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481 PROTOTYPICAL COMMERCIAL BUILDINGS FOR 20 URBAN MARKET AREAS

(Technical documentation of building loads data base developed for the GRI Cogeneration Market Assessment Model)

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RESEARCH SUMMARY

One of the Gas Research Institute's (GRI) many objectives is to establish a foundation of information on the technical and sector-related factors that affect the use of natural gas in the commercial sector that will provide direction for continued research and development. The commercial sector holds particular appeal for potential advances in gas technologies because the sector is a relatively large energy consumer and contains a vast number of physical structures, each requiring individual systems.

To enhance its technology assessment, GRI contracted with RCG/Hagler-Bailly, Inc. (HBI) and LBL to develop a market assessment tool for analyzing the potential of cogeneration for commercial buildings in twenty representative city markets. HBI's responsibility was to develop a microcomputer program that will allow GRI to track the potential cogeneration market depending on different institutional and technical factors. LBL's responsibility was to characterize the building stock in these cities by 1) estimating the number and sizes of buildings by class type, location, vintage, and equipment, 2) developing prototypical buildings for each category, and 3) performing DOE-2 computer simulations for these prototypical buildings.

The first task required extensive analysis of building stock data such as those from F.W. Dodge, the Energy Administration Agency, and sector-specific data for hospitals and schools. The second task required further analysis of the same data sources to determine average building and energy use characteristics, combined with review of 20 engineering studies from across the nation. The final building descriptions include physical dimensions, shell construction, zoning, equipment configuration, and hourly energy use profiles disaggregated by major end-uses, e.g., lighting, hot water, etc. An iterative procedure was used to calibrate the energy uses of these prototypes against the measured energy use data for their building sector.

The total number of prototypical buildings simulated is 481, including hospitals, schools, prisons, hotels, restaurants, offices, supermarkets, apartments, and retail stores (see Table). The completed data base is available from GRI in electronic format and consists of : (1) DOE-2 input files, (2) output files with the hourly building loads (heating, total and latent cooling), electricity use (A/C and non-A/C), outdoor temperatures and humidities, and (3) a Fortran computer program that permits users to extract monthly totals, peak loads, and loads binned by hour-of-day or outdoor conditions.

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NOMENCLATURE

The following terms are used throughout this report in describing the methodology used to develop building prototypes and derive building market sizes.

Market Area	The 20 representative markets defined for this project, comprising either in whole or parts of 13 major metropolitan areas
Project Building Type	The eleven building types defined for this project.
Dodge Major Building Category	Eleven major building categories used in Dodge Building Stock data.
Dodge Requested Building Category	Building types defined for data search of Dodge Building Start data. These were selected out of the 115 available. Some are equivalent to Project Building Types but others are more aggregated.
Building Prototype	A DOE-2 input model that is representative of the average building stock for the particular building type.
Stock Vintage	Buildings built before 1981
Current Vintage	Buildings built between 1981 and 1988.
Average Vintage	Buildings of all vintages.
Old Equipment	HVAC Equipment installed before 1981
New Equipment	HVAC Equipment installed after 1981
Fuel/Electric Ratio	Ratio of fuel to electricity consumption of building in the same thermal units
Window/Wall Ratio	Ratio of window area to exterior wall area of building or zone

1. INTRODUCTION

1.A PURPOSE OF DATA BASE

This report documents the methodology used to determine the load patterns and estimate the building populations for various commercial and multi-family buildings in 20 representative markets of the U.S. The task involved describing nearly 500 prototypical buildings by building type, vintage, and city, defining their internal conditions and operating schedules, and then simulating their hourly energy profiles using the DOE-2.1D building energy simulation program. The simulated energy usages were then calibrated against statistical data and the building descriptions modified to better correlate to measured energy end-use intensities and fuel/electric ratios. A secondary task involved using statistical data on construction activity and surveys to estimate the numbers and total floor areas represented by each of the prototypical buildings.

The primary objective of this project is to supply input information on building loads and market sizes for a microcomputer program being developed by RCG/Hagler-Bailly, Inc. (HBI 1989) for the Gas Research Institute (GRI) under GRI Contract No. 5807-293-1647. The purpose of this program, here referred to as the Commercial Cogeneration Assessment Model (CCAM), is to assess the potential of cogeneration in commercial and multi-family buildings from the present to the year 2000. A secondary objective for this project is to provide GRI with a large data base of hourly load profiles for prototypical commercial buildings that can be used for other technical studies. Detailed descriptions of the data output are given in Chapter 5.

The data files needed by the microcomputer market assessment tool consist of 3-dimensional bin tables of three building end-use loads (heating and hot water loads, cooling loads, and essential electricity) binned against three levels of end-use energy intensity. Separate bin tables are needed for different utility rate periods, so that for any particular building, there may be as many as six tables by rate periods.

Due to their size, the detailed data files are supplied to GRI only in electronic format, with a utility fortran program that will allow users to extract summary reports from the data files as needed.

1.B SELECTION OF MARKET AREAS

Following the proposal work plan, HBI, in conjunction with GRI, selected twenty metropolitan areas to be covered in the market assessment model. This selection was derived by assessing a variety of different potential selection criteria including the following: variations in selected climate parameters, building stock per location, forecast building sector growth rates, electricity rates, and fuel prices. Table 1.B.1 shows the resultant twenty metropolitan areas. In several instances, separate metropolitan areas have been

Table 1.B.1 Market Areas Covered in Cogeneration Market Assessment Tool

Market Area	Electric Utility	Gas Utility	Counties
Northeast			
Boston	Boston Edison	Boston Gas	Middlesex,Suffolk
New York 1	Con Edison	Brooklyn Union Gas	New York, Bronx, Westchester, ½ Queens
New York 2	Con Edison	Con Edison	Kings, Richmond, ½ Queens
Philadelphia 1	Phil Elec	Phil Elec	Bucks,Montgomergy, Delaware
Philadelphia 2	Phil Elec	Phil Gas Works	Philadelphia
North Central			
Chicago 1	Com Edison	Peoples GL&C	½ Cook
Chicago 2	Com Edison	No. Illinois Gas	½ Cook
Detroit 1	Detroit Edison	Michigan Con Gas	Wayne
Detroit 2	Detroit Edison	Consumer Power	Oakland
St. Louis	Union Elec	Laclede Gas	Jefferson, St. Charles, St. Louis
South			
Miami 1	Florida P&L	CGC of Florida	Dade
Miami 2	Florida P&L	Peoples Gas System	Broward
New Orleans 1	New Orl Pub Serv	New Orl Pub Serv	Orleans
New Orleans 2	Louisiana P&L	Louisiana Gas Serv	Jefferson
Houston	Houston L&P	Entex	Harris
West			
Los Angeles 1	LADWP	So Calif Gas	Los Angeles
Los Angeles 2	So Cal Edison	So Calif Gas	Orange
San Diego	San Diego G&E	San Diego G&E	San Diego
San Francisco	Pacific G&E	Pacific G&E	Alameda, Contra Costa, San Francisco, San Mateo
Phoenix	Arizona Public Serv	Southwest Gas	Maricopa

defined for portions of an urban area served by different utility districts. For the building loads analysis, the characteristics of the building stock in these metropolitan areas are assumed to be the same. Consequently, the total number of climate variations for which regional prototypes have been developed is 13.

1.C SELECTION OF BUILDING TYPES AND BUILDING TYPE VARIATIONS

The selection of building types and building type variations to be analyzed for the cogeneration market assessment model required the following steps: (1) categorizing the entire commercial buildings sector into building types that differ significantly in their energy use patterns and/or thermal/electric ratios, (2) ranking the potential cogeneration market in these building types using the following four factors : building sector size, operational hours, system configuration, and concurrent thermal and electric loads, and (3) selecting the most promising building types for incorporation into the building loads data base. The four factors listed in (2) are general indicators for the importance of the building sector and the applicability of cogeneration to that sector.

Figure 1.1 shows schematically how the commercial and residential building stock has been disaggregated into subsectors to distinguish between different end-use intensities and load shapes. At the left of the flow chart are the two general types of commercial and residential buildings (A). These are then disaggregated into 9 major building categories following the SIC codes used by the U.S. government (B). The SIC codes are then subdivided into Building Use sectors whenever those uses cause significant differences in energy intensities or schedules (C). Some of these 18 Building Use sectors include large variations in building size that can also affect their energy use patterns. Therefore, the retail, office, and multifamily sectors have been further divided by building size (D). As a final step, those subsectors with pronounced variations in hours of operations, e.g., 24-hour computer centers versus standard 12-hour offices, are also differentiated (E). The buildings in each subsector share enough similarity in their energy usage that the sectoral analysis can be carried out using representative prototypical buildings.

To narrow the scope of the analysis, 23 of the 25 building types were ranked from 1 to 3 for the four criteria listed in Table 1.C.1 (A = sector size, B = hours of operation, C = system configuration, and D = concurrency of thermal with electric loads). * For the last criteria (concurrency of loads), two rankings were defined depending on whether or not gas cooling was considered. The final ranking for each building type was computed by multiplying its ranking for each criteria (A*B*C*D1 or A*B*C*D2). Higher ranking values indicate that those building types should be assigned lower priorities. A final ranking was then calculated as the sum of the two preliminary rankings (see Table

* Single-family and small multi-family residential buildings fall outside the scope of this study, but are shown on Figure 1.1 for completeness.

Figure 1.1 Flow Chart of Building Stock Disaggregation for the Cogeneration Market Assessment Data Base

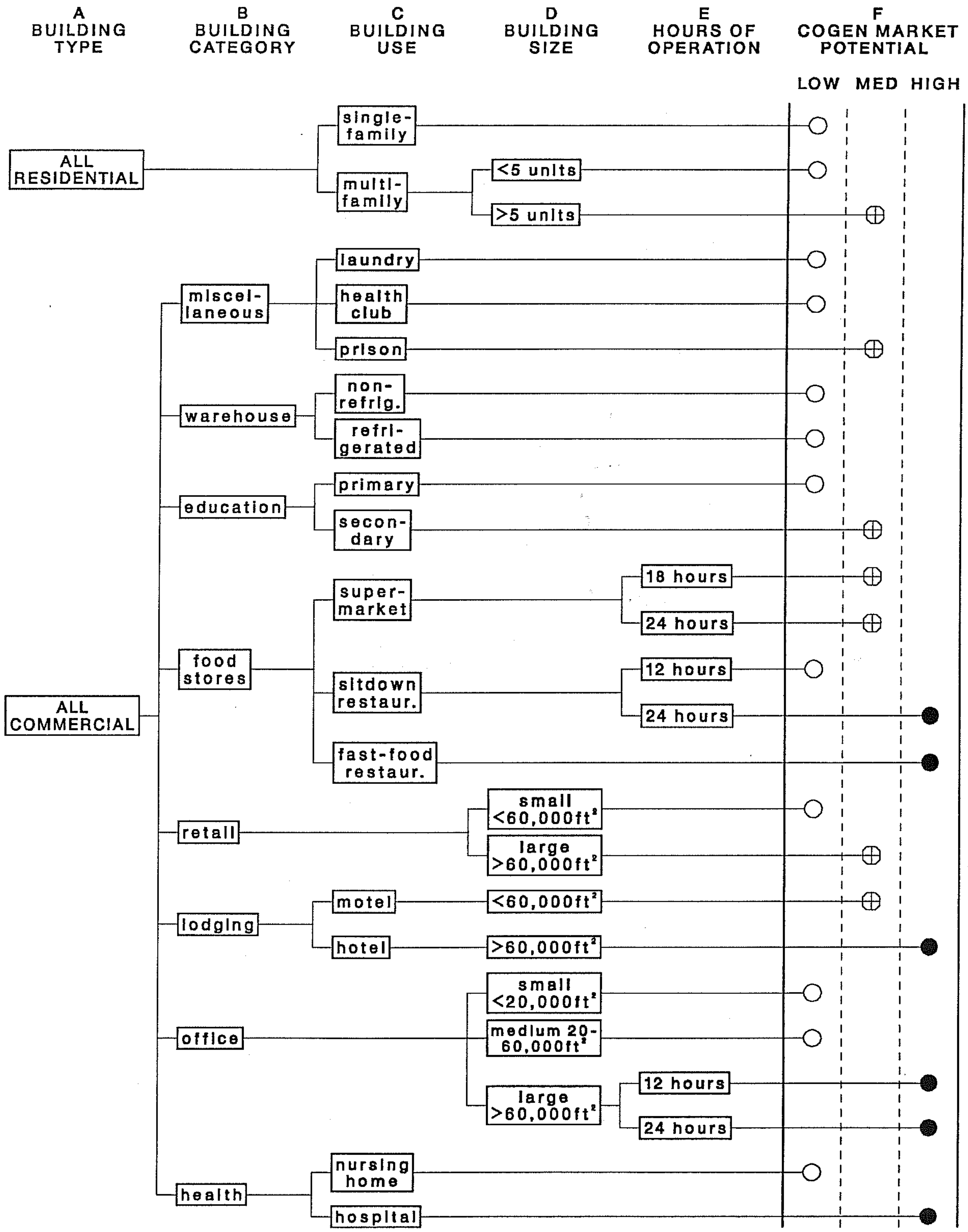


Table 1.C.1 Criteria for ranking building types for analysis of co-generation Potential

A.	Building sector size (ft^2 of floor area *) (ranked as 1, 2 or 3)
B.	Hours of operation (24 hours = 1, 12 hours = 2, < 12 hours or seasonal = 3)
C.	System configuration (central = 1, distributed = 3)
D.	Concurrent thermal and electric loads (ranked as 1, 2, or 3) 1. with conventional HVAC configuration 2. with gas-cooling HVAC configuration

* source : NBECS (Energy Information Administration 1979, 1983)

1.C.2). Based on the final ranking, the 23 building types were categorized as high, medium, low or very low priority. Those are shown in the three columns on the right portion of Figure 1.1. Those building types ranked as low or very low priorities were considered unlikely cogeneration candidates and excluded from the study. As a result, the data base covers only the building types given high and medium priorities, i.e., the first 13 listed in Table 1.C.2.

The load profiles and use intensities of these buildings can vary substantially depending on their shell construction and system configuration. To account for such variations within each building sector, two to three shell/system combinations have been considered for each of the 13 selected building types. For those buildings that have envelope-dominant loads, two shell vintages (*Stock* and *Current*) have been defined, using 1980 as the cutoff year; for buildings with process-dominant loads, an *Average* vintage has been used for all buildings of that type. For all buildings, two equipment types have been defined, *Old* to represent equipment installed before 1980, and *New* more energy efficient equipment being installed today. In addition, *Stock* buildings retrofitted with *New* equipment have been also considered. Table 1.C.3 identifies the 37 building variations simulated for each location.

Table 1.C.2 Priority Rankings by Building Types

Building type	Economic Factors: Sector size (A)	Economic Factors: Oper. hours (B)	Institutional Factors: System config (C)	Technical Factors: Concurrent loads * w/o cool. (D1)	Technical Factors: Concurrent loads * w/ cool. (D2)	Rankings: w/o cool. (E) (A·B·C·D1)	Rankings: w/ cool. (F) (A·B·C·D2)	Rankings: (E+F)
HIGH PRIORITY								
Hospital	**2**	**1**	**1**	**1**	**1**	**2**	**2**	**4**
Large Hotel	**2**	**1**	**1**	**1**	**1**	**2**	**2**	**4**
Sit-down Rest. 24hr	**3**	**1**	**1**	**1**	**1**	**3**	**3**	**6**
Fast Foods Rest.	**3**	**1**	**1**	**1**	**1**	**3**	**3**	**6**
Large Office 24hr	**2**	**1**	**1**	**3**	**1**	**6**	**2**	**8**
Large Office 12hr	**1**	**2**	**1**	**3**	**1**	**6**	**2**	**8**
MEDIUM PRIORITY								
Supermarket 24hr	**3**	**1**	**1**	**3**	**1**	**9**	**3**	**12**
Apartments	**1**	**1**	**3**	**2**	**2**	**6**	**6**	**12**
Prisons	**3**	**1**	**1**	**2**	**2**	**6**	**6**	**12**
Large Retail	**1**	**2**	**1**	**na**	**1**	**20**	**2**	**22**
Supermarket 18hr	**3**	**2**	**1**	**3**	**1**	**18**	**6**	**24**
Sec. School/College	**1**	**2**	**1**	**na**	**2**	**20**	**4**	**24**
Small Hotel/Motel	**2**	**1**	**3**	**2**	**2**	**12**	**12**	**24**
LOW PRIORITY								
Ref. Warehouse	3	1	3	na	1	20	9	29
Sit-down Rest. 12hr	3	2	1	3	2	18	12	30
Medium Office	1	2	3	3	2	18	12	30
Laundry	3	2	3	1	1	18	18	36
Health Club	3	2	3	1	1	18	18	36
Clinic/Nursing home	3	1	3	2	2	18	18	36
VERY LOW PRIORITY								
Primary School	2	3	1	na	3	20	18	38
Small Retail	2	3	3	na	3	20	27	47
Small Office	2	2	3	na	3	20	36	56
Nonref. Warehouse	1	3	3	na	na	20	40	60

* cooling refers to gas-driven cooling.
na = non applicable, concurrent loads are from small to nonexistent.

Table 1.C.3 Building Variations per City

Building Type	Shell Vintage	Equipment Vintage
Hospital	Stock Stock Current	Old : 4PFC rooms, CVCT public areas New : 4PFC rooms, CVCT clean areas, VAV public areas New : 4PFC rooms, CVCT clean areas, VAV public areas
Large Hotel	Stock Stock Current	Old : 4PFC rooms, CVCT public areas New : 4PFC rooms, VAV public areas New : 4PFC rooms, VAV public areas
Extended-hr Sit-down Restaurant	Average Average	Old : CVCT New : VAV
Fast-food Restaurant	Average Average	Old : CVVT New : CVVT
24-hr Large Office	Stock Stock Current	Old : CVCT New : VAV New : VAV
12-hr Large Office	Stock Stock Current	Old : CVCT New : VAV New : VAV
24-hr Supermarket	Stock Stock Current	Old : CVVT New : CVVT/HR New : CVVT/HR
Apartment	Stock Stock Current	Old : 2PFC New : 4PFC New : 4PFC units, CVVT public areas
Prisons	Stock Stock Current	Old : SZRH, RFHS public areas New : SZRH units, VAV public areas New : SZRH units, VAV public areas
Large Retail	Stock Stock Current	Old : CVVT New : CVVT New : CVVT
18-hr Supermarket	Stock Stock Current	Old : CVVT New : CVVT/HR New : CVVT/HR
Secondary School/ College	Stock Stock Current	Old : CVVT New : VAV New : VAV
Small Hotel/ Motel	Stock Stock Current	Old : 2PFC New : 4PFC New : 4PFC

HVAC equipment abbreviations :

CVCT = Constant volume constant temperature, **CVVT** = Constant volume variable temperature **(w/HR** = with heat recovery), **VAV** = Variable air volume (w/RH = with reheat), **DD** = Dual duct, **PSZ** = Packaged single zone, **RHFS** = Reheat fan system, **SZRH** = Single zone reheat, **2PFC** = Two pipe fan coil, **4PFC** = Four pipe fan coil.

2. DATA SOURCES

The project team utilized a wide assortment of data to carry out the following two major tasks : (1) estimate the size of the building stock for the 13 building types in the 13 urban areas, and (2) define prototypical buildings to represent each of these building subsectors. These data include demographic information such as census figures, statistical data bases such as the Non-residential Building Energy Consumption Survey (NBECS), building construction data such as those from F.W. Dodge, Inc., and other national, regional, or sectoral data bases of either building population or energy use in both paper and magnetic formats. In addition, the staff reviewed over twenty technical reports from across the country describing similar engineering efforts that either defined average building conditions or developed prototypical buildings. Several of the public-domain data bases such as NBECS, RECS, and ICP have been installed on LBL computers. However, many of the existing studies are available only in report form.

The aim of this chapter is to give a general overview of how the various data sources were used in the course of this project. Full references for the 35 data sources that were consulted are given in Chapter 7. Descriptions of the data sources, along with highlights and results from statistical searches through those data, are given in the appendix in Chapter 8. Furthermore, descriptions and comments related to the existing prototypes from the literature search are presented in their respective sections by building type in Chapter 4.

As described in Chapter 1, the market disaggregation effort defined 13 building types for each of the 13 urban areas making up the 20 representative market areas (see Tables 1.B.1 and 1.C.3). For the first task of estimating the size of the building stock by building type and market area, we relied on statistical data from the sources listed in Table 2.1. The table summarizes the geographical level of detail, the building types covered, and any information that can be used for characterizing building prototypes, as well for estimating building populations. The data sources include : (1) the 1980 census data and subsequent estimates and projections (McNally), (2) the Nonresidential Building Energy Consumption (NBECS) survey, (3) the construction data base from F. W. Dodge, and (4) sectoral data on building population for hospitals (American Hospital Association), schools (National Center of Educational statistics), and jails (American Correctional Association and Department of Justice data). The Institutional Conservation Project (ICP) data base was not used in this task since it covered only a portion of the school and hospital sectors.

The above data were useful for estimating building populations by market area and building type (see Chapter 6 for details). However, with the notable exception of NBECS, they provide almost no information on building conditions or operating schedules that can be used for developing prototypical buildings. For this second task, i.e., defining prototypical buildings by building type and market area, the project team relied on analyses

Table 2.1 Data Sources for Estimating Building Populations by Market Area and Building Type

(all available at LBL except Dodge)

Data source	Level of detail	Building types	Available information
American Correctional Association (ACA)	County	federal and state penitentiaries	Complete enumeration including no. of inmates and staff
Amer. Hospital Assoc. (AHA)	Zip code, address & phone	hospitals	Bed counts per institution for all hospitals in U.S., some data on vintages.
Census	County	n.a.	1980 Census, 1988 estimated, and 1993 projected populations by county
Dept. of Justice	County	county jails	Complete enumeration including no. of inmates and staff
F.W.Dodge (yearly)	County	all buildings, (100+ categories, mostly industrial)	Floor area, estimated no. of buildings by building type and county.
National Ctr of Educational Statistics (NCES)	Zip code, address, & phone	schools and colleges	Complete enumeration and enrollments for 16,000 school districts, 120,000 schools and 12,000 colleges
NBECS (1979,1983)	Region	all buildings, 110 categories (1979) or 14 categories (1983)	Stock floor area, energy use, hours of operation, general shell characteristics and fuel usages.

n.a. = not applicable

of the NBECS data, survey data on building energy use from utility or other government sources (the Institutional Conservation Program), and review of over twenty existing technical studies.

To develop city-specific building prototypes, we would need, in principle, data on building characterististics on an individual city basis. In almost all instances, such geographically specific data is not available. For example, the NBECS data are statistically valid only at the regional level. Consequently, the prototypical buildings that were developed are in reality composites of the best available regional or even national data, pilot studies, and engineering estimates.

A quick review of the existing survey data and building prototypes indicates that data are most readily available for building physical characteristics, and progressively less so for HVAC equipment, building operations, and the energy end-uses. To define city-specific prototypical buildings, the project team utilized first the available information from the data sources in Table 2.1 to create a skeletal framework of building conditions. The NBECS data were used for defining building envelope conditions, hours of operations, and energy use intensities; the ICP and utility surveys were used for equipment characteristics and energy use intensities.

To "flush out" the prototypical building descriptions to the level of detail required for hourly energy simulations, additional information was added based on review of the existing technical studies and prototypes, combined with the engineering judgement of the project team. Table 2.2 summarizes the secondary data sources that were consulted in finalizing the prototype building descriptions. The table differentiates between building characterizations, which are descriptions of selected building conditions such as square footages or end-use intensities, and building prototypes, which are actual input files or descriptions of prototypical buildings in sufficient detail to permit building modeling.

