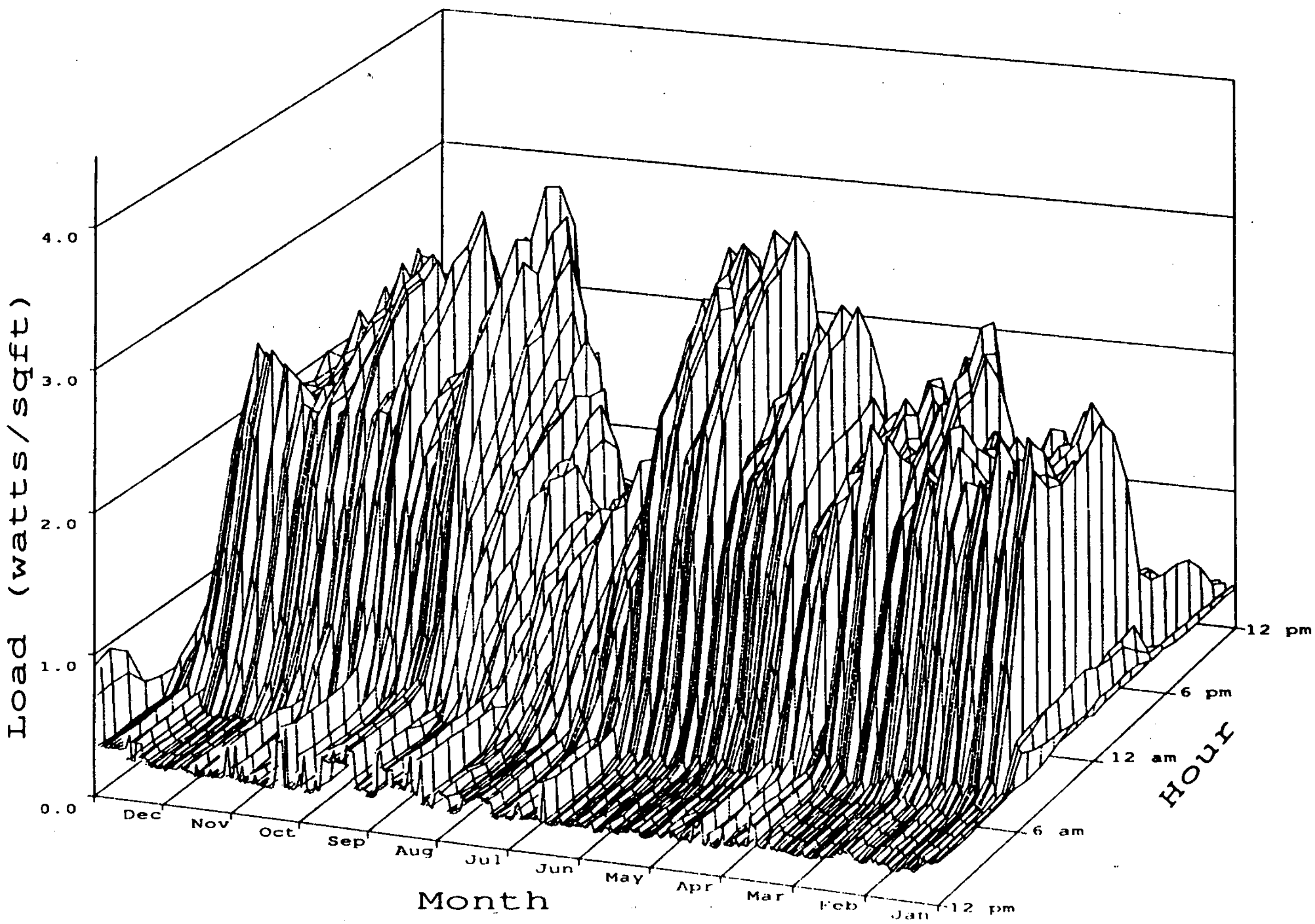
Figures IV-2ii. Average Whole-Building Load Shapes for Health - Non-Coastal Region.



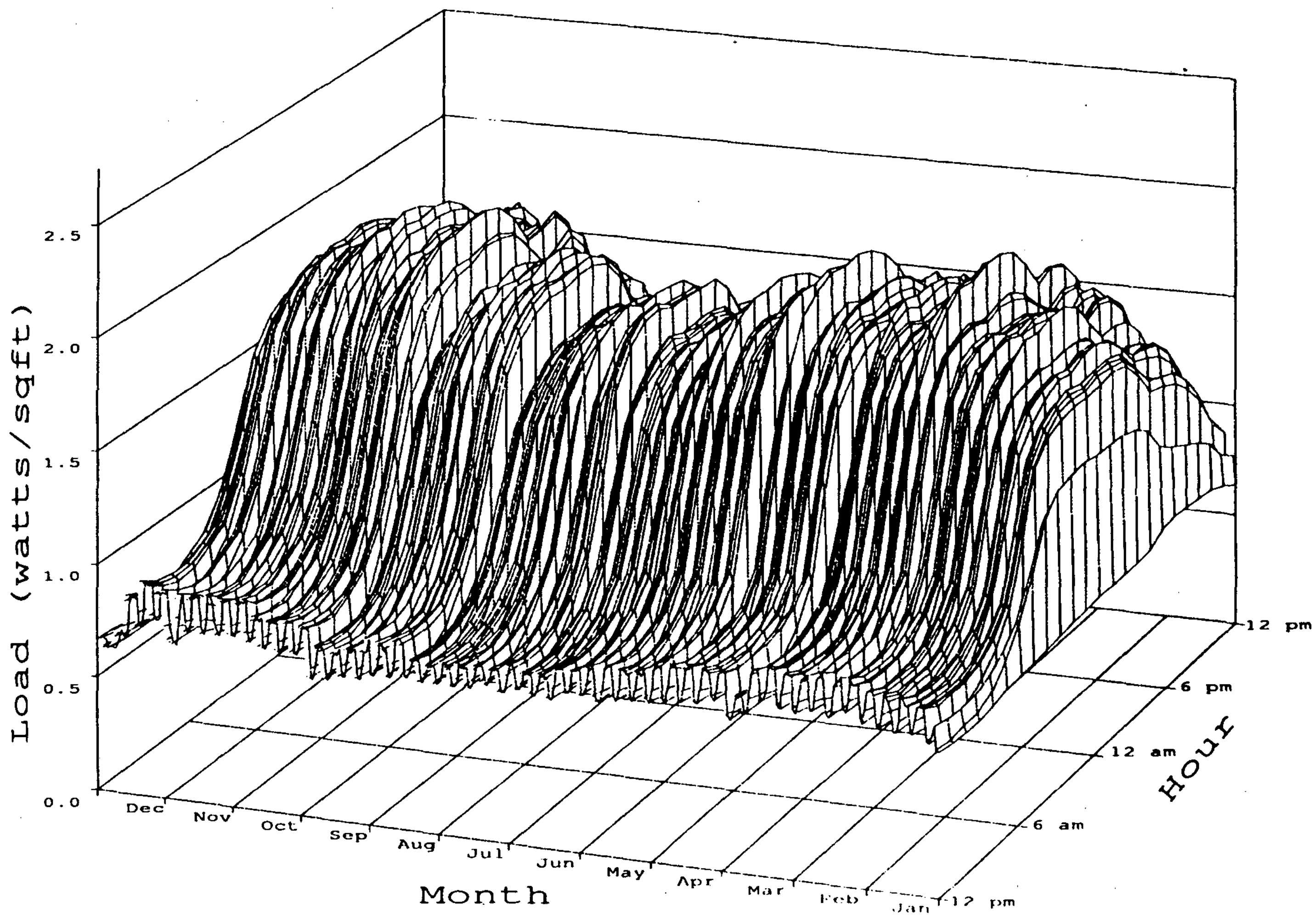
Figures IV-3i. Average Whole-Building Load Shapes for School - Coastal Region.



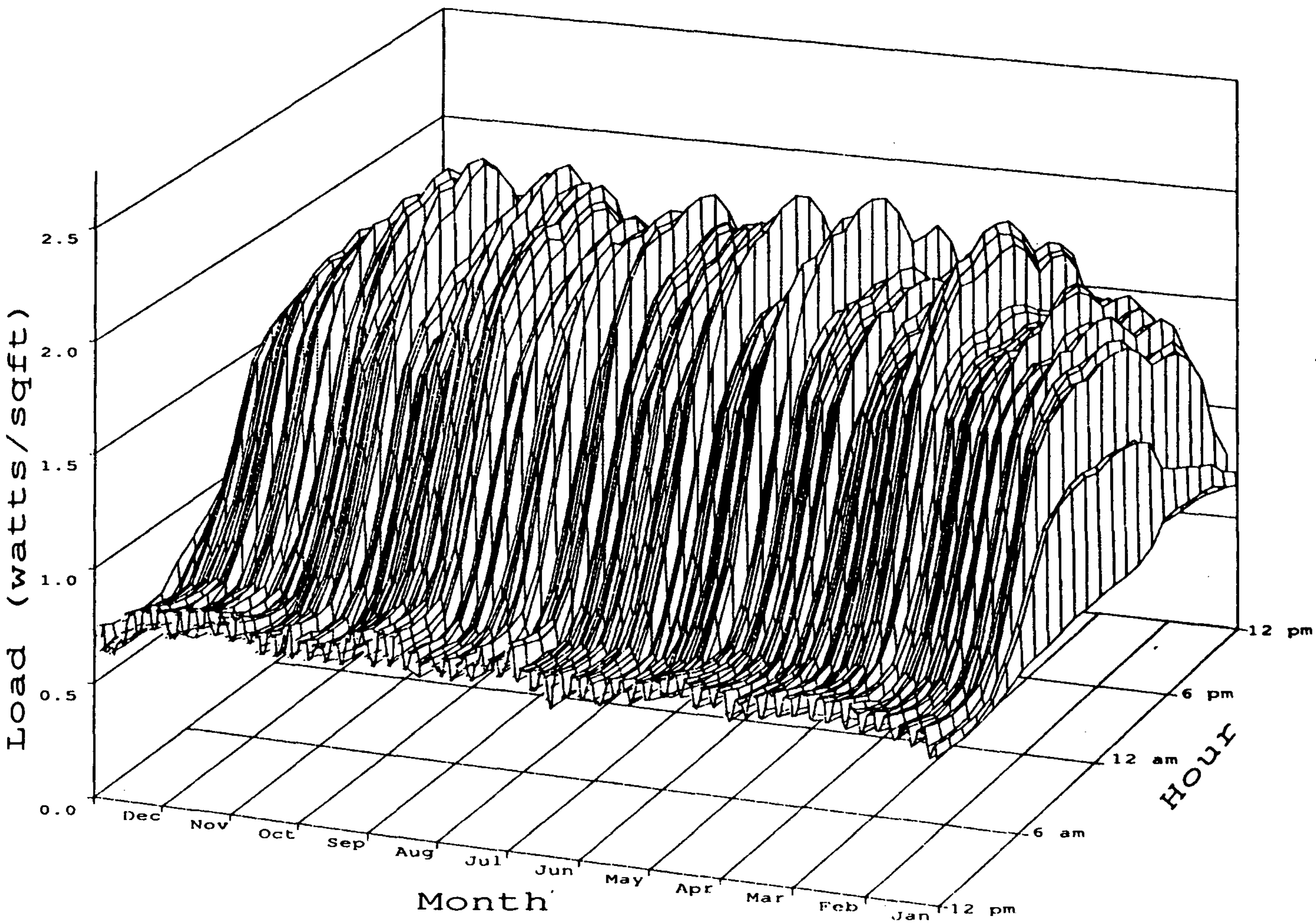
Figures IV-3ii. Average Whole-Building Load Shapes for School - Non-Coastal Region.



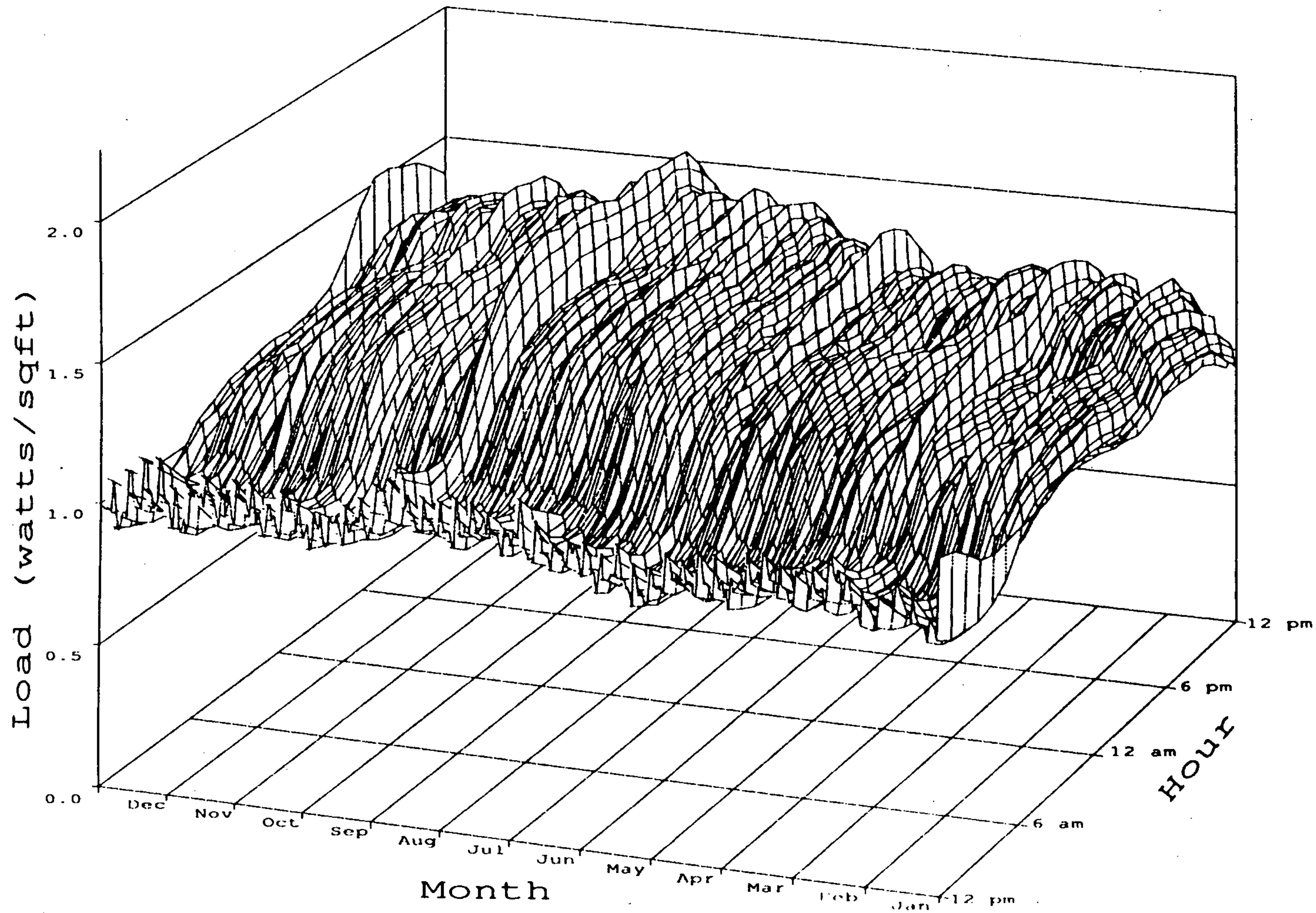
Figures IV-4l. Average Whole-Building Load Shapes for College - Coastal Region.



Figures IV-4ii. Average Whole-Building Load Shapes for College - Non-Coastal Region.



Figures IV-5i. Average Whole-Building Load Shapes for Lodging - Coastal Region.



Figures IV-5ii. Average Whole-Building Load Shapes for Lodging - Non-Coastal Region.

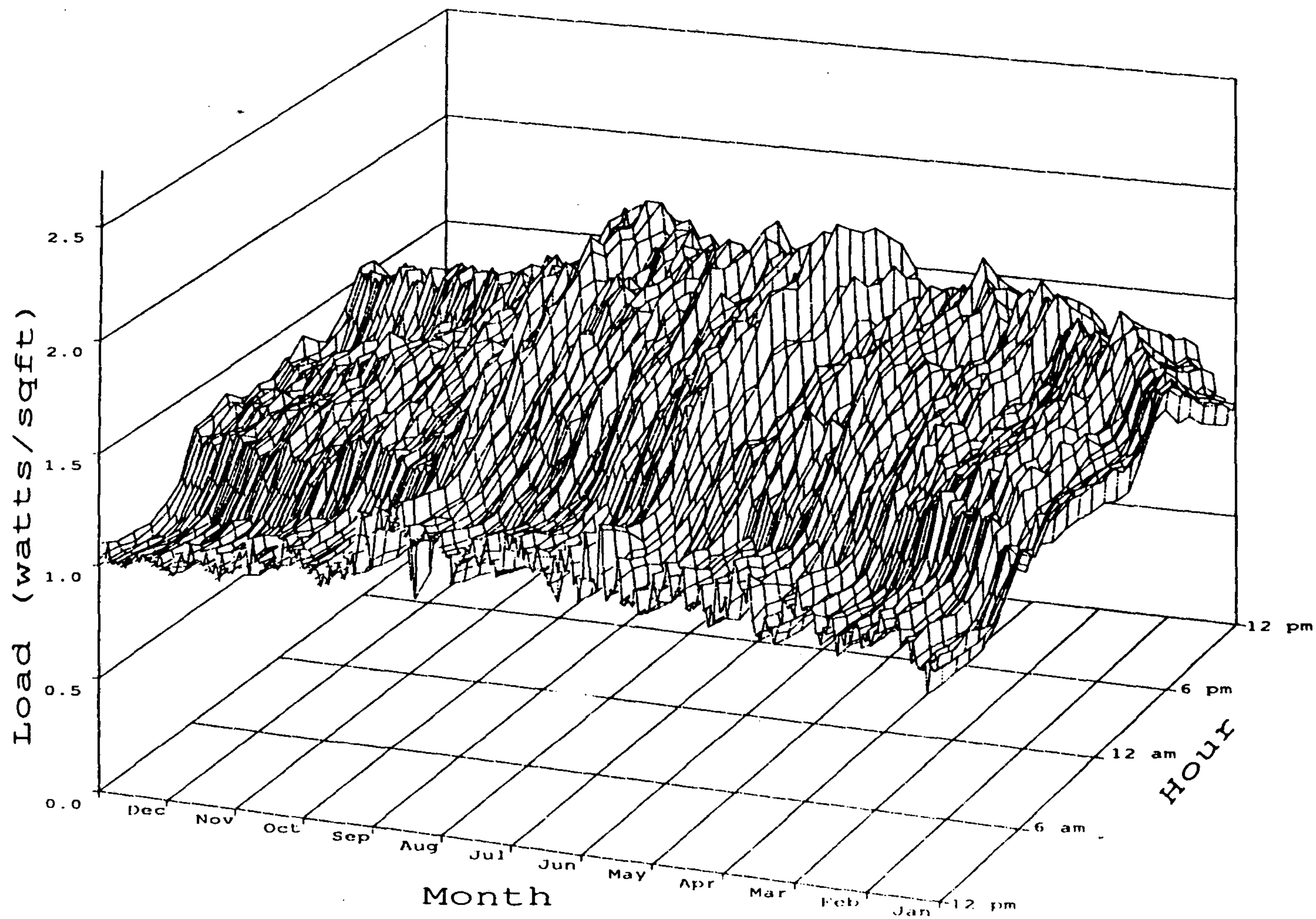


Figure IV-6. Mean Hourly Loads by Day of Week for Health. LRD in the coastal and non-coastal regions were examined to determine the number of standard and non-standard operating days. On the basis of this analysis, Monday through Friday were selected as standard days; the remaining days became non-standard.

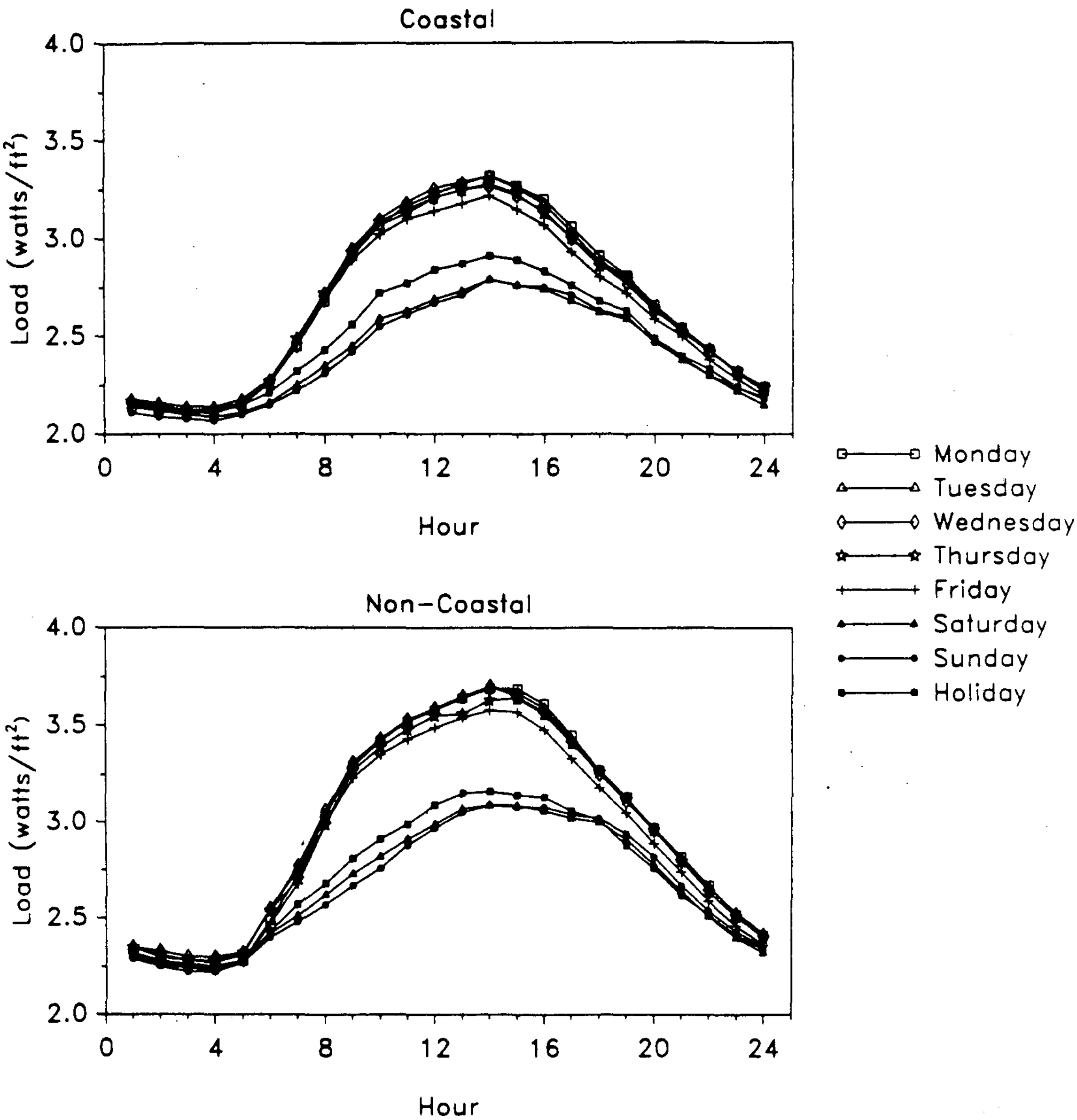


Figure IV-7. Mean Hourly Loads by Day of Week for School. LRD in the coastal and non-coastal regions were examined to determine the number of standard and non-standard operating days. On the basis of this analysis, Monday through Friday were selected as standard days; the remaining days became non-standard.

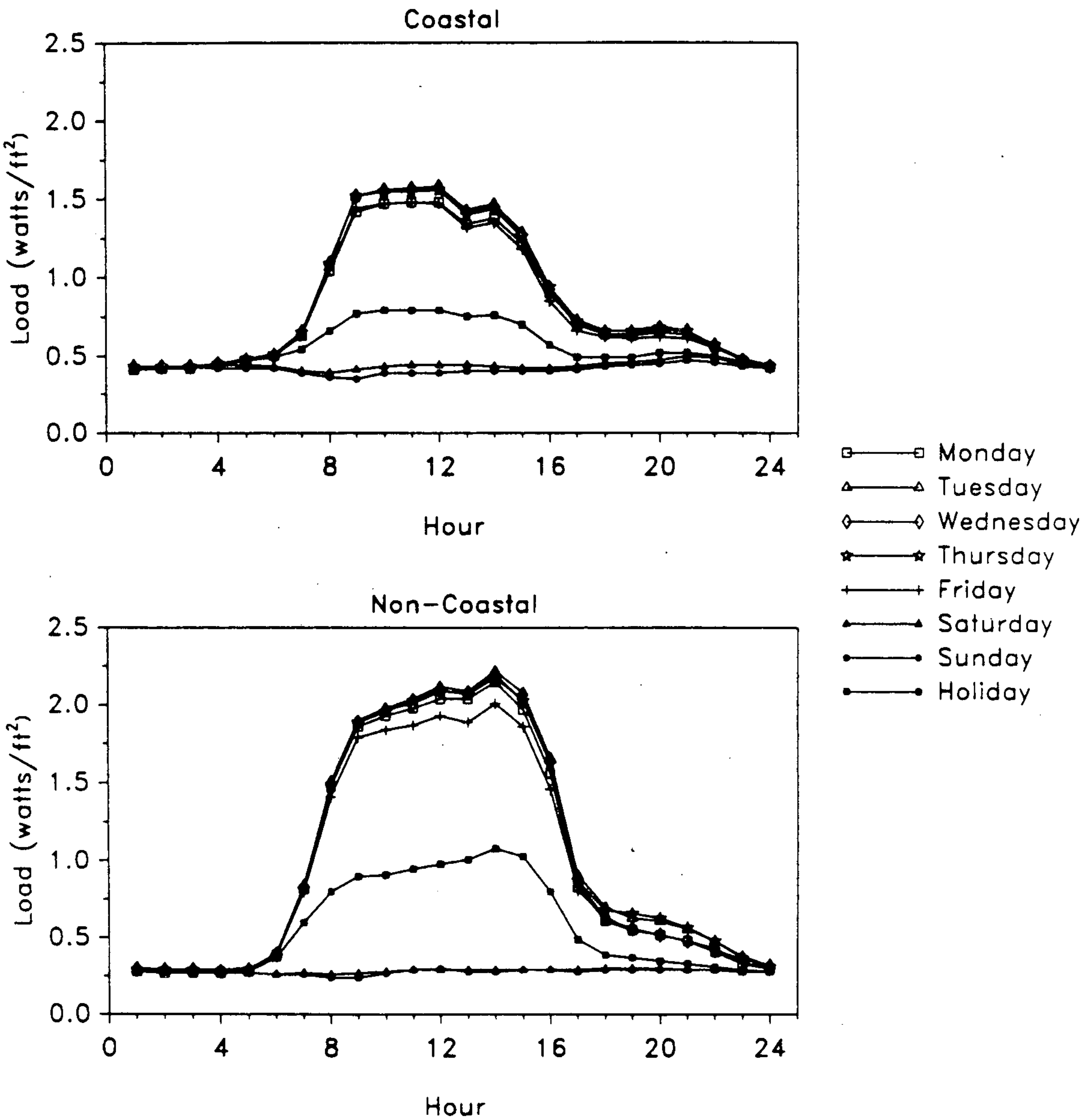


Figure IV-8. Mean Hourly Loads by Day of Week for College. LRD in the coastal and non-coastal regions were examined to determine the number of standard and non-standard operating days. On the basis of this analysis, Monday through Friday were selected as standard days; the remaining days became non-standard.

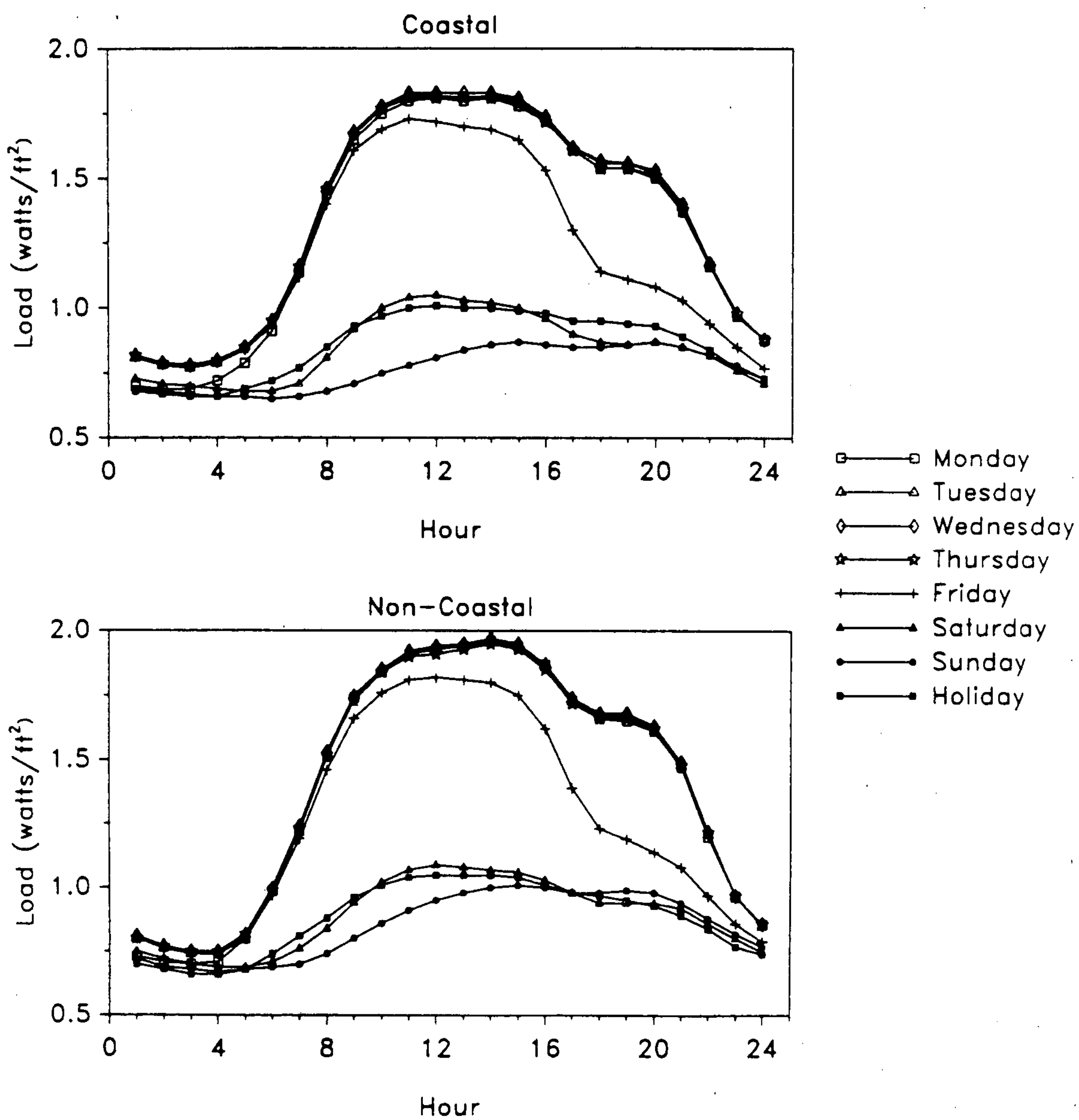
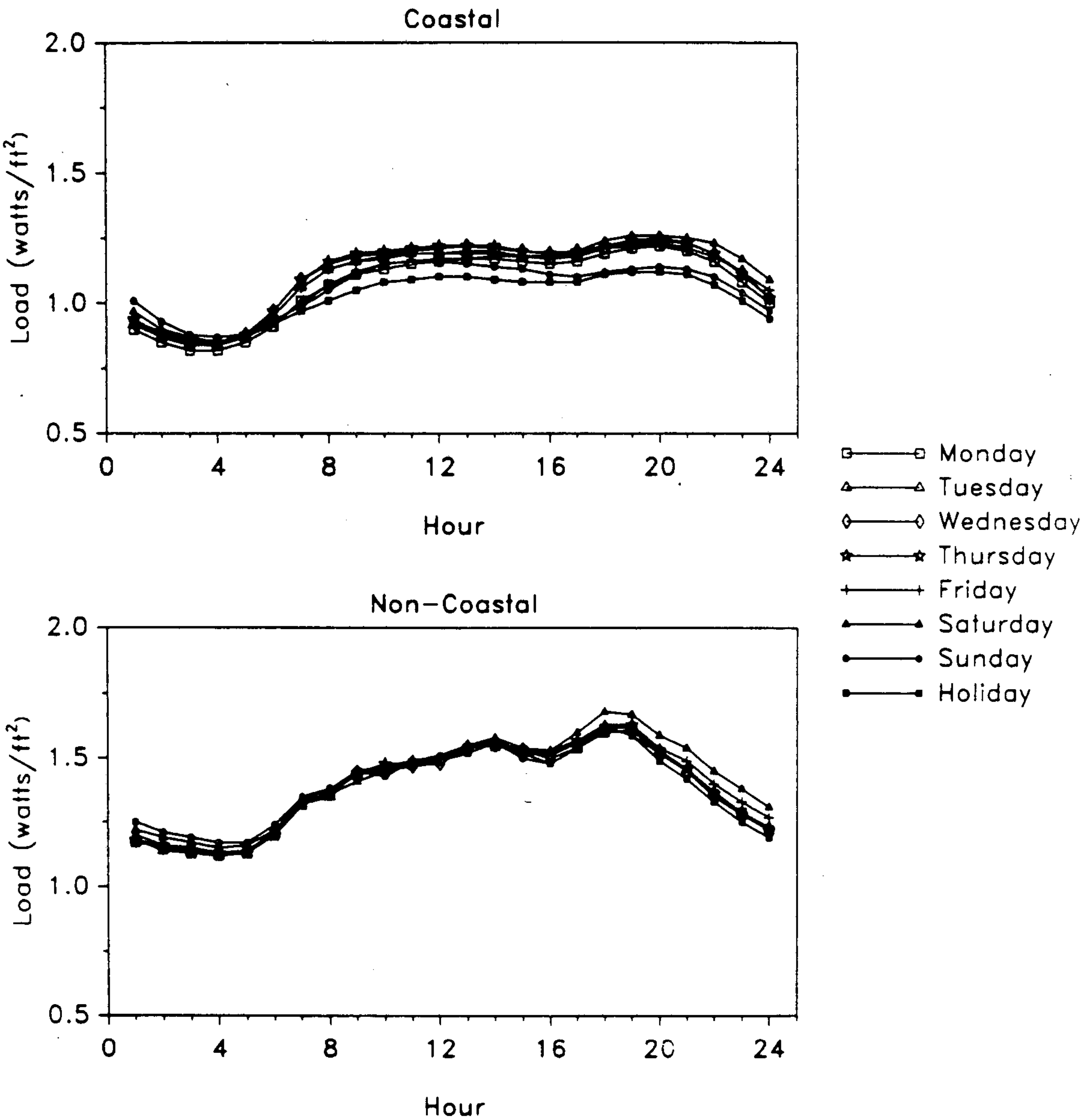


Figure IV-9. Mean Hourly Loads by Day of Week for Lodging. LRD in the coastal and non-coastal regions were examined to determine the number of standard and non-standard operating days. On the basis of this analysis, every day was deemed a standard day; there were no non-standard days for this building type.



Load-temperature regression results

The final data base integration task was a regression analysis of the averaged whole-building load shapes against historic weather data to determine the correlation of whole-building hourly loads to hourly temperature. The regressions were performed separately for each of the 24 hours in a day, summer and winter seasons, and standard and non-standard day types. For each hour, season and day type, in which the dry bulb temperature was greater than 60°F, the whole-building load was regressed versus dry-bulb and dew-point temperatures. Those hours which had an F statistic significance less than 0.001 were considered acceptable and were then used to estimate temperature and non-temperature dependent loads during the reconciliation. The temperature-dependent cooling loads during the hours that were not considered acceptable were estimated from the DOE-2 simulations rather than from the temperature regressions.

As an example, the data from the Health LRD regressed against coastal weather for winter standard days is presented in **Table IV-4**. For each hour 6 numbers are presented: The base load intercept is the assumed base load of the building at 60°F dry bulb and 50°F dew point. The dew point coefficient is the number of watts per square foot that the building load increases for each degree rise in dew point temperature. The dry bulb coefficient is the number of watts per square foot that the building load increases for each degree rise in dry bulb temperature. R^2 is the multiple correlation coefficient which indicates how much of the variation in the load can be accounted for by the linear regression. The significance of the F statistic shows to what level of significance the model is an adequate explanation of the true situation (it does not say whether or not there are other better models). N is the number of days used for the regression. The results of all the regressions are presented in Appendix D.

Table IV-5 summarizes the hours of significant temperature dependent cooling load (i.e. an F statistic significance of less than 0.001). With the exception of coastal Colleges and Schools, all buildings show significant day-time correlation on both winter and summer standard days. In general, the winter significant hours occur later in the day than during the summer, usually not until 10:00 a.m. Health also shows significant correlation during non-standard days which indicates that these buildings are at least partially occupied. Schools show the least correlation, being significant only in the afternoon in the inland zone.

Table IV-4. LRD Regression Parameters for Coastal Health - Winter Standard Day

Hour	Regression Parameters			Statistics		
	Base Load Intercept (W/ft^2)	Dew Point Coefficient ($W/ft^2/°F$)	Dry Bulb Coefficient ($W/ft^2/°F$)	R^2	Significance of F-Statistic	N
1	2.135	0.020	0.046	0.70	0.001	14
2	2.156	0.016	0.032	0.50	0.086	9
3	2.049	0.032	0.051	0.84	0.010	7
4	2.174	0.000	0.070	0.97	0.033	4
5	2.320	-0.020	0.050	0.98	0.017	4
6	2.470	-0.021	0.008	0.71	0.155	5
7	2.555	-0.006	0.045	0.87	0.017	6
8	2.689	0.005	0.047	0.42	0.029	15
9	2.903	-0.000	0.024	0.22	0.013	37
10	3.032	0.002	0.025	0.44	0.000	65
11	3.039	0.002	0.026	0.60	0.000	96
12	3.017	0.006	0.032	0.71	0.000	112
13	2.995	0.008	0.033	0.71	0.000	116
14	3.034	0.009	0.032	0.68	0.000	115
15	2.980	0.008	0.032	0.66	0.000	115
16	2.945	0.007	0.030	0.59	0.000	116
17	2.816	0.007	0.031	0.64	0.000	117
18	2.734	0.005	0.030	0.58	0.000	105
19	2.696	0.005	0.031	0.50	0.000	79
20	2.603	0.004	0.038	0.60	0.000	63
21	2.552	0.004	0.032	0.53	0.000	43
22	2.484	0.003	0.034	0.49	0.000	29
23	2.370	0.005	0.037	0.53	0.001	21
24	2.250	0.007	0.061	0.69	0.000	16

Table IV-5. Hours of Significant Load/Temperature Correlation

	Summer		Winter	
	Standard	Non-Standard	Standard	Non-Standard
Health				
Coastal	1-24	1-24	10-24	10-21
Inland	1-24	1-24	10-23	10-19
College				
Coastal	-	-	11-16	-
Inland	1-16	12-19	11-19	-
Lodging				
Coastal	1-24	N/A	10-17	N/A
Inland	1-24	N/A	9-22	N/A
School				
Coastal	-	-	-	-
Inland	10-16	-	12-16	-

Chapter V

Reconciliation of End-Use EUIs and Load Shapes

The basic idea in the reconciliation process is to adjust each hourly load from the initial simulations of the prototypes (which have subsequently been weighted together into building types) so that the end-use hourly loads sum to exactly match the control total provided by the whole-building load shapes. The development of the initial load shapes was described in Chapter III, while the development of the whole-building load shapes or control totals was described in Chapter IV. The overall reconciliation process is described in the Phase I final report (Akbari et al 1989). This Chapter describes unique aspects of its application to the current project and the results for each building type. In the Chapter VI, we describe the derivation of inputs for the CEC forecasting model from these reconciled values.

Overview of the Reconciliation Process

The reconciliation follows the general procedures documented in the Phase I report (Akbari, et. al., 1989). In this section, we briefly focus on three aspects of the reconciliation that are unique with respect to the Phase I project or are of particular significance: 1) the magnitude of the adjustments required to achieve reconciliation between the initial estimates and the control total; 2) the use of climate adjustment factors to permit separate reconciliations for a coastal and non-coastal zone; and 3) the application of smoothing procedures to facilitate reconciliation during shoulder hours when the mismatch between HVAC loads and the control total is particularly large.

Since the process is repeated for each hour of the year, reconciliation is automatically achieved for the annual total EUIs. One can develop a feeling for the magnitude of the adjustments introduced by the reconciliation by comparing the initial whole-building EUI (i.e., the sum of initial, estimated end-use load shapes) to the whole-building EUI from the control total. (See **Table V-1**) If the differences are large on a whole-building EUI basis, one can expect that the final end-use EUIs will also be quite different from the preliminary estimates.[1] Generally, we observed that the differences are within 40%.

As described in Chapter II, while ideally we would run a separate reconciliation for each of the four SCE climate zones, lack of sufficient quantities of LRD limited us to reconciliation for two regions, the existing coastal region and the combination of inland, desert and valley into a single, non-coastal region. We also lacked data on whole-building EUIs by climate zone (used to develop the whole-building load shapes described in Chapter IV). We addressed these limitations by running additional DOE-2 simulations of the prototype with a representative climate in each of the two regions and used the simulation results to scale the whole-building EUIs for each climate region. Table V-1 presents the resulting adjustment factors.

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[1] Nevertheless, it is inappropriate to conclude that small differences between the initial and control total whole-building EUIs indicate good agreement in the constituent end-use LSs and EUIs.

Table V-1. Preliminary and Final Total Electricity EUIs

Building Type	Floor Area (ft^2)	Preliminary (kWh/ft^2-yr)	Final (kWh/ft^2-yr)	Preliminary/ Final	Adjustment Coastal	Adjustment Non-Coastal
Health		26.4	24.5	1.08	0.98	1.04
Hospital	248,511	29.6				
Nursing	29,200	8.6				
School		9.4	6.7	1.40	0.99	1.01
Primary	35,000	13.2				
Secondary	240,000	8.3				
College		13.9	10.3	1.35	0.98	1.03
Class/Office	128,500	14.0				
Dorm	52,000	10.2				
Library	40,000	26.5				
Lodging		13.8	11.7	1.18	0.88	1.00
Large Hotel	206,000	14.8				
Small Hotel	26,680	11.4				

Running separate reconciliations for two climate zones has the un-intended effect of producing two reconciled estimates for non-HVAC end uses. Generally speaking, the differences are quite small, nevertheless, they are an inherent by-product of the current reconciliation procedures.[2] Since we expect that these end uses should not be affected by climate, we have averaged the non-HVAC end-use EUIs from each climate zone in our final presentations.

As found in the Phase I report, the initial reconciliations yield large discontinuities in the shoulder hours for many end uses. We determined that, once again, 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 possibly 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 continued the practice (developed in Phase I) of running EDA iteratively. The first EDA run is used to determine the number of shoulder hours

[2] We plan to improve this and other aspects of the reconciliation procedure through a CIEE exploratory research grant to validate the EDA methodology with measured end-use data from the SCE commercial building metering project.

over which the discontinuities were most pronounced. Then we 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.

Guide to the Presentation of Reconciled Results

The remainder of this Chapter presents the results from the reconciliations. The results are presented by building type and include a standardized set of tables and figures. Discussion is limited to unique features of the reconciliation for each building type.

There is a summary table for each building type comparing our initial or preliminary EUI estimates to the final reconciled values, end-use by end-use. As mentioned above, these tables present only a single value for non-HVAC end-use EUI, which is the average of the reconciled non-HVAC EUIs from the two climate zones. Within the non-coastal zones (inland, desert, and valley), separate HVAC end-use EUIs were developed by scaling the reconciled non-coastal EUI with additional DOE-2 simulations for each individual climate zone (as described in Chapter II).

Following the Table, we present a series of eight Figures. The first two present averaged daily end-use load shapes for standard and non-standard days for the Coastal zone: the first figure presents the initial or preliminary estimate of these end-uses, while the second presents the final reconciled values.[3] Visual comparison of these two figures illustrates the magnitude and direction of the adjustments introduced by the reconciliation process to match the control total. Note that our analysis of the LRD for the lodging building type did not reveal the presence of non-standard days of operation (see Chapter IV); accordingly, only results for the standard day are presented.

The next six figures present average monthly load shapes, by day-type (standard and non-standard), and by end use. The first three contain the results from the reconciliation for the coastal zone. The second three contain results from the reconciliation for the non-coastal zone.

We also developed temperature-humidity index (THI) matrices from the hourly reconciled cooling electricity load shapes. The structure of the matrices corresponds to that used by the CEC's peak demand forecasting model. However, the LBL matrices contain many missing values because not every temperature-humidity condition was observed in the weather used for the reconciliation for every hour of the day. Thus, they may not be suitable for use in the CEC peak demand model without additional analysis.[4] The matrices are contained in Appendix E.

[3] Although end-use data for both Coastal and non-Coastal zones were developed, for presentation purposes, we only show the average annual load shapes for the Coastal zone.

[4] A separate LBL project is examining methods for interpolating, extrapolating, and smoothing these types of matrices using data from residential end-use metering projects.

Health

The Health building type has the high load factor, typical of this building class, with evening loads of more than 60 percent of the peak daily load (see **Figure V-2**). From analysis of the LRD (detailed in Chapter IV), both Saturday and Sunday were determined to be non-standard days. Although these days are significantly different from the weekdays, they still show temperature dependent loads during the day indicating that there is still significant space conditioning.

Because of the good LRD regression results almost all of the temperature dependent load is captured in the cooling end use. This resulted in very little seasonal variation in the other end uses (See **Figures V-3 - V-8**). The non-standard load shapes are similar to the standard day shapes but with lower day time peaks.

As shown in **Table V-2**, most non-HVAC EUIs increased slightly from the initial estimates and the cooling EUIs decreased slightly. The coastal cooling is lower than the non-coastal cooling but within the non-coastal zone it does not vary significantly.

Table V-2. Initial and Reconciled EUIs for Health

Location	Cooling	Ventilation	Indoor Lighting	Outdoor Lighting	Miscellaneous Equipment	Hospital Equipment	Cooking	Refrigeration	Total
Initial									
Coast	4.7	2.3	9.3	0.4	4.3	0.9	0.1	0.6	22.0
Inland	5.7	2.4							23.1
Desert	5.9	3.4							24.2
Valley	5.8	3.3							24.0
Reconciled									
Coastal	4.4	2.1	10.7	0.4	4.9	1.1	0.1	0.6	24.2
Inland	5.3	2.2							25.2
Desert	5.5	2.2							25.4
Valley	5.4	2.1							25.2

Figure V-1. Average Annual Unreconciled Load Shapes for Coastal Health. These unreconciled load shapes result from the initial DOE-2 simulations of the prototypes.

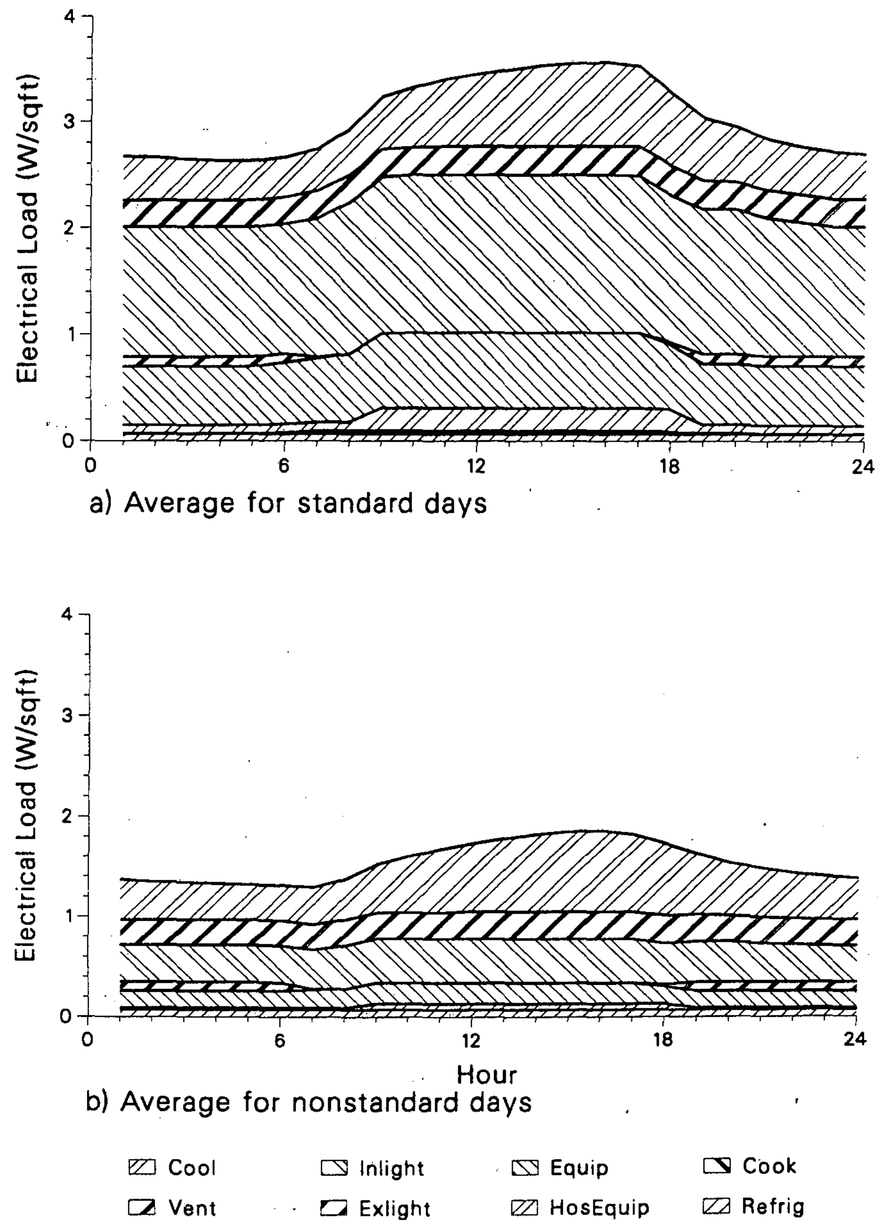


Figure V-2. Average Annual Reconciled Load Shapes for Coastal Health. These reconciled load shapes can be compared to those in the previous Figure.

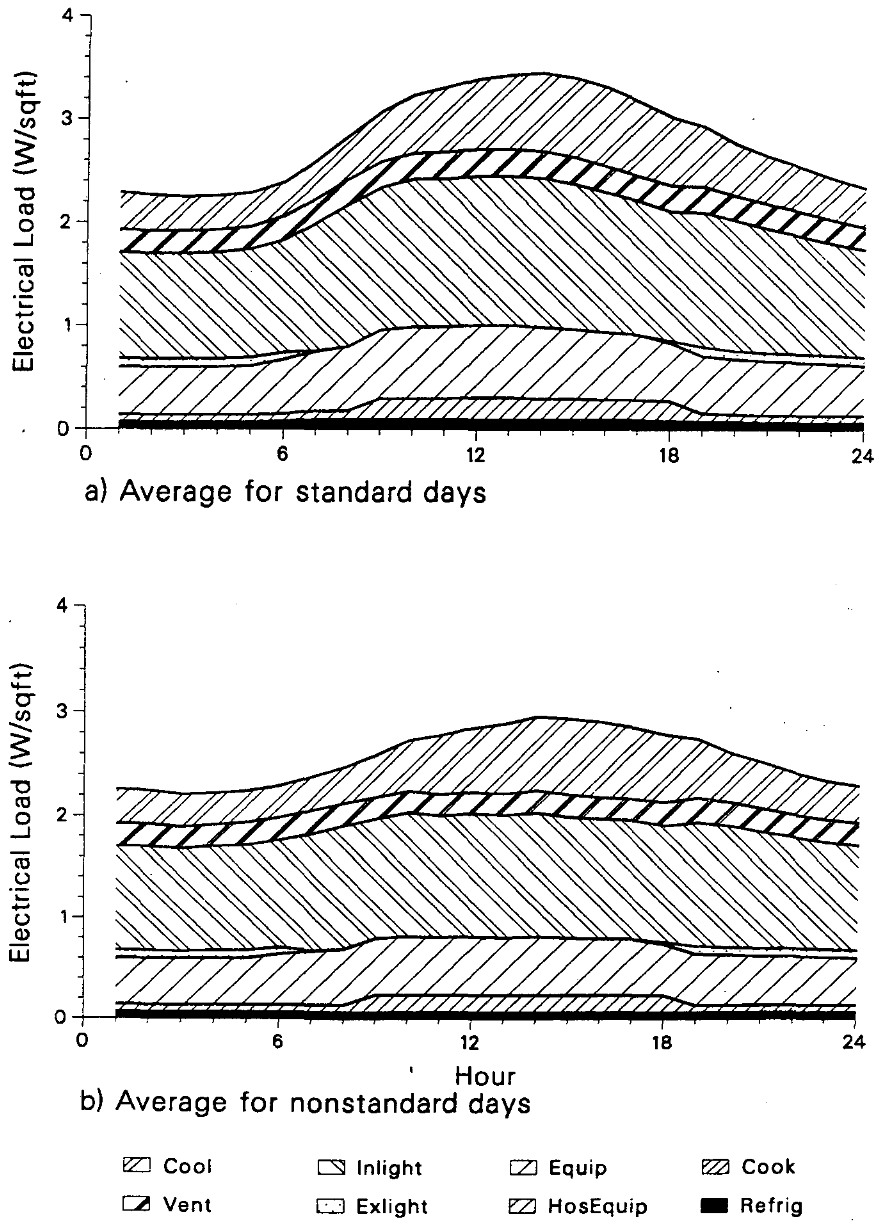


Figure V-3. Reconciled Cooling and Ventilation Load Shapes for Coastal Health. Solid lines are profiles for months May through October and broken lines are profiles for months November through April.