The table indicates that data or existing prototypes are available from at least one source for nearly all building types at the national or regional levels. City-specific data or prototypes, however, are available only for 4 to 5 cities. It should be pointed out that the geographical specificity of the existing prototypes vary greatly from project to project. In some instances, the prototypes have been based on statistical analysis of survey results from thousands of buildings. In others, a prototype was developed from a single building that was judged to be typical.

Summaries of the existing prototypes and descriptions of the final prototypes developed by this project are given in in Chapter 4.

Table 2.2 Existing building characterizations for building prototype development

(see Table 2.3 for coding and Appendix 8.A for descriptions of data sources)

Building Type	Type of Info.*	National	Northeast			North Central			South			West			
			Bos-ton	New York	Phila-delphia	Det-roit	Chi-cago	St. Louis	New Orleans	Hous-ton	Miami/ Ft.Laud	San Fran.	Los Angeles	San Diego	Phoe-nix
Hospital ‡	Prototype	EPRI,PNL†	NEU3	ConEd		MEOS					FPL	<---	CEC1(2)	--->	
													SCE1		
	Bldg char	*GRI4,5*		*NYSEG ‡*			*WEP ‡*					*PGE*	*CEC2*	*SDGE*	
Hotel/Motel	Prototype	EPRI,GRI3		ConEd		MEOS					FPL	<---	CEC1(2)	--->	
													SCE1		
	Bldg char	*GRI5*	*NEU5*	*NYSEG ‡*			*WEP ‡*					*PGE*		*SDGE*	
Restaurant	Prototype	EPRI,GRI3				MEOS					FPL	<---	CEC1(2)	--->	
						(fast fds)							SCE1(fast fds)		
	Bldg char	*GRI5,PNL2*	*NEU5*	*NYSEG ‡*			*WEP ‡*					*PGE*	*CEC2(2)*	*SDGE*	
Large Office	Prototype	EPRI,GRI1	NEU1,2	ConEd		MEOS(2)				UTA	FPL	<---	CEC1(2)	--->	
		PNL†											SCE1		
	Bldg char	*GRI5*		*NYSEG ‡*			*WEP ‡*					*PGE*	*CEC2*	*SDGE*	
Supermarket	Prototype	EPRI,		ConEd		MEOS						<---	CEC1(2)	--->	
	Bldg char	*GRI5,EPRI/PGE*	*NEU5*	*NYSEG ‡*			*WEP ‡*				*FPL*	*PGE*	*CEC2*	*SDGE*	
Apartment	Prototype	GRI3	<---	GRI2	--->	<---	GRI2	--->	<---	GRI2	--->	<---	GRI2	--->	--->
	Bldg char	*GRI5*													
Large Retail	Prototype	EPRI,PNL†		ConEd		MEOS(2)				UTA	FPL	<---	CEC1(2)	--->	
													SCE1		
	Bldg char		*NEU4*	*NYSEG ‡*			*WEP ‡*					*PGE*	*CEC2*	*SDGE*	
Sec.Sch/College	Prototype	PNL†	NEU3								FPL	<---	CEC1(2)	--->	
	Bldg char		*NEU4*	*NYSEG ‡*			*WEP ‡*						*SDGE*		
Prisons	Prototype			SWA											

* Prototype refers to relatively complete building characterizations, generally in the form of DOE-2 or ADM-2 input files. *Bldg char* refers to incomplete building characterizations for specific variables, such square footages, end-use intensities, etc. Note that the table shows only analytical results, not raw data sources such as NBECS, Dodge, and ICP.

† these PNL prototypes are the same as those in the GARD Desiccant Study (GRI3).

‡ Since NYSEG is for upstate New York, and WEP is for Wisconson, the appropriateness of using these two studies for the designated cities needs to be assessed.

Table 2.3 Correlation of Acronyms to References

Acronym	Reference
ACA	American Correctional Association 1988
AHA	American Hospital Association 1989
CEC/SCE	Akbari,H., Eto,J., Turiel,I., Rainer,L. et al. 1989
CEC1	California Energy Commission 1988.
CEC2	Akbari,H., Eto,J., Turiel,I., Rainer,L. et al. 1989
Census	Bureau of the Census 1989
ConEd	XEnergy, Inc. 1987a
EPRI	XEnergy, Inc. 1988
EPRI/PGE	Foster-Miller, Inc. 1989
FPL	Synergic Resources Corp. 1986
GRI1	Briggs,R.S., Crawley,D.B. and Belzer,D.B. 1989
GRI2	Ritschard,R.L. and Huang,Y.J. 1989a.
GRI3	Chamberlain GARD 1990
GRI4	United Enertec, Inc. 1983
GRI5	Science Applications International Corp. 1984
GRI6	Foster-Miller, Inc. 1985
ICP	Carroll,W.L., Kammerud,R.C., Birdsall,B.E. et al. 1987
MEOS	Synergic Resources Corp. 1987a
NBECS	Energy Information Administration 1979, 1983
NEU1	Synergic Resources Corp. 1985
NEU2	Applied Management Sciences, Inc. 1987b
NEU3	Synergic Resources Corp. 1986b
NEU4	XEnergy, Inc. 1986
NEU5	XEnergy, Inc. 1987b
NYSEG	XEnergy, Inc. and Synergic Resources Corp. 1987c
PGE	McCollister,G. and Turiel,I. 1985
PNL1	Pacific Northwest Laboratories 1983
PNL2	Mazzucchi,R.P. 1986.
RECS	Energy Information Administration 1984
SCE1	Synergic Resources Corp. 1987b
SCE2	ADM Associates, Inc. 1986
SDGE	McCollister,G. and Turiel,I. 1987
SWA	Tuluca,A. 1989.
UTA	Hunn,B., Akbari,H. et al. 1986
WEP	McMenamin,S. 1986

3. METHODOLOGY

This chapter describes the procedure by which prototypical buildings were defined based on literature survey and analyses of various data bases, and then refined through iterative DOE-2 simulations to calibrate the simulated building energy use against available energy consumption data. After the building descriptions have been finalized, the DOE-2 program is used to simulate the hourly energy use patterns of the prototypical buildings in each Market Area with two to six combinations of shell and HVAC equipment vintage and operating schedules.

The completed data base includes 481 building loads profiles covering 13 building types in 13 different cities. This information has been processed into two distinct formats: 1) 3-dimensional bin tables by utility district and rate periods used as inputs to the market assessment model developed by HBI, and 2) lengthy files of hourly loads by end-use stored on magnetic tape that are supplied to GRI.

3.A APPROACH

The prototype selection process described in Section 1 identified the major non-random parameters affecting building energy use patterns and defined 37 prototypical buildings to be analyzed in each Market Area. These buildings differ by activity, shell and HVAC equipment vintages, and, in some cases, hours of operation (see Table 1.C.4). The data sources listed in Section 2 were then used to define a total of 481 prototypes (37 buildings in 13 cities) in terms of their size, construction, geometry, end-use intensities, operating conditions, equipment, and other characteristics needed for making hourly simulations. This section gives a summary of the general approach used in developing the prototypical buildings. Detailed descriptions of each prototype are given in Section 4, arranged by building type.

In general, information is most available for building physical characteristics, less so for building operations or system characteristics, and least for detailed end-use profiles or measured energy consumptions. In terms of geographical precision, data are most available at the national or regional levels, and scarce at the city or county levels. In terms of building type, data are most available for the larger sectors such as offices and practically unavailable for small sectors such as prisons. Information on building sizes are based either the Dodge Building Start data or the sector data bases such the AHA for hospitals, the NCES for schools, and the ACA for prisons. Information on building characteristics such as levels of insulation, window-to-wall ratios, internal load intensities, and operational hours are based primarily on the NBECS data base, supplemented by available prototype studies. Although the NBECS data base also gives information on HVAC equipment characteristics, this information is too ambiguous for modeling purposes. The final equipment specifications are based on discussions with engineers, review of existing studies, and staff judgement.

The objective in creating the prototype buildings is to capture the average energy consumption patterns and intensities of a specific building sector, and not necessarily to create realistic looking "typical" buildings. To keep the modeling effort reasonable, those building characteristics that have minor impact on building energy use patterns have been ignored, while those with significant impacts have been simplified into generalized relationships that can be applied to all buildings within that category. For example, the number of building zones has been reduced whenever possible, and their location within the building left unspecified. Zone floor areas are expressed as percentages of the total building, as are the amounts of exterior wall, windows, and interior walls adjoining other spaces. This approach avoids the arbitrariness of devising floor plans for hypothetical buildings, but retains the correct thermal loading and interactions between different zones.

Instead of devising arbitrary building geometries, average *aspect ratios* (length to width ratio) and *surface-to-volume ratios* have been defined based on review of building plans and actual buildings, and then used to calculate the amounts of exterior wall per zone. The walls in each zone are equally distributed in the four directions to avoid directional bias in the results. This non-directional orientation of the walls, while hardly typical, gives results that are the average of thousands of individual buildings.

Internal loads from building operations and equipment are taken from existing prototype studies, measured data, or staff judgement. Whenever possible, the internal loads have been expressed as energy intensities per floor area so that they can be scaled to buildings of different sizes in different cities.

Although ideally the prototype building should have characteristics representing the average of the building sector it represents, the lack of data often makes it impossible to verify whether the selected characteristics are indeed representative. Many decisions on the acceptable levels of detail in the building descriptions have been based on the sensitivity analyses described in Section 3.C. In some instances, e.g., end-use intensities or hourly schedules, the prototype building characteristics have been based on a few available data sources, supplemented by engineering judgement.

3.B CALIBRATION

Due to the large degree of uncertainty in the prototype descriptions, calibration is a crucial part in the prototype development process. After a draft building description is developed, trial DOE-2 simulations are made and the calculated energy usage compared to measured energy consumption data for that market sector. The comparisons are done using the average annual fuel and electricity use, the annual fuel/electric ratio, and, if available, measured end-use data from existing studies. In almost all cases, the energy consumption data are taken from NBECS. Since specific observations on the calibration effort by each building type are given in Section 4, this section will present only general comments about the calibration procedure.

Once the calculated energy usages have been compared to the measured data, the prototype building descriptions are adjusted to reduce the discrepancies. This calibration process, however, must be done judiciously since the measured data also require careful interpretation and might be anomalous or unrepresentative of the building sector. In many cases, differences in climate and vintage between the simulated results and the measured data must also be considered.

Since NBECS is the only data source with measured energy uses, it becomes, by default, the calibration "yardstick" against which the simulated energy uses were compared. However, it must be remembered that this data base also has its limitations. The 13 building types defined for this study are all subsets of NBECS building categories. Therefore, there are no assurances that the NBECS observations extracted for these building types are statistically representative. For some building types, it is also not possible to extract NBECS observations that correspond exactly to the defined building types. For example, the NBECS data for fast-food restaurants has been extracted using the identifier for cafeterias and limited-menu restaurants. Therefore, they can be expected to show lower energy use intensities than true fast-food restaurants. Lastly, there are also instances where the NBECS data are clearly anomalous. For example, NBECS shows that small hotels in the West region are five times as energy intensive as large hotels! There are many plausible explanations for this variation - the existence of a heated pool, an error in the data gathering, etc. - but the main point is that the calibration effort cannot be done in a mechanical fashion. In addition to calibrating energy use against NBECS on a building-by-building basis, checks are also made to insure consistency across building types based on general engineering knowledge. For example, hospitals are assumed to be more energy use intensive than motels and schools, and offices more intensive than apartments.

To reduce the observed discrepancy between the simulated and measured data, the trial building descriptions are modified starting with the areas of greatest uncertainty, such as in building operations, thermostat setting, and end-use intensities. There is always an element of arbitrariness in this calibration procedure, although the modifications are kept within the range of published values or typical engineering estimates. In most cases, the spirit has been more along the lines of recognizing mistakes in the initial assumptions rather than in adjusting input values to fit the measured data. No attempt has been made to stretch input assumptions beyond comfortable engineering ranges solely to create complete correlation with the measured data.

The final point that must be stressed is that calibration to *annual* energy use intensities or fuel/electric ratios is no guarantee that the resultant hourly load shapes, particularly on an end-use basis, will be representative of the building stock. However, the scarcity of measured hourly load shapes and the efforts required to analyze that data, let alone determine their representativeness by building sector or location, makes it unfeasible for this project to attempt any calibration to measured hourly load shapes.

3.C SENSITIVITY ANALYSIS

The use of prototypical buildings is based on the premise that the energy use patterns of the prototype building, once scaled for total floor area, will adequately reflect the patterns of its respective market sector. Some building parameters, such as interior lighting levels, are fairly well defined within a building type and can be addressed by using an average value. There are other parameters, such as building size, however, where the variations within a building type, e.g., large offices, may be easily on an order of 10 or more. Under those conditions, it is worthwhile to investigate whether the calculated energy use intensity per floor area will be significantly affected by the size chosen for the prototypical building.

Another issue with the prototypical approach is the possibility of a variety of HVAC equipment types occurring in buildings of the same type. An earlier study treated this problem by simulating the prototypical building with a mix of HVAC equipment serving portions of the building (ConEd). Such an approach is considered unusable for this study since it would produce unrepresentative hourly load shapes. For this study, the decision is to model realistic system configurations and to treat significant HVAC equipment variations in the market sector through separate DOE-2 simulations with different equipment configurations based on vintage. Luckily the HVAC equipment mix in most building types within the same vintage is quite narrow.

This section describes the analysis of the dependence of building thermal loads on variations in some of the input parameters. Most of this analysis have been done using the large office prototype which is described in more detail in Section 4.E. The analysis covers the variations in the building's energy use intensity with respect to variations in floor area, the modeling approach for the external walls, zoning of the building, and type of HVAC system. Other analysis has been done using the hospital prototype (see Section 4.A) for the variations in the building's calculated loads and energy use with respect to different zoning strategies. Lastly, analysis also has been done using the supermarket prototype (see Section 4.F) with respect to variations in building loads with respect to assumed building orientation.

3.C.1 Building Size

Figure 1 shows the sensitivity of the building total energy use intensity in $kBtu/ft^2 \cdot yr$ with respect to the total floor area of the building. For small building sizes, the figure shows a significant effect of the floor area on the energy use intensity of the building. However, when the building size is over a certain threshold, the size effect is less

Figure 1
Building Size

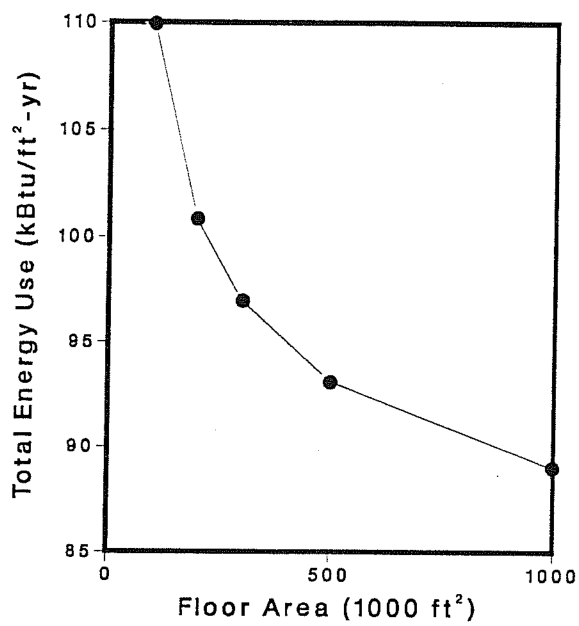


Figure 2
Modeling of Exterior Wall

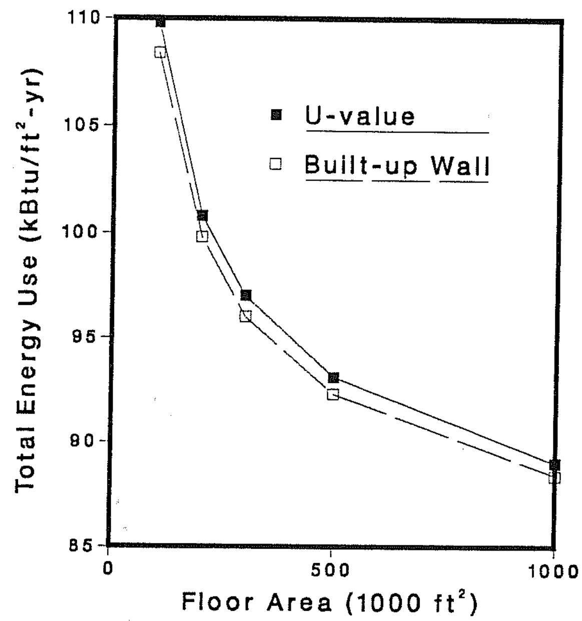


Figure 3
Building Zoning

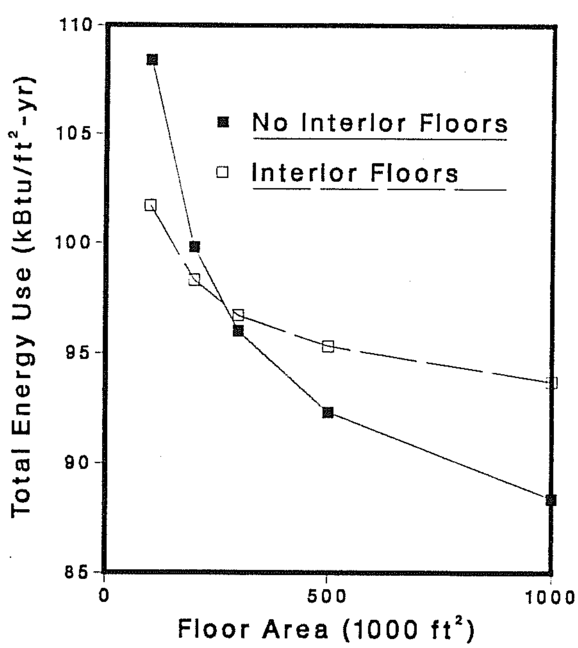
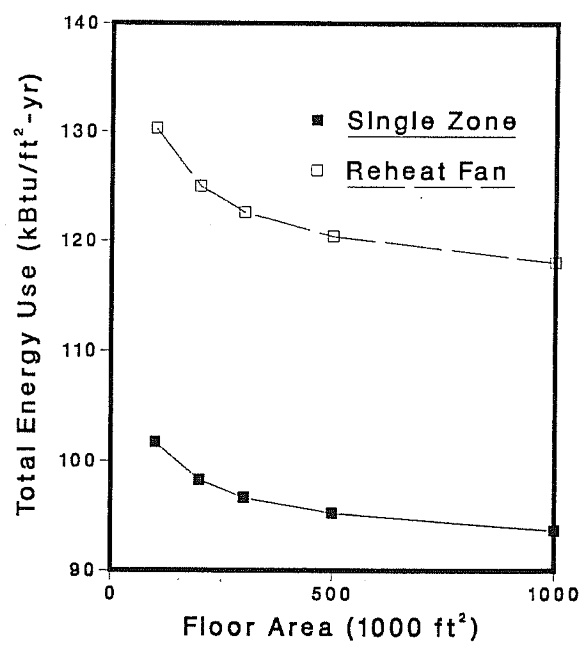


Figure 4
HVAC System



note change in vertical scale.

significant. For example, a 50% variation in building size for a building of 150,000 ft^2 would only change the total energy intensity by about 2%.

3.C.2 Modeling of Exterior Wall

The DOE-2.1D program can simulate exterior walls either using an overall U-value or as a *delayed wall* with thermal lag effects that requires defining wall material properties, construction, and layering. Figure 2 shows the energy use intensity of the building versus floor areas, using the two modeling method for exterior walls. The impact of the wall modeling method on the total energy use intensity is less that 1%. Nevertheless, the delayed wall method has been used for the DOE-2 simulations.

3.C.3 Zoning

Figures 1 and 2 show the results for the test large office prototype with the building divided into five zones, four for the perimeter and one for the core, with heat flow through interior floors ignored, although their thermal storage effects are always treated through use of zone weighting factors. Sensitivity analysis has been done to see the impact if the building were simulated with five zones per floor, i.e., include the effects of heat flows through interior floors. The results using the more detailed modeling are shown in Figure 3, with the results from Figure 2 superimposed. On the average, the total building energy use for the two modeling strategies are within 5% of each other. However, the more detailed model is much less sensitive to floor area changes than the earlier model assuming no heat flow through interior floors. Based on the this analysis, the prototypical buildings have been simulated using the more detailed zoning with heat flows through interior floors included.

3.C.4 HVAC System Type

The initial simulations for the large office have been performed using two constant volume single zone systems: one for the perimeter zones and the other for the core zone. The impact of the system type on the building energy use has been analyzed by repeating the simulations with reheat-fan systems. As shown in Figure 4, the building energy use intensity increased by about 30%. However, the variation of energy intensity with floor area remained basically the same. This sensitivity analysis clearly demonstrates that, of all the building parameters considered, the choice of system type has the greatest impact on the building's energy use.

Based on this analysis, separate prototypical buildings have been defined for major variations in equipment vintage. Luckily, in most building types such as supermarkets, restaurants, schools, retails, etc., there is little variation in the installed system type within the same vintage. On the other hand, building types such as hospitals and large hotels use a variety of system types within a single building. Based on this analysis, it has also been decided to maintain this distinction between zones served by different system types in the building modeling. Additional sensitivities done on this issue for a test hospital prototype are described in the following section.

3.C.5 Zoning by HVAC System Types

Since the prototype buildings are hypothetical, it is desirable to simplify the building description as much as possible, while still capturing the characteristic load shapes of actual buildings. Review of existing DOE-2 input files for actual buildings show that they are generally very complex, especially for building types such as hospitals, hotels, and schools that have very distinct operations in different building areas. For example, the input file for a hospital used for ASHRAE 90.1-1989 has 26 zones served by 7 systems of 5 types.

This level of detail in zoning is unwarranted and impossible to substantiate for a prototype study. After reviewing actual building plans and input files, simplified zoning schemes have been developed for each building type whereby zones with similar usage patterns and system types are lumped into one generalized zone. For example, spaces in the PNL hospital defined as operating rooms, intensive care, etc., are all considered part of a "clinic" zone requiring 100% outside air. Through this approach, the number of zones in the prototypical hospital has been reduced to five - clinic, core/public, perimeter, hallway, and kitchen (see Section 4.A).

To test the impact of this approach on the calculated buildings loads, a sensitivity analysis has been done using the ASHRAE 90.1-1989 hospital as the base case. Three simplified input files have been developed from the original by combining the original 26 zones into (1) 5 zones served by same system type, and (2) 2 zones, one served by a variable air volume system and one served by either a four-pipe fan coil or a reheat-fan system. The building surfaces, internal loads, and schedules of the original 26 zones have all been similarly combined appropriately into the larger lumped zones. There are no problems with interzone heat flows since the entire building is maintained at the same thermostat settings, 74 F for heating and 76 F for cooling.

The results are shown in Tables 3.1 and 3.2 with the test hospital simulated in Boston. Table 3.1 shows the differences in the constant temperature Loads (i.e., Loads from the DOE-2 Loads Module) between the three modeling alternatives. Note that the total loads (heating plus cooling) are quite close together, indicating that the lumped input parameters are correct. However, with the more lumped zones, the heating loads progressively disappear because they occur only in a few perimeter zones. Once those zones are combined with interior zones with high internal loads and small shell losses, heating is no longer needed.

Table 3.2 shows the system loads for the 26-, 5-, and the two 2-zone models. Note that the 5-zone model shows almost no change in heating and cooling loads from the original 26-zone model. However, in the 2-zone models, the loads differ a great deal from those of the original depending on the assumed system of one of the two zones. The conclusions from this sensitivity analysis are that: 1) merging zone descriptions and

Table 3.1 Comparison of constant temperature loads for hospital prototype

		Annual Loads (MBtu)								
Model	Mode	Walls	Roofs	Und Sur	Gl Con	Gl Sol	Occup	Lights	Equip	Total
26 Zone	Heat	-145.5	-54.8	-8.9	-356.9	48.0	73.9	198.5	31.0	-214.8
	Sen Cool	-616.0	-269.4	-783.1	-529.7	753.9	1975.5	17755.0	5774.9	24061.1
	Lat Cool						751.7			751.7
	Total	-761.5	-324.2	-792.0	-886.6	801.9	2801.1	17953.5	5805.9	24598.0
5 Zone	Heat	-145.7	-37.8	0.0	-347.2	57.9	74.9	154.1	24.3	-219.4
	Sen Cool	-591.1	-286.6	-792.1	-522.3	730.2	1991.6	17722.1	5760.6	24012.5
	Lat Cool						621.8			621.8
	Total	-736.8	-324.4	-792.1	-869.5	788.1	2688.3	17876.2	5784.9	24414.9
2 Zone	Heat	-0.4	-0.2	0.0	-0.4	0.0	0.1	0.7	0.1	0.0
	Sen Cool	-736.4	-324.2	-792.1	-869.0	788.1	2061.8	17859.3	5795.8	23783.4
	Lat Cool						643.2			643.2
	Total	-736.8	-324.4	-792.1	-869.4	788.1	2705.1	17860.0	5795.9	24426.6

Table 3.2 Comparison of System Loads for Different Hospital Models

Zone Model	Total Heating (MBtu)	Peak Heating (kBtu/hr)	Total Cooling (MBtu)	Latent Cooling (MBtu)	Peak Cooling (kBtu/hr)
26-zone	49364	14956	47930	16336	24570
5-zone	48872	14849	47158	15978	24153
2-zone w/FPFC	35901	17589	25215	8684	20396
2-zone w/RHFS	56214	16948	54190	19100	26542

FPFC = Four-pipe fan coil; RHFS = Reheat fan system.

Table 3.3 Sensitivity of supermarket cooling energy use to building orientation

Building Orientation	Cooling (kWh)	Fan (kWh)	Total (kWh)
0	93418	5833	99251
90	94711	6085	100796
180	94960	6050	101010
270	97083	6666	103749
Average (A)	95043	6159	101202
Non-directional Prototype (B)	95214	6211	101425
Percent Δ (A - B)	-0.2	-0.8	-0.2

schedules into larger zones introduce little error into the simulations as long as the zones are served by the same system type, and 2) choosing the correct system type is the most important factor in the zoning of a building.

For the prototypical hospital, the appropriate model is the one with five zones, each composed of hospital areas with similar comfort and health criteria and served by a distinctive system type appropriate for meeting these criteria. Such a model avoids the extraneous detail in the 26-zone building description, while still capturing the diversity in energy use intensities between different areas due to their differing comfort criteria and HVAC system configurations.

3.C.6 Building Orientation

Building orientation may have a significant impact on the heating and cooling energy requirements of a building. The degree to which building orientation affects a building's energy use is a strong function of the distribution of its windows. Some buildings such as large offices typically have windows equally distributed on all sides. However, other buildings such as supermarkets usually have windows on only one side of the building.

To develop an average prototypical building, a typical question is how to deal with the building orientation. The way this issue has been treated in this project is to assume that all prototypical buildings have equal amounts of external walls and windows on all four sides of the prototype building. To check the accuracy of this assumption, parametric simulations on window orientation have been performed with a prototype small supermarket with a floor area of 5627 ft^2. Simulations have been done for a typical building with all the windows located on one side of the building while varying the building orientation, and for the averaged prototypical model with the same amount of windows equally distributed on all four external walls.

Table 3.3 shows the simulated fan and cooling energy requirements from these parametric simulations. Building orientation can potentially have as much as a 4% effect on cooling energy use of the building. However, the difference between the cooling energy use of the averaged prototypical building and the average of the cooling energy uses of the four directional buildings is only about 0.2%. This analysis indicates that the method of using directionally-averaged prototypes reproduces the average condition of a multitude of individual buildings of various orientations even for a highly directional building type such as a supermarket.

3.D. ANALYSIS TECHNIQUES AND SOFTWARE DEVELOPMENT

The large number of prototypical buildings and the amount of simulated data in this project has made it necessary to develop systematic procedures for processing both the simulation inputs and outputs. For the systematic processing of the DOE-2 inputs, the project utilized the new "Input Macro" feature in the 2.1D version of the program that made it possible to maintain a limited number of master input files. For processing the output, the project wrote several fortran program and utility routines that read DOE-2 summary and hourly output files in binary form and then processed the data into the two formats of (1) three-dimensional bin tables for the market assessment model and (2) hourly data files containing weather information, heating and cooling loads, and end-uses by fuel type.

The DOE-2 input files have been written to utilize the new "Input Macro" feature in DOE-2.1D. This feature has been added to the Building Description Language (BDL) in DOE-2 to increase its flexibility and is intended for advanced users familiar with the basic structure of DOE-2 BDL. The basic capabilities of this feature are:

1. Incorporating external files containing pieces of BDL into the main BDL input stream. This is called the "General Library " feature.
2. Selectively accepting or skipping portions of the input.
3. Defining a block of input with parameters and later referencing this block.
4. Performing arithmetic and logical operations on the input.
5. Input macro debugging and listing control.

For details and samples of how this DOE-2 input procedure works, readers should refer to the 2.1D update to the DOE-2.1 User's Manual (Simulation Research Group 1989).

For this project, four general input files have been created with BDL input for location, loads report, systems report, and plant report. In addition, master input files have been created for each of the 13 building type listed in Table 1.C.4. for the three BDL portions for loads, systems, plant. The DOE-2.1D simulation are performed by merging together these eight files for a specific building type and defining the location and the shell and equipment vintages of each simulation. These input files have been all supplied to GRI as part of the project deliverables. For the file structure and file names, the reader should refer to Section 8.

To facilitate processing of the output data, the DOE-2 simulations have been done using the binary output file features in DOE-2.1D that permit both the summary and the hourly outputs to be written as clean binary data files. These features are not documented in the DOE-2.1 User's Manual, but do exist in the public release version of DOE-2.1D. The binary output form for the summary report is activated by the BDL keyword "POST-PROCESSOR PARTIAL", while that for the hourly report is activated using the keyword "HOURLY-DATA-SAVE= YES". Readers interested in using or recreating this procedure are urged to contact the Simulation Research Group at LBL.

A utility UNIX AWK program has been written to extract the annual energy consumptions by end-use from the BEPS report in the binary summary output. These one-line abbreviated outputs are used in the calibration process and shown in Tables 4.X.6

in Chapter 4.

Two Fortran programs have been written to process the binary hourly file. One reads the hourly data and sorts the hourly values into the three-dimensional bins required as input for the market assessment model being developed by HBI. The other writes a lengthy ASCII file of building loads for heating, cooling, hot water, non-air-conditioning and air-conditioning electricity for each hour of the year. For descriptions of these output files, see Chapter 5.

4. BUILDING PROTOTYPES

In this chapter we present the major characteristics of the prototypes developed in this study, discuss the data used in their development, compare them with other available prototypes, and present summary simulation results of their annual energy uses as simulated using the DOE-2.1D program.

Prototypical buildings have been developed for each of the 37 building types in the 13 metropolitan areas represented by the 20 representative markets. For those metropolitan areas with two market areas, single prototype buildings were developed and used for both markets in lieu of further differentiation at the submetropolitan level.

A variety of sources were used in the creation of each prototypical building. The large statistical data sets such as the Dodge/DRI, AHA, and NCES data bases were useful only for defining very general building characteristics such as the average size or number of floors per building. The NBECS data base was used extensively to define general construction characteristics such as insulation levels, general equipment types, and operational conditions such as the numbers of hours of use, etc. NBECS was also virtually the only source of energy use characteristics for use in calibrating the prototype building energy use in terms of fuel intensities and fuel/electric ratios.

For all but the restaurants, two vintage variations have been considered for each building type, one representing pre-1980 construction (identified throughout this report as *Stock*), and another post-1980 construction (identified as *Current*). The conservation levels for the *Stock* vintage prototypes have been derived by multiplying the percentage of insulation from NBECS by the insulation levels specified in the 1980 ASHRAE 90-75 standards for ceilings, walls, and windows. For example, the wall insulation level for *Stock* retail buildings in the Northeast region have been derived as follows: (1) ASHRAE 90-75 states that walls should be insulated to R-3; (2) this R-value is then multiplied by the fraction of retail buildings insulated as shown in NBECS, which is only 11%; therefore, a wall R-value of R-0.33 (.11 x 3) has been used for that region.

The conservation levels for the *Current* vintage prototypes are taken from the 1990 ASHRAE 90.1-1989 commercial building standards. ASHRAE 90.1-1989 stipulates different levels of conservation depending on a location’s heating and cooling degree days, but applies equally to all building types within that location. Table 4.1 shows the assumed conservation levels based on ASHRAE 90.1-1989 for Current buildings in the 13 cities making up the 20 market areas covered in this project.

Detailed information of building zoning, hourly occupant and use profiles, end-use intensities, and equipment performance are not available on a statistical basis. For these, the project relied on numerous existing studies and prototypes, as well as engineering judgement.

Table 4.1 ASHRAE 90.1-1989 Envelope Standards

Region	City	Heating deg. days base 65	Cooling deg. days base 65	Cooling deg. hours base 80	Wall R-value	Ceil R-value	Window panes
North-east	Boston	5775	695	1601	11	17	2-pane*
	New York	5022	834	911	10	16	2-pane*
	Philadelphia	4923	1065	3172	10	16	2-pane*
	Average	5240	865	1895	10	16	2-pane*
North Central	Chicago	6151	1015	3190	12	19	2-pane*
	Detroit	5997	922	2238	11	18	2-pane*
	St. Louis	4860	1467	5379	10	17	2-pane*
	Average	5669	1135	3602	11	18	2-pane*
South	Miami	185	4045	9165	1	13	1-pane
	New Orleans	1392	2578	7380	4	13	1-pane
	Houston	1346	2891	10569	4	14	1-pane
	Average	974	3171	9038	3	14	1-pane
West	Los Angeles	1494	472	136	4	9	1-pane
	San Diego	1275	662	383	4	9	1-pane
	San Francisco	3238	73	254	7	11	1-pane
	Phoenix	1382	3647	34521	4	22	1-pane
	Average	1847	1214	8824	5	12	1-pane

* double-pane if window/wall ratio is greater than .10.

Explanation of Subsections

Each of the following sections which describe the various building types follow the same format, starting with a table of available prototypical information from previous studies (Table 4.X.1). This table is then followed by a second table that presents, if available, the regional building characteristics derived from NBECS (Table 4.X.2). For some building types, preliminary analysis of the NBECS data indicated significant differences between the urban and rural observations. Consequently, the final NBECS searches were limited to the Standard Metropolitan Statistical Areas (SMSA's) for the following building types: hospitals, hotels, large retail, and secondary schools. Note that the heating and cooling degree-days shown on these tables are the weighted averages for the NBECS observations of that building type, and hence differ by building type.

Based on the available regional and city-specific information summarized in the previous two tables, the major characteristics of the prototype buildings are presented in Table 4.X.3. If there are more detailed variations by building zone, these are presented in an optional Table 4.X.4. The hourly breakdown of end-use schedules are presented in Table 4.X.5.

After the prototype buildings have been created, the initial simulation results are compared with available data on actual building energy consumption (Table 4.X.6). Consumption data are mainly obtained from NBECS in the form of energy intensity (kBtu/ft^2) and fuel/electric ratios. In most cases, multiple iterations were required whereby the original input assumptions were modified to improve the correlations between the simulated results and the NBECS consumption data.

The results of the final simulations are presented in Tables 4.X.7. The end-uses of each building are broken down as follows:

Heating

Elec. Electricity used by resistance heating, heat pumps, and hot water distribution pumps.

Fuel Fuel used by the boiler or furnace for space heating.

Cooling

Elec. Electricity used by the chiller, cooling tower, cold water distribution pumps,and packaged air conditioning equipment.

Fan

Elec. Electricity used by the supply, return, and exaust ventilation systems.

DHW (Domestic Hot Water)

Elec. Electricity used by the domestic hot water boiler.

Fuel Fuel used by the domestic hot water boiler.

Lighting

Elec. Electricity used by indoor lighting.

Misc.

Elec. Electricity used by plug-in equipment, vertical transportation, cooking, and refrigeration.

Fuel Fuel used by cooking equipment.

4.A. HOSPITAL

Hospitals are prime candidates for cogeneration because they are generally large and have high demands for both heat and electricity. Hospital operations and load demands, however, fluctuate with the time of day and climate, so that there may not be concurrency in the thermal and electric loads. In order to correctly predict the hourly fluctuations in load demands, a prototypical building must account for the variety of usage patterns, schedules, and equipment types typically found in a hospital.

Existing Data Sources

In our literature search, we identified five hospital prototype descriptions from earlier studies. These are summarized in Table 4.A.1. The five descriptions vary greatly in their levels of detail. The four utilities-related studies (ConEd, EPRI, MEOS, and NEU) were concerned with developing average whole-building characteristics, with no breakdowns of usage patterns or end-use intensities by building areas. The ConEd, MEOS, and NEU prototypes are regional to their respective service area, while the EPRI prototype represents a national average. Except for the ConEd study, the studies all assumed a single system type for the entire building. The ConEd prototype defined three HVAC equipment types and the percent of building served by each.

In contrast to the statistically derived prototype descriptions in the utilities-related studies, the PNL/ASHRAE prototype is a detailed DOE-2 input file for an actual hospital modeled with 26 zones served by 7 systems. This study provides the only available information on building zones, system characteristics, and hourly schedules for occupancy, internal loads, and operations. This type of detailed information is essential for developing a hospital prototype with realistic hourly profiles. However, since there is no verification that the PNL/ASHRAE prototype is statistically representative, the detailed input was combined wherever possible with general data from statistical sources such as the above-mentioned utility studies or NBECS. In addition, superfluous details specific only to the modeled hospital were generalized or lumped into generic rules applicable to all hospitals. For example, the various wings of patient rooms have been simplified into a generalized perimeter zone with the same average amounts of walls and windows.

Statistical Data

A preliminary search through the NBECS data showed that hospitals in the Standard Metropolitan Areas (SMSA's) are significantly larger and have higher energy use intensities than those located elsewhere. Since the 20 market areas in the market assessment model are all in major metropolitan areas, the final NBECS statistical search was limited to only hospitals in SMSA's in the four U.S. Census Regions. The output from the NBECS search is shown in Table 4.A.2.

Table 4.A.1. Summary of Existing Studies of Hospitals

Report : (see Table 2.3 for coding)	ConEd	EPRI	MEOS	NEU3	PNL/ ASHRAE
Geometry and U-values:					
Floor Area (ft^2)	320,480	168	127,787	466,129	270,400
Number of Stories	11	4	6	5	4
Percent Glass in Wall	35	25	22	30	12
Wall U-value ($Btu/ft^2 \cdot hr \cdot F$)	0.125	0.100	0.178	0.39	
Roof U-value ($Btu/ft^2 \cdot hr \cdot F$)	0.100	0.040	0.075	0.105	
Glazing type	80% single	single	single	single	single
Number of zones	4	35 (5 uses)	2	1	26
Operating Conditions:					
Cooling Temp Setpoint (F)	78	72	72	N/A	76
Heating Temp Setpoint (F)	72	72	70	N/A	74
Standard Day Schedule	24 hr	24 hr	24 hr	24 hr	24 hr
HVAC Equipment:					
Air Handling System *	40% SZ 25% MZ 15% DD 20% VAV	VAV	Central (2 zones)	MZ	6% SZRH, 48% RHFS, 32% DD, 11% FPIU, 11% FPFC
Cooling Plant Type *	60% DX 25% Centrif. 15% Recip.	Open Centrif.	Hermetic Recip.	N/A N/A	Hermetic Centrif.
Economizer	N/A	N/A	Yes	No	Yes
% Outside Air (annualized)	N/A	50	40	35	
Heating Plant Type	N/A	Gas Hot Water Boiler	Gas Steam Boiler	N/A	Gas Hot Water Boiler
Service Hot Water	N/A	Electric	Electric	N/A	Gas Boiler
Internal Loads (peak):					
Occupants (ft^2/person)	N/A	151	79	476 ‡	248
Lighting (W/ft^2)	0.70	2.00	1.45	1.50	3.1
Equipment/Misc (W/ft^2)	0.80	1.30	1.57	N/A	0.75
Hot Water	0.002 W/ft^2	50 Btu/hr-per	NA	NA	6.76 Btu/ft^2

* DD = Dual-duct, DX = Direct-expansion, FPFC = Four-pipe Fan Coil, FPIU = Four-pipe Induction Unit, MZ = Multi-zone, RHFC = Reheat Fan System, SZ = Single-zone, VAV = Variable-air Volume.

‡ = employees only.

The table shows that hospital shell characteristics did not vary greatly across geographical regions, with moderate amounts of ceiling and wall insulation and prevalence of ‘‘conservation glass’’. Since the South region showed the highest prevalence of ‘‘conservation glass’’ (78.9%), this is interpreted to mean tinted or reflective rather than double-pane glass. The data on building operations showed that, as expected, hospitals had long operating hours (17-22 on all days) and high fuel and electricity intensities, with the South showing significantly more electricity use, and lower fuel/electric ratios than the other three regions (1.08 versus 1.87, 2.34, and 2.98).

Prototype Buildings

The prototype hospital description combines general building characteristics from NBECS, hourly use profiles and system descriptions derived from the PNL/ASHRAE prototype, and general observations about zoning and use patterns based on previous experience in analyzing hospital energy use. Following initial simulations, the prototype descriptions were adjusted to calibrate the calculated energy use intensities and fuel/electric ratios against those shown in NBECS.

Size

The total square footage of the prototype hospitals are derived from the American Hospital Association (AHA) data base. Since this data base does not record the actual building size, the following equation was used to estimate square footage based on a hospital’s bed count (Carroll et al. 1987 LBL-24053) :

$$\text{Area}(\text{ft}^2) = \text{Bed count} \cdot 1156 + 21254 \qquad (1)$$

A statistical search was made by zip code for the 20 market areas, and average hospital sizes calculated for each of the 13 cities comprising the market areas. These are shown on the top part of Table 4.A.3.

Shell Characteristics

The hospitals are modeled with concrete walls, floors, and roofs. The prototype building characteristics are based on the NBECS survey results shown in Table 4.A.2. Since the NBECS data are statistically representative only to the level of Census Regions, the same characteristics were used for all cities within the same region. The building characteristics used for the DOE-2 modeling are listed in the bottom part of Table 4.A.3.

Table 4.A.2. NBECS Statistics for Hospitals (SMSA only)

Parameter	Region Northeast	 North Central	 South	 West
Average Floor Area (x1000 ft^2)	239	200	185	221
Median Fuel/elec ratio	2.34	2.98	1.08	1.87
Average No. Floors	7	6	4	7
Average No. Employees	618	614	416	650
Average Hours Wkday	22	18	17	22
Average Hours Wkend	21	15	17	22
Average Total kBtu/ft^2	181.0	247.0	155.3	284.7
Average Elec kBtu/ft^2	58.7	65.5	71.4	62.6
Average Fuel kBtu/ft^2	122.2	181.5	90.6	222.1
Glass covers <25%	26	36	23	26
Glass covers 25-50%	55	53	63	52
Glass covers 50-75%	19	10	14	23
Glass covers >75%	0	1	0	0
Average glass area (%)	36	31	35	37
% Conservation glass	61	65	79	78
% Wall insulation	40	40	51	33
% Roof/ceiling insulation	73	62	59	73
% Heating setback	57	65	56	95
% Cooling setup	72	66	41	96
% Central heating	79	100	72	100
% Heating system uses furnaces/boilers	73	61	70	100
% Boilers present	47	45	58	71
% Electricity fires boilers	1	0	11	0
% Heat provided by other system	22	43	21	3
% Forced air fans	61	93	71	98
% Heat distributed from baseboards	64	45	9	4
% Electric baseboards	1	1	4	0
% Hot water baseboards	48	43	8	4
% Steam baseboards	31	25	4	0
% Heat fr. radiators/convectors	97	54	15	14
% Heating panels	36	15	7	20
% Other heat distribution	1	8	2	0
% Central air-conditioning	77	70	72	100

Table 4.A.3. Building Descriptions for Hospital Prototypes

Building Parameter	North-east	North Central	South	West
Floor Area (1000 ft^2)	Bos: 347 NY: 386 Phi: 323	Chi: 364 Det: 328 StL: 368	NO: 298 Mia: 315 Hou: 254	LA: 250 SF: 281 SD: 263 Phx: 254
No. of floors	7	6	4	7
Shell characteristics:				
Stock vintage:				
Ceiling R-value	8.8	7.4	5.9	7.3
Wall R-value	1.2	1.2	1.0	1.0
Current vintage:	ASHRAE-90.1 (see Table 4.1)			
Wall Area (% total)	† (see Table 4.A.4 for zone variations)			
Window glass (*Stock*)	1-pane	1-pane	1-pane	1-pane
Window shad. coeff	0.6	0.6	0.4	0.4
Window/wall ratio	0.178 † (see Table 4.A.4 for zone variations)			
Ft^2/person	~ 310 † (see Table 4.A.4 for zone variations)			
Lights W/ft^2	~ 2.1 † (see Table 4.A.4 for zone variations)			
Equip W/ft^2	~ 0.9 † (see Table 4.A.4 for zone variations)			
Hot Water Btu/ft^2	6.76			
Process Btu/ft^2	1.80			
Process W/ft^2	0.07			
System Type	5 systems for clinic, perimeter, kitchen, hallway, and lobby/core; constant volume for first 4, last system varies by vintage.			
Lobby/core *Old* equipment	Constant volume			
Lobby/core *New* equipment	Variable-air-volume			
Heat Sched	72 F all day			
Cool Sched	76 F all day			
Heating plant	gas boiler	gas boiler	gas boiler	gas boiler
Chiller	hermetic centrif.	hermetic centrif.	hermetic centrif.	hermetic centrif.
Hot water plant	gas boiler	gas boiler	gas boiler	gas boiler

† constant for all cities but varies by building zone, numbers are approximate since zone peaks may not be coincident.

Zone Conditions

Based on review of hospital functions and the existing PNL/ASHRAE input file, the prototype hospital has been divided into five generic zones: clinic, core and public areas, perimeter areas, hallways, and kitchen. This zoning reflects distinct variations primarily in the system types, and secondarily, in their functions and usage patterns. This decision criteria is based on a sensitivity study using the PNL/ASHRAE hospital prototype (see Section 3.C) that showed very little loss of accuracy when different zones served by the same type of systems are lumped, but large errors when zones with different systems (e.g., combining zones with VAV systems with those with constant-air systems) are lumped. Table 4.A.4 summarizes the shell and operational characteristics for each hospital zone.

Table 4.A.4. Zone descriptions for Hospital Prototypes

	Zones					
	Clinic	Core/Public	Perimeter	Kitchen	Hallway	Building
Floor Area (% total)	25	35	15	5	20	100
Wall Area (% total)	18	32	35	5	10	100
Window/wall ratio	.10	.20	.35	.10	.35	.178
Ft^2/person	360	360	150	400	720	~ 310
Lights W/ft^2	2.5	2.0	2.0	2.5	1.0	~ 2.1
Equip W/ft^2	1.5	0.5	0.5	3.4	0.0	~ 0.9
System Type **	DD	RHFS or VAV	FPFC	SZRH	RHFS or VAV	-
Min-outside-air	1.0	0.5	0.2	1.0	0.5	0.6

** code for system types: DD = Dual-Duct, SZRH = Single-zone Reheat, PSZ = Packaged Single-zone, FPFC = Four-Pipe-Fan-Coil, RHFS = Reheat-Fan, VAV = Variable-air volume.

(1) *Clinic* includes the operating rooms and intensive care areas. For health requirements, the zone is assumed to have a dual-duct system with 100% outside air.