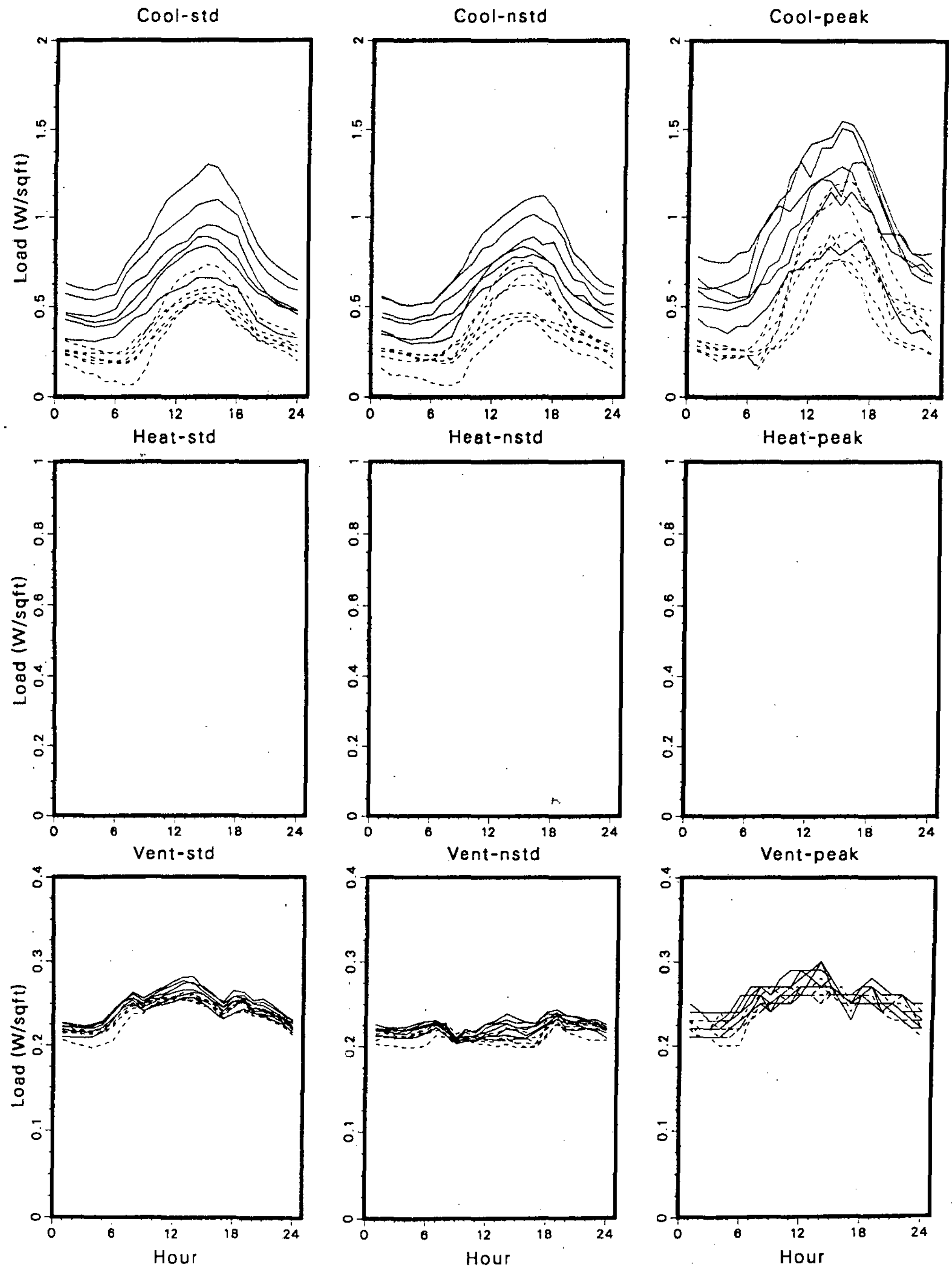


Figure V-4. Reconciled Indoor and Outdoor Lighting, and Misc. Equipment Load Shapes for Coastal Health. Solid lines are profiles for months May through October and broken lines are profiles for months November through April.

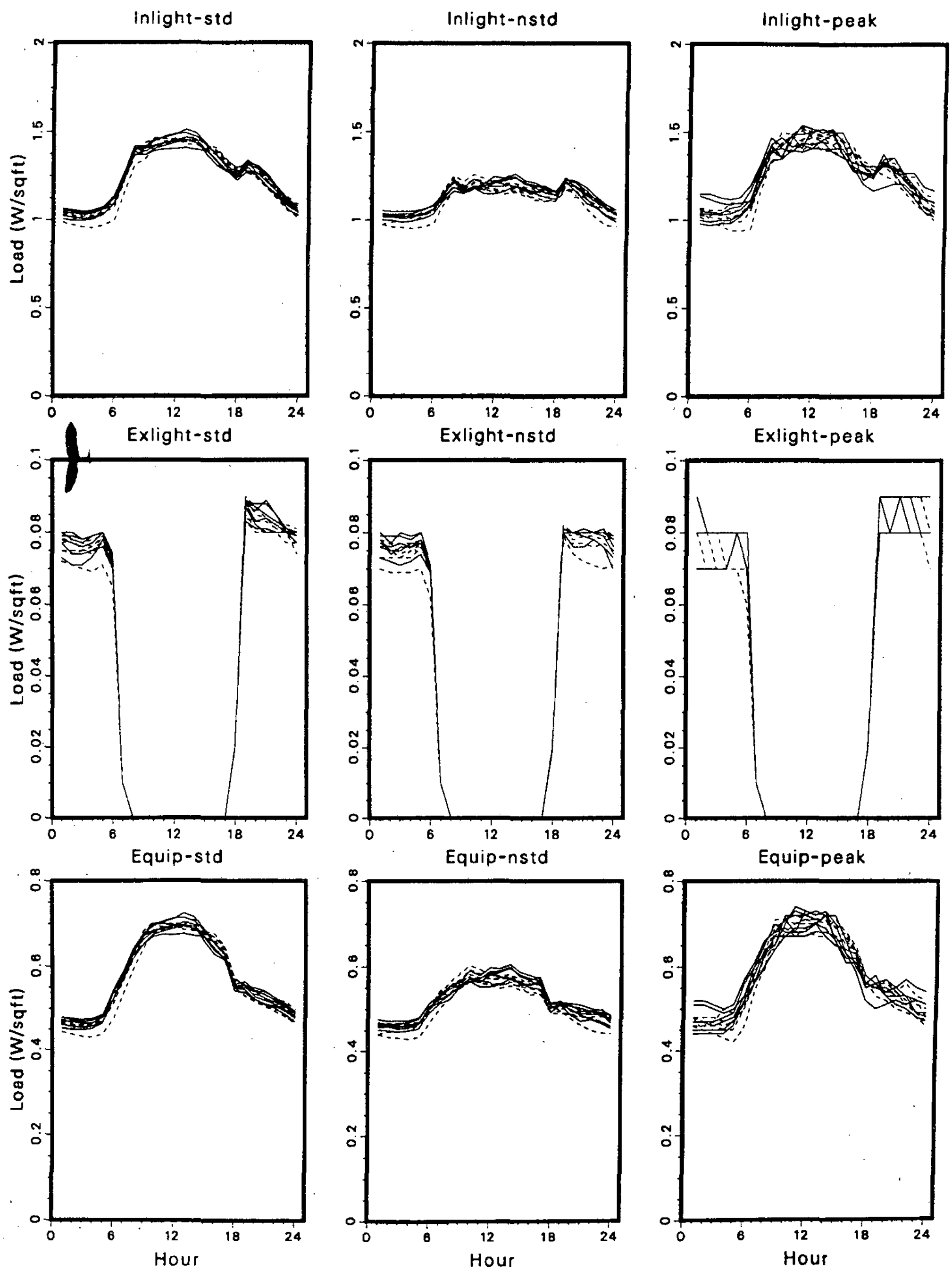


Figure V-5. Reconciled Hospital Equipment, Cooking, and Refrigeration Load Shapes for Coastal Health. Solid lines are profiles for months May through October and broken lines are profiles for months November through April.

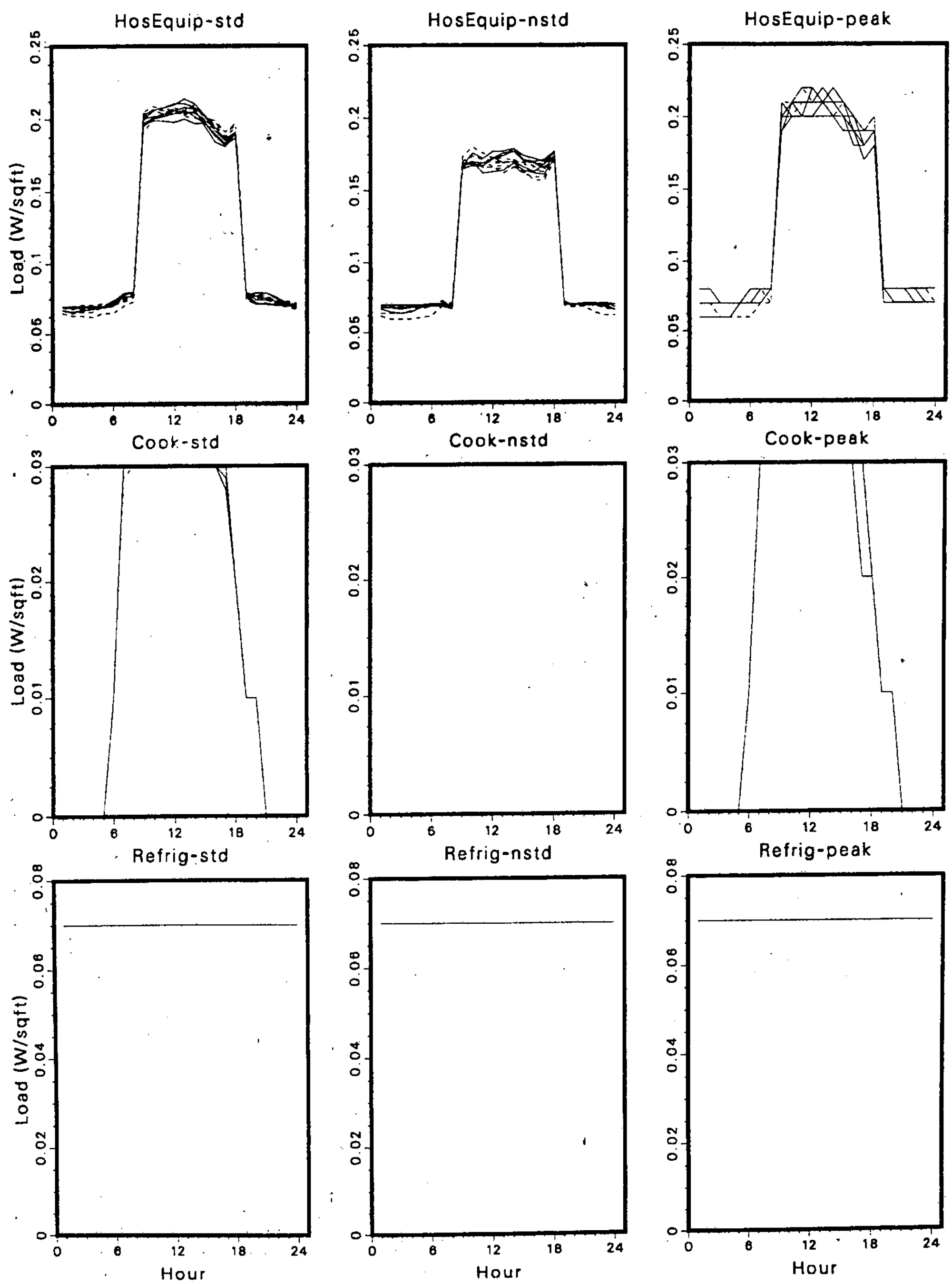


Figure V-6. Reconciled Cooling and Ventilation Load Shapes for Non-Coastal Health. Solid lines are profiles for months May through October and broken lines are profiles for months November through April.

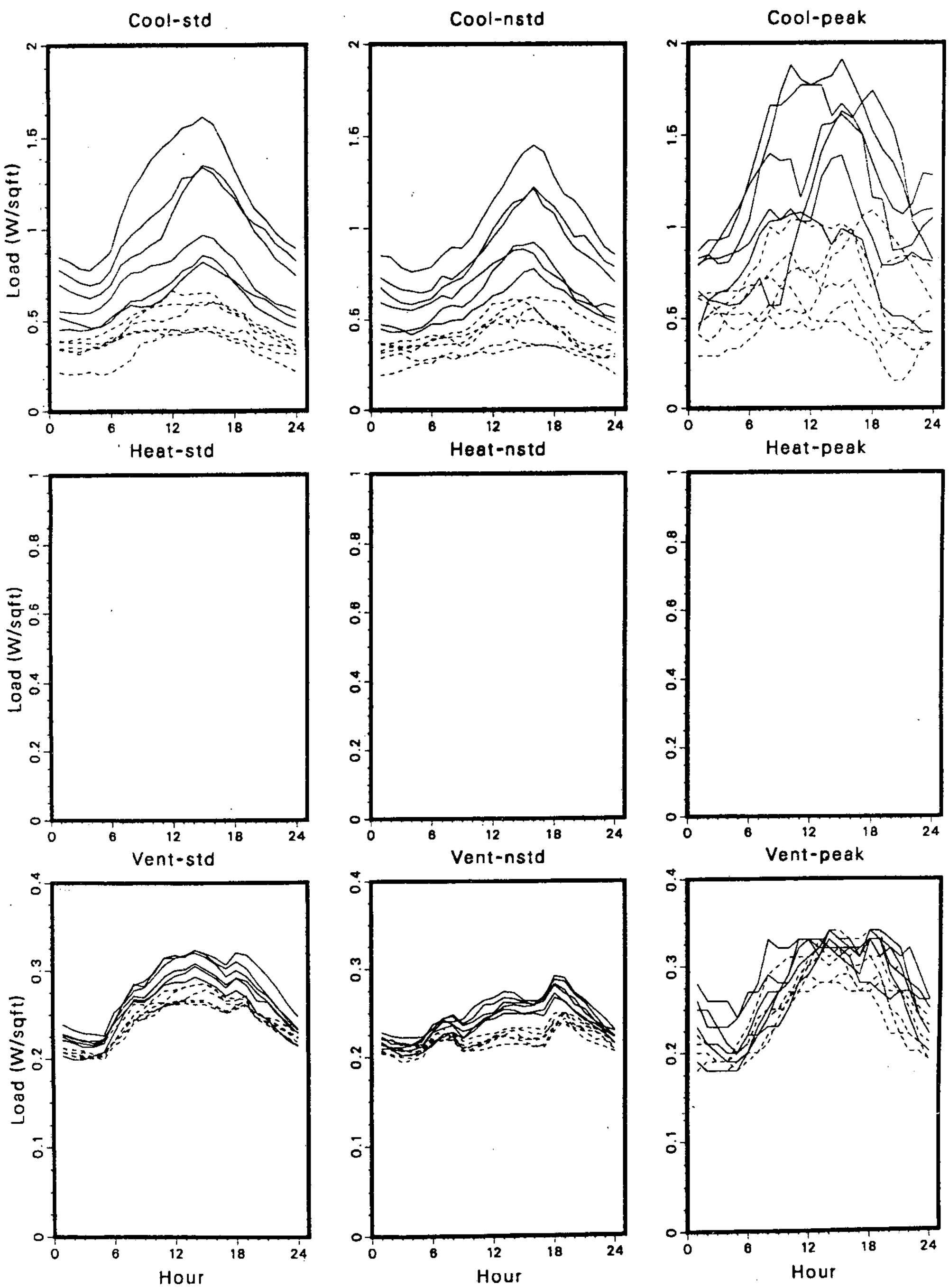


Figure V-7. Reconciled Indoor and Outdoor Lighting, and Misc. Equipment Load Shapes for Non-Coastal Health. Solid lines are profiles for months May through October and broken lines are profiles for months November through April.

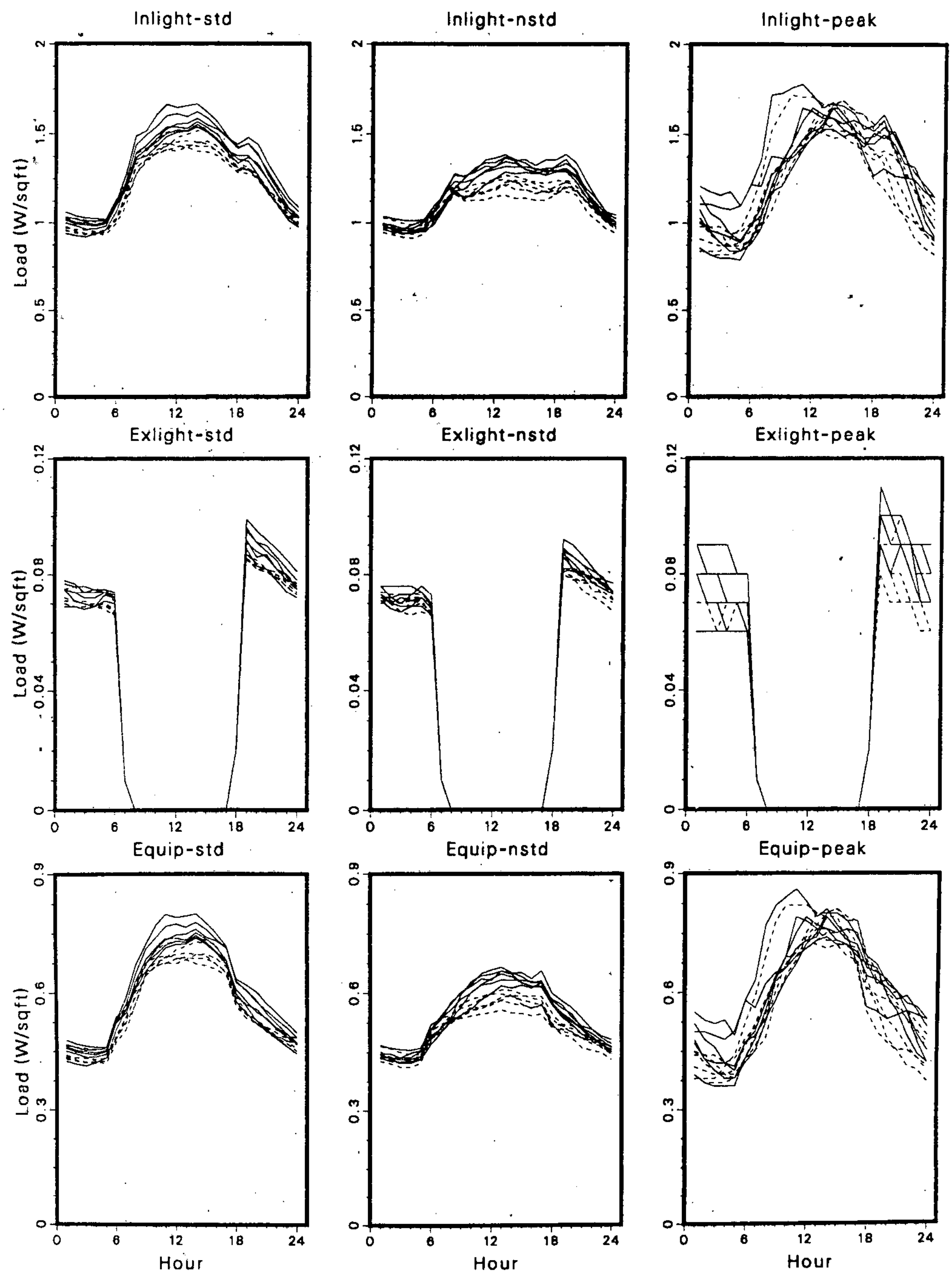
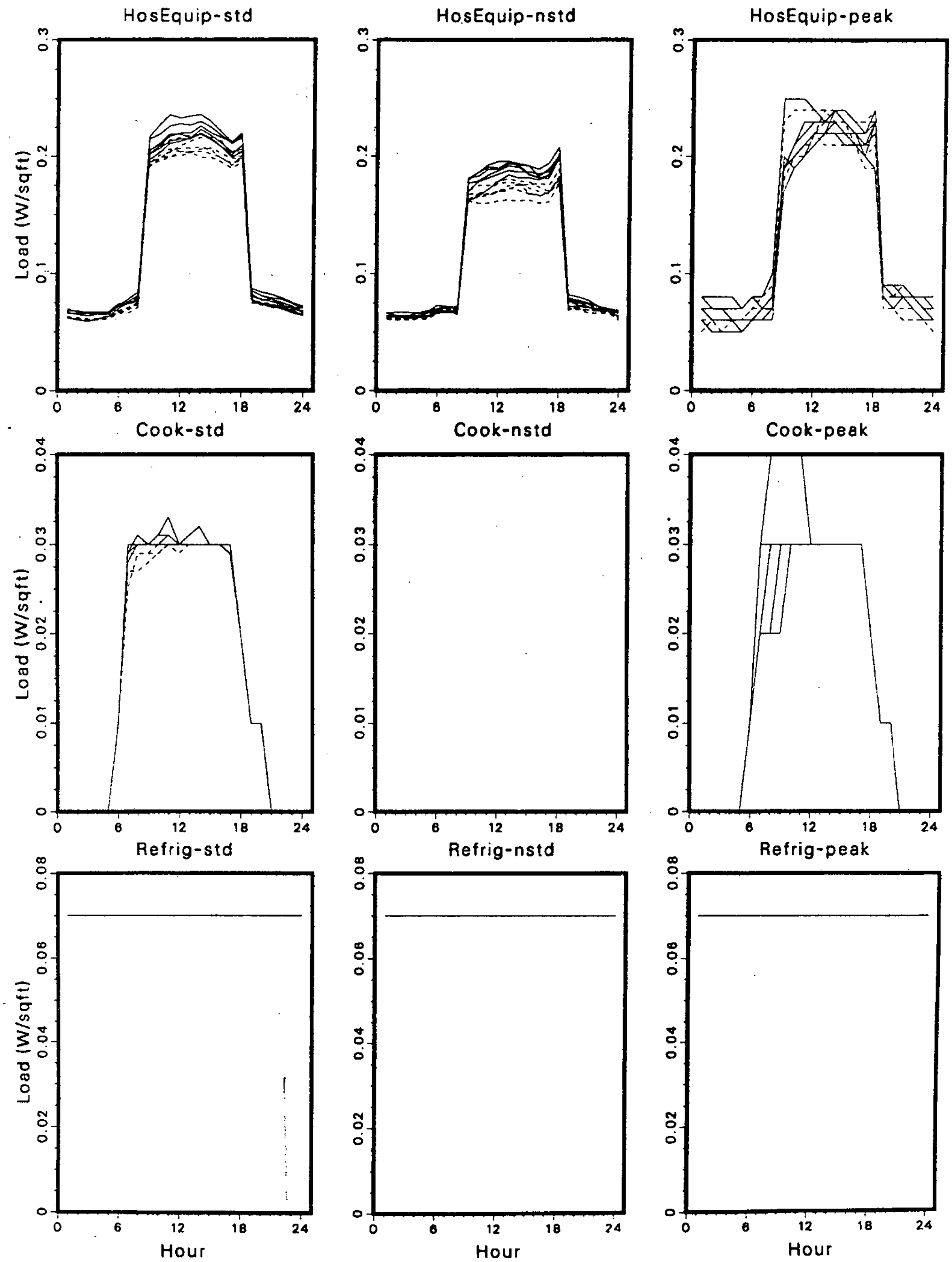


Figure V-8. Reconciled Hospital Equipment, Cooking, and Refrigeration Load Shapes for Non-Coastal Health. Solid lines are profiles for months May through October and broken lines are profiles for months November through April.



School

The analysis of the LRD in Chapter IV shows that there are actually three different day types for schools: weekdays, Saturdays, and Sundays and holidays. Because our reconciliation process provides for only standard and non-standard days, we combined Saturdays, Sundays, and holidays into non-standard days. As shown in **Figure V-10**, the School building standard-day load is relatively flat from 8 a.m. until 3 p.m. with a second lower plateau in the evening from 6 p.m. until 10 p.m. indicating that there is some evening classes or maintenance. The non-standard day load is very flat with the slightly higher day time load due to partial use on Saturdays. The coastal region night-time load is twice that of the non-coastal region. This is most likely an artifact of the different building samples and not due to any physical difference between the regions.

On the whole, the reconciled non-HVAC load shapes show little seasonal variation, indicating that most of the variation has been included in the cooling end use. In some months the non-standard day non-HVAC end uses are almost equal to the standard day non-HVAC end uses (see **Figures V-11 to V-16**). This is caused by in part the imperfect mapping of the summer vacation holidays to non-standard days.