(2) *Core and public areas* include nurses stations, interior patient rooms, lobbies, and dining rooms. The zone is assumed to have a Reheat-fan System (RHF) in pre-1980s and a Variable-Air-Volume (VAV) system in post-1980s construction. For both vintages, health requirements make it necessary to maintain minimum outside air ratio of 50%.

(3) *Perimeter zone* includes doctor's offices and patient rooms along the building exterior. The zone is assumed to be conditioned by a Four-pipe Fan Coil (FPFC)

system with a minimum outside air ratio of 20%.

(4) *Kitchen* is assumed to have a Single-Zone-Reheat (SZRH) system with a minimum outside air ratio of 100%.

(5) *Hallway* includes the circulation spaces and is assumed to have a Packaged-Single-Zone (PSZ) system with a minimum outside air ratio of 50%.

The zone floor areas are expressed as percentages of the total building area, and based on review of the PNL/ASHRAE input file and project staff experience with hospital designs. The relative amounts of wall differ by zone, with the perimeter zone assumed to have twice as much and the core ⅓ less wall than the average for the building. The window/wall ratios are likewise assumed to vary from 0.35 in the perimeter areas, which are assumed to be similar to hotel rooms, to 0.10 in the non-perimeter areas and the clinic. The NBECS data for the amount of windows ranged from 31% to 37%, which has been assumed to apply only to the public areas. These prototype assumptions are summarized in Table 4.A.4.

Schedules

The zone schedules for various activities are amalgamated from the detailed end-use schedules for the 26 zones in the PNL/ASHRAE prototype. These schedules are shown in Table 4.A.5 and represent the fractional value of the maximum heat input to the zone. In the DOE-2 simulations, the hourly schedules are multiplied by the end-use loads shown in Table 4.A.4 (rows 4, 5, and 6) to produce the hourly load by end-use and zone.

Systems

Because of the stringent comfort requirements in hospitals, it is assumed that heating is fixed at 72 F and cooling fixed at 76 F for all hours in all locations. The system types and minimum-air-ratios by zone are given in the bottom part of Table 4.A.4.

Calibration

We simulated the prototype hospitals to estimate their fuel and electricity uses in four test cities (Boston, St. Louis, Houston, and San Francisco) and compared the results to region-wide energy use data from NBECS, ICP, and the EPRI study (Turiel et al.). The initial prototype had fuel and electricity use intensities from 2-3 times that in NBECS. This high energy use was traced back to generous operating assumptions based on the PNL prototype hospital. To reflect better typical energy-use intensities, changes were made in the heating setpoint (from 74 F to 72 F), air-change rate (6 to 3 ACH), and hallway lighting intensities (1.5 to 1 watt/ft^2). These modified assumptions are

Table 4.A.5. Hourly End-use Load Profiles for Hospitals

Zone	End-use(s)	Day type*	Hour of Day 1	2	3	4	5	6	7	8	9	10	11	12
Perimeter	People	WD	0.50	0.50	0.50	0.50	0.50	0.50	0.50	1.00	1.00	1.00	1.00	1.00
"	People	WEH	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
"	Lights	All	0.30	0.30	0.30	0.30	0.30	0.30	0.30	1.00	1.00	1.00	1.00	1.00
"	Equip.	All	0.30	0.30	0.30	0.30	0.30	0.30	0.30	1.00	1.00	1.00	1.00	1.00
Core/Public	People	WD	0.26	0.26	0.26	0.26	0.26	0.48	0.48	0.86	0.75	0.75	0.75	1.00
"	People	WEH	0.26	0.26	0.26	0.26	0.26	0.48	0.48	0.48	0.37	0.37	0.37	0.62
"	Lights	All	0.33	0.33	0.33	0.33	0.33	0.35	0.35	1.00	1.00	1.00	1.00	1.00
"	Equip.	All	0.31	0.31	0.31	0.31	0.31	0.35	0.35	0.97	0.95	0.95	0.95	1.00
Kitchen	People	WD	0.18	0.18	0.18	0.18	0.18	0.84	0.84	1.00	1.00	1.00	1.00	1.00
"	People	WEH	0.18	0.18	0.18	0.18	0.18	0.84	0.84	0.84	0.84	0.84	0.84	0.84
"	Lights	All	0.20	0.20	0.20	0.20	0.20	0.66	0.66	1.00	1.00	1.00	1.00	1.00
"	Equip.	All	0.25	0.25	0.25	0.25	0.25	0.93	0.93	1.00	1.00	1.00	1.00	1.00
Hallway	People	All	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
"	Lights	All	0.20	0.20	0.20	0.20	0.20	0.20	0.20	1.00	1.00	1.00	1.00	1.00
"	Equip.	All	0.20	0.20	0.20	0.20	0.20	0.20	0.20	1.00	1.00	1.00	1.00	1.00
Clinic	People	WD	0.50	0.50	0.50	0.50	0.50	0.67	0.67	1.00	1.00	1.00	1.00	1.00
"	People	WEH	0.50	0.50	0.50	0.50	0.50	0.67	0.67	0.84	0.84	0.84	0.84	0.84
"	Lights	All	0.61	0.61	0.61	0.61	0.61	0.73	0.73	1.00	1.00	1.00	1.00	1.00
"	Equip.	All	0.69	0.69	0.69	0.69	0.69	0.90	0.90	1.00	1.00	1.00	1.00	1.00
Building	Kitch Elec	All	0.20	0.20	0.20	0.20	0.20	0.80	0.80	0.80	0.80	0.80	0.80	0.80
"	Hot Water	All	0.18	0.18	0.18	0.25	0.25	0.65	1.00	0.86	0.80	0.69	0.69	0.73
"	Kitch Fuel	All	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00
"	Elevator	All	0.10	0.10	0.10	0.10	0.10	0.10	0.10	1.00	1.00	1.00	1.00	1.00

Zone	End-use(s)	Day type*	Hour of Day 13	14	15	16	17	18	19	20	21	22	23	24
Perimeter	People	WD	1.00	1.00	1.00	1.00	1.00	0.50	0.50	0.50	0.50	0.50	0.50	0.50
"	People	WEH	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
"	Lights	All	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	0.50	0.50	0.30	0.30
"	Equip.	All	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	0.50	0.50	0.30	0.30
Core/Public	People	WD	0.96	0.93	0.75	0.75	0.75	0.62	0.59	0.55	0.26	0.26	0.26	0.26
"	People	WEH	0.59	0.55	0.37	0.37	0.37	0.62	0.59	0.55	0.26	0.26	0.26	0.26
"	Lights	All	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.41	0.41	0.41	0.33	0.33
"	Equip.	All	0.99	0.99	0.95	0.95	0.95	1.00	0.99	0.44	0.39	0.39	0.31	0.31
Kitchen	People	WD	1.00	1.00	1.00	1.00	1.00	0.84	0.84	0.18	0.18	0.18	0.18	0.18
"	People	WEH	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.18	0.18	0.18	0.18	0.18
"	Lights	All	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.24	0.24	0.24	0.20	0.20
"	Equip.	All	0.66	0.66	1.00	1.00	1.00	0.66	0.66	0.60	0.25	0.25	0.25	0.25
Hallway	People	All	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
"	Lights	All	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.30	0.30	0.30	0.20	0.20
"	Equip.	All	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.30	0.30	0.30	0.20	0.20
Clinic	People	WD	1.00	1.00	1.00	1.00	1.00	0.84	0.84	0.52	0.52	0.52	0.50	0.50
"	People	WEH	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.52	0.52	0.52	0.50	0.50
"	Lights	All	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.64	0.64	0.64	0.61	0.61
"	Equip.	All	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.70	0.70	0.70	0.69	0.69
Building	Kitch Elec	All	0.50	0.50	0.80	0.80	0.80	0.50	0.50	0.50	0.20	0.20	0.20	0.20
"	Hot Water	All	0.73	0.57	0.69	0.84	0.73	0.66	0.50	0.48	0.46	0.42	0.43	0.33
"	Kitch Fuel	All	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
"	Elevator	All	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.10	0.10

* WD = weekdays, WEH = weekends and holidays, All = all days.

judged to be still a quite typical.

Comparisons of the energy usage of the finalized prototypes to NBECS and ICP consumption data are shown in Table 4.A.6.

Table 4.A.6 Comparison of prototype building energy use to NBECS for hospitals

Region	NBECS				City	DOE-2 Simulation		
	Total Electric * (kBtu/ft^2)	Total Fuel (kBtu/ft^2)	F/E Ratio Median	F/E Ratio Avg		Total Electric * (kBtu/ft^2)	Total Fuel (kBtu/ft^2)	F/E Ratio
Northeast	58.7	122.2	2.34	2.08	Boston	97.4	174.8	1.79
					New York	100.7	161.7	1.61
					Philadelphia	102.3	156.5	1.53
North Central	65.5	181.5	2.98	2.77	Chicago	101.3	174.9	1.73
					Detroit	98.3	176.8	1.80
					St. Louis	105.1	150.6	1.43
South	71.3	90.6	1.08	1.27	Miami	132.9	87.4	0.66
					New Orleans	121.4	108.2	0.89
					Houston	122.3	109.4	0.90
West	62.6	222.1	1.87	3.55	Los Angeles	100.7	92.6	0.92
					San Diego	103.2	85.0	0.82
					San Francisco	91.2	113.5	1.24
					Phoenix	110.3	84.2	0.76

* electricity kWh are converted to site Btus (1 kWh = 3413 Btu).

The DOE-2 calculated fuel intensities compare well to those from NBECS, except for the West region. Comparisons for the West region is questionable since 1) the region includes several cold-climate cities such as Seattle and Denver, and 2) the much higher NBECS fuel intensity compared to the other regions is unexplained and may represent sampling errors. The DOE-2 calculated electricity intensities are twice those from NBECS. Although it was tempting to arbitrarily reduce the assumed electrical intensities and schedules, this was not done since the inputs seemed reasonable. We concluded that the NBECS electricity intensities may be low. According to NBECS, hospital electricity uses are the same as those in large offices, despite their longer hours of operation.

In contrast, the ICP hospital data base showed an average total energy intensity more than double that of NBECS (450 versus 220 kBtu/ft^2·yr, see Figure 2.3). Since the program tended to attract large hospitals with high energy bills, the ICP average is probably skewed. However, the factor of two difference with NBECS indicates that the DOE-2 calculated intensities (average = 260 kBtu/ft^2·yr) is within typical ranges. Because of the higher calculated electricity intensity, the DOE-2 fuel/electric ratios are also 30-100% lower than those shown in NBECS.

Simulation Results

Table 4.A.7 provides information on the calculated annual energy intensities for heating, cooling, lighting, and equipment end uses for the finalized hospital prototypes.

4.B LARGE HOTEL

Large hotels are promising candidates for cogeneration applications because of their concurrent needs for both electricity and thermal energy. The thermal energy is used for space heating, hot water, kitchen, laundry, and, in some cases, a heated swimming pool. The electricity is used for lighting, air conditioning, elevator, and other miscellaneous end uses.

Existing Data Sources

Five of the engineering studies reviewed have developed prototype lodging buildings. Three of these prototypes are of 60,000 ft^2 or smaller and more representative of small hotels or motels than large hotels. These prototypes are reviewed in a later section. The remaining two prototypes from the ConEd and PNL studies are of 251,000 and 315,00 ft^2, respectively, and are judged to be large hotel prototypes. The building characteristics of these two prototypes are summarized in Table 4.B.1. The ConEd prototype is for buildings in the Northeast, while the PNL prototype represents an actual building.

Although the two buildings are of similar size, there are significant differences in their building characteristics. The ConEd building has 22 floors, while the PNL building has only 10. The ConEd building also has less window area, more wall and ceiling insulation, and a much smaller lighting intensity. Since hotels have 24-hour operational schedules with fairly stringent comfort requirements, it is not surprising that the two prototypes have similar operating conditions - 78°F for cooling, and either 70°F, or 72°F with a 4°F night setback, for heating. The ConEd study reported an equipment intensity of 0.50 W/ft^2.

There is no description of the HVAC system for the ConEd prototype. The PNL prototype is configured with a four-pipe fan coil HVAC system with a central chiller.

Table 4.A.7 Summary of annual end use intensities for prototype hospitals
(electricity in kWh/ft^2 and fuel in kBtu/ft^2)

City	Shell	Eqp	Heating Elec.	Heating Fuel	Cooling Elec.	Fan Elec.	DHW Elec.	DHW Fuel	Lighting Elec.	Misc. Elec.	Misc. Fuel	Total Elec.	Total Fuel	F/E Ratio
Northeast														
Boston	Stk	Old	1.06	120.3	3.73	4.17	0.00	46.4	12.56	7.02	8.1	28.54	174.8	1.79
Boston	Stk	New	0.85	97.6	3.35	3.36	0.00	46.4	12.56	7.01	8.1	27.13	152.1	1.64
Boston	Cur	New	0.77	87.5	3.60	3.35	0.00	46.4	12.56	7.03	8.1	27.31	142.0	1.52
New York	Stk	Old	0.93	107.2	4.80	4.18	0.00	46.4	12.56	7.03	8.1	29.50	161.7	1.61
New York	Stk	New	0.70	83.8	4.33	3.37	0.00	46.4	12.56	7.02	8.1	27.98	138.3	1.45
New York	Cur	New	0.63	75.0	4.52	3.34	0.00	46.4	12.56	7.02	8.1	28.07	129.5	1.35
Philadelphia	Stk	Old	0.89	102.0	5.27	4.24	0.00	46.4	12.56	7.01	8.1	29.97	156.5	1.53
Philadelphia	Stk	New	0.66	79.3	4.76	3.43	0.00	46.4	12.56	7.01	8.1	28.42	133.8	1.38
Philadelphia	Cur	New	0.58	70.0	4.74	3.36	0.00	46.4	12.56	7.03	8.1	28.27	124.5	1.29
North Central														
Chicago	Stk	Old	1.06	120.4	4.79	4.31	0.00	46.4	12.56	6.96	8.1	29.68	174.9	1.73
Chicago	Stk	New	0.84	100.1	4.30	3.49	0.00	46.4	12.56	6.97	8.1	28.16	154.6	1.61
Chicago	Cur	New	0.75	88.3	4.29	3.41	0.00	46.4	12.56	6.97	8.1	27.98	142.8	1.49
Detroit	Stk	Old	1.04	122.3	4.07	4.16	0.00	46.4	12.56	6.97	8.1	28.80	176.8	1.80
Detroit	Stk	New	0.83	101.8	3.57	3.32	0.00	46.4	12.56	6.97	8.1	27.25	156.3	1.68
Detroit	Cur	New	0.74	90.3	3.52	3.26	0.00	46.4	12.56	6.96	8.1	27.04	144.7	1.57
St. Louis	Stk	Old	0.84	96.1	6.08	4.33	0.00	46.4	12.56	6.98	8.1	30.79	150.6	1.43
St. Louis	Stk	New	0.66	77.5	5.77	3.56	0.00	46.4	12.56	6.98	8.1	29.53	132.0	1.31
St. Louis	Cur	New	0.59	68.6	6.06	3.53	0.00	46.4	12.56	6.97	8.1	29.71	123.1	1.21
South														
Miami	Stk	Old	0.40	32.9	14.60	4.59	0.00	46.4	12.56	6.79	8.1	38.94	87.4	0.66
Miami	Stk	New	0.12	8.6	13.27	3.74	0.00	46.4	12.56	6.79	8.1	36.48	63.1	0.51
Miami	Cur	New	0.11	8.4	13.18	3.70	0.00	46.4	12.56	6.78	8.1	36.33	62.9	0.51
New Orleans	Stk	Old	0.55	53.7	11.12	4.55	0.00	46.4	12.56	6.79	8.1	35.57	108.2	0.89
New Orleans	Stk	New	0.28	26.6	10.01	3.70	0.00	46.4	12.56	6.79	8.1	33.34	81.0	0.71
New Orleans	Cur	New	0.26	24.0	9.88	3.63	0.00	46.4	12.56	6.78	8.1	33.11	78.5	0.69
Houston	Stk	Old	0.56	54.9	11.33	4.58	0.00	46.4	12.56	6.80	8.1	35.83	109.4	0.90
Houston	Stk	New	0.28	28.2	10.25	3.73	0.00	46.4	12.56	6.79	8.1	33.61	82.7	0.72
Houston	Cur	New	0.26	25.4	10.09	3.65	0.00	46.4	12.56	6.78	8.1	33.34	79.9	0.70
West														
Los Angeles	Stk	Old	0.37	38.1	5.40	4.15	0.00	46.4	12.56	7.02	8.1	29.50	92.6	0.92
Los Angeles	Stk	New	0.15	13.3	4.68	3.34	0.00	46.4	12.56	7.02	8.1	27.75	67.8	0.72
Los Angeles	Cur	New	0.13	11.3	4.70	3.30	0.00	46.4	12.56	7.03	8.1	27.72	65.8	0.70
San Diego	Stk	Old	0.31	30.5	6.12	4.22	0.00	46.4	12.56	7.03	8.1	30.24	85.0	0.82
San Diego	Stk	New	0.10	8.3	5.40	3.41	0.00	46.4	12.56	7.04	8.1	28.51	62.8	0.65
San Diego	Cur	New	0.09	7.1	5.42	3.39	0.00	46.4	12.56	7.02	8.1	28.48	61.6	0.63
San Francisco	Stk	Old	0.50	59.0	2.79	3.86	0.00	46.4	12.56	7.01	8.1	26.72	113.5	1.24
San Francisco	Stk	New	0.28	28.3	2.34	2.98	0.00	46.4	12.56	7.01	8.1	25.17	82.8	0.96
San Francisco	Cur	New	0.24	23.4	2.38	2.96	0.00	46.4	12.56	7.03	8.1	25.17	77.9	0.91
Phoenix	Stk	Old	0.30	29.8	7.98	4.46	0.00	46.4	12.56	7.02	8.1	32.32	84.2	0.76
Phoenix	Stk	New	0.16	15.5	7.70	3.86	0.00	46.4	12.56	7.01	8.1	31.29	70.0	0.66
Phoenix	Cur	New	0.13	12.8	7.51	3.73	0.00	46.4	12.56	7.01	8.1	30.94	67.3	0.64

Table 4.B.1 Summary of Existing Studies of Large Hotels

Report: (see Table 2.3 for coding)	ConEd	PNL
Geometry and U-values:		
Floor Area (ft^2)	250,497	315,000
Number of Stories	22	10
Percent of Glass in Wall (%)	31	50
Wall U-value ($Btu/ft^2{\cdot}hr{\cdot}F$)	0.189	.27-.41
Roof U-value ($Btu/ft^2{\cdot}hr{\cdot}F$)	0.050	0.12
Operating Conditions:		
Cooling Setpoint (F)	78	78
Heating Setpoint (F)	70	72/68
Standard Day Schedule	N/A	N/A
HVAC Equipment:		
Air Handling System Type	N/A	4 Pipe Fan Coil
Cooling Plant Type	N/A	Hermetic Centrifugal
Economizer	N/A	Y
% Outside Air (annualized)	N/A	N/A
Heating Plant Type	N/A	Gas Hot Water Generator
Internal Loads (peak):		
Occupants (ft^2/person)	N/A	109
Lighting (Watts/ft^2)	0.50	1.30
Equipment/Misc (Watts/ft^2)	0.50	N/A

Statistical Data

NBECS statistical data for large hotels are shown in Table 4.B.2 for four geographical regions. Note that these data have been limited to large hotels only in larger urban areas, i.e., SMSA's. The variations in the NBECS buildings are much smaller than those shown in Table 4.B.1—96,000 to 250,000 ft^2 in 6 to 10 floors. The NBECS buildings are about the same in Northeast and North Central part of the country ~150,000 ft^2. Surprisingly, average floor area for large hotels in South is only 96,000 ft^2. In design of our prototype, we use other sources of information for the prototypical floor area. Also, we would like to emphasize that variation in the sizes of the hotels do not significantly affect their energy use intensity, provided that the same services are offered. The average floor area per occupant obtained from the NBECS data base does not include the guests. In our analysis, we assume a peak occupancy of two guests per room; and an

Table 4.B.2 NBECS Statistics for Large Hotels (4+ stories, SMSA only)

	Region			
Parameter	Northeast	North Central	South	West
Average Floor Area (x1000 sf)	153	153	96	253
Median Fuel/elec ratio	6.75	1.76	0.40	1.16
Average No. Floors	6	10	7	10
Average No. Employees	148	140	111	591
Average Hours Wkday	13	20	24	24
Average Hours Wkend	11	22	24	24
Average Total kBtu/sf	103.0	194.6	123.7	226.3
Average Elec kBtu/sf	21.0	62.5	72.6	107.5
Average Fuel kBtu/sf	82.0	132.2	51.1	118.9
Glass covers <25%	1	2	15	54
Glass covers 25-50%	85	57	55	39
Glass covers 50-75%	14	41	19	5
Glass covers >75%	0	0	11	3
Average glass area (%)	41	47	44	27
% Conservation glass	6	44	73	98
% Wall insulation	14	19	65	87
% Roof/ceiling insulation	74	100	69	29
% Heating setback	17	98	82	69
% Cooling setup	17	99	90	70
% Central heating	99	76	79	52
% Heating system uses furnaces/boilers	97	58	46	44
% Boilers present	98	64	59	91
% Electricity fires boilers	0	0	0	1
% Heat provided by other system	2	18	36	15
% Forced air fans	27	40	67	52
% Heat distributed from baseboards	16	6	1	2
% Electric baseboards	1	6	1	2
% Hot water baseboards	1	0	1	0
% Steam baseboards	13	0	0	0
% Heat fr. radiators/convectors	87	69	18	0
% Heating panels	1	1	7	7
% Other heat distribution	0	10	32	4
% Central air-conditioning	28	46	76	91

average room size of 400 ft^2. Similarly, the reported operational hours for all NBECS large hotel buildings only reflects the working hours of the hotel staff. For all practical purposes, hotels operate 24 hours a day, however, with varying schedules.

NBECS also reports the average glass area which is fairly constant in the range of 41 - 48%, except for the West which is 27%. Large hotels in all geographical areas have some level of insulation at walls and ceilings. In North mostly ceiling are insulated, but with low insulation level in walls. In South, significant insulation is used in both ceiling and walls, but in West, walls are mainly insulated. In our prototype buildings, we simulate the insulation levels using the averages reported in NBECS. In all regions, over 40% of hotels use boilers. Boilers are more common in Northeast part of the country. Central air-conditioning are mainly present in South and West; only 28% and 46% of the large hotels in Northeast and North Central, respectively, are air-conditioned. This is also evident by high (6.75) fuel/electric ratio in Northeast compared to other regions which is 0.40-1.76. The energy intensity of the NBECS large hotels are in the range of 103 to 226 kBtu/ft^2, all site energy. It is rather surprising that the fuel energy use intensity in North Central and West is about 70% and 50%, respectively, higher than the Northeast. The explanation for these variations should be sought for in the statistical significance of these intensities. We have used these intensities to calibrate our prototype large hotel prototype.

Prototype Buildings

Using the data discussed above and the DODGE database, we have developed 26 prototype large hotel buildings (13 for *Stock* vintage, 13 for *Current* vintage) shown in Table 4.B.3 for each city of interest. The size and characteristics of the buildings are discussed below.

Size

The sizes of our prototype large hotel buildings for the *Stock* and the *Current* vintages vary from 110,000 in the San Diego CA to 490,000 ft^2 in the New York NY. Although the average floor areas vary by over a factor of four, the average number of floors, based on the *Dodge Project Detail*, is fairly constant in the range of 6 to 10.

Shell Characteristics

The large hotel buildings are modeled with concrete walls, floors, and roofs. The window/wall ratios vary by region, but the windows in the stock vintage are assumed to be single pane in all cities. The window shading coefficients are assumed to be 0.6 in the Northeast and North Central and 0.4 in South and West regions. For the stock vintage, the walls have minimal amounts of insulation, but the roofs are from R-6 to R-16.

Table 4.B.3 Building Descriptions for Large Hotel Prototypes

Building Parameter	North-east	North Central	South	West
Floor Area (1000 ft^2)				
Stock vintage	Bos: 144 NY: 489 Phi: 239	Chi: 491 Det: 259 StL: 212	Mia: 172 NO: 312 Hou: 244	LA: 207 SFO: 359 SD: 113 Phx: 169
Current vintage	Bos: 126 NY: 494 Phi: 187	Chi: 218 Det: 203 StL: 283	Mia: 194 NO: 371 Hou: 250	LA: 203 SFO: 221 SD: 248 Phx: 178
No. of floors	6	10	7	10
Shell characteristics:				
Stock vintage:				
Ceiling R-value	15.5	15.5	13.8	5.8
Wall R-value	0.4	0.8	2.0	2.6
Current vintage:	ASHRAE-90.1 (see Table 4.1)			
Wall Area (% total)	† (see Table 4.B.4 for zone variations)			
Window glass (*Stock*)	1-pane	1-pane	1-pane	1-pane
Window shad. coeff	0.6	0.6	0.4	0.4
Window/wall ratio	0.40	0.47	0.44	0.27
Ft^2/person	200 † (see Table 4.B.4 for zone variations)			
Lights W/ft^2	1.2 † (see Table 4.B.4 for zone variations)			
Equip W/ft^2	0.6 † (see Table 4.B.4 for zone variations)			
Hot Water Btu/ft^2	5.0 † (see Table 4.B.4 for zone variations)			
Process Btu/ft^2	0.8 † (see Table 4.B.4 for zone variations)			
System Type	3 system types: four pipe fan-coil for rooms, single-zone reheat for kitchen; either constant-volume (*Old*) or VAV (*New*) for lobby/conference			
Heat Sched	70 F day, 65 F night			
Cool Sched	78 F all day			
Heating plant	gas boiler	gas boiler	gas boiler	gas boiler
Chiller	hermetic centrif.	hermetic centrif.	hermetic centrif.	hermetic centrif.
Hot water plant	gas boiler	gas boiler	elec boiler	gas boiler

† constant for all cities but varies by building zone, numbers are approximate since zone peaks may not be coincident.

NBECS indicates that 100% of large hotels in North Central region have roof insulation. However, we feel that North Central is not that different from Northeast Region. Hence, in our prototypes for North Central regions, we assume the same percentage of the ceiling insulation as Northeast. For the current vintage, the walls and roofs are modeled with ASHRAE 90.1-1989 insulation levels. The lighting intensities are assumed to be the same for all regions and vary from 1 W/ft^2 in guest rooms to 2 W/ft^2 in the kitchen. Similarly, equipment energy intensities are assumed constant between the prototypes but vary from 0.5 W/ft^2 in the lobby area to 3.0 W/ft^2 in the kitchen. The hot water usage is 34,000 Btu/person per day. Peak power usages for elevators is approximately 37 kW per 100,000 ft^2 of total floor area. Schedules and intensities by building zone are summarized in Table 4.B.4.

Table 4.B.4 Zone Descriptions for Large Hotel Prototype

	Guest Rooms/ Corridors	Lobby/Conf. Rooms	Kitchen/ Laundry
Floor Area (% total)	70	25	5
Wall Height (ft)	10	10	10
Window/wall ratio	varies (see Table 4.B.3)	0.20	0.05
Ft^2/person	200	200	400
Occup. Schedule †	R-P	L-P	K-P
Light W/ft^2	1.0	1.5	2.0
Light Schedule†	R-L	L-L	K-L
Equip. W/ft^2	0.6	-	3.0
Equip. Schedule†	R-E	-	R-E
Hot Water Btu/ft^2·hour	7.1	-	-
Process Btu/ft^2·hour	-	-	16

† code for hourly loads schedules in Table 4.B.5.

Zones Conditions

For simulation, we have assumed that the an aspect ratio (length to width) of the building is 1. The large hotels are simulated with three major zones: guest rooms and hallways (70% of the total area); kitchen, laundry, and restaurant (5% of the total area); and lobby and conference rooms (25% of the total area). The walls heights are assumed to be 10 feet. The average ft^2 per person for the guest rooms and lobby are 200; the corresponding number for kitchen is 400 ft^2/person. All the internal loads and schedules are summarized in Table 4.B.4.

Schedules

The occupancy, equipment, and hot water schedules are summarized in Table 4.B.5. The guest rooms have 90% occupancy during the night and 20% during the day. The lights and equipment in guest rooms have the same schedules as the occupancy. The hot water usage in the guest rooms peaks at 60% in the early morning hours, levels off to about 40% during the day, and decreases to about 30% during the late night hours.

The lobby and conference area lights are assumed to be always on, but their occupancies vary from about 6% during the day to about 80% during the evening hours. Lobby occupancy is about 10% during the night time hours.

Kitchen and laundry area is assumed to be closed between the hours of 24:00 to 4:00. The maximum kitchen occupancy is about 90% and occurs during the day. Lighting schedule mainly follows the occupancy schedules. However, the equipment schedule only reduces to 20% during the night hours and stay very much constant at 80% during the day.

Operational schedules in large hotels during the weekend is slightly different than weekdays, as shown in Table 4.B.5. The basic difference is in lower level of occupancy and late start of normal operation during the weekend and holidays. weekends and holidays lighting schedule is 20 per cent.

Systems

The large hotel is simulated basically with three systems, one for each zone. The guest rooms are conditioned with a four-pipe fan coil system. For the buildings with old equipment, the lobby and conference areas are served with a constant volume single zone reheat system. For the buildings with new equipment, the lobby is modeled with a VAV system with a terminally-controlled economizer. The kitchen is served with a separate constant single-zone reheat system.

Gas boilers are used for space and water heating (both process and DHW). The air-conditioning chillers are hermetic centrifugal systems with cooling towers. Chilled and hot water are circulated to the guest room units.

Calibration

We have simulated the prototype buildings to estimate the heating and cooling loads of the buildings. The prototype building and system characteristics have been adjusted so that the simulation results generally agree with the NBECS consumption data. The simulated total electricity and fuel use of the prototypical office buildings in 13 cities and comparison with NBECS consumption data are shown in Table 4.B.6.

Table 4.B.5 Hourly End-use Load Profiles for Large Hotels

Zone	End-use(s)	Code	Day type*	Hour of Day 1	2	3	4	5	6	7	8
Rooms	People	R-P	WD	0.90	0.90	0.90	0.90	0.90	0.90	0.70	0.40
	"		WEH	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
	Lights	R-L	WD	0.20	0.15	0.10	0.10	0.10	0.20	0.40	0.50
	"		WEH	0.30	0.30	0.20	0.20	0.20	0.20	0.30	0.40
	DHW	R-D	WD	0.21	0.20	0.20	0.20	0.22	0.20	0.51	0.61
	"		WEH	0.30	0.25	0.22	0.22	0.25	0.31	0.51	0.55
Lobby	People	L-P	WD	0.10	0.10	0.10	0.10	0.10	0.20	0.40	0.60
	"		WEH	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
	Lights	L-L	All	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Kitchen	People	K-P	WD	0.00	0.00	0.00	0.00	0.50	0.70	0.70	0.90
	"		WEH	0.00	0.00	0.00	0.00	0.00	0.50	0.60	0.60
	Lights	K-L	All	0.10	0.10	0.10	0.10	0.90	0.90	0.90	0.90
	Equipment	K-E	All	0.20	0.20	0.20	0.20	0.20	0.80	0.80	0.80
Zone	End-use(s)	Code	Day type*	Hour of Day 9	10	11	12	13	14	15	16
Rooms	People	R-P	WD	0.40	0.20	0.20	0.20	0.20	0.20	0.20	0.30
	"		WEH	0.50	0.50	0.50	0.30	0.30	0.20	0.20	0.20
	Lights	R-L	WD	0.40	0.40	0.25	0.25	0.25	0.25	0.25	0.25
	"		WEH	0.40	0.30	0.30	0.30	0.30	0.20	0.20	0.20
	DHW	R-D	WD	0.59	0.48	0.42	0.48	0.45	0.40	0.35	0.35
	"		WEH	0.52	0.57	0.51	0.51	0.45	0.42	0.35	0.32
Lobby	People	L-P	WD	0.60	0.40	0.20	0.20	0.20	0.20	0.20	0.30
	"		WEH	0.40	0.40	0.30	0.30	0.30	0.30	0.30	0.40
	Lights	L-L	All	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Kitchen	People	K-P	WD	0.90	0.70	0.40	0.70	0.70	0.30	0.30	0.30
	"		WEH	0.80	0.80	0.50	0.60	0.60	0.20	0.20	0.20
	Lights	K-L	All	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
	Equipment	K-E	All	0.80	0.80	0.80	0.80	0.50	0.50	0.80	0.80
Zone	End-use(s)	Code	Day type*	Hour of Day 17	18	19	20	21	22	23	24
Rooms	People	R-P	WD	0.50	0.50	0.50	0.70	0.70	0.80	0.90	0.90
	"		WEH	0.30	0.40	0.40	0.60	0.60	0.70	0.70	0.70
	Lights	R-L	WD	0.25	0.25	0.60	0.80	0.90	0.80	0.60	0.30
	"		WEH	0.20	0.20	0.50	0.70	0.80	0.50	0.50	0.30
	DHW	R-D	WD	0.33	0.45	0.60	0.65	0.55	0.50	0.48	0.20
	"		WEH	0.32	0.42	0.52	0.52	0.43	0.52	0.43	0.25
Lobby	People	L-P	WD	0.60	0.80	0.80	0.70	0.50	0.30	0.30	0.10
	"		WEH	0.40	0.50	0.50	0.40	0.40	0.30	0.30	0.10
	Lights	L-L	All	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Kitchen	People	K-P	WD	0.50	0.60	0.80	0.90	0.70	0.40	0.40	0.00
	"		WEH	0.50	0.60	0.70	0.80	0.60	0.30	0.20	0.00
	Lights	K-L	All	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.00
	Equipment	K-E	All	0.80	0.50	0.50	0.50	0.20	0.20	0.20	0.20

* WD = weekdays, WEH = weekends and holidays, All = all days.

Table 4.B.6 Comparison of prototype building energy use to NBECS for large hotels

Region	NBECS				City	DOE-2 Simulation		
	Total Electric * (kBtu/ft²)	Total Fuel (kBtu/ft²)	F/E Ratio Median	F/E Ratio Avg		Total Electric * (kBtu/ft²)	Total Fuel (kBtu/ft²)	F/E Ratio
Northeast	21.0	82.0	6.75	3.90	Boston	47.7	163.3	3.43
					New York	48.6	141.5	2.91
					Philadelphia	49.4	139.3	2.82
North Central	62.5	132.2	1.76	2.12	Chicago	50.1	166.8	3.33
					Detroit	47.7	176.5	3.70
					St. Louis	54.1	136.4	2.52
South	72.6	51.1	0.40	0.70	Miami	68.0	25.3	0.37
					New Orleans	59.7	54.4	0.91
					Houston	61.1	55.3	0.91
West	107.5	118.8	1.16	1.11	Los Angeles	43.1	59.7	1.38
					San Diego	43.9	50.6	1.15
					San Francisco	40.3	96.1	2.38
					Phoenix	54.7	51.8	0.95

* electricity kWh are converted to site Btus (1 kWh = 3413 Btu).

The NBECS data show energy consumption variations between different regions that are difficult to interpret. Fuel usage is high in the North Central and West, but low in the Northeast and South, while electricity usage is high in the South and North Central, and very high in the West. The simulated results, however, show high fuel usages in both Northeast and North Central cities and high electricity uses in the South, as would be expected based on their climates. Because of the observed anomalies in the NBECS data, the calibration has been done using national averages, rather than regional energy consumptions.

Simulation Results

Table 4.B.7 provides information on annual energy intensities for heating, cooling, lighting, and equipment end uses for the finalized large hotel prototypes.

Table 4.B.7 Summary of annual end use intensities for prototype large hotels
(electricity in kWh/ft^2 and fuel in kBtu/ft^2)

City	Shell	Eqp	Heating Elec.	Heating Fuel	Cooling Elec.	Fan Elec.	DHW Elec.	DHW Fuel	Lighting Elec.	Misc. Elec.	Misc. Fuel	Total Elec.	Total Fuel	F/E Ratio
Northeast														
Boston	Stk	Old	1.20	142.8	1.62	2.11	0.00	12.4	6.06	2.99	8.1	13.98	163.3	3.43
Boston	Stk	New	0.94	111.3	2.09	1.78	0.00	12.4	6.06	2.96	8.1	13.83	131.8	2.79
Boston	Cur	New	0.87	102.3	2.10	1.74	0.00	12.4	6.06	2.97	8.1	13.74	122.8	2.62
New York	Stk	Old	0.98	121.0	2.16	2.05	0.00	12.4	6.06	2.99	8.1	14.24	141.5	2.91
New York	Stk	New	0.77	95.2	2.61	1.74	0.00	12.4	6.06	2.97	8.1	14.15	115.7	2.40
New York	Cur	New	0.71	87.7	2.59	1.71	0.00	12.4	6.06	2.96	8.1	14.03	108.2	2.26
Philadelphia	Stk	Old	0.96	118.8	2.41	2.07	0.00	12.4	6.06	2.97	8.1	14.47	139.3	2.82
Philadelphia	Stk	New	0.75	93.3	2.83	1.76	0.00	12.4	6.06	2.99	8.1	14.39	113.8	2.32
Philadelphia	Cur	New	0.69	85.9	2.84	1.74	0.00	12.4	6.06	2.97	8.1	14.30	106.4	2.18
North Central														
Chicago	Stk	Old	1.21	146.9	2.26	2.18	0.00	11.9	6.06	2.97	8.1	14.68	166.8	3.33
Chicago	Stk	New	0.96	116.4	2.64	1.84	0.00	11.9	6.06	2.97	8.1	14.47	136.4	2.76
Chicago	Cur	New	0.90	109.2	2.69	1.82	0.00	11.9	6.06	2.97	8.1	14.44	129.1	2.62
Detroit	Stk	Old	1.25	156.5	1.59	2.09	0.00	11.9	6.06	2.99	8.1	13.98	176.5	3.70
Detroit	Stk	New	0.99	123.9	2.00	1.74	0.00	11.9	6.06	2.98	8.1	13.77	143.8	3.06
Detroit	Cur	New	0.94	116.3	2.01	1.72	0.00	11.9	6.06	2.98	8.1	13.71	136.3	2.91
St. Louis	Stk	Old	0.95	116.4	3.62	2.26	0.00	11.9	6.06	2.96	8.1	15.85	136.4	2.52
St. Louis	Stk	New	0.75	91.7	4.00	1.97	0.00	11.9	6.06	2.98	8.1	15.76	111.7	2.08
St. Louis	Cur	New	0.70	86.2	3.97	1.95	0.00	11.9	6.06	2.97	8.1	15.65	106.2	1.99
South														
Miami	Stk	Old	0.05	5.0	8.56	2.28	0.00	12.2	6.06	2.97	8.1	19.92	25.3	0.37
Miami	Stk	New	0.04	4.2	8.56	1.94	0.00	12.2	6.06	2.97	8.1	19.57	24.5	0.37
Miami	Cur	New	0.04	4.3	8.61	1.95	0.00	12.2	6.06	2.97	8.1	19.63	24.6	0.37
New Orleans	Stk	Old	0.31	34.0	5.91	2.24	0.00	12.2	6.06	2.97	8.1	17.49	54.4	0.91
New Orleans	Stk	New	0.24	27.5	6.27	1.96	0.00	12.2	6.06	2.99	8.1	17.52	47.8	0.80
New Orleans	Cur	New	0.24	26.9	6.24	1.95	0.00	12.2	6.06	2.97	8.1	17.46	47.2	0.79
Houston	Stk	Old	0.31	35.0	6.29	2.26	0.00	12.2	6.06	2.98	8.1	17.90	55.3	0.91
Houston	Stk	New	0.25	28.1	6.62	1.99	0.00	12.2	6.06	2.98	8.1	17.90	48.4	0.79
Houston	Cur	New	0.24	27.4	6.57	1.98	0.00	12.2	6.06	2.96	8.1	17.81	47.7	0.78
West														
Los Angeles	Stk	Old	0.35	39.8	1.40	1.85	0.00	11.9	6.06	2.97	8.1	12.63	59.7	1.38
Los Angeles	Stk	New	0.28	33.3	2.12	1.54	0.00	11.9	6.06	2.98	8.1	12.98	53.3	1.20
Los Angeles	Cur	New	0.27	32.5	2.12	1.54	0.00	11.9	6.06	2.99	8.1	12.98	52.5	1.19
San Diego	Stk	Old	0.28	30.6	1.65	1.89	0.00	11.9	6.06	2.98	8.1	12.86	50.6	1.15
San Diego	Stk	New	0.22	26.3	2.38	1.55	0.00	11.9	6.06	2.97	8.1	13.18	46.2	1.03
San Diego	Cur	New	0.22	25.6	2.36	1.55	0.00	11.9	6.06	2.97	8.1	13.16	45.6	1.01
San Francisco	Stk	Old	0.65	76.1	0.47	1.65	0.00	11.9	6.06	2.98	8.1	11.81	96.1	2.38
San Francisco	Stk	New	0.50	61.0	1.04	1.34	0.00	11.9	6.06	2.98	8.1	11.92	81.0	1.99
San Francisco	Cur	New	0.47	58.1	1.03	1.33	0.00	11.9	6.06	2.98	8.1	11.87	78.1	1.93
Phoenix	Stk	Old	0.29	31.8	4.66	2.04	0.00	11.9	6.06	2.98	8.1	16.03	51.8	0.95
Phoenix	Stk	New	0.23	26.0	5.05	1.88	0.00	11.9	6.06	2.98	8.1	16.20	46.0	0.83
Phoenix	Cur	New	0.23	25.3	4.98	1.86	0.00	11.9	6.06	2.98	8.1	16.11	45.3	0.82

4.C. EXTENDED HOUR SIT-DOWN RESTAURANT

Most of the energy use in restaurants occur as process load in the kitchens. These process loads include cooking, either electric or gas, hot water for dishwashing and cooking, and refrigeration. Restaurants also use significant amounts of energy for lighting, space heating, air conditioning, and ventilation. Because of the coincidence in their thermal and electrical demands, restaurants are prime candidates for cogeneration.

The two main factors that determine the appropriateness of cogeneration application in restaurants are the coincidence of their thermal and electrical loads and their hours of operations. For this project, we have identified the following two types of restaurants as prime cogeneration candidates: extended-hour sit-down and fast-food restaurants. Both of these restaurants have long hours of operation and high demands for thermal and electrical energy. In comparison to sit-down restaurants, however, fast-food restaurants have reduced dishwashing loads. This section of the report discusses the prototype development for the extended-hour sit-down restaurant. Fast-food restaurants are discussed in the next section.

Existing Data Sources

Literature information on prototypical sit-down restaurants are scarce. Of the various studies surveyed, only the LBL study has descriptions for a prototypical building based on on-site data obtained for Southern California (LBL 1989). The characteristics of the LBL building prototype are summarized in Table 4.C.1. Note that this prototype has 13 hours/day operation, rather than the extended 18 hours/day judged to be a better candidate for cogeneration.

This prototype sit-down restaurant is a single story building of 5,250 ft^2, and fairly high levels of insulation in the walls and roofs, probably reflecting the influence of state energy codes. The amount of exterior glass is about 13% of the floor area, all of which is single pane. The cooling set point is 75 F and the heating set point 72 F. The lighting intensity is 1.1 W/ft^2 which is typical for limited-hour sit-down restaurants, but rather low for 18-hour restaurants. The combined equipment and process load is 5.35 W/ft^2, and the peak floor area per occupant is 69 ft^2/person.

The heating and cooling of the restaurant is provided with a roof-top packaged single-zone system. Heating fuel can be either electricity or gas. The prototype does not have an economizer, but the percentage of outside fresh air is 40%. Hot water is provided by a gas fired water heater.

Besides the LBL prototype, we also reviewed monitored data on restaurant energy end-uses from another study (Mazzucchi 1986). This study conducted detailed end-use monitoring for seven restaurants including a coffee shop, a full-service limited-menu restaurant, and a expanded-menu full-service restaurant. Although there is no assurance

Table 4.C.1 Summary of Existing Studies of Sit-down Restaurants

Report: (see Table 2.3 for coding)	LBL
Geometry and U-values:	
Floor Area (ft^2)	5,252
Number of Stories	1
Percent of Glass in Wall (%)	12.0
Wall U-value ($Btu/ft^2 \cdot hr \cdot F$)	6.6
Roof U-value ($Btu/ft^2 \cdot hr \cdot F$)	12.8
Operating Conditions:	
Cooling Setpoint (F)	74.5
Heating Setpoint (F)	71.7
Standard Day Schedule	13 hrs
HVAC Equipment:	
Air Handling System Type	Packaged Single-zone
Cooling Plant Type	Packaged Single-zone
Economizer	N/A
% Outside Air (annualized)	40
Heating Plant Type	Packaged Single-zone
Internal Loads (peak):	
Occupants (ft^2/person)	69
Lighting (Watts/ft^2)	1.09
Equipment/Misc (Watts/ft^2)	5.35

Table 4.C.1A Summary of End Use Energy Intensities for Seven Restaurants

	Energy usage by end use (MBtu/ft^2)						
Restaurant Type	Food Prep.	Sani-tation	Refrig.	Light.	non-HVAC	HVAC	Total
Cafeteria	243.0	178.0	20.1	43.9	484	128	612
Coffee shop	114.0	85.8	13.9	64.8	279	112	391
Full-service limited menu	99.5	84.7	41.5	73.9	299	108	407
Full-service expanded menu	179.0	132.0	37.3	61.9	410	140	550
Pizza	159.0	93.8	46.8	65.3	364	151	515
Fast-food limited menu	324.0	66.6	30.5	140.0	561	173	734
Fast-food expanded menu	216.0	42.0	33.2	67.9	359	263	622

notes: Food Prep. includes processing, cooking, and heating of food. Sanitation includes water heating, dishwashing, and laundry. Refrig. includes refrigeration, coolers, and freezers. Light. includes interior and extrior lighting. HVAC includes space heating, cooling, and ventilation.

Source: Mazzucchi 1986.

that these buildings are statistically representative, the data has been helpful for specifying the internal and process loads in the prototype restaurants. Table 4.C.1A summarizes the energy use intensities from the Mazzucchi study.

Statistical Data

Statistical data obtained from NBECS for sit-down restaurants are shown in Table 4.C.2 for four U.S. census regions. These buildings are a subset of the "Food Sales" building type selected using the building activity identifier of "Full-service restaurant". Therefore, the buildings may not be statistically balanced but they are still useful for defining average building characteristics. These NBECS buildings have average floor areas ranging from 2,900 to 5,700 ft^2, and are all single-storied. The reported operational hours by region are about 11 to 14 hours during the weekdays, and 9 to 14 hours during the weekend. For this project, a 18-hour sit-down restaurant has been simulated.

NBECS also reports the average glass area to be fairly constant from 22 to 29% of the wall area, and that restaurants in all four census regions have some insulation in the walls and ceilings. The NBECS restaurants have either gas or fuel heating, electric cooling, and fuel/electric ratio varying from 0.8 in the South to 2.0 in the Northeast. The energy intensities of the NBECS data are in the range of 262 to 364 $kBtu/ft^2$ in site energy. Although the NBECS energy intensities are lower than those reported by Mazzucchi (1986), they are used for calibrating the prototype sit-down restaurants since the sampling size is larger and covers different areas of the nation.