As shown in **Table V-3**, for almost all EUIs final estimates are less than the initial estimates. The exception is the outdoor lighting which increased significantly due to the high nighttime load exhibited by the LRD.

Table V-3. Initial and Reconciled EUIs for Schools

Location	Cooling	Ventilation	Indoor Lighting	Outdoor Lighting	Miscellaneous Equipment	Cooking	Refrigeration	Total
Initial								
Coast	1.5	1.7	4.7	0.5	0.5	0.1	0.2	9.2
Inland	1.3	1.8						9.1
Desert	1.6	1.8						9.4
Valley	1.7	1.9						9.6
Reconciled								
Coastal	0.7	0.8	3.3	1.2	0.4	0.1	0.2	6.5
Inland	0.8	1.0						6.8
Desert	0.9	1.0						6.9
Valley	0.9	1.0						7.0

Figure V-9. Average Annual Unreconciled Load Shapes for Coastal School. These unreconciled load shapes result from the initial DOE-2 simulations of the prototypes.

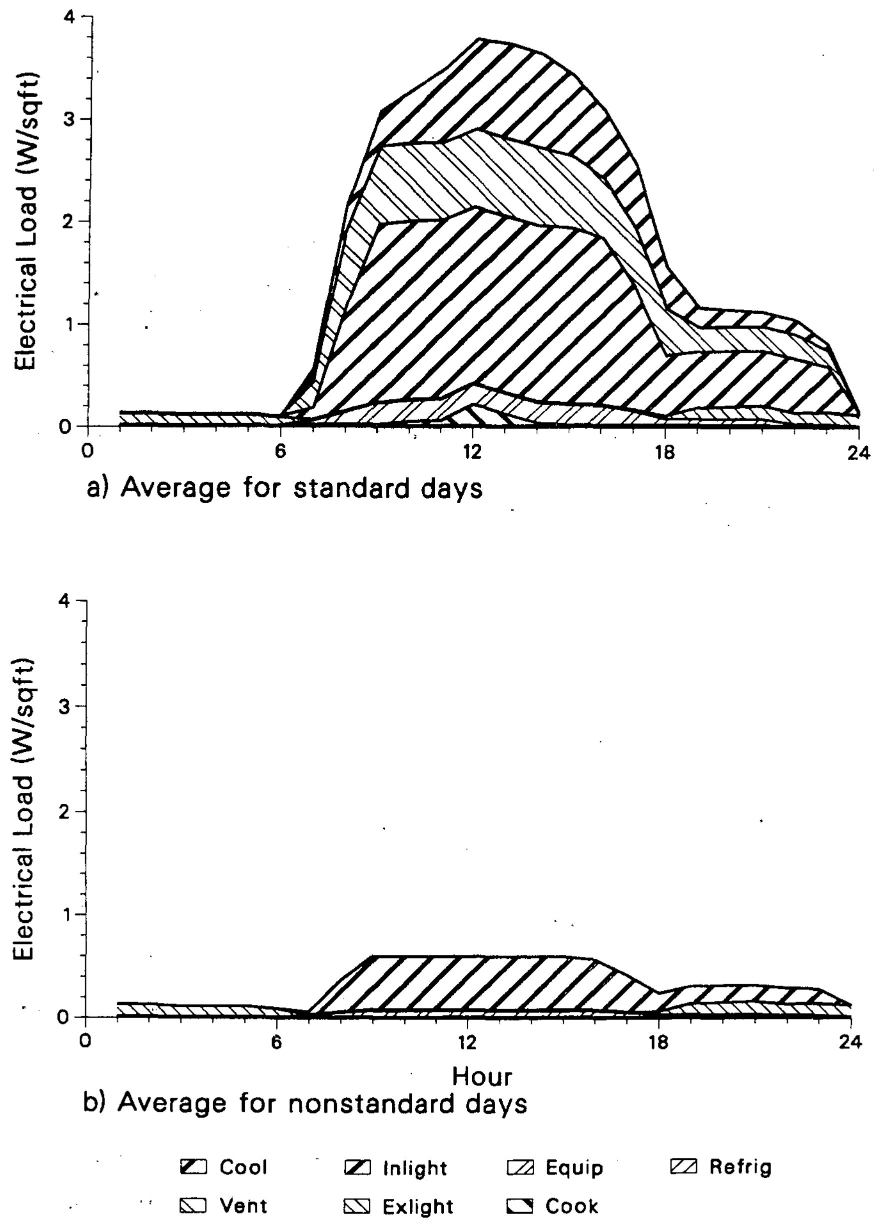


Figure V-10. Average Annual Reconciled Load Shapes for Coastal School. These reconciled load shapes can be compared to those in the previous Figure.

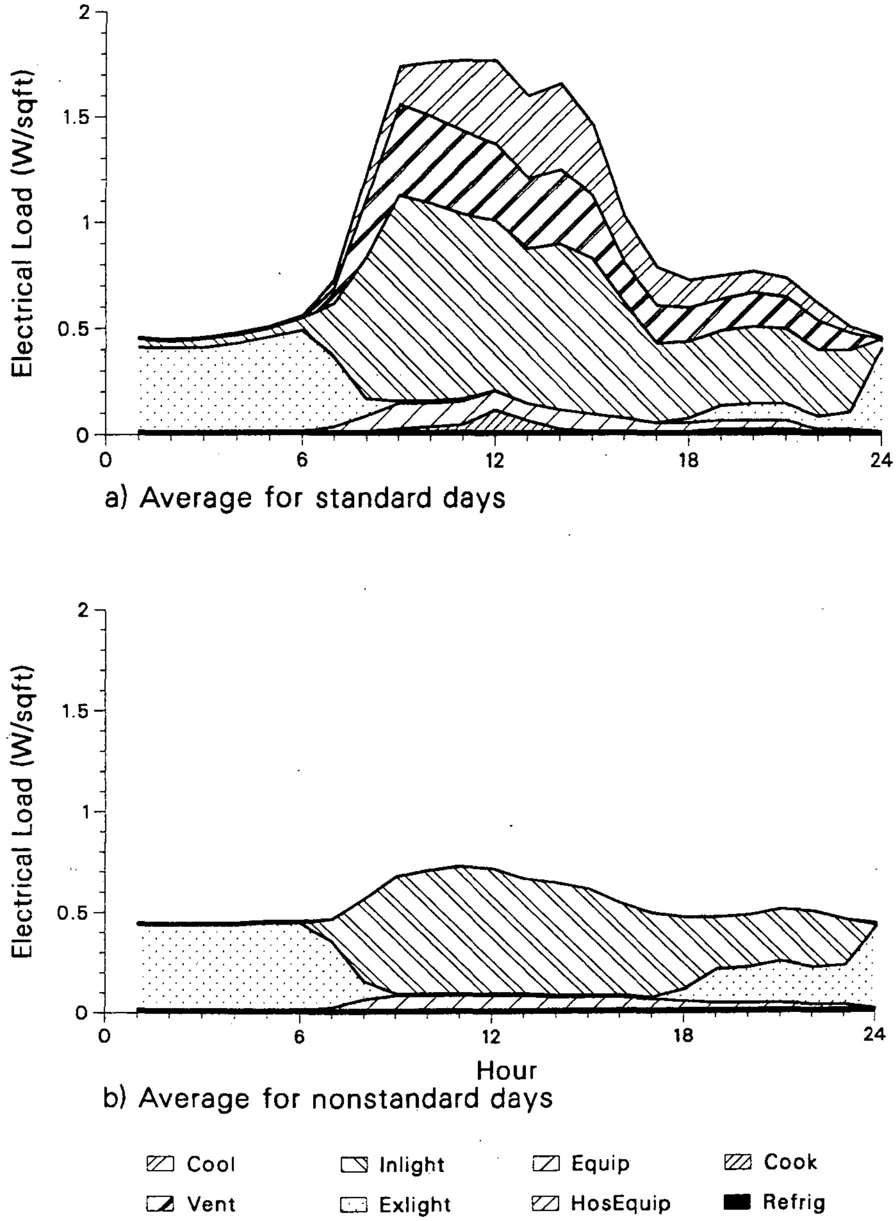


Figure V-11. Reconciled Cooling and Ventilation Load Shapes for Coastal School. Solid lines are profiles for months May through October and broken lines are profiles for months November through April.

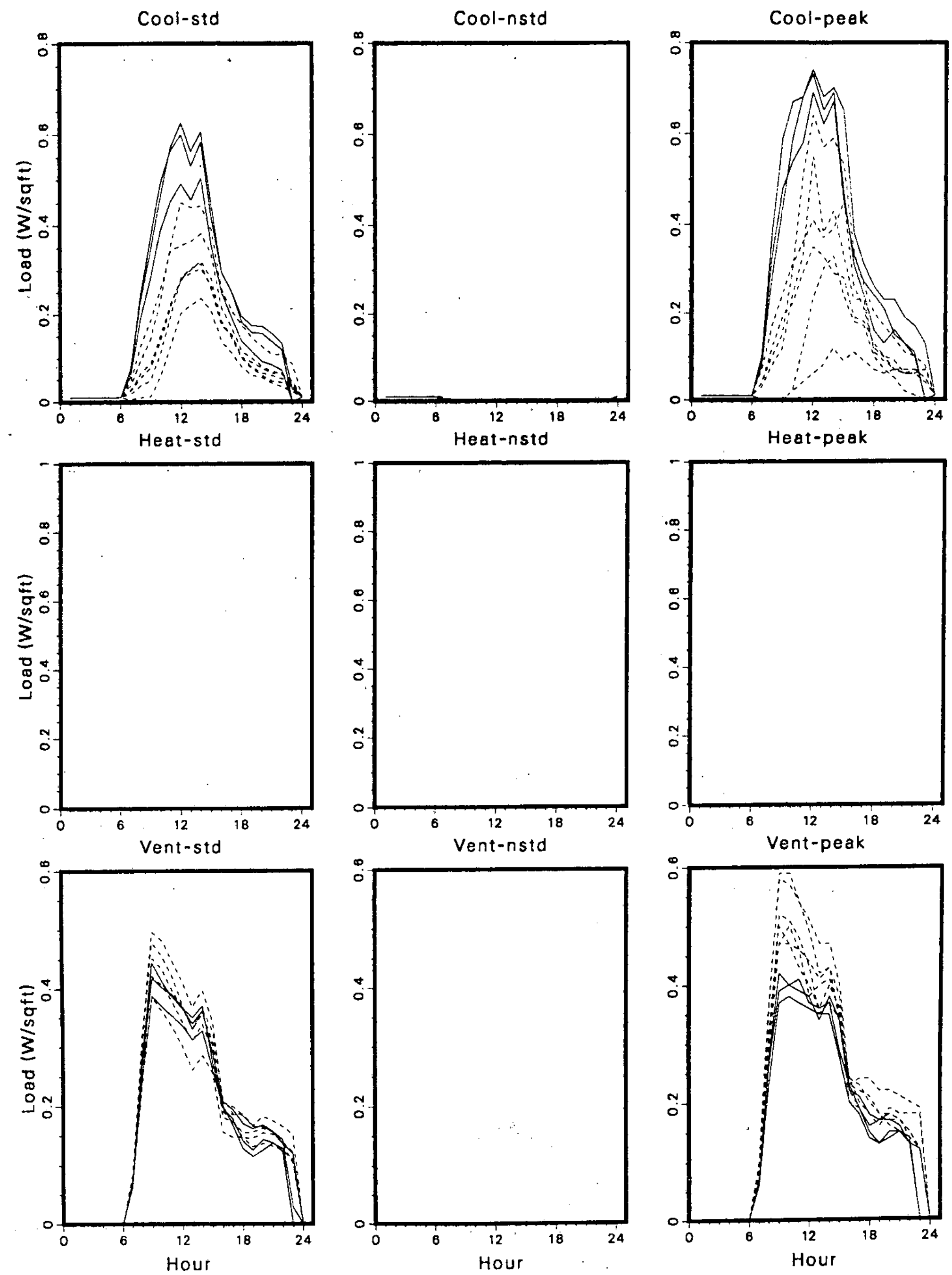


Figure V-12. Reconciled Indoor and Outdoor Lighting, and Misc. Equipment Load Shapes for Coastal School. Solid lines are profiles for months May through October and broken lines are profiles for months November through April.

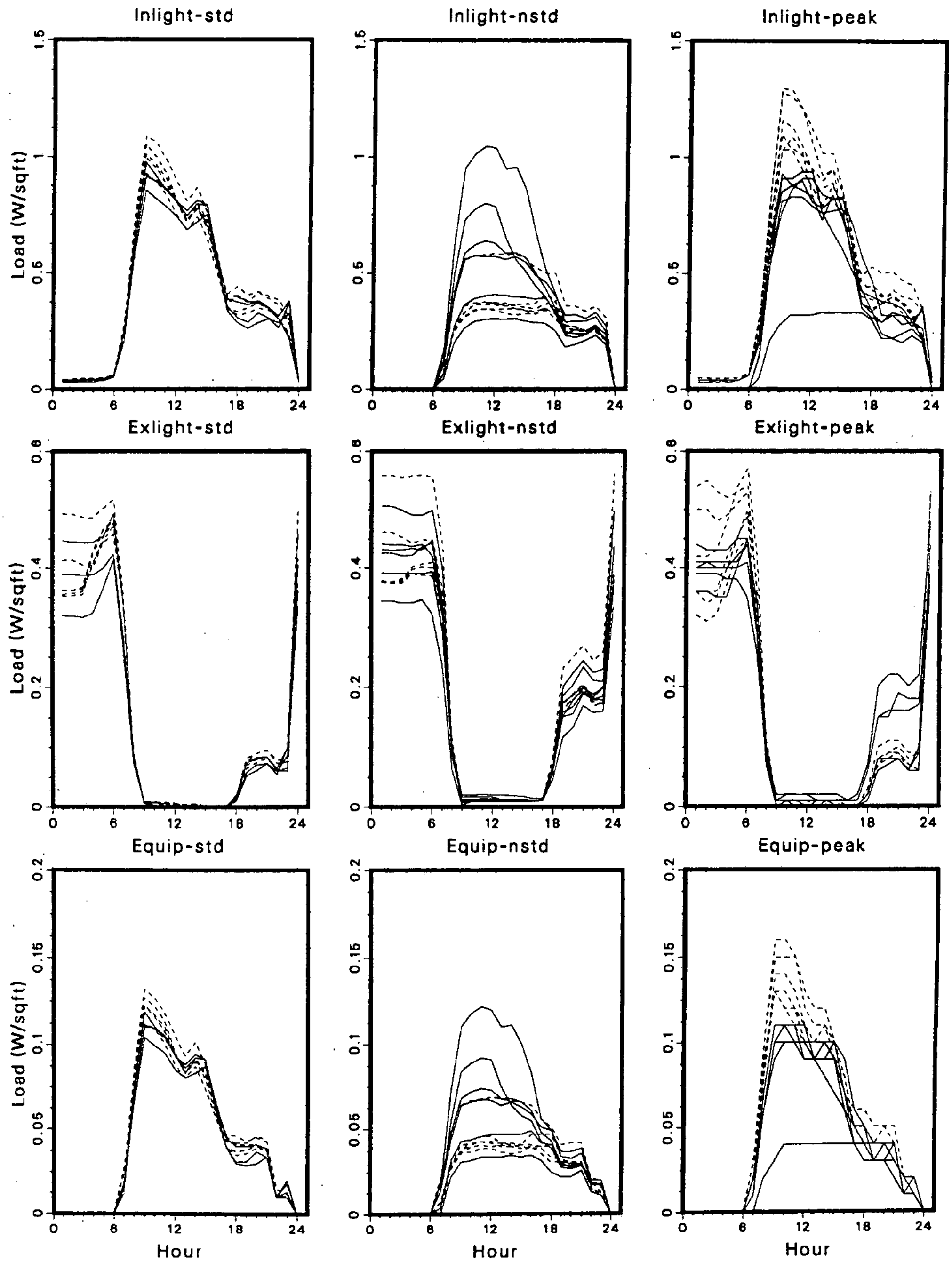


Figure V-13. Reconciled Cooking and Refrigeration Load Shapes for Coastal School. Solid lines are profiles for months May through October and broken lines are profiles for months November through April.

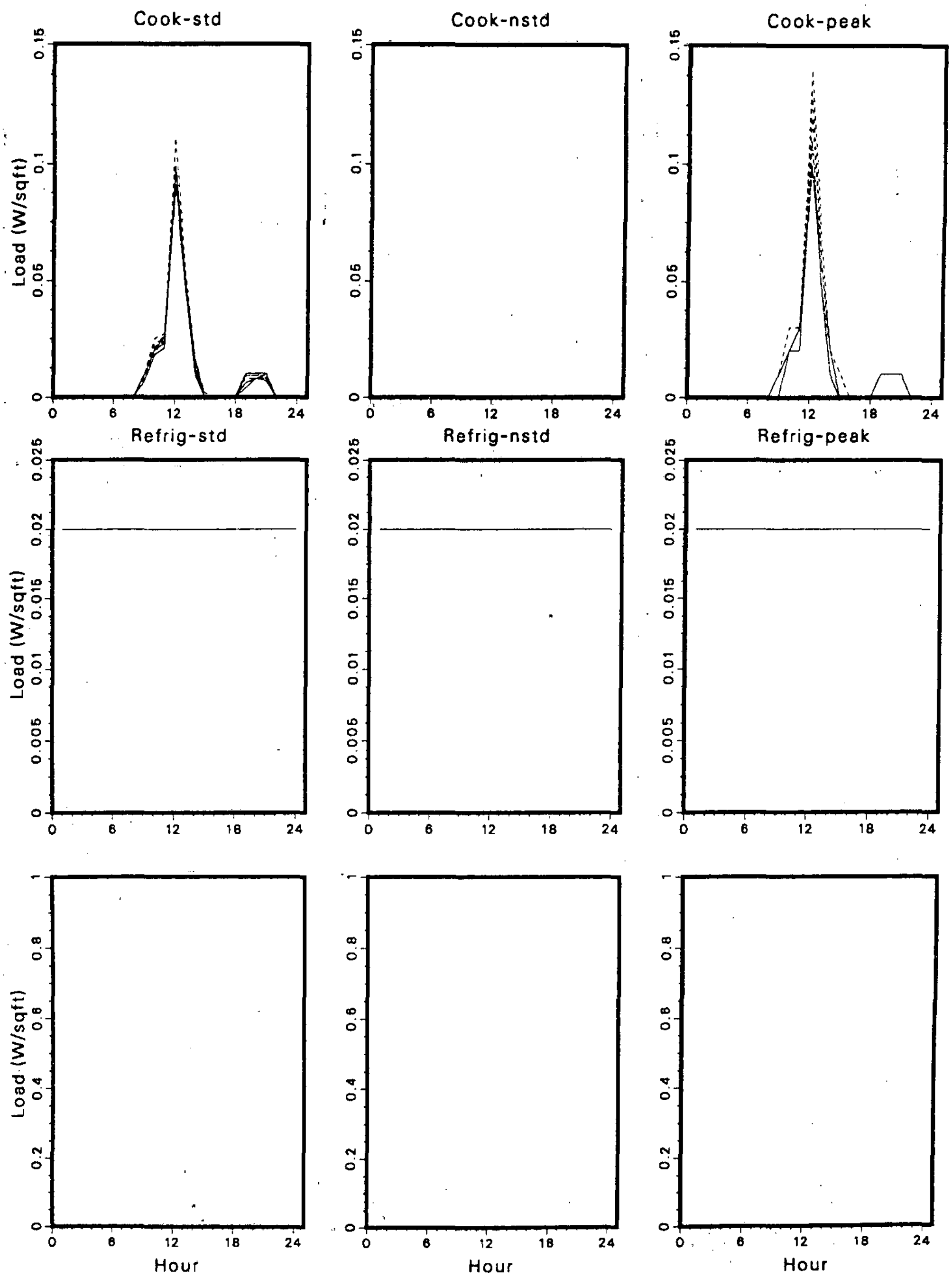


Figure V-14. Reconciled Cooling and Ventilation Load Shapes for Non-Coastal School. Solid lines are profiles for months May through October and broken lines are profiles for months November through April.

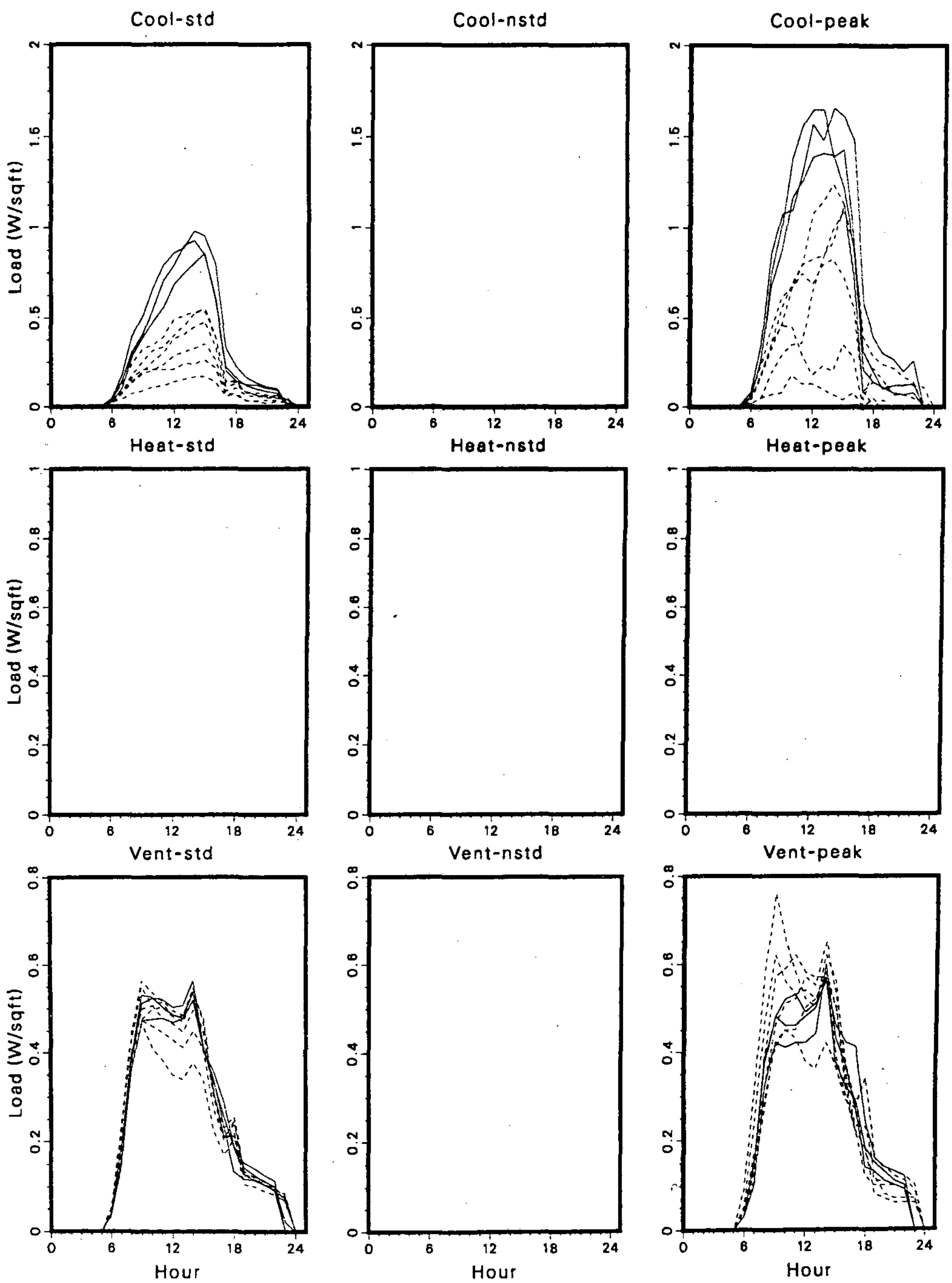


Figure V-15. Reconciled Indoor and Outdoor Lighting, and Misc. Equipment Load Shapes for Non-Coastal School. Solid lines are profiles for months May through October and broken lines are profiles for months November through April.