Prototype Buildings

Prototype sit-down restaurants with extended-hour operations have been developed for the 13 cities of interest based on the data discussed above. Since restaurants are process loads dominant buildings, vintage variations in the building shell have been ignored and the analyses done using a single average building in each Market Area. The major characteristics of these prototype buildings are listed in Table 4.C.3. Comments of the sizes and characteristics of the buildings are discussed below.

Size

The prototype building sizes are derived from the Dodge Building Start data that show the numbers and total square footages of "Food Sales" buildings constructed in each Market Area from 1966 to 1988. Roughly 2-5% of the buildings which are over 20,000 ft^2 have been eliminated as either data errors or non-restaurant buildings. Based on national statistics, half of the remaining buildings are assumed to be fast-food restaurants (see following section) with a fixed square footage of 2,500 ft^2. The average sizes of the sit-down restaurants are then calculated by dividing the remaining square

Table 4.C.2 NBECS Statistics for Sit-down Restaurants

Parameter	Region Northeast	 North Central	 South	 West
Average Floor Area (x1000 ft^2)	5.7	4.8	2.9	3.1
Median Fuel/elec ratio	2.0	1.3	0.8	1.3
Average No. Floors	1	1	1	1
Average No. Employees	14	19	11	13
Average Hours Wkday	13	14	11	13
Average Hours Wkend	11	14	9	12
Average Total $kBtu/ft^2$	299	262	464	352
Average Elec $kBtu/ft^2$	124	114	240	148
Average Fuel $kBtu/ft^2$	175	149	229	204
Glass covers <25%	54	66	57	60
Glass covers 25-50%	25	31	28	29
Glass covers 50-75%	21	3	15	11
Glass covers >75%	0	0	0	0
Average glass area (%)	29	22	27	25
% Conservation glass	51	64	38	49
% Wall insulation	48	45	49	45
% Roof/ceiling insulation	31	54	40	55
% Heating setback	65	85	90	90
% Cooling setup	62	85	91	57
% Central heating	80	92	71	76
% Heating system uses furnaces/boilers	68	84	34	57
% Boilers present	36	13	6	3
% Electricity fires boilers	0	0	3	0
% Heat provided by other system	31	14	44	19
% Forced air fans	48	81	62	61
% Heat distributed from baseboards	27	15	5	9
% Electric baseboards	24	8	4	9
% Hot water baseboards	4	6	1	0
% Steam baseboards	1	0	0	0
% Heat fr. radiators/convectors	39	10	3	0
% Heating panels	38	17	3	7
% Other heat distribution	13	9	16	14
% Central air-conditioning	44	68	69	55

Table 4.C.3 Building Descriptions for Sit-down Restaurant Prototypes

Building Parameter	North-east	North Central	South	West
Floor Areas (x1000 ft^2)				
	Bos: 5.14	Chi: 3.30	Mia: 3.78	LA: 3.58
	NY: 3.08	Det: 3.25	NO: 3.30	SF: 7.70
	Phi: 3.70	StL: 4.40	Hou: 3.50	SD: 5.00
				Phx: 5.25
No. of floors	1	1	1	1
Shell characteristics (*Average* vintage)				
Ceiling R-value	5.0	9.7	5.6	6.6
Wall R-value	4.8	5.0	1.5	2.3
Window glass	1-pane	1-pane	1-pane	1-pane
Window shad. coeff				
Window/wall ratio	0.29	0.22	0.27	0.25
Internal loads				
Ft^2/person	50	50	50	50
Lights W/ft^2				
dining	2.0	2.0	2.0	2.0
kitchen	2.5	2.5	2.5	2.5
Equip W/ft^2	10.0	10.0	10.0	10.0
Process kBtu/ft^2	90	90	90	90
Refrig. W/ft^2	1.0	1.0	1.0	1.0
System Type	2 systems; one for dining area and one for kitchen.			
Old equipment	Packaged single zone constant volume for all regions			
New equipment	Packaged single zone variable-air-volume for all regions			
Heat setpoint	72 F			
Cool setpoint	75 F			
Heating plant	Gas furnace	Gas furnace	Gas furnace	Gas furnace
Compresssor	Direct expansion	Direct expansion	Direct expansion	Direct expansion
Hot water	gas	gas	gas	gas

footages by the remaining building counts.

These sizes are fairly uniform and essentially the same as shown by NBECS. The prototypes are somewhat larger in the West (3600 to 7700 ft^2), and from 3000 to 4000 ft^2 in the other three regions, except for 5140 ft^2 in Boston (see Table 4.C.3).

Shell Characteristics

The sit-down restaurants are modeled with wood-frame construction and a square shape. An *Average* vintage representing both existing and future construction has been derived by averaging the amounts of insulation from NBECS with those recommended by ASHRAE 90.1-1989 standards. The NBECS data covers buildings built prior to 1983, while the ASHRAE standard covers buildings built from 1990 on. Since the NBECS data are statistically representative only at the level of census regions, the same characteristics were used for all cities within the same region. The building characteristics used for the DOE-2 modeling are listed in the bottom part of Table 4.C.3.

Zone Conditions

The prototypical sit-down restaurants are modeled with two very different occupancy and load patterns. The kitchen occupies 20% of the building, with the remaining 80% being the dining area including the lobby and washrooms. The lighting intensity is assumed to be 2.5 W/ft^2 in the kitchen and 2.0 W/ft^2 in the dining area. The equipment intensity is assumed to be 0.1 W/ft^2 in the dining area, and 10.0 W/ft^2 in the kitchen to account for the process load of oven, ranges, and other cooking equipment. The process thermal load is assumed to be 90 kBtu/ft^2·hr. The hot water usage is 50 Btu/person per day.

Schedules

The occupancy, equipment, hot water and lighting schedules are summarized in Table 4.C.5. The lighting schedule is assumed to be 90 percent of the peak lighting intensity for hours 7 a.m. to 5 p.m. during the normal weekday operations. For other weekday hours and during weekends and holidays lighting schedule is 20 per cent. The lighting and equipment schedules are modeled as simple square waves, i.e., 100 per cent for 7 a.m. to 5 p.m. of weekdays and 17 per cent for all other hours of the weekday and all weekends and holidays.

Systems

The sit-down restaurants prototypes are modeled with heating and cooling supplied by two rooftop packaged single-zone air-conditioning units, one serving the kitchen and

Table 4.C.5 Hourly Load Profiles for Sit-down Restaurant

Zone	End-use(s)	Day type*	1	2	3	4	5	6	7	8	9	10	11	12
Dining	People	WD	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.30	0.10	0.05	0.20	0.50
"	"	WEH	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.40	0.50	0.20	0.20	0.30
Kitchen	"	All	0.50	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Dining	Light	All	0.20	0.20	0.20	0.20	0.20	0.20	1.00	1.00	1.00	1.00	1.00	1.00
Kitchen	"	All	0.10	0.10	0.10	0.10	0.10	1.00	1.00	1.00	1.00	1.00	1.00	1.00
"	Equipment	All	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.10	0.15	0.20	0.60	0.70
Building	Refrigeration + Ext. Lights	All	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.90	0.90	0.90	0.90	0.90

Zone	End-use(s)	Day type*	13	14	15	16	17	18	19	20	21	22	23	24
Dining	People	WD	0.50	0.40	0.20	0.05	0.10	0.40	0.60	0.50	0.40	0.20	0.10	0.00
"	"	WEH	0.50	0.50	0.50	0.35	0.25	0.50	0.80	0.80	0.70	0.40	0.20	0.00
Kitchen	"	All	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Dining	Light	All	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Kitchen	"	All	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
"	Equipment	All	0.50	0.40	0.10	0.10	0.40	0.70	0.80	0.55	0.40	0.35	0.10	0.00
Building	Refrigeration + Ext. Lights	All	0.90	0.90	0.90	0.90	0.90	0.90	1.00	1.00	1.00	1.00	1.00	1.00

(Hour of Day)

* WD = weekdays, WEH = weekends and holidays, All = all days.

the other serving the dining area. The heating and cooling setpoints are assumed to be 72 F and 75 F, respectively. The system is assumed to be a constant air volume system for buildings with *Old* (pre-1981) equipment and a variable air volume system for buildings with *New* (post-1981) equipment.

Calibration

We have simulated the prototype buildings to estimate the heating and cooling load of buildings. Before finalizing the prototype descriptions, we have compared the simulation results with NBECS and other available measured data and accordingly modified the prototypes for better comparisons. The simulated total electricity and fuel use of the prototypical sit-down restaurants in 13 cities and comparison with NBECS consumption data are shown in Table 4.C.6.

Table 4.C.6 Comparison of prototype building energy use to NBECS for sit-down restaurants

Region	NBECS				City	DOE-2 Simulation		
	Total Electric * (kBtu/ft^2)	Total Fuel (kBtu/ft^2)	F/E Ratio Median	F/E Ratio Avg		Total Electric * (kBtu/ft^2)	Total Fuel (kBtu/ft^2)	F/E Ratio
Northeast	124.1	175.1	2.00	1.41	Boston	139.5	214.8	1.54
					New York	158.5	208.4	1.31
					Philadelphia	155.5	201.7	1.30
North Central	113.5	149.2	1.30	1.31	Chicago	154.9	225.8	1.46
					Detroit	149.4	236.8	1.58
					St. Louis	154.6	188.6	1.22
South	240.4	229.4	0.80	0.95	Miami	203.1	110.6	0.54
					New Orleans	183.0	129.6	0.71
					Houston	183.5	130.5	0.71
West	148.3	203.8	1.30	1.37	Los Angeles	148.6	119.8	0.81
					San Diego	140.1	113.6	0.81
					San Francisco	121.8	135.8	1.11
					Phoenix	175.6	121.2	0.69

* electricity kWh are converted to site Btus (1 kWh = 3413 Btu).

Simulation Results

Table 4.C.7 provides information on annual energy intensities for heating, cooling, lighting, and equipment end uses for the finalized sit-down restaurant prototypes.

Table 4.C.7 Summary of annual end use intensities for prototype sit-down restaurants
(electricity in kWh/ft^2 and fuel in kBtu/ft^2)

			Heating		Cooling	Fan	DHW		Lighting	Misc.		Total	Total	F/E
City	Shell	Eqp	Elec.	Fuel	Elec.	Elec.	Elec.	Fuel	Elec.	Elec.	Fuel	Elec.	Fuel	Ratio
Northeast														
Boston	Avg	Old	0.00	109.5	4.38	4.22	0.00	59.6	27.71	4.56	45.6	40.87	214.8	1.54
Boston	Avg	New	0.00	109.5	3.44	4.22	0.00	59.6	27.71	4.57	45.6	39.94	214.8	1.58
New York	Avg	Old	0.00	103.2	5.99	4.50	0.00	59.6	31.39	4.56	45.6	46.44	208.4	1.31
New York	Avg	New	0.00	103.2	4.81	4.50	0.00	59.6	31.39	4.57	45.6	45.27	208.4	1.35
Philadelphia	Avg	Old	0.00	96.5	6.56	4.59	0.00	59.6	29.85	4.56	45.6	45.56	201.7	1.30
Philadelphia	Avg	New	0.00	96.5	5.29	4.59	0.00	59.6	29.85	4.57	45.6	44.30	201.7	1.33
North Central														
Chicago	Avg	Old	0.00	120.6	5.76	4.26	0.00	59.6	30.79	4.58	45.6	45.39	225.8	1.46
Chicago	Avg	New	0.00	120.6	4.67	4.26	0.00	59.6	30.79	4.55	45.6	44.27	225.8	1.49
Detroit	Avg	Old	0.00	131.5	4.36	3.96	0.00	59.6	30.91	4.54	45.6	43.77	236.8	1.58
Detroit	Avg	New	0.00	131.5	3.52	3.96	0.00	59.6	30.91	4.56	45.6	42.95	236.8	1.62
St. Louis	Avg	Old	0.00	83.3	8.12	3.98	0.00	59.6	28.63	4.57	45.6	45.30	188.6	1.22
St. Louis	Avg	New	0.00	83.3	6.66	3.98	0.00	59.6	28.63	4.56	45.6	43.83	188.6	1.26
South														
Miami	Avg	Old	0.00	5.4	20.74	4.51	0.00	59.6	29.68	4.58	45.6	59.51	110.6	0.54
Miami	Avg	New	0.00	5.4	17.18	4.51	0.00	59.6	29.68	4.56	45.6	55.93	110.7	0.58
New Orleans	Avg	Old	0.00	24.4	13.78	4.48	0.00	59.6	30.79	4.57	45.6	53.62	129.6	0.71
New Orleans	Avg	New	0.00	24.4	11.32	4.48	0.00	59.6	30.79	4.57	45.6	51.16	129.6	0.74
Houston	Avg	Old	0.00	25.2	14.32	4.58	0.00	59.6	30.31	4.56	45.6	53.77	130.5	0.71
Houston	Avg	New	0.00	25.2	11.79	4.58	0.00	59.6	30.31	4.57	45.6	51.25	130.5	0.75
West														
Los Angeles	Avg	Old	0.00	14.5	4.41	4.46	0.00	59.6	30.11	4.56	45.6	43.54	119.8	0.81
Los Angeles	Avg	New	0.00	14.5	3.01	4.46	0.00	59.6	30.11	4.55	45.6	42.13	119.8	0.83
San Diego	Avg	Old	0.00	8.4	4.88	3.74	0.00	59.6	27.86	4.57	45.6	41.05	113.6	0.81
San Diego	Avg	New	0.00	8.4	3.54	3.74	0.00	59.6	27.86	4.56	45.6	39.70	113.6	0.84
San Francisco	Avg	Old	0.00	30.5	1.60	3.65	0.00	59.6	25.87	4.57	45.6	35.69	135.8	1.11
San Francisco	Avg	New	0.00	30.5	1.04	3.65	0.00	59.6	25.87	4.57	45.6	35.13	135.8	1.13
Phoenix	Avg	Old	0.00	16.0	14.28	5.03	0.00	59.6	27.59	4.55	45.6	51.45	121.2	0.69
Phoenix	Avg	New	0.00	16.0	11.64	5.03	0.00	59.6	27.59	4.55	45.6	48.81	121.2	0.73

4.D FAST-FOOD RESTAURANT

The previous section discussed the development of prototypical buildings for extended-hour sit-down restaurants. This section describes a similar effort to develop prototypical buildings for fast-food restaurants.

There are basically three types of fast-food restaurants: fast-food with limited menu, fast-food with expanded menu, and coffee shops. In this study, specialty restaurants such as pizza parlors have not been considered.

Energy is used in fast-food restaurants for HVAC, lighting, and kitchen processes. These process loads include cooking (either electric or gas), hot water for dishwashing and cooking, and refrigeration. Since fast-food restaurants use disposable dishes, hot water usage is limited to dish washing for kitchen application only. On the other hand, fast-food restaurants usually have higher energy intensities than sit-down restaurants for lighting, space heating, air conditioning, and ventilation.

Existing Data Sources

Literature information on prototypical fast-food restaurants is limited to studies by EPRI, MEOS, and LBL. The EPRI study represents national data, while the MEOS study is representative of the North Central region. The LBL study produced a prototype fast-food restaurant based on on-site data obtained from a southern California utility company. The characteristic highlights of these three prototypes are summarized in Table 4.D.1.

The prototypical restaurants in all three studies are single-story buildings with floor areas of 1,400 to 4,000 ft^2. Their levels of ceiling and wall insulation vary by a factor of 2, with the restaurants in the East (EPRI and MEOS) better insulated than in the West (LBL). The percentage of exterior glass area also varies from 8% to 30%. The LBL study shows a much lower percentage of exterior glass because it averages extended-hour fast-food with family-owned limited-hours operations which are more like traditional coffee shops. The cooling set point varies from 72 to 75 F and the heating set point from 68 to 72 F. The lighting intensities are in the range of 1.4 to 1.7 W/ft^2, which are typical of fast-food restaurants (The higher lighting intensity of 1.7 W/ft^2, however, is more appropriate for the extended-hour chain fast-food restaurants being considered in this project). The electric equipment and process load varies from 0.3 to 5.1 W/ft^2. This large variation depends on whether the prototype uses gas or electricity for kitchen equipment. The peak occupancy in the three prototypes also varies substantially from 29 to 82 ft^2/person.

The heating and cooling systems in all three studies are assumed to be packaged single-zone systems, with the heating fuel either electricity or gas. The prototypes do not have economizers, but the percentages of outside fresh air are fairly high, from 22 to

Table 4.D.1 Summary of Existing Studies of Fast Food Restaurants

Report: (see Table 2.3 for coding)	EPRI	MEOS	LBL
Geometry and U-values:			
Floor Area (ft^2)	4,000	1,764	1,391
Number of Stories	1	1	N/A
Percent of Glass in Wall (%)	21	30	8
Wall U-value ($Btu/ft^2 \cdot hr \cdot F$)	0.11	0.184	0.177
Roof U-value ($Btu/ft^2 \cdot hr \cdot F$)	0.05	0.075	0.111
Operating Conditions:			
Cooling Setpoint (F)	75/82	72/off	73
Heating Setpoint (F)	72/68	68/65	68
Standard Day Schedule	7-24	7-21	9-21
HVAC Equipment:			
Air Handling System Type	PSZ	PSZ	PSZ
Cooling Plant Type	Direct Expansion	Direct Expansion	Direct Expansion
Economizer	N/A	N	N/A
% Outside Air (annualized)	22	20	31
Heating Plant Type	Gas Furnace	Gas Furnace	N/A
Internal Loads (peak):			
Occupants (ft^2/person)	57	29	82
Lighting (Watts/ft^2)	1.64	1.68	1.38
Equipment/Misc (Watts/ft^2)	0.50	0.29	5.11

31%. The prototypes use gas water heater for domestic hot water and dish washing applications.

Besides these prototypical studies, monitored data on several actual fast-food restaurants are also available from another study (Mazzucchi 1986, see Table 4.C.1A). This study conducted detailed end-use energy monitoring data for seven restaurants, of which two are fast-food restaurants. Although there is no assurance that these buildings are statistically representative, the data has been helpful for specifying the internal and process loads in the prototype fast-food restaurants.

Table 4.D.2 NBECS Statistics for Fast-foods Restaurants

Parameter	Region: Northeast	North Central	South	West
Average Floor Area (x1000 ft^2)	4.6	5.1	2.6	1.4
Median Fuel/elec ratio	1.1	1.2	0.8	0.0
Average No. Floors	1	1	1	1
Average No. Employees	17	21	12	37
Average Hours Wkday	12	15	11	11
Average Hours Wkend	12	14	9	12
Average Total kBtu/ft^2	458	464	417	182
Average Elec kBtu/ft^2	210	207	263	118
Average Fuel kBtu/ft^2	249	257	154	63
Glass covers <25%	23	59	44	24
Glass covers 25-50%	74	24	33	31
Glass covers 50-75%	3	17	23	45
Glass covers >75%	0	0	9	0
Average glass area (%)	32	27	40	43
% Conservation glass	58	60	21	32
% Wall insulation	35	66	41	31
% Roof/ceiling insulation	56	50	83	55
% Heating setback	72	83	71	79
% Cooling setup	47	85	51	24
% Central heating	88	100	68	69
% Heating system uses furnaces/boilers	77	75	50	48
% Boilers present	19	2	0	24
% Electricity fires boilers	0	0	0	0
% Heat provided by other system	23	48	27	22
% Forced air fans	58	91	60	48
% Heat distributed from baseboards	20	11	6	31
% Electric baseboards	0	9	6	31
% Hot water baseboards	18	0	0	0
% Steam baseboards	2	2	0	0
% Heat fr. radiators/convectors	14	10	1	0
% Heating panels	12	17	14	2
% Other heat distribution	0	0	0	31
% Central air-conditioning	63	77	74	22

Statistical Data

Statistical data obtained from NBECS for fast-food restaurants are shown in Table 4.D.2 for four U.S. census regions. These buildings are a subset of the "Food Sales" building type selected using the building activity identifiers of "Limited-service restaurant" or "Cafeteria". Therefore, the buildings may not be statistically balanced but they are still useful for defining average building characteristics. These NBECS buildings have average floor areas ranging from 2,600 to 14,200 ft^2, and are all single-storied. The reported operational hours for these NBECS "fast-food restaurants" are about 11 to 15 hours during weekdays and 9 to 14 hours during weekends. For this project, 18-hour fast-food restaurants have been simulated.

NBECS also reports these restaurants have average glass areas varying from 27 to 43% depending on census region, and some wall and ceiling insulation in all regions. In our prototype buildings, we simulate the insulation levels using the averages reported in NBECS. The NBECS "fast-food" restaurants have either gas or fuel heating, electric cooling equipment, and fuel/electric ratios varying from 0.0(!) in the West to 1.2 in North Central. The absence of fuel usage is not considered representative for even one region of the country.

The energy intensity of the NBECS "fast-food" restaurants range from 180 to 460 kBtu/ft^2 in site energy. These intensities are lower than those reported by Mazzucchi (1986), particularly for the West region. This can be attributed to the imprecise building activity identifier, which probably included cafeterias and other non-fast-food restaurants. For this project, the energy intensities from both the Mazzucchi study and NBECS have been used to calibrate the prototype fast-food restaurants.

Prototype Buildings

Prototype fast-food restaurants have been developed for the 13 cities of interest combining the data discussed above and engineering judgement. Since restaurants are process loads dominant buildings, vintage variations in the building shell have been ignored and the analyses done using a single average building in each Market Area. The major characteristics of these prototype buildings are listed in Table 4.D.3. Comments on the sizes and characteristics of the buildings are discussed below.

Size

Based on staff experience in developing the LBL restaurant prototype, it has been observed that fast-food restaurants do not vary greatly in building size. The average building sizes obtainable from the Dodge Building Start data are for both sit-down and fast-foods restaurants. As discussed in the previous section, these variations in

Table 4.D.3 Building Descriptions for Fast Food Restaurant Prototypes

Building Parameter	North-east	North Central	South	West
Floor Area (ft^2)	2500	2500	2500	2500
No. of floors	1	1	1	1
Shell characteristics (*Average* vintage)				
Ceiling R-value	9.0	9.0	11.6	6.6
Wall R-value	3.5	7.3	1.2	1.6
Window glass	1-pane	1-pane	1-pane	1-pane
Window shad. coeff				
Window/wall ratio	0.32	0.27	0.40	0.43
Internal loads				
Ft^2/person	65	65	65	65
Lights W/ft^2 (kitchen)	2.5	2.5	2.5	2.5
Lights W/ft^2 (dining)	1.7	1.7	1.7	1.7
Equip W/ft^2	5.0	5.0	5.0	5.0
Process kBtu/ft^2	20	20	20	20
Process W/ft^2	1.4	1.4	1.4	1.4
System Type	2 systems; one for dining area and one for kitchen.			
Old equipment	Packaged single zone constant volume for all regions			
New equipment	Packaged single zone variable-air-volume for all regions			
Heat setpoint	72 F			
Cool setpoint	75 F			
Heating plant	gas furnace	gas furnace	gas furnace	gas furnace
Chiller type	direct expansion	direct expansion	direct expansion	direct expansion
Hot water	gas	gas	gas	gas

† constant for all cities but varies by building zone, numbers are approximate since zone peaks may not be coincident.

restaurant size by Market Area have been attributed to the sit-down, and not the fast-food, restaurant stock. The sizes of the fast-food restaurants have been assumed to be 2,500 ft^2 in all market areas, based on staff experience and review of the Mazzucchi study (1986).

Shell Characteristics

An average shell condition representing existing and future construction has been derived by averaging the amounts of insulation from NBECS with those recommended by ASHRAE 90.1-1989 standards. The NBECS data covers buildings built prior to 1983, while the ASHRAE standard covers buildings built from 1990 on. Since the NBECS data are statistically representative only at the level of census regions, the same characteristics were used for all cities within the same region. The building characteristics used for the DOE-2 modeling are listed in the bottom part of Table 4.D.3.