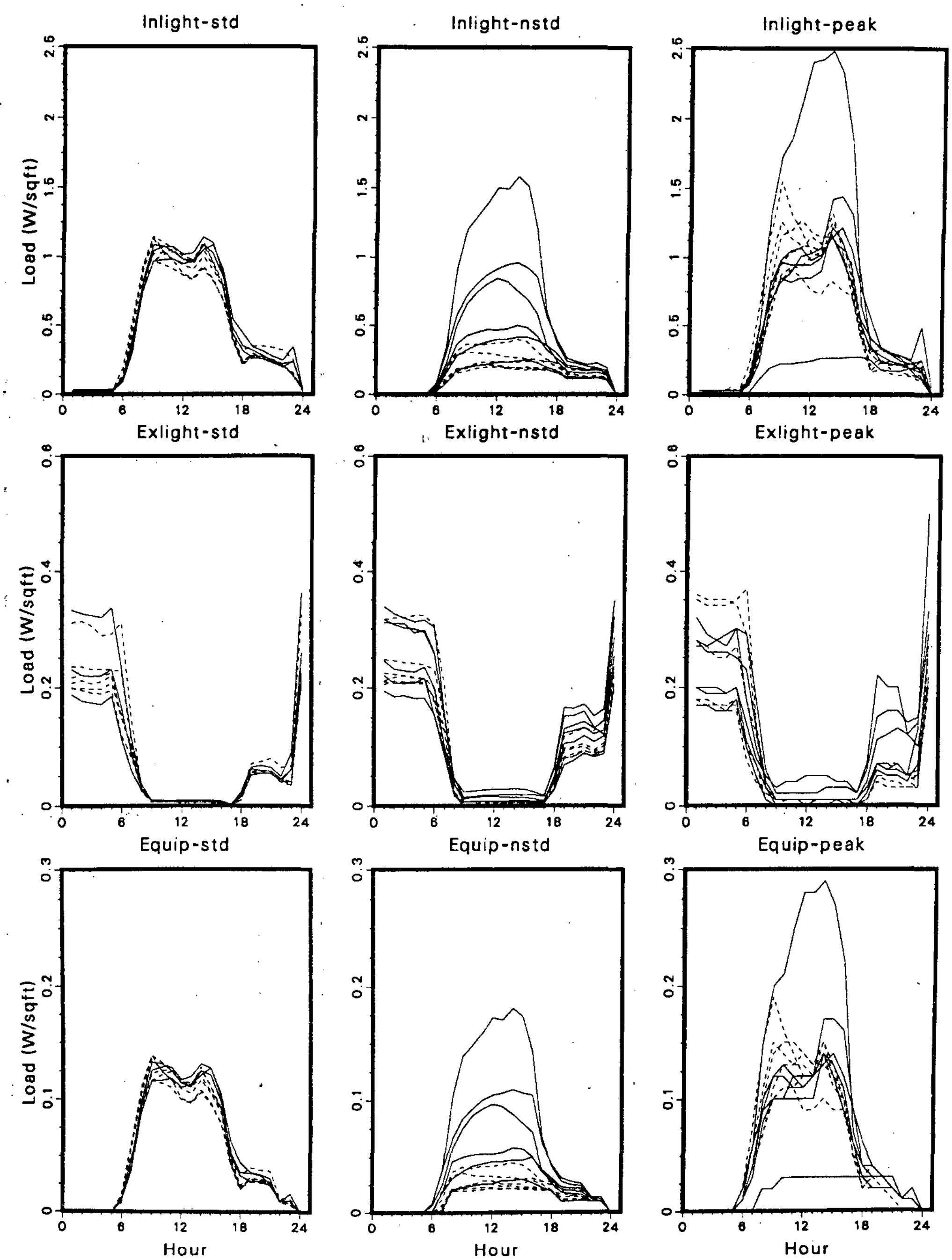
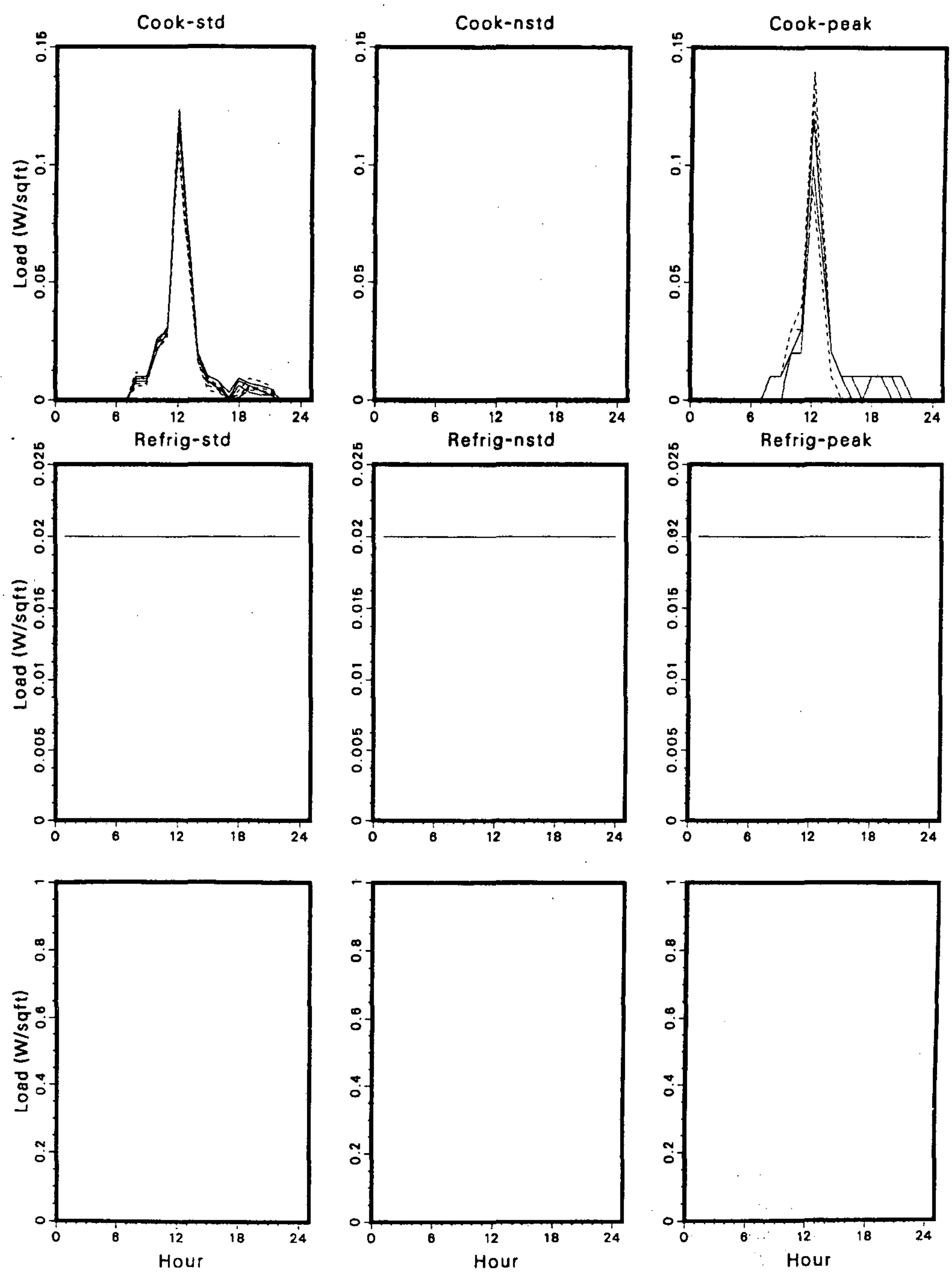


Figure V-16. Reconciled Cooking and Refrigeration Load Shapes for Non-Coastal School. Solid lines are profiles for months May through October and broken lines are profiles for months November through April.



College

The model used to study college campuses is designed to represent many different buildings at one site, rather than a single average building. Therefore, it is hard to attribute a feature or element of the load shapes to any particular building; i.e. the nighttime indoor lighting might be due to a data center while the refrigeration is due to a combination of food service and laboratory units. The complete lack of any on-site data from the PG&E survey complicates the situation further.

The campus standard-day load peaks early in the morning and continues at a reduced level until 10 in the evening. Non-standard day loads are relatively flat, rising slightly 8 a.m. and tapering off by 10 p.m. Although the LRD indicates 24 hour operation for most of the campus, the weather regressions showed very little temperature sensitivity (see Chapter IV).

The reconciled end uses shown in **Figures V-19 to V-24** show 24 hour standard-day cooling loads with large daily peaks. Non-standard day cooling loads are flatter but still occur at all hours. Non-HVAC end uses show little seasonal variation with the non-standard day end uses being significantly lower.

As shown in **Table V-4**, the final non-HVAC EUI estimates changed little but the final cooling and ventilation EUIs were reduced from the initial estimates. Non-coastal regions had higher cooling EUIs but ventilation EUIs where not affected.

Table V-4. Initial and Reconciled EUIs for College Campus (kWh/ft^2-yr)

Location	Cooling	Ventilation	Indoor Lighting	Outdoor Lighting	Miscellaneous Equipment	Cooking	Refrigeration	Total
Initial								
Coast	1.7	3.4	5.3	0.4	2.2	0.1	0.9	13.7
Inland	2.0	3.6						14.5
Desert	2.1	3.6						14.6
Valley	2.2	4.0						15.1
Reconciled								
Coast	1.3	2.2	3.8	0.3	1.6	0.1	0.9	10.2
Inland	1.5	2.4						10.6
Desert	1.6	2.4						10.7
Valley	1.7	2.6						11.0

Figure V-17. Average Annual Unreconciled Load Shapes for Coastal College. These unreconciled load shapes result from the initial DOE-2 simulations of the prototypes.

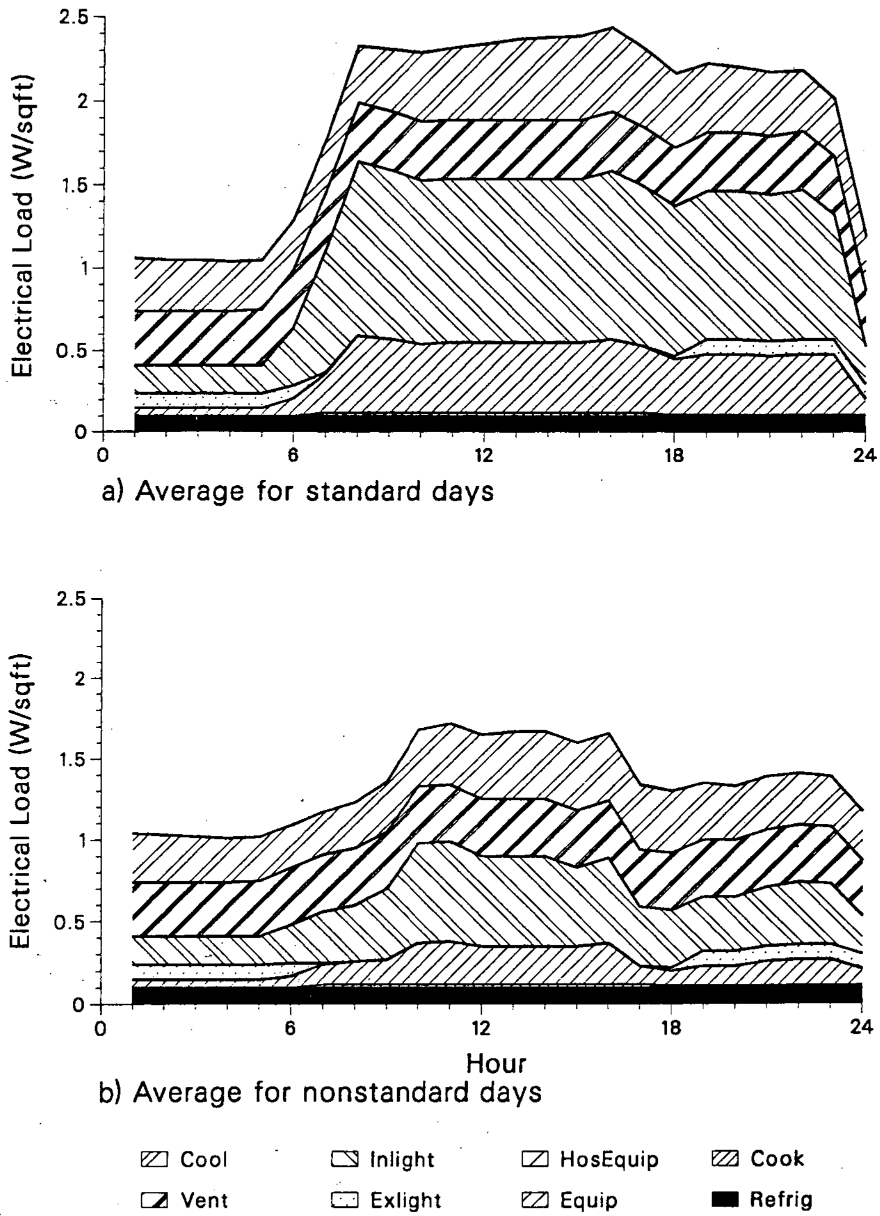


Figure V-18. Average Annual Reconciled Load Shapes for Coastal College. These reconciled load shapes can be compared to those in the previous Figure.

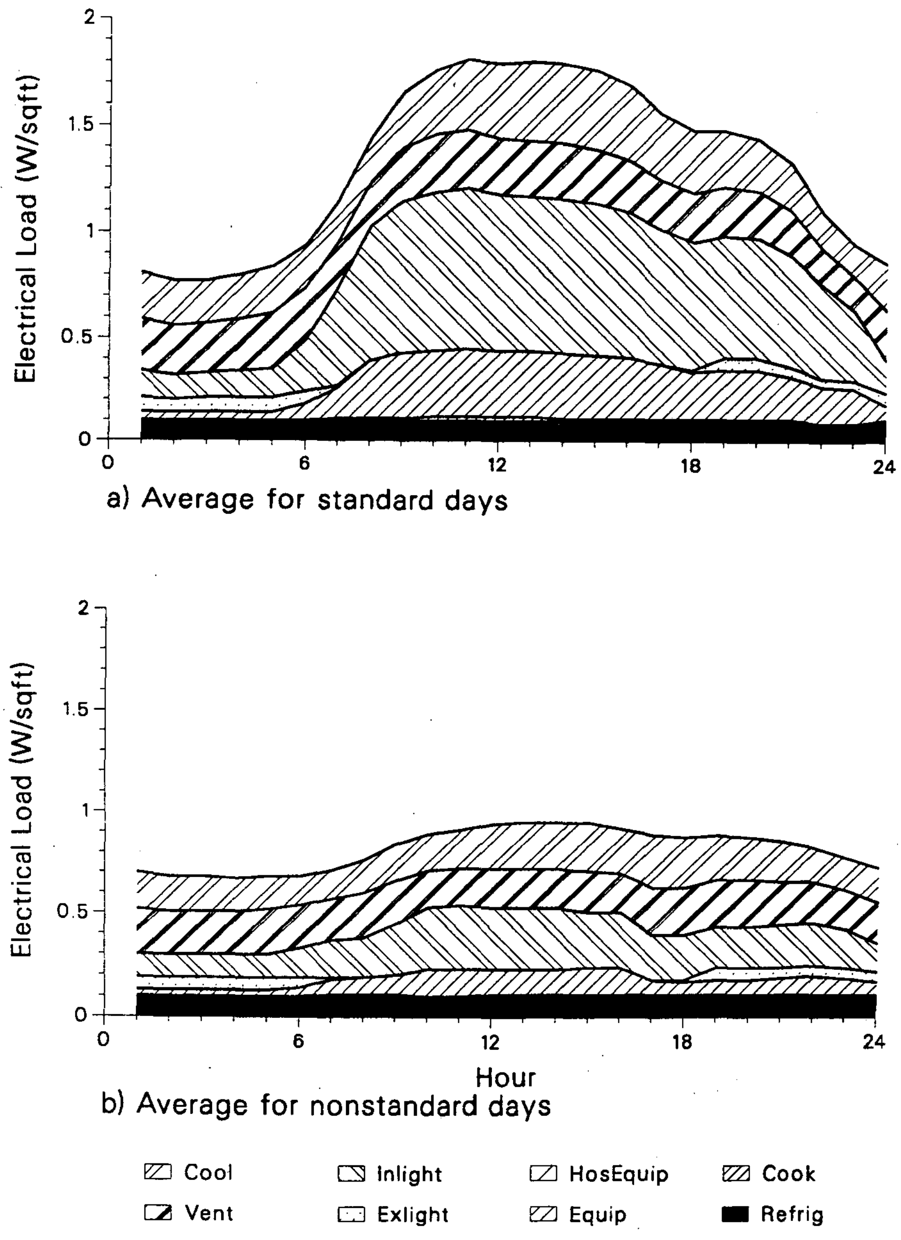


Figure V-19. Reconciled Cooling and Ventilation Load Shapes for Coastal College. Solid lines are profiles for months May through October and broken lines are profiles for months November through April.

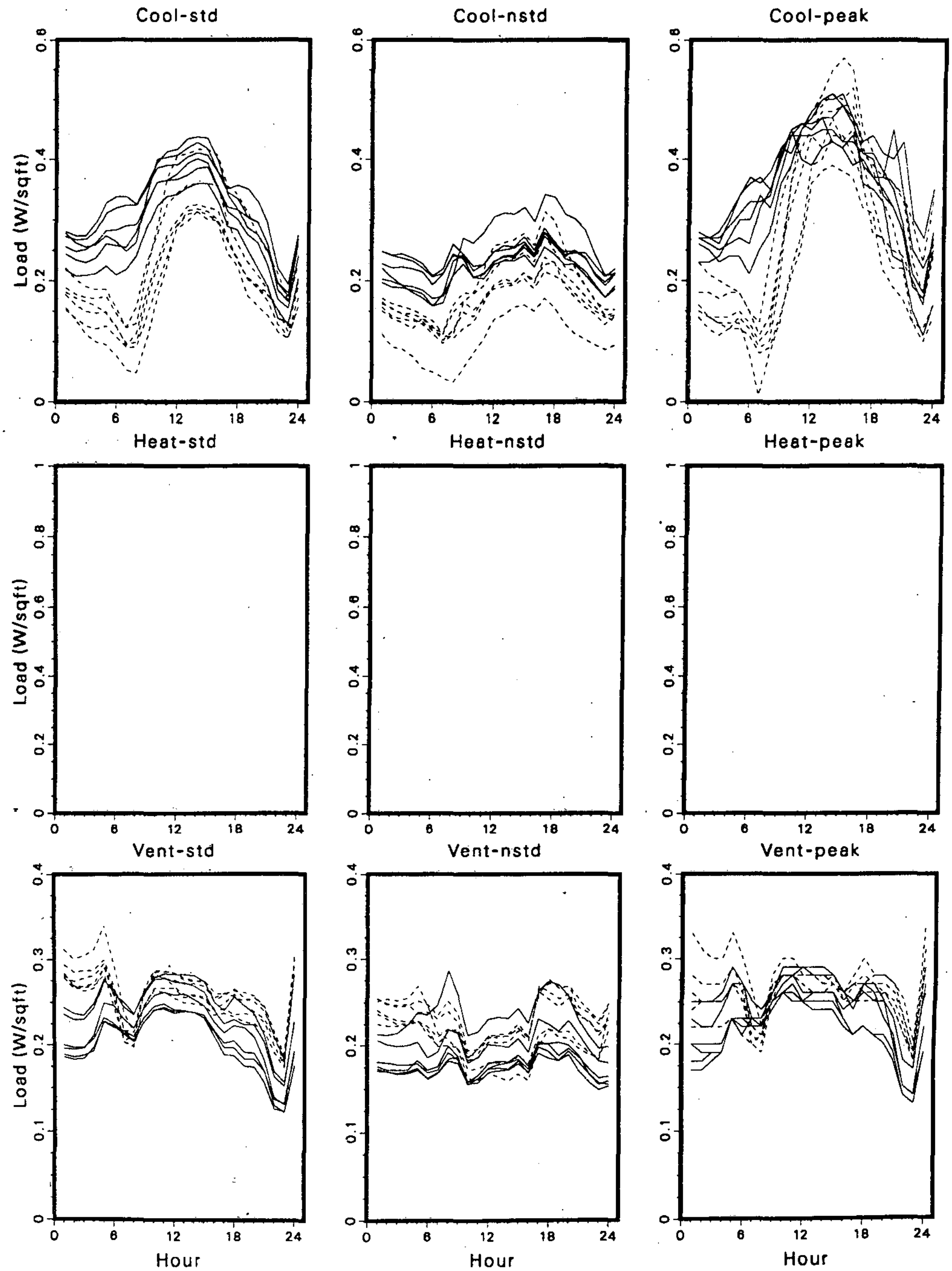


Figure V-20. Reconciled Indoor and Outdoor Lighting, and Misc. Equipment Load Shapes for Coastal College. Solid lines are profiles for months May through October and broken lines are profiles for months November through April.

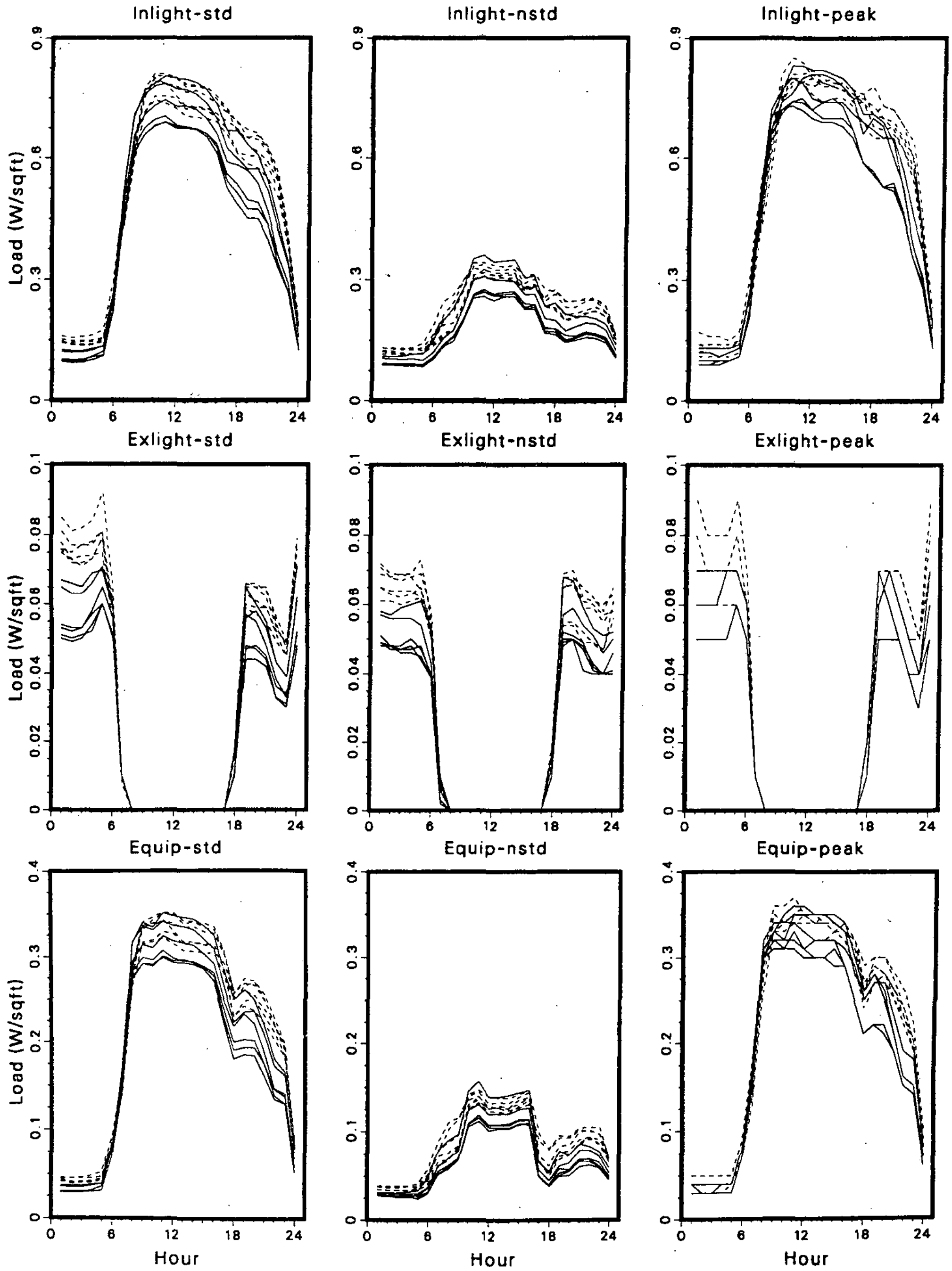


Figure V-21. Reconciled Cooking and Refrigeration Load Shapes for Coastal College. Solid lines are profiles for months May through October and broken lines are profiles for months November through April.

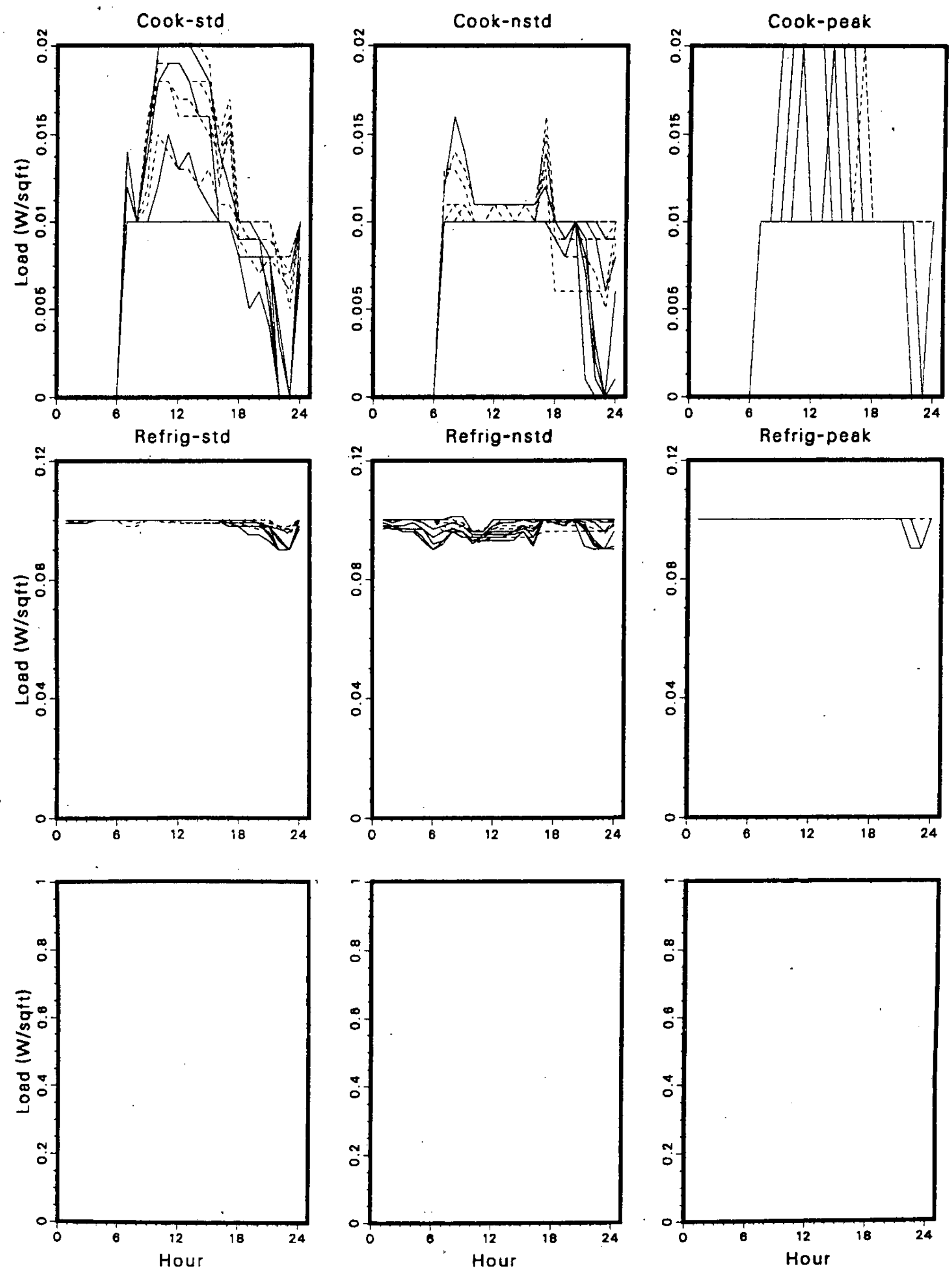


Figure V-22. Reconciled Cooling and Ventilation Load Shapes for Non-Coastal College. Solid lines are profiles for months May through October and broken lines are profiles for months November through April.