The fast-food restaurant is modeled as a square slab-on-grade building with concrete block walls with single-pane windows and a built-up roof. The floor area is evenly divided between dining and kitchen areas. The kitchen has no windows and the dining area has a window/wall ratio of between 0.27 and 0.43 depending on the region.

Zone Conditions

The prototypical fast-food restaurants are modeled with two very different occupancy and load patterns. The dining area has recessed fluorescent lighting with an intensity of 1.7 W/ft^2 and no equipment or process loads. The kitchen area has suspended fluorescent lighting with an intensity of 2.5 W/ft^2, an equipment intensity of 5 W/ft^2 and a hot water load of 20 $kBtu/ft^2$-hr. Refrigeration load is assumed to be 1.4 W/ft^2, none of which contributes to the internal gains since the condensers and compressors are roof mounted.

Schedules

The occupancy, equipment, hot water and lighting schedules are summarized in Table 4.D.5. The prototype fast-food restaurant is open from 7:00 a.m. until 12:00 a.m. every day. Occupancy varies between 5 percent and 80 percent of peak with higher rates on the weekends. Indoor lighting has a constant on level of 90 percent of peak and an off level of 20 percent of peak. The outdoor lighting is lumped into the refrigeration so as not to add to the internal gains.

Table 4.D.5 Hourly Load Profiles for Fast-foods Restaurant

Zone	End-use(s)	Day type*	Hour of Day 1	2	3	4	5	6	7	8	9	10	11	12
Bldg	People	WD	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.30	0.10	0.05	0.05	0.20
"	"	WEH	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.40	0.50	0.20	0.20	0.30
"	Lights	All	0.20	0.20	0.20	0.20	0.20	0.20	0.90	0.90	0.90	0.90	0.90	0.90
"	Fans	All	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Zone	End-use(s)	Day type*	Hour of Day 13	14	15	16	17	18	19	20	21	22	23	24
Bldg	People	WD	0.35	0.40	0.20	0.05	0.05	0.20	0.40	0.40	0.20	0.20	0.10	0.05
"	"	WEH	0.55	0.80	0.50	0.35	0.25	0.50	0.60	0.80	0.70	0.30	0.20	0.10
"	Lights	All	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
"	Fans	All	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

* WD = weekdays, WEH = weekends and holidays, All = all days.

Systems

The fast-food restaurant prototypes are modeled with heating and cooling supplied by two rooftop packaged single-zone air-conditioning units, one serving the kitchen and the other serving the dining area. The heating and cooling setpoints are assumed to be 72° F and 75° F, respectively. The system is assumed to be a constant air volume system for buildings with *Old* (pre-1981) equipment and a variable air volume system for buildings with *New* (post-1981) equipment.

Calibration

In order to calibrate the fast-food restaurant, initial end-use intensities from the prototype were compared to those in the Mazzucchi study. HVAC energy use was reasonable but other peak energy intensities had to be adjusted so that the percentage of total energy use was similar.

The simulated total electricity and fuel use of the prototypical fast-food restaurants in 13 cities and comparison with NBECS consumption data are shown in Table 4.D.6.

Table 4.D.6 Comparison of prototype building energy use to NBECS for fast-foods restaurants

Region	NBECS				City	DOE-2 Simulation		
	Total Electric * (kBtu/ft^2)	Total Fuel (kBtu/ft^2)	F/E Ratio Median	F/E Ratio Avg		Total Electric * (kBtu/ft^2)	Total Fuel (kBtu/ft^2)	F/E Ratio
Northeast	209.8	248.5	1.10	1.18	Boston	142.8	313.8	2.20
					New York	148.3	278.4	1.88
					Philadelphia	151.7	274.4	1.81
North Central	206.5	257.3	1.20	1.25	Chicago	148.4	318.5	2.15
					Detroit	141.1	336.0	2.38
					St. Louis	159.4	262.1	1.64
South	263.4	153.6	0.80	0.58	Miami	216.0	91.6	0.42
					New Orleans	183.9	133.1	0.72
					Houston	186.8	135.2	0.72
West	118.3	63.2	0.00	0.53	Los Angeles	141.7	130.3	0.92
					San Diego	141.4	116.2	0.82
					San Francisco	132.5	195.9	1.48
					Phoenix	195.2	127.7	0.65

* electricity kWh are converted to site Btus (1 kWh = 3413 Btu).

Simulation Results

Table 4.D.7 provides information on annual energy intensities for heating, cooling, lighting, and equipment end uses for the existing stock of fast-food restaurants.

Table 4.D.7 Summary of annual end use intensities for prototype fastfoods restaurants
(electricity in kWh/ft^2 and fuel in $kBtu/ft^2$)

			Heating		Cooling	Fan	DHW		Lighting	Misc.		Total	Total	F/E
City	Shell	Eqp	Elec.	Fuel	Elec.	Elec.	Elec.	Fuel	Elec.	Elec.	Fuel	Elec.	Fuel	Ratio
Northeast														
Boston	Avg	Old	0.00	232.6	4.64	5.54	0.00	34.1	25.77	5.89	47.1	41.84	313.8	2.20
Boston	Avg	New	0.00	232.6	3.90	5.54	0.00	34.1	25.77	5.90	47.1	41.11	313.8	2.24
New York	Avg	Old	0.00	197.1	6.25	5.56	0.00	34.1	25.77	5.87	47.1	43.45	278.4	1.88
New York	Avg	New	0.00	197.1	5.24	5.56	0.00	34.1	25.77	5.89	47.1	42.46	278.4	1.92
Philadelphia	Avg	Old	0.00	193.2	7.11	5.67	0.00	34.1	25.77	5.90	47.1	44.45	274.4	1.81
Philadelphia	Avg	New	0.00	193.2	5.96	5.67	0.00	34.1	25.77	5.88	47.1	43.28	274.4	1.86
North Central														
Chicago	Avg	Old	0.00	237.2	6.35	5.47	0.00	34.1	25.77	5.89	47.1	43.48	318.5	2.15
Chicago	Avg	New	0.00	237.2	5.34	5.47	0.00	34.1	25.77	5.90	47.1	42.48	318.5	2.20
Detroit	Avg	Old	0.00	254.8	4.42	5.28	0.00	34.1	25.77	5.87	47.1	41.34	336.0	2.38
Detroit	Avg	New	0.00	254.8	3.74	5.28	0.00	34.1	25.77	5.88	47.1	40.67	336.0	2.42
St. Louis	Avg	Old	0.00	180.9	9.61	5.42	0.00	34.1	25.77	5.90	47.1	46.70	262.1	1.64
St. Louis	Avg	New	0.00	180.9	8.07	5.42	0.00	34.1	25.77	5.89	47.1	45.15	262.1	1.70
South														
Miami	Avg	Old	0.00	10.4	26.05	5.57	0.00	34.1	25.77	5.90	47.1	63.29	91.6	0.42
Miami	Avg	New	0.00	10.4	21.74	5.57	0.00	34.1	25.77	5.90	47.1	58.98	91.6	0.46
New Orleans	Avg	Old	0.00	51.9	16.73	5.51	0.00	34.1	25.77	5.87	47.1	53.88	133.1	0.72
New Orleans	Avg	New	0.00	51.9	13.98	5.51	0.00	34.1	25.77	5.90	47.1	51.16	133.1	0.76
Houston	Avg	Old	0.00	53.9	17.47	5.60	0.00	34.1	25.77	5.89	47.1	54.73	135.2	0.72
Houston	Avg	New	0.00	53.9	14.61	5.60	0.00	34.1	25.77	5.88	47.1	51.86	135.2	0.76
West														
Los Angeles	Avg	Old	0.00	49.1	3.77	6.08	0.00	34.1	25.77	5.90	47.1	41.52	130.3	0.92
Los Angeles	Avg	New	0.00	49.1	2.97	6.08	0.00	34.1	25.77	5.88	47.1	40.70	130.3	0.94
San Diego	Avg	Old	0.00	35.0	4.25	5.51	0.00	34.1	25.77	5.90	47.1	41.43	116.2	0.82
San Diego	Avg	New	0.00	35.0	3.45	5.51	0.00	34.1	25.77	5.88	47.1	40.61	116.2	0.84
San Francisco	Avg	Old	0.00	114.7	1.55	5.60	0.00	34.1	25.77	5.90	47.1	38.82	195.9	1.48
San Francisco	Avg	New	0.00	114.7	1.29	5.60	0.00	34.1	25.77	5.90	47.1	38.56	195.9	1.49
Phoenix	Avg	Old	0.00	46.5	18.94	6.58	0.00	34.1	25.77	5.90	47.1	57.19	127.7	0.65
Phoenix	Avg	New	0.00	46.5	15.78	6.58	0.00	34.1	25.77	5.90	47.1	54.03	127.7	0.69

4.E LARGE OFFICE

Large offices are, in general, the fastest growing sector in all major utility service areas across the country. For that reason analysis of the energy consumption in large offices has been the subject of many detailed studies. The potential of large offices in providing their energy services through cogeneration systems is of real interest, particularly in offices with long hours of operation. For this project, large office prototypes have been developed with two operating modes: 12 and 24 hours of operation.

Existing Data Sources

Literature information for large offices are generally more available than any other building types. We have obtained information on 10 earlier studies addressing office buildings. The characteristics for building prototypes resulted from these studies are summarized in Table 4.E.1. Most previous studies reflect the characteristics of buildings in fairly limited areas. For instance, the four studies in Northeast Utilities service area (NEU) describe characteristics for large office buildings with VAV and non-VAV systems with and without mainframe computers. Other studies are also fairly regional: MEOS summarizes building characteristics for Michigan; LBL's is for southern California; EPRI's is derived from NBECS data and it does not have any regional variation; ConEd's is for buildings in Northeast; and PNL's represents an actual building.

The prototype building characteristics among these studies are fairly similar; variations in floor area does not significantly affect the energy use intensities. The floor areas ranges from 60,000 to over 500,000 ft^2 with a majority in the range of 80,000 - 160,000 ft^2. Except for two studies, PNL and ConEd, the prototypes have 6-7 stories. The wall and roof insulations of all these prototypes agree within a factor of two. The percentage of exterior glass are mainly in the range of 28 to 36. The operational schedules are usually 8-18, the cooling set point are 75 F to 78 F with nighttime set up, and the heating set points are 70 F to 72 F with nighttime setback of 65 F. The lighting intensity is in the range of 1.5 to 2.2 W/ft^2. The equipment load in these studies vary widely: form 0.07 to 1.23 W/ft^2. These variations could be attributed mainly to presense of significant computer loads in some prototypes.

By far the most variation in these buildings are in heating, cooling equipment, and distribution systems. Prototypes of newer office buildings tend to have VAV air handling systems with central heating and cooling plants; gas or fuel boilers where ever available. Some buildings also are equipped with economizers.

Table 4.E.1 Building Descriptions for Large Office Prototypes

Report:	ConEd	EPRI	MEOS	NEU1(1)*	NEU1(2)*	NEU1(3)*	NEU1(4)*	NEU2	PNL	LBL
Geometry and U-values:										
Floor Area (ft^2)	215,840	91,000	146,685	100,166	159,910	88,782	83,947	645,421	684,000	66,147
Number of Stories	27	7	7	6	7	4.5	3.5	6	38	N/A
Percent of Glass in Wall (%)	40	28	28	32	18	36	28	13	25	31
Wall U-value (Btu/ft^2·hr·F)	0.142	0.11	0.126	0.102	0.081	0.081	0.081	N/A	0.27-0.43	0.19
Roof U-value (Btu/ft^2·hr·F)	0.100	0.04	0.074	0.106	0.082	0.090	0.076	0.06	.047-.090	0.063
Operating Conditions:										
Cooling Setpoint (°F)	78/80	75/78	75/off	N/A	N/A	N/A	N/A	74/off	78/off	73
Heating Setpoint (°F)	72/65	70/65	70/65	N/A	N/A	N/A	N/A	70/63	72/55	72
Standard Day Schedule	N/A	9-17	9-18	9-17	9-17	8-17	8-17	8-17	8-18	8-18
HVAC Equipment:										
Air Handling System Type	N/A	VAV	Central	VAV	VAV	2/4 Pipe Fan Coil	2/4 Pipe Fan Coil	Single Duct	VAV Reheat	PSZ SZRH
Cooling Plant Type	N/A	Open Centrifugal	Hermetic Recip.	Centrifugal	Centrifugal	Heatpump	Heatpump	Centrifugal	Hermetic Centrifugal	N/A
Economizer	N/A	N/A	N	Y	Y	N	N	N/A	Y	N
% Outside Air (annualized)	N/A	7	20	20	20	20	20	N/A	30	14
Heating Plant Type**	N/A	GHWB	GHWB	GHWB	GHWB	GHWB	GHWB	GSB	GHWB	N/A
Internal Loads (peak):										
Occupants (ft^2/person)	N/A	140	135	222	526	222	263	222	N/A	256
Lighting (Watts/ft^2)	1.5	1.76	1.89	2.2	1.8	1.8	2.1	2.0	2.1	1.59
Equipment/Misc (Watts/ft^2)	0.2	0.66	0.75	1.23	0.05	1.39	0.07	0.65	N/A	0.48

* NEU1(1) - Large VAV with mainframe; NEU1(2) - Large VAV without mainframe; NEU1(3) - Large non-VAV with mainframe; NEU1(4) - Large non-VAV without mainframe

** GHWB - Gas Hot Water Boiler; GSB - Gas Steam Boiler;

Statistical Data

Statistical data obtained from NBECS reflect the same information; these data are shown in Table 4.E.2 for four geographical regions. Note that the data reflect characteristics of buildings in the Standard Metropolitan Statistical Areas (SMSA's). The NBECS buildings have 150,000 to 190,000 ft^2 in 7 to 9 floors. The average floor area per occupant varies from 390 to 530 ft^2 per person, indicating that office spaces tend to be larger in the South. The reported operational hours for all NBECS office buildings are about 12 hours. In this project, two office conditions have been simulated, one with normal 12-hour operations and another with 24-hour operations.

NBECS also reports the average glass area which is fairly constant in the range of 42 - 50%. Buildings in all geographical areas have some level of insulation at walls and ceilings. In our prototype buildings, we simulate the insulation levels using the averages reported in NBECS. Office in all regions have gas or fuel heating and electric cooling equipment except South which has all electric equipment. This is also evident by a low (0.06) fuel/electric ratio for South compared to other regions which is 0.72 - 1.4. The energy intensity of the NBECS office buildings are in the range of 97 t0 135 kBtu/ft^2, all site energy. We have used these intensities to calibrate our prototype office buildings.

Prototype Buildings

Using the data discussed above, prototype large office buildings of two vintages have been developed for each of the 13 cities of interest (see Table 4.E.3). The size and characteristics of the buildings are widely different as discussed below.

Size

The sizes of the prototype large office buildings vary significantly from less than 150,000 in the West to over 500,000 ft^2 in the eastern regions. Although the average floor areas vary by a factor of three, the average number of floors are fairly constant in the range of 7 to 9. As shown in the *Dodge Project Detail* data summarized in the top part of Table 4.E.3, the size variations between the *Stock* and *Current* vintages are fairly insignificant.

Shell Characteristics

The offices are modeled with steel frame construction with light-weight curtain walls. The window/wall Ratios of the prototypes vary from 0.41 in Northeast to 0.50 in South. For the *Stock* vintage, the windows are assumed to be single pane in all cities. The procedure for defining the ceiling and wall insulation levels for the *Stock* and *Current* vintage buildings is described in Section 4.0.

Table 4.E.2 NBECS Statistics for Large Offices (SMSA only)

Parameter	Region Northeast	North Central	South	West
Avg Floor area (x1000 ft^2)	177	172	192	151
Median Fuel/elec ratio	1.25	1.41	0.06	0.72
Avg No. Floors	8	9	7	7
Avg No. Employees	422	451	534	389
Avg Hours Wkday	12	12	13	12
Avg Hours Wkend	6	5	5	3
Avg Total kBtu/ft^2	97.3	135.1	120.0	126.5
Avg Elec kBtu/ft^2	51.3	56.1	75.4	85.1
Avg Fuel kBtu/ft^2	46.0	79.0	44.7	41.4
Glass covers <25%	27	15	27	15
Glass covers 25-50%	42	52	20	48
Glass covers 50-75%	19	18	29	21
Glass covers >75%	12	14	24	16
Avg glass area (%)	42	45	50	47
% Conservation glass	72	74	81	79
% Wall insulation	36	50	56	52
% Roof/ceiling insulation	52	76	79	71
% Heating setback	94	95	90	68
% Cooling setup	93	96	98	89
% Central heating	98	96	97	99
% Heating system uses furnaces/boilers	68	63	59	57
% Boilers present	56	50	48	48
% Electricity fires boilers	6	10	2	2
% Heat provided by other system	37	52	46	52
% Forced air fans	61	63	96	87
% Heat distributed from baseboards	40	43	8	14
% Electric baseboards	14	12	7	3
% Hot water baseboards	21	21	1	8
% Steam baseboards	10	15	0	5
% Heat fr. radiators/convectors	66	64	26	22
% Heating panels	10	9	4	20
% Other heat distribution	11	14	14	13
% Central air-conditioning	93	59	100	94

Table 4.E.3 Building Descriptions for Large Office Prototypes

Building Parameter	North-east	North Central	South	West
Floor Areas (1000 ft^2)				
Stock Vintage	Bos: 186 NY: 557 Phi: 271	Chi: 349 Det: 226 StL: 321	Mia: 149 NO: 272 Hou: 204	LA: 196 SF: 267 SD: 148 Phx: 161
Current Vintage	Bos: 197 NY: 419 Phi: 203	Chi: 352 Det: 150 StL: 198	Mia: 159 NO: 342 Hou: 253	LA: 197 SF: 197 SD: 146 Phx: 142
No. of floors	8	9	7	9
Shell characteristics				
Stock vintage:				
Ceiling R-value	6.2	9.1	7.9	7.1
Wall R-value	1.1	1.5	1.1	1.0
Window glass	1-pane	1-pane	1-pane	1-pane
Current vintage:	ASHRAE-90.1 (see Table 4.1)			
Window shad. coeff	0.6	0.6	0.6	0.6
Window/wall ratio	0.41	0.45	0.50	0.47
Internal loads				
Ft^2/person	420	380	360	390
Lights W/ft^2 (*Stock*)	1.8	1.9	2.0	2.0
Lights W/ft^2 (*Current*)	1.57	1.57	1.57	1.57
Equip W/ft^2 (12-hr Off.)	0.75	0.75	0.75	0.75
Equip W/ft^2 (24-hr Off.)	1.2	1.2	1.2	1.2
Hot Water Btu/ft^2	175	175	175	175
Process Btu/ft^2	N/A	N/A	N/A	N/A
Process W/ft^2	N/A	N/A	N/A	N/A
System Type	2 systems; one for perimeter and one for core zone.			
Old equipment	Constant volume for all regions			
New equipment	Variable-air-volume for all regions			
Heat Sched	74 F day, 65 F night			
Cool Sched	78 F day, 85 F night			
Heating plant	gas boiler	gas boiler	gas boiler	gas boiler
Chiller type	hermetic centrif.	hermetic centrif.	hermetic centrif.	hermetic centrif.
Hot water plant	gas boiler	gas boiler	gas boiler	gas boiler

Zone Conditions

For simulation, we have assumed that the aspect ratio (length to width) of the building is 0.67. Each floor is divided into five zones—four perimeter zones and one core zone. The wall height is 10 feet and the depth of the perimeter zone is 15 feet.

The internal loads and occupancy intensities have been assumed constant throughout the buildings. The lighting intensity is assumed 2 W/ft^2 in the South and West, 1.8 W/ft^2 in the Northeast, and 1.9 W/ft^2 in the North Central regions. The equipment energy intensity is 0.75 W/ft^2, the hot water usage 175 Btu/person per day, and the peak power usage for elevators 57 kW for all cities. Since there are no differences in operating and internal load conditions from zone to zone, Table 4.E.4 is unnecessary.

Schedules

The prototype large office buildings have been simulated with both a 12-hour normal operating schedule and a 24-hour schedule representative of data processing centers. The occupancy, equipment, hot water and elevator schedules are summarized in Table 4.E.5.

The offices with normal 12-hour operations are unoccupied between 7 p.m. and 6 a.m. on week days, and between 1 p.m. and 7 a.m. on weekends and holidays. The week day occupancy is 1.0 from 9 a.m. to 5 p.m. on week days and 0.2 from 10 to 11 a.m. on weekends. For the transition hours from 7 to 8 a.m. and from 5 to 6 p.m. on weekdays, and from 8 to 9 a.m. and 11 a.m. to noon on weekends, a linear transition is assumed from the occupied to the unoccupied schedules. The domestic hot water usage is assumed to follow closely the occupancy schedule.

The lighting schedule is assumed to be 90% of the peak lighting intensity from 7 a.m. to 5 p.m. during normal week days. For the other week day hours, as well as weekends and holidays, the lighting schedule is 20%. The schedules for lighting, equipment, and elevator are all modeled as simple square waves with no ramping. For example, the equipment intensity is 100% from 7 a.m. to 5 p.m. on week days and 17% for all other week day hours, weekends, and holidays.

The occupancy and lighting schedules for the 24-hour offices differ from those for the 12-hour offices during the off hours. Instead of 0% or 20%, these schedules never fall below 33% of the peak levels. The equipment and elevator schedules are the same as in the 12-hour office. These schedules are shown in the bottom part of Table 4.E.5.

Systems

The heating is done with gas boilers, and the cooling with central centrifugal chillers with cooling towers in all cities. Two systems are modeled for the building, one for the perimeter zones and the other for the central zone. The systems are Reheat-fan with

Table 4.E.5. Occupancy and Equipment Schedules for Large Offices

A. 12-hour Office

Zone	Parameter	Day type*	1	2	3	4	5	6	7	8
Bldg	People, Hot Water	WD	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.67
	" "	WEH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07
Bldg	Lights	WD	0.20	0.20	0.20	0.20	0.20	0.20	0.90	0.90
	"	WEH	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Bldg	Equipment,	WD	0.17	0.17	0.17	0.17	0.17	0.17	0.17	1.00
	Elevators	WEH	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17

Zone	Parameter	Day type*	9	10	11	12	13	14	15	16
Bldg	People, Hot Water	WD	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	" "	WEH	0.13	0.20	0.20	0.10	0.00	0.00	0.00	0.00
Bldg	Lights	WD	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
	"	WEH	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Bldg	Equipment,	WD	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Elevators	WEH	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17

Zone	Parameter	Day type*	17	18	19	20	21	22	23	24
Bldg	People, Hot Water	WD	1.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00
	" "	WEH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bldg	Lights	WD	0.90	0.20	0.20	0.20	0.20	0.20	0.20	0.20
	"	WEH	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Bldg	Equipment,	WD	1.00	0.17	0.17	0.17	0.17	0.17	0.17	0.17
	Elevators	WEH	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17

B. 24-hour Office

Zone	Parameter	Day type*	1	2	3	4	5	6	7	8
Bldg	People, Hot Water	WD	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.67
	" "	WEH	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
Bldg	Lights	WD	0.33	0.33	0.33	0.33	0.33	0.33	0.90	0.90
	"	WEH	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
Bldg	Equipment,	WD	0.17	0.17	0.17	0.17	0.17	0.17	0.17	1.00
	Elevators	WEH	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17

Zone	Parameter	Day type*	9	10	11	12	13	14	15	16
Bldg	People, Hot Water	WD	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	" "	WEH	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
Bldg	Lights	WD	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
	"	WEH	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
Bldg	Equipment,	WD	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Elevators	WEH	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17

Zone	Parameter	Day type*	17	18	19	20	21	22	23	24
Bldg	People, Hot Water	WD	1.00	0.50	0.33	0.33	0.33	0.33	0.33	0.33
	" "	WEH	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
Bldg	Lights	WD	0.90	0.33	0.33	0.33	0.33	0.33	0.33	0.33
	"	WEH	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
Bldg	Equipment,	WD	1.00	0.17	0.17	0.17	0.17	0.17	0.17	0.17
	Elevators	WEH	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17

* WD = weekdays, WEH = weekends and holidays

constant volume for the *Old* vintage equipment, and variable-air-volume with economizer for the *New* vintage equipment.