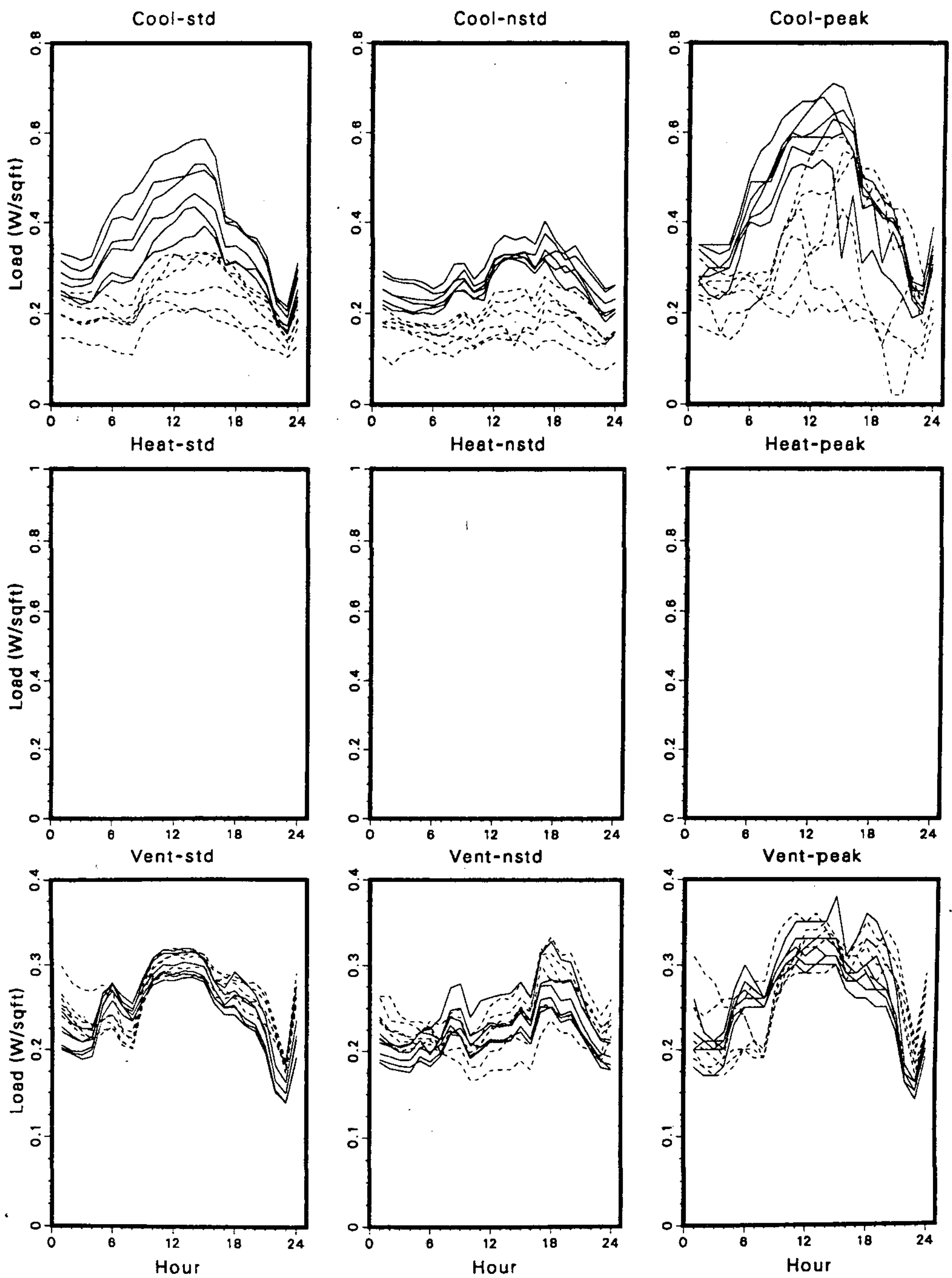


Figure V-23. Reconciled Indoor and Outdoor Lighting, and Misc. Equipment Load Shapes for Non-Coastal College. Solid lines are profiles for months May through October and broken lines are profiles for months November through April.

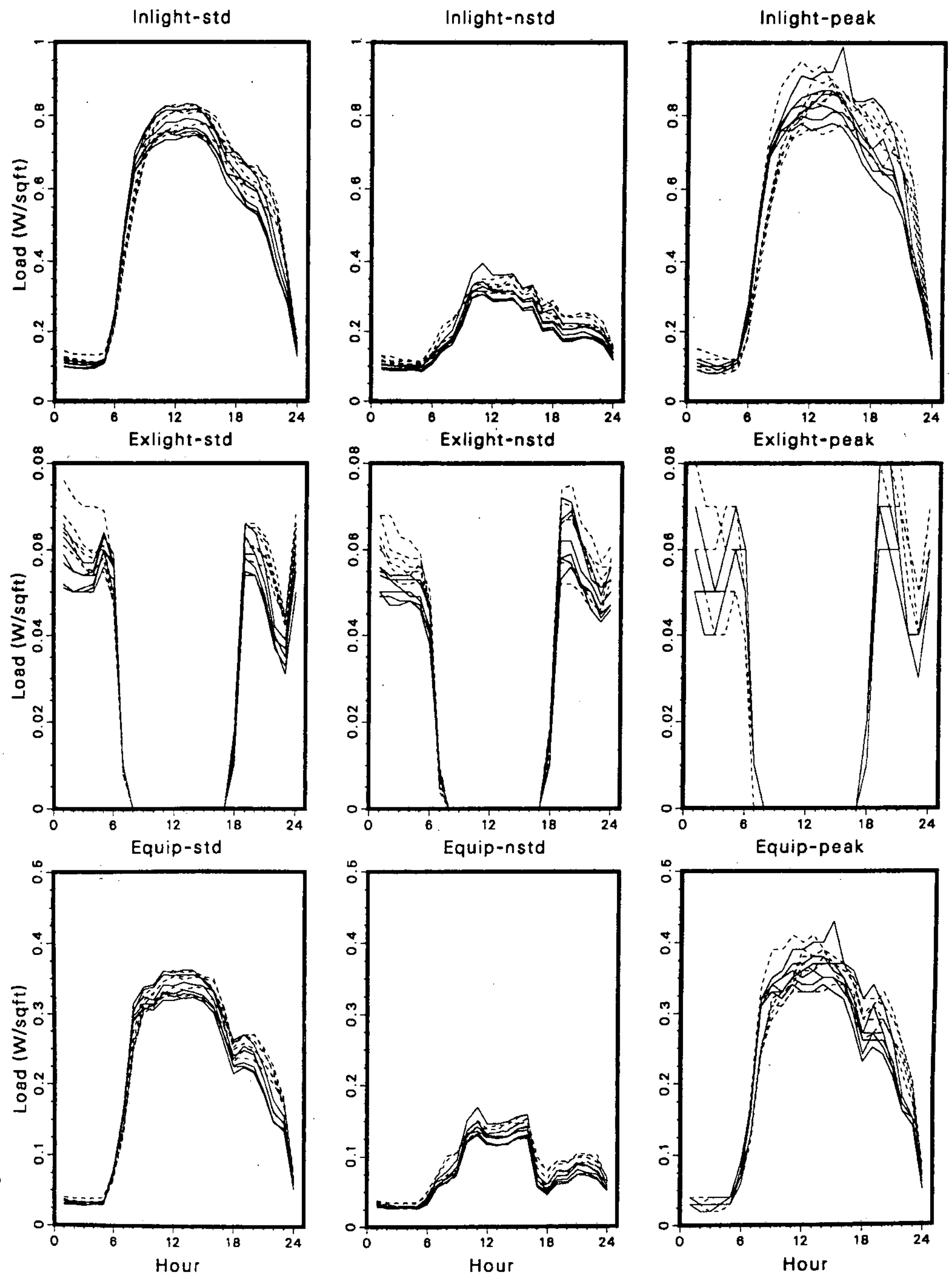
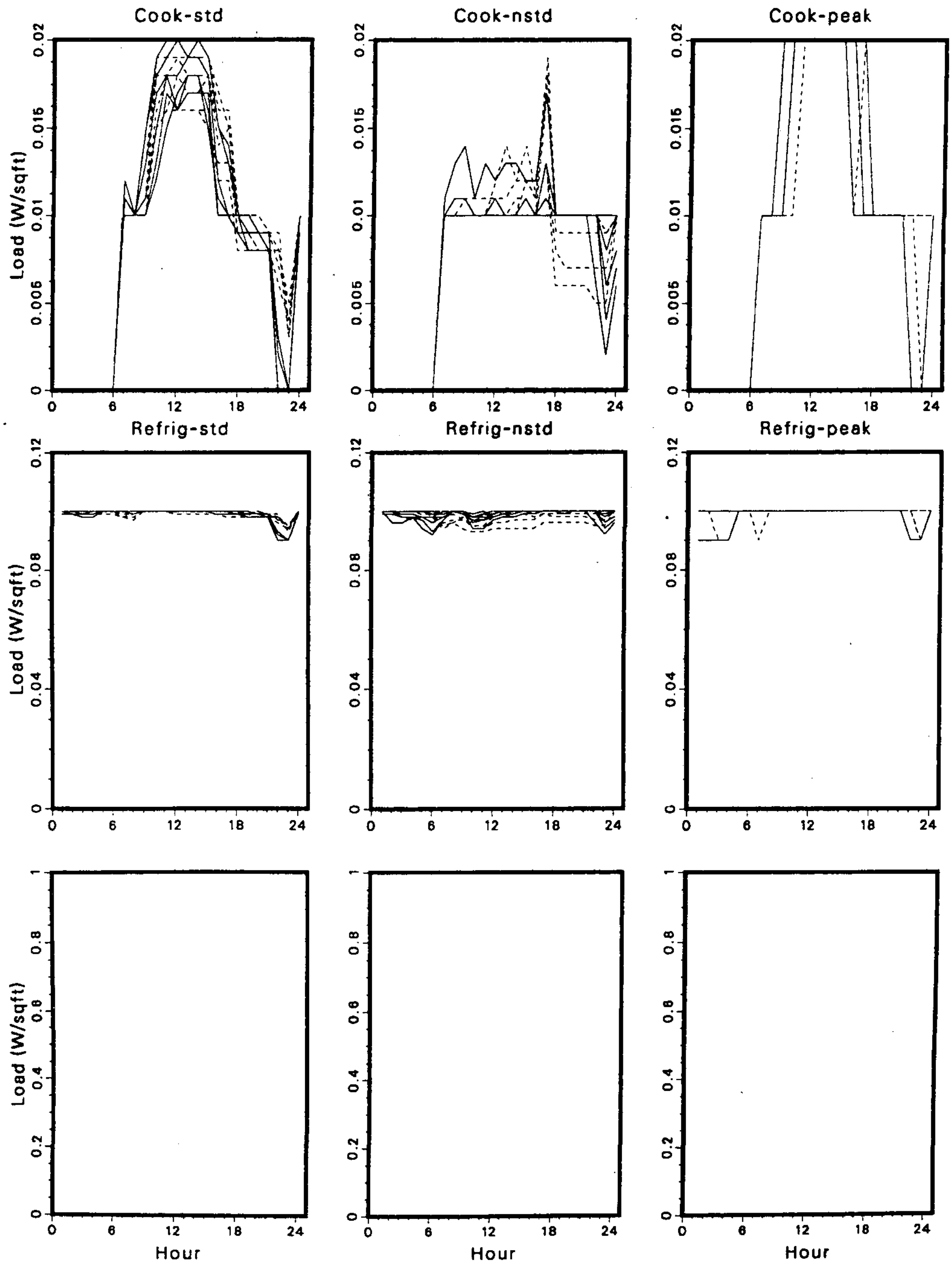


Figure V-24. Reconciled Cooking and Refrigeration Load Shapes for Non-Coastal College. Solid lines are profiles for months May through October and broken lines are profiles for months November through April.



Lodging

The lodging LRD showed no variation with respect to day type so all days were assumed to be standard days (see Chapter IV). The whole-building load shape is very flat with lowest loads occurring between the hours of midnight and 6 a.m. (see **Figure V-26**).

The reconciled cooling end use peaks at 4 p.m. during the summer but is relatively flat during the winter (see **Figures V-27 and V-30**). All the non-HVAC end uses show little seasonal variation indicating that most of the variation has be incorporated in the cooling end use.

As shown in **Table V-5**, most final EUI estimates were reduced from their initial values. In particular, the non-coastal cooling EUIs were reduced significantly.

Table V-5. Initial and Reconciled EUIs for Lodging

Location	Cooling	Ventilation	Indoor Lighting	Outdoor Lighting	Miscellaneous Equipment	Cooking	Refrigeration	Total
Initial								
Coast	2.4	0.8	4.2	0.6	1.6	0.1	1.3	11.0
Inland	3.6	0.8						12.1
Desert	4.0	1.4						13.2
Valley	4.8	1.4						13.9
Reconciled								
Coastal	2.2	0.8	4.0	0.6	1.5	0.1	1.3	10.6
Inland	2.9	0.8						11.3
Desert	3.2	0.8						11.6
Valley	3.8	0.9						12.2

Figure V-25. Average Annual Unreconciled Load Shapes for Coastal Lodging. These unreconciled load shapes result from the initial DOE-2 simulations of the prototypes.

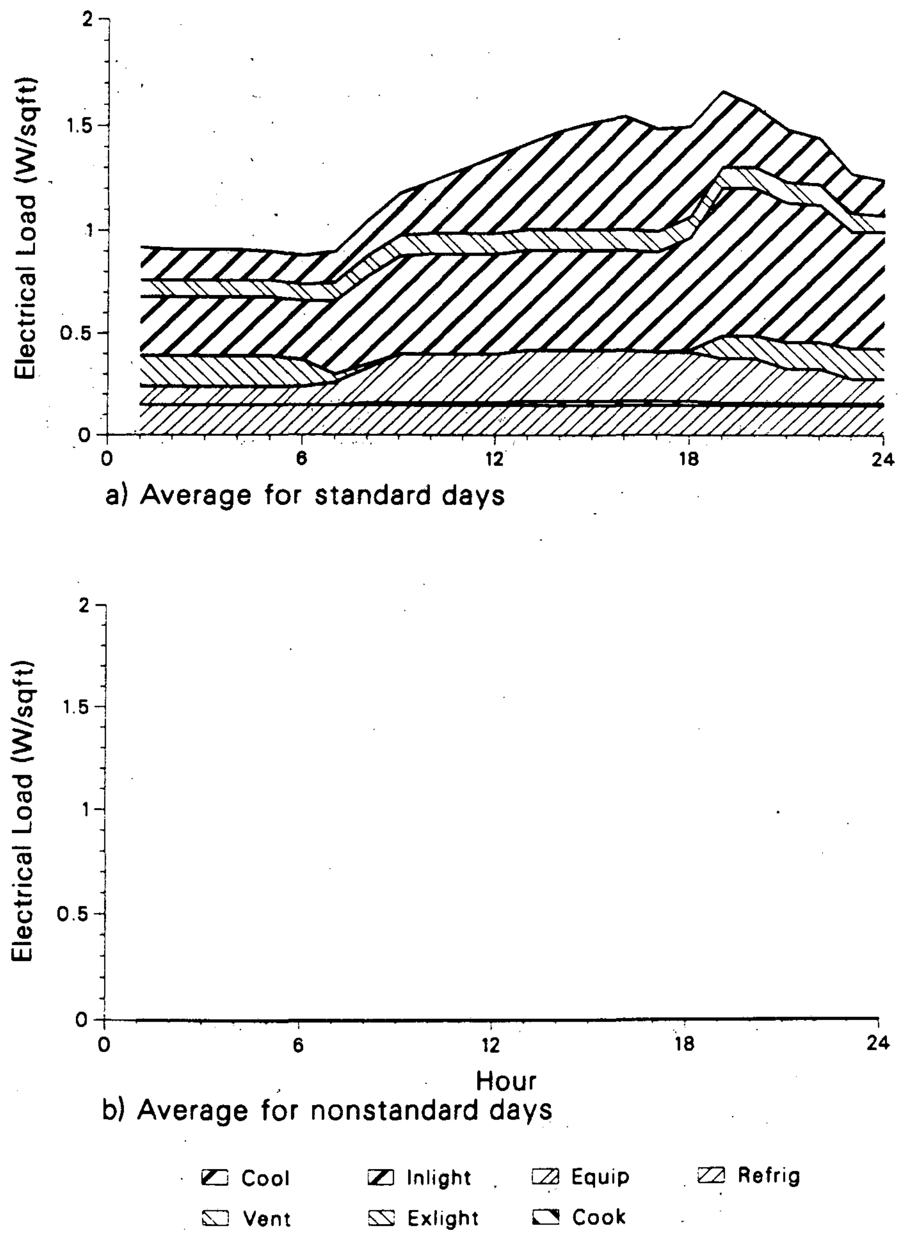


Figure V-26. Average Annual Reconciled Load Shapes for Coastal Lodging. These reconciled load shapes can be compared to those in the previous Figure.

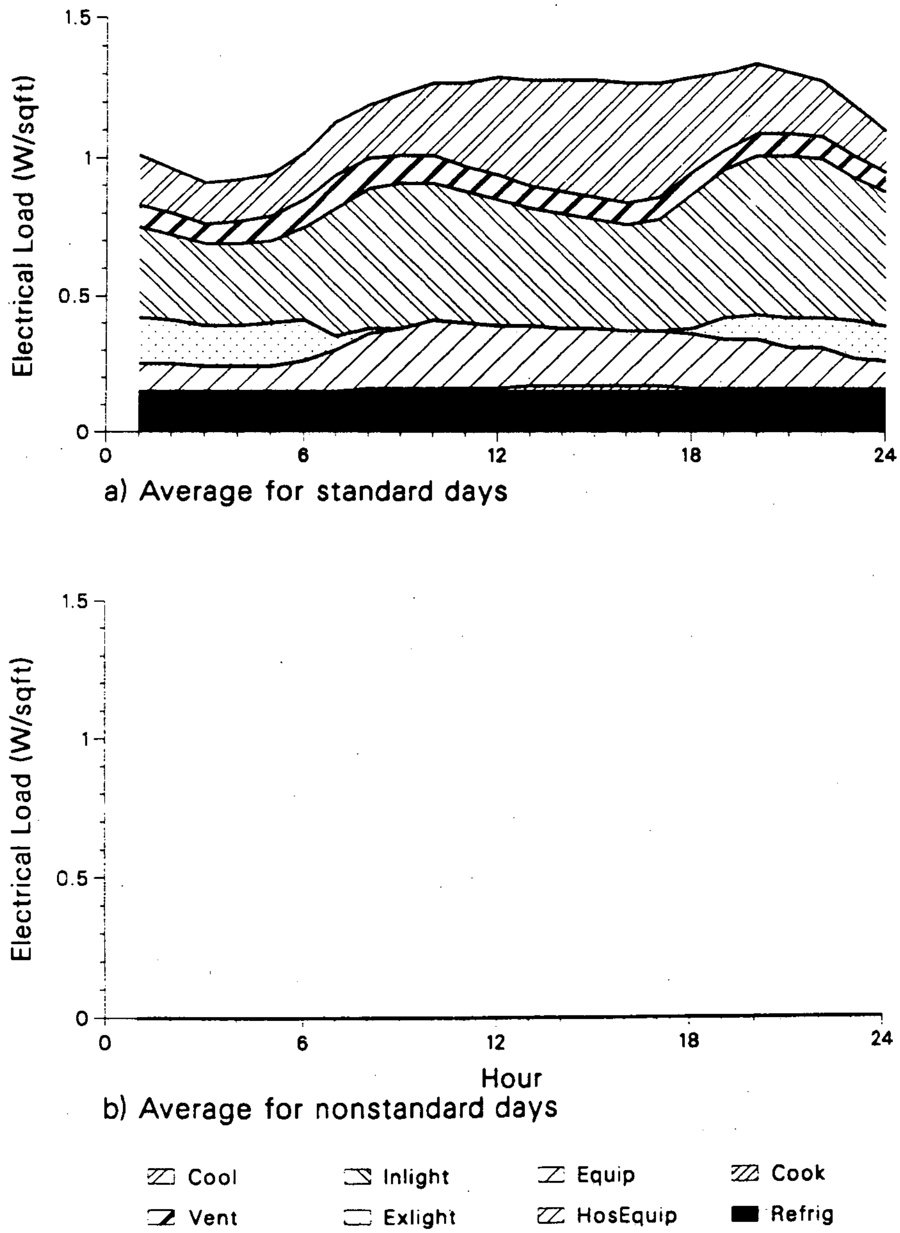


Figure V-27. Reconciled Cooling and Ventilation Load Shapes for Coastal Lodging. Solid lines are profiles for months May through October and broken lines are profiles for months November through April.

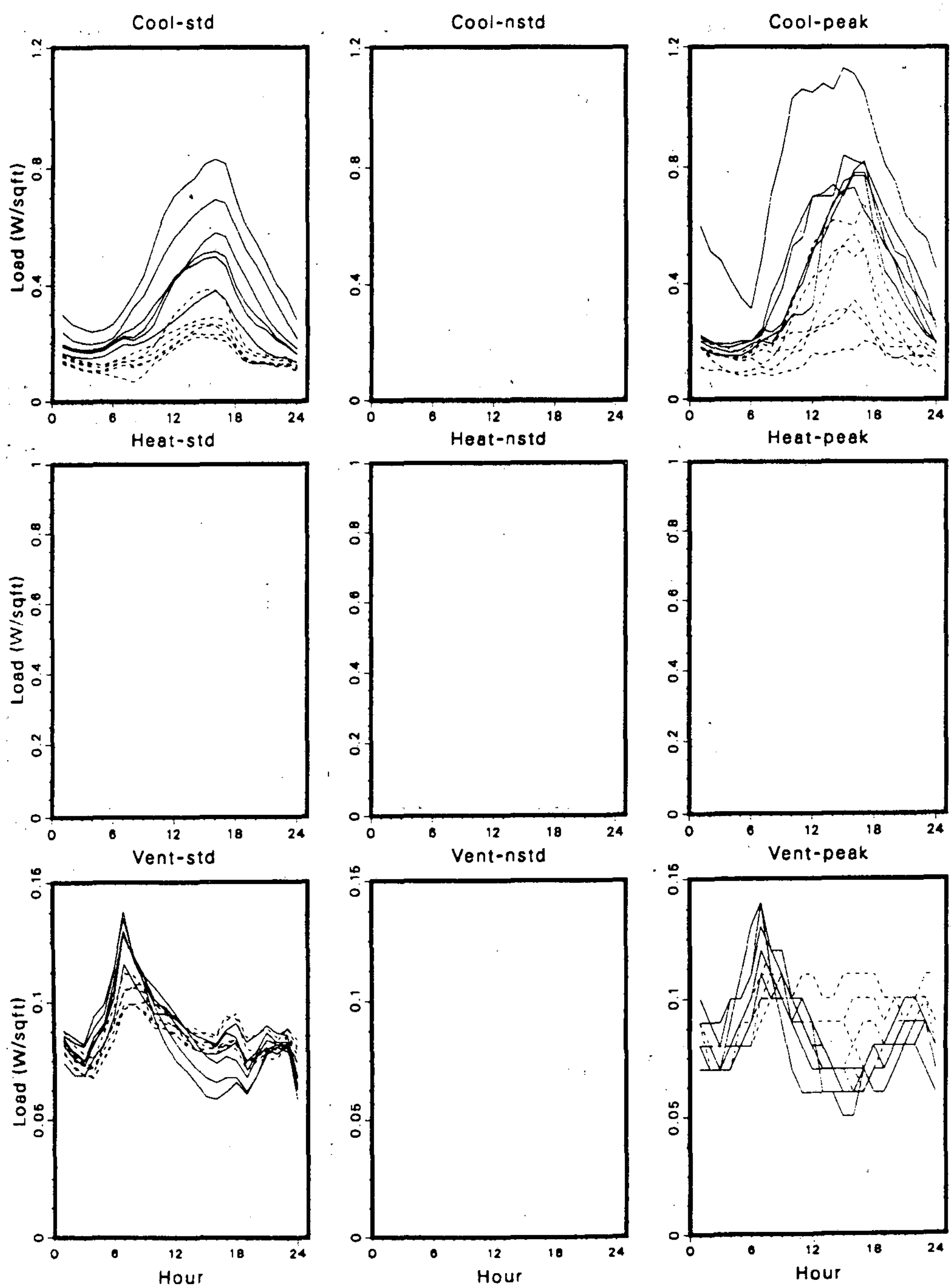


Figure V-28. Reconciled Indoor and Outdoor Lighting, and Misc. Equipment Load Shapes for Coastal Lodging. Solid lines are profiles for months May through October and broken lines are profiles for months November through April.

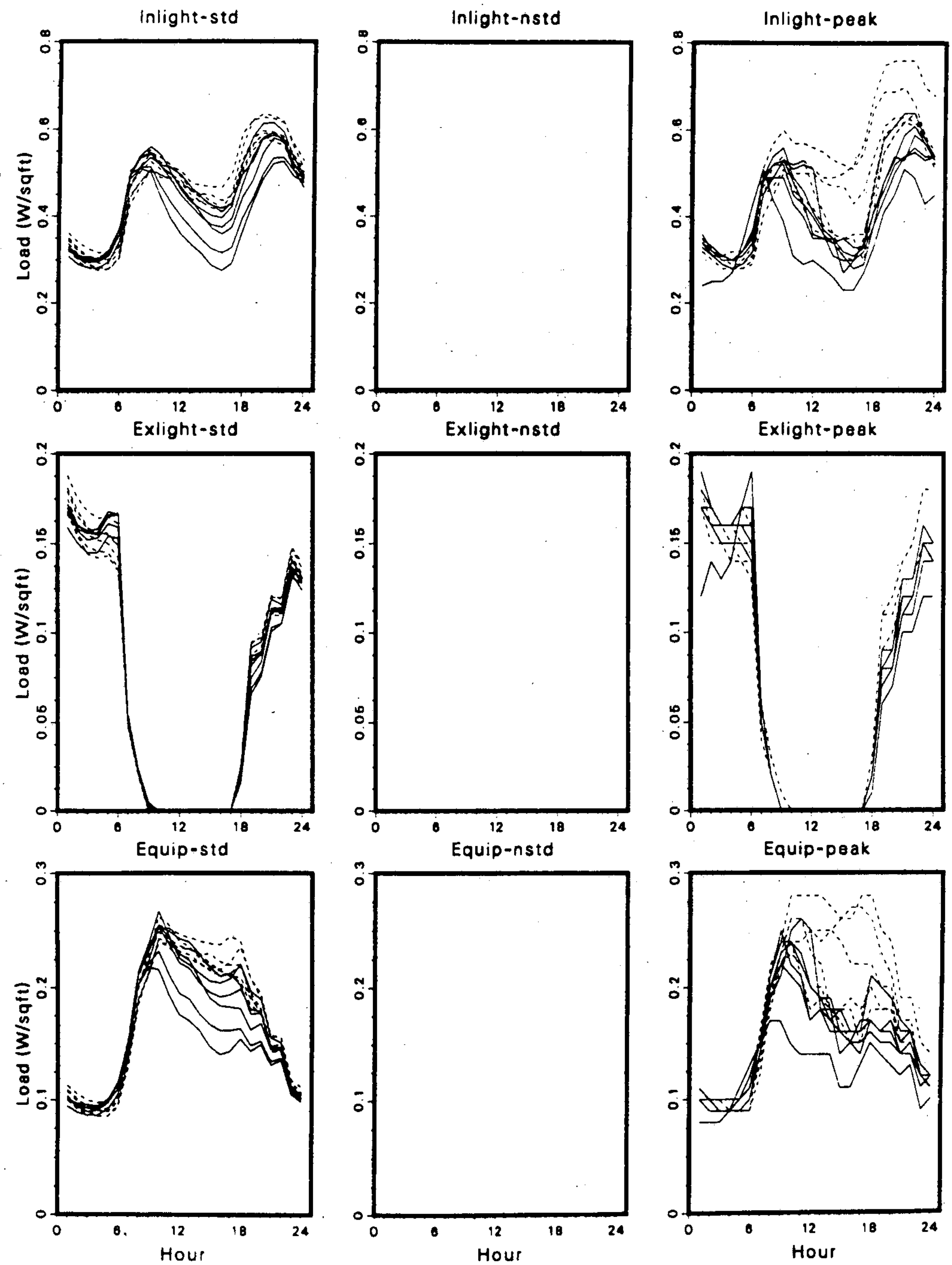


Figure V-29. Reconciled Cooking and Refrigeration Load Shapes for Coastal Lodging. Solid lines are profiles for months May through October and broken lines are profiles for months November through April.

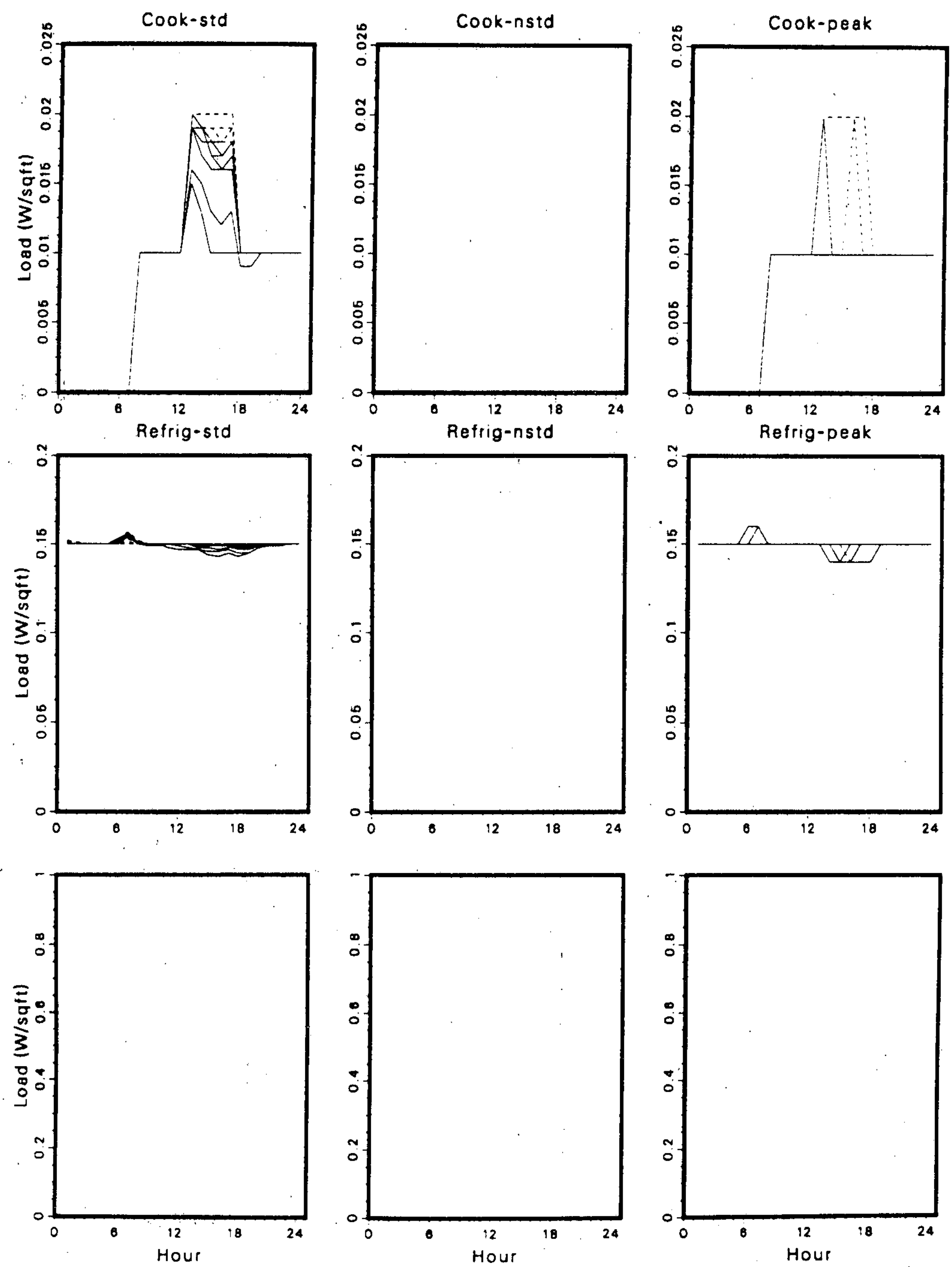


Figure V-30. Reconciled Cooling and Ventilation Load Shapes for Non-Coastal Lodging. Solid lines are profiles for months May through October and broken lines are profiles for months November through April.

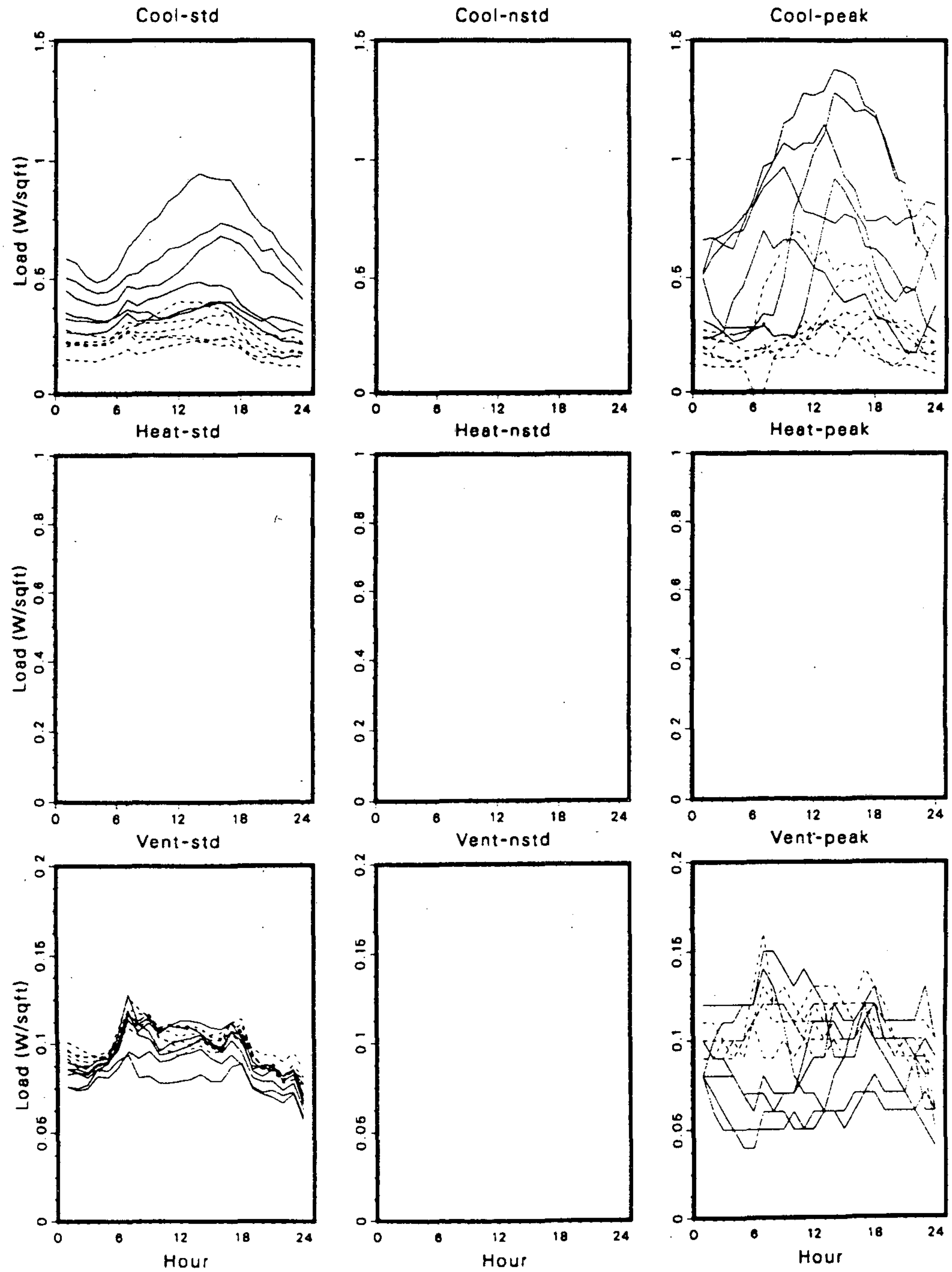


Figure V-31. Reconciled Indoor and Outdoor Lighting, and Misc. Equipment Load Shapes for Non-Coastal Lodging. Solid lines are profiles for months May through October and broken lines are profiles for months November through April.

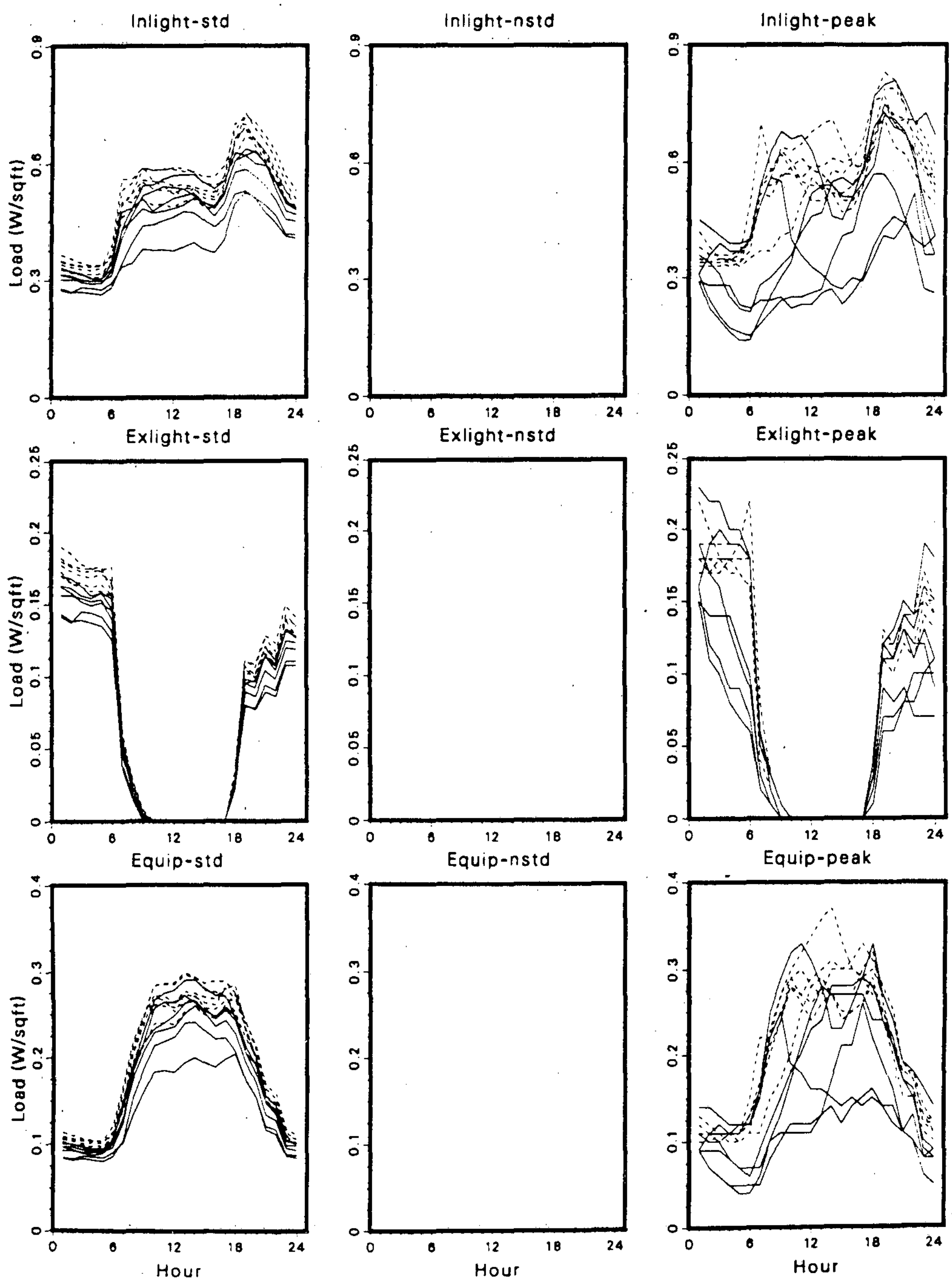
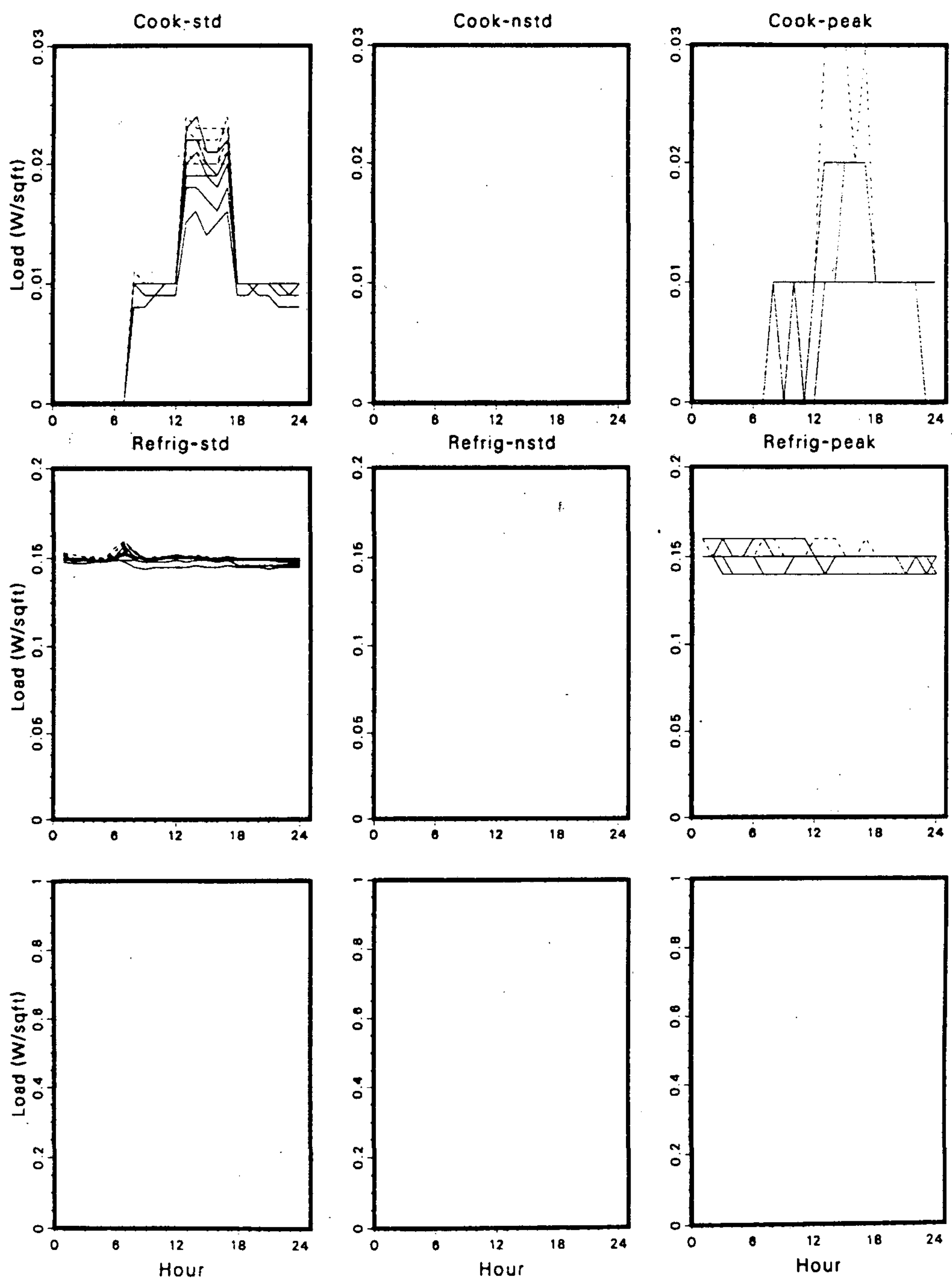


Figure V-32. Reconciled Cooking and Refrigeration Load Shapes for Non-Coastal Lodging. Solid lines are profiles for months May through October and broken lines are profiles for months November through April.



Chapter VI

Developing EUIs for the CEC Forecasting Model

At the end of the reconciliation process presented in Chapter V, the reconciled EUIs represent the combined influences of various building vintages (and equipment choices), electricity saturations as of 1986 (note that climatic influences have already been addressed in Chapter V). The CEC forecasting model, however, represents each of these influences explicitly and indexes all energy use to a 1975 base year. In addition, there are several electric and non-electric end uses that could not be estimated using our reconciliation procedures, given available data. Chapter II outlined the overall procedure for using additional data to extract inputs for the CEC forecasting model from the reconciled EUIs. In this chapter, we document these procedures on an end use by end use basis.

The goal of our efforts is to create what the CEC labels U75 and EUI79 values for electricity, natural gas, and other. U75 is the average EUI (kBtu/ft^2) for buildings built between 1965 and 1978 (i.e., prior to the first generation of building and appliance standards), indexed to a 1975 base year. EUI79 is expressed as a percentage change in EUI from the U75 value for buildings built between 1979 and 1983 (corresponding to the influence of the first generation of building and appliance standards).

The end uses for which U75 and EUI79 are developed include heating, cooling, ventilation, hot water, cooking, refrigeration, indoor lighting, miscellaneous/office equipment, and outdoor lighting. Several end uses are never met with non-electrical energy sources (such as ventilation, lighting, refrigeration, and office equipment) and others have not been affected by building and equipment standards thereby eliminating the need to estimate distinct EUI79 (such as cooking, indoor lighting, miscellaneous/office equipment, and outdoor lighting). As described in Chapter II, we did not develop U75 values for non-electric cooking and miscellaneous nor did we develop a EUI79 value for water heating due to the absence of data for these end uses and vintages.

The results of our efforts are summarized in **Tables VI-1 to VI-5**. Table VI-1 presents U75 values for non-HVAC end uses, which remain unchanged for each climate region. Tables VI-2 to VI-5 present U75 and EUI79 values for the HVAC end uses (heating, cooling, and ventilation) separately by climate zone.

Following this summary, we describe the specific steps used to develop the U75 and EUI79 values for each end use. The steps and data used are documented by end use in nine tables (**Table VI-6 to VI-14**). Two additional supporting Tables to develop fuel saturation data by end use and building type (**Table VI-15**) and to develop weighted average equipment efficiencies by fuel for heating and cooling (Table VI-14) are also included.

Table VI-1. U75s for Non-HVAC End Uses[1] (kBtu/ft^2-yr)

	Fuel	HotW	Cook	Refr	InLt	Misc	OffE	OtLt
School	elec	2.96	1.24	0.69	12.00	1.22	0.09	4.31
	ngas	3.63	n/e	n/a	n/a	n/e	n/a	n/a
	othr	3.63	n/e	n/a	n/a	n/e	n/a	n/a
College	elec	12.52	1.27	3.89	12.78	4.87	0.27	0.95
	ngas	15.33	n/e	n/a	n/a	n/e	n/a	n/a
	othr	15.33	n/e	n/a	n/a	n/e	n/a	n/a
Health	elec	30.88	1.21	2.26	38.95	19.75	1.65	1.28
	ngas	37.83	n/e	n/a	n/a	n/e	n/a	n/a
	othr	37.83	n/e	n/a	n/a	n/e	n/a	n/a
Lodging	elec	9.79	2.03	7.04	14.75	5.49	0.04	2.30
	ngas	11.99	n/e	n/a	n/a	n/e	n/a	n/a
	othr	11.99	n/e	n/a	n/a	n/e	n/a	n/a

n/e Not estimated in this study.
n/a Not applicable for this end use.

1. For derivation of each value, see the following Tables:

Hot Water	HotW	Table VI-9
Cooking	Cook	Table VI-10
Refrigeration	Refr	Table VI-11
Indoor Lighting	InLt	Table VI-12
Outdoor Lighting	OtLt	Table VI-13
Miscellaneous	Misc	Table VI-14
Office Equipment	OffE	Table VI-14

Table VI-2. HVAC U75 and EUI79 for the Coast Region[1]

		U75 (kBtu/ft^2-yr)			EUI79 (% of U75)		
		Heat	Cool	Vent	Heat	Cool	Vent
School	elec	5.62	8.08	2.86	32.4	43.3	81.5
	ngas	13.56	32.05	n/a	34.5	39.5	n/a
	othr	13.56	32.05	n/a	34.5	39.5	n/a
College	elec	23.14	16.69	7.43	13.5	56.6	54.9
	ngas	64.02	118.81	n/a	14.9	45.1	n/a
	othr	64.02	118.81	n/a	14.9	45.1	n/a
Health	elec	17.89	33.64	9.17	18.9	76.8	77.7
	ngas	26.16	182.96	n/a	16.6	63.7	n/a
	othr	26.16	182.96	n/a	16.6	63.7	n/a
Lodging	elec	20.60	22.32	4.02	54.5	51.8	65.0
	ngas	43.43	69.32	n/a	55.4	53.3	n/a
	othr	43.43	69.32	n/a	55.6	53.3	n/a

Table VI-3. HVAC U75 and EUI79 for the Inland Region[1]

		U75 (kBtu/ft^2-yr)			EUI79 (% of U75)		
		Heat	Cool	Vent	Heat	Cool	Vent
School	elec	5.15	8.96	3.63	28.0	47.8	79.4
	ngas	12.44	35.55	n/a	29.8	43.6	n/a
	othr	12.44	35.55	n/a	29.7	43.6	n/a
College	elec	23.50	17.78	7.94	13.1	56.7	53.8
	ngas	65.02	126.54	n/a	14.4	45.2	n/a
	othr	65.02	126.54	n/a	14.4	45.2	n/a
Health	elec	14.30	36.31	9.44	22.5	79.2	81.3
	ngas	20.90	197.51	n/a	19.8	65.7	n/a
	othr	20.90	197.51	n/a	19.8	65.7	n/a
Lodging	elec	16.74	24.56	4.31	51.6	56.8	67.2
	ngas	35.28	76.29	n/a	52.5	58.4	n/a
	othr	35.28	76.29	n/a	52.7	58.4	n/a

Table VI-4. HVAC U75 and EUI79 for the Desert Region[1]

		U75 (kBtu/ft²-yr)			EUI79 (% of U75)		
		Heat	Cool	Vent	Heat	Cool	Vent
School	elec	4.87	10.18	3.52	33.2	59.8	80.5
	ngas	11.74	40.38	n/a	35.4	54.6	n/a
	othr	11.74	40.38	n/a	35.4	54.6	n/a
College	elec	23.49	18.46	7.85	14.5	59.8	55.5
	ngas	65.00	131.38	n/a	16.0	47.6	n/a
	othr	65.00	131.38	n/a	16.0	47.6	n/a
Health	elec	12.43	37.15	9.16	30.9	83.0	82.6
	ngas	18.18	202.08	n/a	27.2	68.8	n/a
	othr	18.18	202.08	n/a	27.2	68.8	n/a
Lodging	elec	19.69	27.34	4.21	57.3	59.8	67.4
	ngas	41.51	84.91	n/a	58.3	61.5	n/a
	othr	41.51	84.91	n/a	58.4	61.5	n/a

Table VI-5. HVAC U75 and EUI79 for the Valley Region[1]

		U75 (kBtu/ft²-yr)			EUI79 (% of U75)		
		Heat	Cool	Vent	Heat	Cool	Vent
School	elec	9.14	10.65	3.74	38.5	54.9	80.2
	ngas	22.04	42.27	n/a	41.0	50.1	n/a
	othr	22.04	42.27	n/a	40.9	50.1	n/a
College	elec	29.27	19.59	8.59	17.0	59.8	53.2
	ngas	80.97	139.47	n/a	18.7	47.6	n/a
	othr	80.97	139.47	n/a	18.7	47.6	n/a
Health	elec	24.15	35.61	9.28	36.0	81.5	79.4
	ngas	35.31	193.68	n/a	31.7	67.6	n/a
	othr	35.31	193.68	n/a	31.7	67.6	n/a
Lodging	elec	26.88	31.12	4.28	61.9	63.3	68.7
	ngas	56.67	96.66	n/a	63.0	65.1	n/a
	othr	56.67	96.66	n/a	63.2	65.1	n/a

Notes:

n/e Not estimated in this study.

n/a Not applicable for this end use.

1. For derivation of each value, see the following Tables:

Cooling	Cool	Table VI-6
Heating	Heat	Table VI-7
Ventilation	Vent	Table VI-8

Cooling

The development of the cooling U75 and EUI79 values is presented in Table VI-6. First, the reconciled cooling electricity EUI (from Chapter V) is divided by the saturation of electric cooling in the SCE service territory in order to estimate cooling EUI for 100% saturation. Second, the cooling load is estimated by multiplying the EUI by the annual average efficiency of the cooling equipment (which is taken from the simulation of the prototype in each climate zone). Third, the cooling load is adjusted by the ratio of cooling load from the simulation of the prototype for vintage A (see Chapter II for definition of the vintages) to the cooling load from the simulation of the original prototype. Fourth, the cooling load is converted back to an EUI by fuel type using the CEC's estimates for weighted average energy conversion efficiency by fuel type and vintage (65-78). Fifth, the adjusted EUIs are expressed in the 1975 base year (i.e., as U75s) by removing the short-run effects of price between 1975 and 1986. The EUI79 value is simply the ratio of cooling loads between the simulation of the vintage A and vintage C prototypes.

Heating

Electric heating was not estimated using the reconciliation procedures in Chapter V because the saturation of electric heating in the SCE service territory is very low. However, simulations of the vintage A and C prototypes yield engineering estimates for heating loads that can be expressed as U75 and EUI79 values. It is important to remember that these values have not benefited from reconciliation with measured energy use.

The development of the heating U75 and EUI79 values is presented in Table VI-7. U75 is calculated by converting the heating load from the simulation of vintage A prototype to an EUI by energy source using the CEC's estimates for weighted average energy conversion efficiency by fuel type and for this vintage (65-78). As with the cooling values, the short-run effects of prices between 1975 and 1986 are also removed so that the final U75 value is indexed to the 1975 base year. Once again, the EUI79 value is the ratio of heating loads between the simulation of the vintage A and vintage C prototypes.

Ventilation

The development of ventilation EUIs is presented in Table VI-8. First, the reconciled ventilation EUI (from Chapter V) is adjusted upward to reflect the saturation of electric ventilation in the SCE service territory. Second, the reconciled EUI is modified using the ratio of electricity used for ventilation in the simulation of the original prototype to the simulation of the vintage A prototype. Third, the short-run effects of prices between 1975 and 1986 are removed to yield the final U75 value. The EUI79 value is the ratio of ventilation electricity use between the simulation of the vintage A and vintage C prototypes.

Hot Water

Hot water, like heating, was not estimated using the reconciliation procedures due to the low saturation of electric water heating in the SCE service territory. Consequently, as with heating, the engineering simulations used to estimate U75 and EUI79 have not benefited from reconciliation with measured data.

The development of water heating EUIs is presented in Table VI-9. U75 is calculated by converting the water heating load from the simulation of the original prototype to an EUI by energy source using the CEC's estimates for weighted average energy conversion efficiency by fuel type and vintage (65-78). The short-run effects of prices between 1975 and 1986 are also removed to yield the final U75 value. We did not estimate EUI79 for this end use.

Cooking

The development of the cooking U75 value is presented in Table VI-10. First, the reconciled cooking electricity EUI (from Chapter V) is adjusted upward to reflect the saturation of electric cooking in the SCE service territory. Second, the adjusted EUI is expressed in the 1975 base year (i.e. as the final U75 value) by removing the short-run effects of price between 1975 and 1986. We did not estimate U75 for non-electrical energy sources nor did we estimate EUI79 for this end use.

Refrigeration

The development of the refrigeration U75 value is presented in Table VI-11. First, the reconciled refrigeration electricity EUI (from Chapter V) is adjusted upward to reflect the saturation of electric refrigeration in the SCE service territory. Second, the adjusted EUI is expressed in the 1975 base year by removing the short-run effects of price between 1975 and 1986. There is no U75 for non-electrical energy sources. We did not estimate EUI79 for this end use.

Indoor Lighting

The development of lighting EUIs is presented in Table VI-12. Since the saturation of electricity for lighting is 100% and since building and appliance standards do not affect this end use in these building types, only one adjustment is required. Only the short-run effects of prices between 1975 and 1986 need to be removed to yield a final U75 value.

Outdoor Lighting

The development of lighting EUIs is presented in Table VI-13. Since the saturation of electricity for outdoor lighting is 100%, and since this end use is not affected by building or appliance standards, only one adjustment is required. Only the short-run effects of prices between 1975 and 1986 need to be removed to yield an EUI indexed to 1975.

Miscellaneous/Office Equipment

Since the saturation of electricity for miscellaneous (including office equipment) is 100%, the reconciled EUI from Chapter V requires no adjustment to account for saturation effects. Similarly, the end use is not affected by building and appliance standards. However, the CEC forecasts energy use separately for miscellaneous and office equipment, while the reconciliation process yields a single value for the combination of these two end uses.

The development of miscellaneous/office equipment EUIs is presented in Table VI-14. Three additional pieces of information were required to extract U75s for miscellaneous and office equipment from the reconciled values presented in Chapter V: 1) the ratio of office equipment to miscellaneous from CEC's existing U75 for these end uses; 2) the growth in energy use for office equipment between 1975 and 1986, which the CEC estimates to be 19.5% for all building types, except offices (see Chapter II); and 3) the short-term effect of prices on miscellaneous energy use between 1975 and 1986, which which the CEC estimates to be -7% (again see Chapter II). We did not estimate non-electrical U75s for these two end uses.

Table VI-6. U75 and EUI79 for Cooling

	Fuel	EUI[1]	Sat[2]	Eff[3]	A/P[4]	CECeff[5]	PrEfct[6]	U75[7]	C/A[8]	EffR[9]	EUI79[10]
School											
Coast	elec	2.29	40.5	3.13	100.0	2.34	1.07	8.08	50.2	0.86	43.3
	ngas					0.59		32.05		0.79	39.5
	othr					0.59		32.05		0.79	39.5
Inland	elec	2.56	40.5	3.10	100.0	2.34	1.07	8.96	55.4	0.86	47.8
	ngas					0.59		35.55		0.79	43.6
	othr					0.59		35.55		0.79	43.6
Desert	elec	3.04	40.5	2.97	100.0	2.34	1.07	10.18	69.4	0.86	59.8
	ngas					0.59		40.38		0.79	54.6
	othr					0.59		40.38		0.79	54.6
Valley	elec	3.17	40.5	2.97	100.0	2.34	1.07	10.65	63.7	0.86	54.9
	ngas					0.59		42.27		0.79	50.1
	othr					0.59		42.27		0.79	50.1
College											
Coast	elec	7.06	50.7	4.18	112.5	4.20	1.07	16.69	57.3	0.99	56.6
	ngas					0.59		118.81		0.79	45.1
	othr					0.59		118.81		0.79	45.1
Inland	elec	7.65	50.7	4.06	114.2	4.20	1.07	17.78	57.4	0.99	56.7
	ngas					0.59		126.54		0.79	45.2
	othr					0.59		126.54		0.79	45.2
Desert	elec	7.95	50.7	4.11	112.6	4.20	1.07	18.46	60.5	0.99	59.8
	ngas					0.59		131.38		0.79	47.6
	othr					0.59		131.38		0.79	47.6
Valley	elec	8.43	50.7	4.09	113.2	4.20	1.07	19.59	60.5	0.99	59.8
	ngas					0.59		139.47		0.79	47.6
	othr					0.59		139.47		0.79	47.6

Table VI-6. U75 and EUI79 for Cooling cont.

	Fuel	EUI[1]	Sat[2]	Eff[3]	A/P[4]	CECeff[5]	PrEfct[6]	U75[7]	C/A[8]	EffR[9]	EUI79[10]
Health											
Coast	elec	15.05	72.4	3.87	125.4	3.21	1.07	33.64	81.0	0.95	76.8
	ngas					0.59		182.96		0.79	63.7
	othr					0.59		182.96		0.79	63.7
Inland	elec	18.16	72.4	3.62	119.9	3.21	1.07	36.31	83.5	0.95	79.2
	ngas					0.59		197.51		0.79	65.7
	othr					0.59		197.51		0.79	65.7
Desert	elec	18.70	72.4	3.76	114.6	3.21	1.07	37.15	87.5	0.95	83.0
	ngas					0.59		202.08		0.79	68.8
	othr					0.59		202.08		0.79	68.8
Valley	elec	18.26	72.4	3.66	115.8	3.21	1.07	35.61	85.9	0.95	81.5
	ngas					0.59		193.68		0.79	67.6
	othr					0.59		193.68		0.79	67.6
Lodging											
Coast	elec	7.65	75.7	2.50	151.3	1.83	1.07	22.32	67.7	0.76	51.8
	ngas					0.59		69.32		0.79	53.3
	othr					0.59		69.32		0.79	53.3
Inland	elec	9.76	75.7	2.42	134.9	1.83	1.07	24.56	74.3	0.76	56.8
	ngas					0.59		76.29		0.79	58.4
	othr					0.59		76.29		0.79	58.4
Desert	elec	10.96	75.7	2.56	126.4	1.83	1.07	27.34	78.2	0.76	59.8
	ngas					0.59		84.91		0.79	61.5
	othr					0.59		84.91		0.79	61.5
Valley	elec	13.04	75.7	2.61	118.6	1.83	1.07	31.12	82.8	0.76	63.3
	ngas					0.59		96.66		0.79	65.1
	othr					0.59		96.66		0.79	65.1

Notes for Table VI-6.

1. Reconciled cooling EUI (kBtu/ft^2) from Tables V-2 to V-5; converted to Btu using 3.413 kBtu per kWh.
2. Saturation of electric cooling by building type from Table II-7; supporting analysis presented on Table VI-15.
3. Annual average energy conversion efficiency from DOE-2 simulation of prototype.
4. Ratio of loads from DOE-2 simulations of vintage A prototype to original prototype.
5. CEC weighted equipment energy conversion efficiencies by fuel and building type for vintage 1965-75 from **Table VI-16**.
6. Short-run effect of price on energy use; derived from CEC price elasticity of demand and SCE average electricity prices from 1975 to 1986.
7. U75 = ((EUI/Sat)*Eff*A/P/CECeff)*PrEfct
8. Ratio of loads from DOE-2 simulations of vintage C prototype to vintage A prototype.
9. Ratio of CEC weighted equipment energy conversion efficiencies by fuel and building type for vintage 1965-75 to vintage 1975-83 from Table VI-16.
10. EUI79 = C/A*EffR

Table VI-7. U75 and EUI79 for Heating

	Fuel	EUI[1]	Eff[2]	A/P[3]	CECeff[4]	PrEfct[5]	U75[6]	C/A[7]	EffR[8]	EUI79[9]
School										
Coast	elec				159.3	1.07	5.62	39.20	0.83	32.4
	ngas	13.31	62.9	100.0	66.0		13.56		0.88	34.5
	othr				66.0		13.56		0.88	34.5
Inland	elec				159.3	1.07	5.15	33.80	0.83	28.0
	ngas	12.52	61.3	100.0	66.0		12.44		0.88	29.8
	othr				66.0		12.44		0.88	29.7
Desert	elec				159.3	1.07	4.87	40.20	0.83	33.2
	ngas	11.86	61.1	100.0	66.0		11.74		0.88	35.4
	othr				66.0		11.74		0.88	35.4
Valley	elec				159.3	1.07	9.14	46.50	0.83	38.5
	ngas	20.56	66.1	100.0	66.0		22.04		0.88	41.0
	othr				66.0		22.04		0.88	40.9
College										
Coast	elec				183.5	1.07	23.14	16.90	0.80	13.5
	ngas	45.88	72.6	119.2	66.3		64.02		0.88	14.9
	othr				66.0		64.02		0.88	14.9
Inland	elec				183.5	1.07	23.50	16.40	0.80	13.1
	ngas	44.56	72.7	124.5	66.3		65.02		0.88	14.4
	othr				66.0		65.02		0.88	14.4
Desert	elec				183.5	1.07	23.49	18.20	0.80	14.5
	ngas	45.14	72.8	122.7	66.3		65.00		0.88	16.0
	othr				66.0		65.00		0.88	16.0
Valley	elec				183.5	1.07	29.27	21.30	0.80	17.0
	ngas	56.96	72.1	122.2	66.3		80.97		0.88	18.7
	othr				66.0		80.97		0.88	18.7

Table VI-7. U75 and EUI79 for Heating cont.

	Fuel	EUI[1]	Eff[2]	A/P[3]	CECeff[4]	PrEfct[5]	U75[6]	C/A[7]	EffR[8]	EUI79[9]
Health										
Coast	elec				96.6	1.07	17.89	18.90	1.00	18.9
	ngas	8.36	63.2	305.9	66.1		26.16		0.88	16.6
	othr				66.0		26.16		0.88	16.6
Inland	elec				96.6	1.07	14.30	22.50	1.00	22.5
	ngas	7.72	60.4	276.8	66.1		20.90		0.88	19.8
	othr				66.0		20.90		0.88	19.8
Desert	elec				96.6	1.07	12.43	30.90	1.00	30.9
	ngas	8.70	62.4	206.8	66.1		18.18		0.88	27.2
	othr				66.0		18.18		0.88	27.2
Valley	elec				96.6	1.07	24.15	36.00	1.00	36.0
	ngas	17.88	67.3	181.3	66.1		35.31		0.88	31.7
	othr				66.0		35.31		0.88	31.7
Lodging										
Coast	elec				139.2	1.07	20.60	63.00	0.86	54.5
	ngas	27.55	67.6	143.9	66.0		43.43		0.88	55.4
	othr				66.0		43.43		0.88	55.6
Inland	elec				139.2	1.07	16.74	59.70	0.86	51.6
	ngas	21.67	66.6	150.9	66.0		35.28		0.88	52.5
	othr				66.0		35.28		0.88	52.7
Desert	elec				139.2	1.07	19.69	66.20	0.86	57.3
	ngas	28.25	66.5	136.3	66.0		41.51		0.88	58.3
	othr				66.0		41.51		0.88	58.4
Valley	elec				139.2	1.07	26.88	71.60	0.86	61.9
	ngas	40.02	68.3	127.8	66.0		56.67		0.88	63.0
	othr				66.0		56.67		0.88	63.2

Notes for Table VI-7.

1. Unreconciled heating EUI (kBtu/ft^2) from DOE-2 simulation of original prototype; converted to Btu using 3.413 kBtu per kWh.
2. Annual average energy conversion efficiency from DOE-2 simulation of prototype.
3. Ratio of loads from DOE-2 simulations of vintage A prototype to original prototype.
4. CEC weighted equipment energy conversion efficiencies by fuel and building type for vintage 1965-75 from Table VI-16.
5. Short-run effect of price on energy use; derived from CEC price elasticity of demand and SCE average electricity prices from 1975 to 1986.
6. U75 = ((EUI/Sat)*Eff*A/P/CECeff)*PrEfct
7. Ratio of loads from DOE-2 simulations of vintage C prototype to vintage A prototype.
8. Ratio of CEC weighted equipment energy conversion efficiencies by fuel and building type for vintage 1965-75 to vintage 1975-83 from Table VI-16.
9. EUI79 = C/A*EffR

Table VI-8. U75 and EUI79 for Ventilation (kBtu/ft^2-yr)

		EUI[1]	Sat[2]	A/P[3]	PrEfct[4]	U75[5]	EUI79[6]
School	Coast	2.66	99.6	100.0	1.07	2.86	81.5
	Inland	3.38		100.0		3.63	79.4
	Desert	3.28		100.0		3.52	80.5
	Valley	3.48		100.0		3.74	80.2
College	Coast	6.76	100.0	102.8	1.07	7.43	54.9
	Inland	7.27		102.1		7.94	53.8
	Desert	7.17		102.4		7.85	55.5
	Valley	7.88		101.8		8.59	53.2
Health	Coast	7.00	100.0	122.5	1.07	9.17	77.7
	Inland	7.51		117.4		9.44	81.3
	Desert	7.44		115.0		9.16	82.6
	Valley	7.30		118.7		9.28	79.4
Lodging	Coast	2.56	100.0	146.6	1.07	4.02	65.0
	Inland	2.83		142.1		4.31	67.2
	Desert	2.83		138.8		4.21	67.4
	Valley	2.90		137.9		4.28	68.7

1. Reconciled cooling EUI (kBtu/ft^2) from Tables V-2 to V-5; converted to Btu using 3.413 kBtu per kWh.
2. Saturation of electric cooling by building type from Table II-7; supporting analysis presented on Table VI-15.
3. Ratio of ventilation electricity use from DOE-2 simulations of vintage A prototype to original prototype.
4. Short-run effect of price on energy use; derived from CEC price elasticity of demand and SCE average electricity prices from 1975 to 1986.
5. U75 = ((EUI/Sat)*A/P*PrEfct
6. Ratio of ventilation electricity use from DOE-2 simulations of vintage C prototype to vintage A prototype.

Table VI-9. U75 for Water Heating (kBtu/ft^2-yr)

	Fuel	Load[1]	Efficiency[2]	Price Effect[3]	U75[4]
School	elec	2.71	98.0	1.07	2.96
	ngas		80.0		3.63
	othr		80.0		3.63
College	elec	11.46			12.52
	ngas				15.33
	othr				15.33
Health	elec	28.28			30.88
	ngas				37.83
	othr				37.83
Lodging	elec	8.96			9.79
	ngas				11.99
	elec				11.99

1. Un-reconciled water heating load estimate (kBtu/ft^2) from preliminary prototype development.
2. Energy conversion efficiency from DOE-2 default equipment values (Btu/Btu). These efficiencies are identical for all building types.
3. Short-run effect of price from CEC short-run price elasticity of demand and SCE average electricity prices from 1975 to 1986. This effect is uniform for all building types and fuels.
4. U75 = (Load/Efficiency)*Price Effect

Table VI-10. U75 for Electric Cooking (kBtu/ft^2-yr)

	EUI[1]	Saturation[2]	Price Effect[3]	U75[4]
School	0.19	16.2	1.07	1.24
College	0.24	20.1		1.27
Health	0.34	30.2		1.21
Lodging	0.24	12.6		2.03

1. Reconciled electric cooking EUIs (kBtu/ft^2) from Tables V-2 to V-5; converted to Btu at 3.413 kBtu per kWh.
2. Saturation of electric cooking from Table II-7, based on supporting Table VI-15.
3. Short-run effect of price from CEC short-run price elasticity of demand and SCE average electricity prices from 1975 to 1986. This effect is uniform for all building types.
4. U75 = (EUI/Saturation)*Price Effect

Table VI-11. U75 for Electric Refrigeration (kBtu/ft^2-yr)

	EUI[1]	Saturation[2]	Price Effect[3]	U75[4]
School	0.61	95.9	1.07	0.69
College	2.97	81.6		3.89
Health	2.08	98.4		2.26
Lodging	4.47	68.0		7.04

1. Reconciled electric refrigeration EUIs (kBtu/ft^2) from Tables V-2 to V-5; converted to Btu at 3.413 kBtu per kWh.
2. Saturation of electric refrigeration from Table II-7, based on supporting Table VI-15.
3. Short-run effect of price from CEC short-run price elasticity of demand and SCE average electricity prices from 1975 to 1986. This effect is uniform for all building types.
4. U75 = (EUI/Saturation)*Price Effect

Table VI-12. U75 for Electric Indoor Lighting (kBtu/ft²-yr)

	EUI[1]	Price Effect[2]	U75[3]
School	11.21	1.07	12.00
College	11.95		12.78
Health	36.40		38.95
Lodging	13.79		14.75

1. Reconciled electric lighting EUIs (kBtu/ft²) from Tables V-2 to V-5; converted to Btu at 3.413 kBtu per kWh. Saturation of electric cooking from Table II-7, based on
2. Short-run effect of price from CEC short-run price elasticity of demand and SCE average electricity prices from 1975 to 1986. This effect is uniform for all building types.
3. U75 = EUI*Price Effect

Table VI-13. U75 for Electric Outdoor Lighting (kBtu/ft²-yr)

	EUI[1]	Price Effect[2]	U75[3]
School	4.03	1.07	4.31
College	0.89		0.95
Health	1.19		1.28
Lodging	2.15		2.30

1. Reconciled electric lighting EUIs (kBtu/ft²) from Tables V-2 to V-5; converted to Btu at 3.413 kBtu per kWh
2. Short-run effect of price from CEC short-run price elasticity of demand and SCE average electricity prices from 1975 to 1986. This effect is uniform for all building types.
3. U75 = EUI*Price Effect

Table VI-14. U75 for Electric Miscellaneous and Office Equipment (kBtu/ft^2-yr)

	EUI[1]	OE Frac[2]	Pr Efct[3]	Tech Efct[4]	U75 Misc.[5]	U75 OffEqp[6]
School	1.25	0.08	1.07	1.195	1.22	0.09
College	4.88	0.06			4.87	0.27
Health	20.43	0.08			19.75	1.65
Lodging	5.17	0.01			5.49	0.04

1. Reconciled electric miscellaneous EUIs (which include contribution of office equipment) from Tables V-2 to V-5 converted to Btu at 3.413 kBtu per kWh (kBtu/ft^2).
2. Ratio of office equipment to miscellaneous electricity use from CEC U75 data for SCE from CFM VIII.
3. Short-run effect of price from CEC short-run price elasticity of demand and SCE average electricity prices from 1975 to 1986 (affects only miscellaneous electricity use). This effect is uniform for all building types.
4. Technology effect of increased office equipment penetration from CEC data. This effect is uniform for all building types (except offices).
5. Miscellaneous U75 = EUI/((1/Price Efct)+(OE Frac*Tech Efct))
6. Office Equipment U75 = Miscellaneous U75 * OE Frac.

Table VI-15. Developing Electricity Saturations by End Use

	School	College	Health	Lodging
Total Floor Area				
1964	102.9950	53.7284	22.4176	28.0415
1974	132.9085	68.9023	58.3822	45.3907
1982	139.0000	73.8531	70.7460	55.6469
1986	140.8199	75.5961	81.4419	74.5047
Changes in Floor Area				
65-74	29.9135	15.1739	35.9646	17.3492
75-82	6.0915	4.9508	12.3638	10.2562
83-86	1.8199	1.7430	10.6959	18.8578
Electric Cooling Saturation by Vintage				
pre-65	32.1	31.5	30.1	53.1
65-74	53.6	97.7	86.5	88.1
75-82	99.5	100.0	84.1	91.4
83-86	100.0	95.0	100.0	89.2
Wtd Avg	40.5	50.7	72.4	75.7
Electric Ventilation Saturation by Vintage				
pre-65	99.6	100.0	100.0	100.0
65-74	99.6	100.0	100.0	100.0
75-82	100.0	100.0	100.0	100.0
83-86	100.0	100.0	100.0	100.0
Wtd Avg	99.6	100.0	100.0	100.0
Electric Cooking Saturation by Vintage				
pre-65	16.2	20.1	30.2	12.6
65-74	16.2	20.1	30.2	12.6
75-82	16.2	20.1	30.2	12.6
83-86	16.2	20.1	30.2	12.6
Wtd Avg	16.2	20.1	30.2	12.6
Electric Refrigeration Saturation by Vintage				
pre-65	95.9	81.6	98.4	68.0
65-74	95.9	81.6	98.4	68.0
75-82	95.9	81.6	98.4	68.0
83-86	95.9	81.6	98.4	68.0
Wtd Avg	95.9	81.6	98.4	68.0

Table VI-16. Heating and Cooling Equipment Efficiency

	Heating				Cooling			
	Boiler	Furnace	Heat Pump	Other	Chiller	Pkg Mult	Pkg Term	Heat Pump
Equipment Efficiencies - Vintage 65-78								
Electric	0.95	0.95	1.90	1.00	4.20	2.04	1.76	1.76
Natural Gas	0.66	0.66	3.00	0.66	0.59	0.36	0.20	0.20
Other	0.66	0.66	3.00	0.66	0.59	0.36	0.20	0.20
Equipment Efficiencies - Vintage 79-83								
Electric	0.95	0.95	2.40	1.00	4.25	2.34	2.41	2.43
Natural Gas	0.75	0.75	3.00	0.66	0.75	0.65	0.20	0.20
Other	0.75	0.75	3.00	0.66	0.75	0.65	0.20	0.20
Equipment Saturations - School								
Electric	8.9	2.7	66.6	21.7	18.4	47.7	21.0	12.8
Natural Gas	24.5	74.6	0.0	0.9	100.0	0.0	0.0	0.0
Other	45.2	54.8	0.0	0.0	100.0	0.0	0.0	0.0
Equipment Saturations - College								
Electric	0.0	0.0	92.8	7.2	100.0	0.0	0.0	0.0
Natural Gas	27.8	72.7	0.0	0.0	100.0	0.0	0.0	0.0
Other	84.8	15.2	0.0	0.0	100.0	0.0	0.0	0.0
Equipment Saturations - Health								
Electric	0.0	68.0	0.0	32.0	54.5	42.7	2.8	0.0
Natural Gas	44.8	55.3	0.0	0.0	100.0	0.0	0.0	0.0
Other	49.7	50.3	0.0	0.0	100.0	0.0	0.0	0.0
Equipment Saturations - Lodging								
Electric	0.0	0.0	43.5	56.5	0.0	25.3	70.0	4.8
Natural Gas	3.3	96.7	0.0	0.0	100.0	0.0	0.0	0.0
Other	97.6	0.0	0.0	2.4	100.0	0.0	0.0	0.0

Table VI-16. Heating and Cooling Equipment Efficiency cont.

	Vintage 1965-1978	
	Heating	Cooling
School		
Electric	1.59	2.34
Natural Gas	0.66	0.59
Other	0.66	0.59
College		
Electric	1.84	4.20
Natural Gas	0.66	0.59
Other	0.66	0.59
Health		
Electric	0.97	3.21
Natural Gas	0.66	0.59
Other	0.66	0.59
Lodging		
Electric	1.39	1.83
Natural Gas	0.66	0.59
Other	0.66	0.59
	Vintage 1978-1983	
	Heating	**Cooling**
School		
Electric	1.93	2.72
Natural Gas	0.75	0.75
Other	0.75	0.75
College		
Electric	2.30	4.25
Natural Gas	0.75	0.75
Other	0.75	0.75
Health		
Electric	0.97	3.38
Natural Gas	0.75	0.75
Other	0.75	0.75
Lodging		
Electric	1.61	2.40
Natural Gas	0.75	0.75
Other	0.75	0.75

Chapter VII

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