Calibration

We have simulated the prototype buildings to estimate the heating and cooling load of buildings. Before finalizing the prototype descriptions, a variety of sensitivity analyses have been performed in the resultant DOE-2 simulation output. Selected results of the sensitivity analysis are discussed in Chapter 3. These include the effects of building size, exterior wall modeling, zoning, and system type.

After the prototypes have been defined, we simulated their total electricity and fuel use under normal 12-hour operations and then compared the results to consumption data from NBECS. In the initial simulations, the prototype offices showed significantly lower consumptions for both electricity and fuel. This discrepancy has been reduced by slightly increasing the operating schedule, thermostat setting, and the domestic hot water usage, so that the final results compare well with NBECS data (Table 4.E.6).

Table 4.E.6 Comparison of prototype building energy use to NBECS for 12-hour large offices

Region	NBECS				City	DOE-2 Simulation		
	Total Electric * (kBtu/ft^2)	Total Fuel (kBtu/ft^2)	F/E Ratio Median	F/E Ratio Avg		Total Electric * (kBtu/ft^2)	Total Fuel (kBtu/ft^2)	F/E Ratio
Northeast	51.3	46.0	0.90	0.90	Boston	87.1	79.0	0.91
					New York	77.8	56.3	0.72
					Philadelphia	83.2	61.3	0.74
North Central	56.1	79.0	1.41	1.41	Chicago	86.1	64.4	0.75
					Detroit	87.5	72.8	0.83
					St. Louis	89.7	57.8	0.64
South	75.4	44.7	0.59	0.59	Miami	109.1	33.8	0.31
					New Orleans	98.6	39.6	0.40
					Houston	103.6	45.2	0.44
West	85.1	41.4	0.49	0.49	Los Angeles	88.3	45.7	0.52
					San Diego	93.5	48.0	0.51
					San Francisco	81.6	51.1	0.63
					Phoenix	104.8	46.9	0.45

* electricity kWh are converted to site Btus (1 kWh = 3413 Btu).

Calibration was not attempted with the 24-hour offices since there are too few of these offices in the NBECS data base to be statistically reliable.

Simulation Results

Table 4.E.7 provides information on annual energy intensities for heating, cooling, lighting, and equipment end uses for the finalized large office prototypes.

4.F SUPERMARKET

Food stores represent a commercial building sector that has undergone substantial changes over the recent decades, with the trend towards increased size and energy use intensity. Neighborhood grocery stores are gradually being supplanted by large supermarkets, which in recent years have gone increasingly towards 24-hour operations. Supermarkets are fairly electricity-intensive buildings, with lighting, refrigeration, and ventilation the predominant end-use. Supermarkets, however, also have appreciable thermal loads. In the winter, there is significant space heating in supermarkets in a large part of the country. In the spring, summer, and fall there is still some space heating demand, particularly in those locations where the refrigerator cases are open and cause significant space heating loads. For this project, supermarket prototypes have been developed with two operating modes: 18 and 24 hours of operation.

Existing Data Sources

The project reviewed the supermarket prototypical characteristics reported in four earlier studies. These characteristics are summarized in Table 4.F.1. Three of the four studies are regional in scope: MEOS summarizes building characteristics for Michigan, LBL for southern California, and ConEd for the Northeast. The EPRI prototype description is derived from NBECS and represents a national average.

The prototype building characteristics among these studies are fairly similar. The floor areas ranges from 5,600 to over 50,000 ft^2. The LBL prototype for southern California includes both small convenient stores as well as supermarket, and hence, has a small floor area. The MEOS and ConEd prototypes are about 20,000 ft^2, while the EPRI prototype at over 50,000 ft^2 seem much larger than a typical supermarket. All four prototypical supermarkets are single-story buildings. The wall and roof insulations agree within less than a factor of two, while the percentages of exterior glass vary from 6 to 14. Typically, supermarkets have glass only on one side of the store that covers about half of the wall area. The operating schedules are from 9 a.m. to 9 p.m., which are shorter than current schedules which are either from 7 a.m. to 11 p.m. or 24 hours continuous. The cooling set point of the shopping areas varies from 71 to 77 F with night time setup,

Table 4.E.7.1 Summary of annual end use intensities for prototype 12-hour large offices
(electricity in kWh/ft^2 and fuel in kBtu/ft^2)

City	Shell	Eqp	Heating Elec.	Heating Fuel	Cooling Elec.	Fan Elec.	DHW Elec.	DHW Fuel	Lighting Elec.	Misc. Elec.	Misc. Fuel	Total Elec.	Total Fuel	F/E Ratio
Northeast														
Boston	Stk	Old	0.63	77.4	6.16	8.03	0.00	1.6	6.63	4.07	0.0	25.52	79.0	0.91
Boston	Stk	New	0.37	49.1	2.30	4.06	0.00	1.6	6.63	4.07	0.0	17.43	50.8	0.85
Boston	Cur	New	0.30	40.7	2.04	3.55	0.00	1.6	5.78	4.06	0.0	15.73	42.3	0.79
New York	Stk	Old	0.45	54.6	5.24	6.40	0.00	1.6	6.63	4.08	0.0	22.80	56.3	0.72
New York	Stk	New	0.25	32.9	2.32	3.32	0.00	1.6	6.63	4.06	0.0	16.58	34.5	0.61
New York	Cur	New	0.23	30.8	2.20	3.13	0.00	1.6	5.79	4.06	0.0	15.41	32.4	0.62
Philadelphia	Stk	Old	0.50	59.6	5.94	7.25	0.00	1.6	6.63	4.06	0.0	24.38	61.3	0.74
Philadelphia	Stk	New	0.27	35.7	2.66	3.76	0.00	1.6	6.63	4.05	0.0	17.37	37.3	0.63
Philadelphia	Cur	New	0.25	32.6	2.53	3.54	0.00	1.6	5.79	4.06	0.0	16.17	34.3	0.62
North Central														
Chicago	Stk	Old	0.54	62.5	6.08	7.54	0.00	1.8	7.00	4.07	0.0	25.23	64.4	0.75
Chicago	Stk	New	0.30	38.2	2.51	3.91	0.00	1.8	7.00	4.09	0.0	17.81	40.0	0.66
Chicago	Cur	New	0.25	32.9	2.27	3.45	0.00	1.8	5.79	4.06	0.0	15.82	34.7	0.64
Detroit	Stk	Old	0.60	71.0	6.09	7.87	0.00	1.8	7.00	4.08	0.0	25.64	72.8	0.83
Detroit	Stk	New	0.34	44.2	2.37	4.05	0.00	1.8	7.00	4.08	0.0	17.84	46.0	0.76
Detroit	Cur	New	0.34	45.2	2.35	4.07	0.00	1.8	5.79	4.06	0.0	16.61	47.0	0.83
St. Louis	Stk	Old	0.49	56.0	6.85	7.87	0.00	1.8	7.00	4.07	0.0	26.28	57.8	0.64
St. Louis	Stk	New	0.26	32.6	3.36	4.16	0.00	1.8	7.00	4.09	0.0	18.87	34.4	0.53
St. Louis	Cur	New	0.26	33.7	3.33	4.15	0.00	1.8	5.78	4.09	0.0	17.61	35.6	0.59
South														
Miami	Stk	Old	0.31	31.7	10.38	9.31	0.00	2.1	7.72	4.25	0.0	31.97	33.8	0.31
Miami	Stk	New	0.09	8.2	7.84	5.22	0.00	2.1	7.72	4.27	0.0	25.14	10.3	0.12
Miami	Cur	New	0.09	8.1	7.21	4.75	0.00	2.1	6.06	4.25	0.0	22.36	10.1	0.13
New Orleans	Stk	Old	0.35	37.5	8.41	8.16	0.00	2.1	7.72	4.25	0.0	28.89	39.6	0.40
New Orleans	Stk	New	0.15	15.3	5.57	4.46	0.00	2.1	7.72	4.25	0.0	22.15	17.4	0.23
New Orleans	Cur	New	0.13	12.9	4.88	3.79	0.00	2.1	6.06	4.24	0.0	19.10	15.0	0.23
Houston	Stk	Old	0.40	43.1	9.09	8.88	0.00	2.1	7.72	4.26	0.0	30.35	45.2	0.44
Houston	Stk	New	0.17	18.3	5.99	4.85	0.00	2.1	7.72	4.27	0.0	23.00	20.4	0.26
Houston	Cur	New	0.15	15.4	5.25	4.12	0.00	2.1	6.06	4.26	0.0	19.84	17.5	0.26
West														
Los Angeles	Stk	Old	0.36	44.1	6.68	8.02	0.00	1.6	7.02	3.79	0.0	25.87	45.7	0.52
Los Angeles	Stk	New	0.18	19.8	3.52	4.22	0.00	1.6	7.02	3.81	0.0	18.75	21.4	0.33
Los Angeles	Cur	New	0.16	18.5	3.16	3.78	0.00	1.6	5.51	3.83	0.0	16.44	20.1	0.36
San Diego	Stk	Old	0.38	46.4	7.42	8.78	0.00	1.6	7.02	3.80	0.0	27.40	48.0	0.51
San Diego	Stk	New	0.18	20.1	4.14	4.66	0.00	1.6	7.02	3.81	0.0	19.81	21.7	0.32
San Diego	Cur	New	0.17	18.5	3.71	4.19	0.00	1.6	5.51	3.79	0.0	17.37	20.1	0.34
San Francisco	Stk	Old	0.41	49.4	5.50	7.16	0.00	1.6	7.02	3.82	0.0	23.91	51.1	0.63
San Francisco	Stk	New	0.22	25.9	1.59	3.65	0.00	1.6	7.02	3.81	0.0	16.29	27.6	0.50
San Francisco	Cur	New	0.21	25.8	1.49	3.42	0.00	1.6	5.51	3.81	0.0	14.44	27.4	0.56
Phoenix	Stk	Old	0.40	45.3	9.17	10.30	0.00	1.6	7.02	3.82	0.0	30.71	46.9	0.45
Phoenix	Stk	New	0.18	19.9	5.59	5.67	0.00	1.6	7.02	3.81	0.0	22.27	21.6	0.28
Phoenix	Cur	New	0.17	18.7	5.14	5.18	0.00	1.6	5.51	3.81	0.0	19.81	20.3	0.30

Table 4.E.7.2 Summary of annual end use intensities for prototype 24-hour large offices
(electricity in kWh/ft^2 and fuel in kBtu/ft^2)

City	Shell	Eqp	Heating Elec.	Heating Fuel	Cooling Elec.	Fan Elec.	DHW Elec.	DHW Fuel	Lighting Elec.	Misc. Elec.	Misc. Fuel	Total Elec.	Total Fuel	F/E Ratio
Northeast														
Boston	Stk	Old	0.66	77.9	8.10	9.93	0.00	2.9	10.99	8.79	0.0	38.47	80.8	0.62
Boston	Stk	New	0.37	46.4	3.09	5.12	0.00	2.9	10.99	8.76	0.0	28.33	49.3	0.51
Boston	Cur	New	0.31	39.4	2.84	4.63	0.00	2.9	9.59	8.77	0.0	26.14	42.3	0.47
New York	Stk	Old	0.49	57.1	7.42	8.51	0.00	2.9	10.99	8.78	0.0	36.19	60.0	0.49
New York	Stk	New	0.26	32.0	3.36	4.53	0.00	2.9	10.99	8.78	0.0	27.92	34.9	0.37
New York	Cur	New	0.24	30.6	3.21	4.29	0.00	2.9	9.59	8.78	0.0	26.11	33.5	0.38
Philadelphia	Stk	Old	0.52	58.8	8.06	9.20	0.00	2.9	10.99	8.79	0.0	37.56	61.7	0.48
Philadelphia	Stk	New	0.27	32.5	3.69	4.89	0.00	2.9	10.99	8.76	0.0	28.60	35.5	0.36
Philadelphia	Cur	New	0.24	30.4	3.53	4.65	0.00	2.9	9.59	8.77	0.0	26.78	33.3	0.36
North Central														
Chicago	Stk	Old	0.58	65.5	8.55	10.02	0.00	3.2	11.60	8.80	0.0	39.55	68.7	0.51
Chicago	Stk	New	0.31	37.1	3.54	5.28	0.00	3.2	11.60	8.80	0.0	29.53	40.3	0.40
Chicago	Cur	New	0.27	33.2	3.27	4.81	0.00	3.2	9.59	8.81	0.0	26.75	36.4	0.40
Detroit	Stk	Old	0.61	70.3	8.20	9.81	0.00	3.2	11.60	8.81	0.0	39.03	73.6	0.55
Detroit	Stk	New	0.33	41.0	3.18	5.11	0.00	3.2	11.60	8.82	0.0	29.04	44.3	0.45
Detroit	Cur	New	0.33	42.0	3.09	5.01	0.00	3.2	9.59	8.79	0.0	26.81	45.3	0.49
St. Louis	Stk	Old	0.49	54.6	9.15	9.92	0.00	3.2	11.60	8.80	0.0	39.96	57.9	0.42
St. Louis	Stk	New	0.26	29.9	4.61	5.40	0.00	3.2	11.60	8.81	0.0	30.68	33.2	0.32
St. Louis	Cur	New	0.26	31.8	4.53	5.33	0.00	3.2	9.59	8.80	0.0	28.51	35.1	0.36
South														
Miami	Stk	Old	0.29	27.0	13.12	11.08	0.00	3.5	12.21	8.92	0.0	45.62	30.5	0.20
Miami	Stk	New	0.06	5.0	10.40	6.52	0.00	3.5	12.21	8.93	0.0	38.12	8.6	0.07
Miami	Cur	New	0.06	5.3	9.61	5.98	0.00	3.5	9.59	8.92	0.0	34.16	8.8	0.08
New Orleans	Stk	Old	0.34	33.1	10.76	9.91	0.00	3.5	12.21	8.91	0.0	42.13	36.6	0.25
New Orleans	Stk	New	0.13	11.7	7.57	5.74	0.00	3.5	12.21	8.92	0.0	34.57	15.2	0.13
New Orleans	Cur	New	0.11	10.2	6.75	5.02	0.00	3.5	9.59	8.91	0.0	30.38	13.7	0.13
Houston	Stk	Old	0.41	42.1	11.98	11.17	0.00	3.5	12.21	8.91	0.0	44.68	45.7	0.30
Houston	Stk	New	0.15	15.3	8.22	6.33	0.00	3.5	12.21	8.92	0.0	35.83	18.8	0.15
Houston	Cur	New	0.14	13.4	7.36	5.56	0.00	3.5	9.59	8.94	0.0	31.59	17.0	0.16
West														
Los Angeles	Stk	Old	0.31	35.2	8.55	9.57	0.00	3.1	12.21	8.53	0.0	39.17	38.3	0.29
Los Angeles	Stk	New	0.13	13.6	4.63	5.25	0.00	3.1	12.21	8.54	0.0	30.76	16.7	0.16
Los Angeles	Cur	New	0.12	12.8	4.16	4.71	0.00	3.1	9.59	8.55	0.0	27.13	15.9	0.17
San Diego	Stk	Old	0.34	39.9	9.52	10.63	0.00	3.1	12.21	8.55	0.0	41.25	43.0	0.31
San Diego	Stk	New	0.14	14.4	5.46	5.84	0.00	3.1	12.21	8.55	0.0	32.20	17.4	0.16
San Diego	Cur	New	0.13	13.6	4.96	5.31	0.00	3.1	9.59	8.55	0.0	28.54	16.7	0.17
San Francisco	Stk	Old	0.37	41.6	7.25	8.84	0.00	3.1	12.21	8.54	0.0	37.21	44.7	0.35
San Francisco	Stk	New	0.19	19.1	2.19	4.63	0.00	3.1	12.21	8.56	0.0	27.78	22.2	0.23
San Francisco	Cur	New	0.19	19.4	2.01	4.32	0.00	3.1	9.59	8.56	0.0	24.67	22.5	0.27
Phoenix	Stk	Old	0.39	43.0	11.75	12.72	0.00	3.1	12.21	8.55	0.0	45.62	46.1	0.30
Phoenix	Stk	New	0.15	16.3	7.30	7.16	0.00	3.1	12.21	8.54	0.0	35.36	19.4	0.16
Phoenix	Cur	New	0.15	15.6	6.71	6.60	0.00	3.1	9.59	8.54	0.0	31.59	18.7	0.17

Table 4.F.1 Summary of Existing Studies of Supermarkets

Report: (see Table 2.3 for coding)	ConEd	EPRI	MEOS	LBL
Geometry and U-values:				
Floor Area (ft^2)	19,497	52,650	21,316	5,627
Number of Stories	1	1	1	N/A
Percent of Glass in Wall (%)	10	14	6	8
Wall U-value (Btu/ft^2·hr·F)	0.20	0.11	0.22	0.17
Roof U-value (Btu/ft^2·hr·F)	0.053	0.050	0.075	0.0704
Operating Conditions:				
Cooling Setpoint (°F)	77/79	75/78	71/74	74
Heating Setpoint (°F)	70/57	72/68	68/65	73
Standard Day Schedule	N/A	9-19	9-21	10-19
HVAC Equipment:				
Air Handling System Type	PSZ	PSZ	PSZ	PSZ
Cooling Plant Type	DX	N/A	DX	N/A
Economizer	N/A	N/A	Y	N/A
% Outside Air (annualized)	N/A	20	25	19
Heating Plant Type	Electric	Gas Furnace	Gas Furnace	N/A
Internal Loads (peak):				
Occupants (ft^2/person)	N/A	137	213	177
Lighting (Watts/ft^2)	1.90	1.34	2.01	1.59
Equipment/Misc (Watts/ft^2)	5.10	1.50	0.56	1.91

and the heating set points are 68 to 72 F with night time setback of 57 to 68 F. The lighting intensities are from 1.34 to 2.01 W/ft^2, while the equipment loads vary widely from 0.56 to 5.10 W/ft^2. These variations between the different studies can be attributed to different assumptions about refrigeration and kitchen equipment.

All four studies describe the building with packaged single-zone air-conditioning systems, while one included an economizer cycle in the cooling equipment. The amounts of outside fresh air range from 19 to 25%. Electricity is described as the major cooling fuel in all four studies, while both gas and electricity furnaces are described for heating.

Statistical Data

The NBECS data on supermarkets do not have sufficient detail to warrant defining building characteristics by Census Regions, or to separate out only the SMSA

Table 4.F.2 NBECS Results for Supermarkets

Parameter	National Average
Average Floor Area (x1000 ft^2)	21.3
Median Fuel/elec ratio	0.33
Average No. floors	1
Average No. employees	37
Average Hr/day Workdays	15
Average Hr/day Weekends	12
Average Total kBtu/ft^2	212
Average Elect kBtu/ft^2	167
Average Fuel kBtu/ft^2	45
Glass covers < 25%	16
Glass covers 25-50%	84
Glass covers 50-75%	0
Glass covers >75%	0
Average glass area (%)	33
% Conservation glass	25
% Wall insulation	26
% Roof/ceiling insulation	57
% Heating setback	65
% Cooling setup	70
% Central heating	79
% Heating system uses furnaces/boilers	33
% Boilers present	0
% Electricity fires boilers	0
% Heat provided by other system	47
% Forced air fans	79
% Heat distributed from baseboards	0
% Electric baseboards	0
% Hot water baseboards	0
% Steam baseboards	0
% Heat fr. by radiators/convectors	3
% Heating panels	0
% Other heat distribution	7
% Central air-conditioning	83

observations. The small sampling size (less than 50) made it necessary to eliminate suspicious data such as a building of 1,000,000 ft^2 or those with less than 10,000 ft^2. Consequently, the final sampling frame was restricted to buildings between 10,000 and 400,000 ft^2. The results are shown in Table 4.F.2.

The NBECS data give an average floor area of ~21,000 ft^2 in a single story building. The average number of employees is 37, which translates to roughly 570 ft^2 per employee. NBECS does not provide information on the number of shoppers present at a given time in the store. The reported hours of operation average 15 hours during the week and 12 hours on the weekends. Since the time the NBECS surveys were conducted in the late 1970s and early 1980s, supermarket have significantly increased their operational schedules. For the cogeneration data base, the prototypical supermarket has been simulated with 18- and 24-hour operating schedules.

The NBECS data shows that supermarkets have an average glass area of 33%, and have moderate amounts of insulation in the ceilings and walls, 57 and 26%, respectively. Supermarkets generally have central heating and packaged cooling systems. Because of their high refrigeration loads, supermarkets have high electricity intensities. NBECS gives the average national electricity and fuel energy intensities of supermarkets as 167 and 45 kBtu/ft^2 in site energy. The median and average fuel/electric ratios are about the same, 0.33 as compared to 0.27.

In addition to the NBECS data, we used an EPRI report (EPRI/PGE) that presented data from the monitoring of a supermarket in Palo Alto, California. This was an 42,139 ft^2 supermarket with 25,600 ft^2 of sales area, 661 feet of refrigeration case, and 2,512 ft^2 of walk-in boxes. Data from this study and the energy intensities and fuel/electric ratios from NBECS are used to calibrate the prototype supermarket.

Prototype Building

The literature search indicated there is not enough existing data for developing different supermarkets prototypes by geographical regions. Therefore, a single supermarket prototype has been developed and used for all 13 cities (see Table 4.F.3). The size and building characteristics of this supermarket prototype is discussed below.

Size

Dodge data cannot be used to define building sizes for supermarkets, since they are lumped with smaller groceries and convenience stores into the ‘‘food sales’’ building category. NBECS and other existing studies suggest a building size of around 20,000 ft^2. For the prototype, the NBECS average size of 21,000 ft^2 has been used for both the *Stock* and *Current* vintages in all 13 cities. In accordance with all data sources, the prototype supermarket is modeled as a single-story structure.

Table 4.F.3 Building Descriptions for Supermarket Prototypes

Building Parameter	North-east	North Central	South	West
Floor Areas (1000 ft^2)	21	21	21	21
No. of floors	1	1	1	1
Shell characteristics				
Stock vintage:				
Ceiling R-value	6.8	6.8	5.7	5.7
Wall R-value	0.8	1.0	0.8	0.8
Window glass	1-pane	1-pane	1-pane	1-pane
Current vintage:	ASHRAE-90.1 (see Table 4.1)			
Window shad. coeff	0.60	0.60	0.60	0.60
Window/wall ratio	0.15	0.15	0.15	0.15
Internal loads				
Ft^2/person	(see Table 4.F.4) †			
Lights W/ft^2	1.5 - 2.5 (see Table 4.F.4) †			
Equip W/ft^2	(see Table 4.F.4) †			
Hot Water Btu/hr.ft^2	50			
Process Btu/ft^2	N/A			
Process W/ft^2	(see Table 4.F.4) †			
System Type	5 systems; all packaged single zone; one per zone.			
Old equipment	Constant volume for all regions			
New equipment	Variable-air-volume for all regions			
Heat Sched	72 F			
Cool Sched	76 F			
Heating plant	Gas furnace			
Chiller type	Direct expansion			
Hot water fuel	gas			

† constant for all cities but varies by building zone, numbers are approximate since zone peaks may not be coincident.

Shell Characteristics

The prototype supermarket is modeled as a square building with equal amounts of walls and windows on four sides. The construction is assumed to be 8" concrete block walls with a light-weight roof. The wall height is 18 ft, except for the office area which has a wall height of 9 ft. Since most supermarkets have a front wall with 50 to 60% windows and blank walls on the other three sides, the prototype has been modeled with an average window/wall ratio of 0.15 on all sides. The windows are assumed to be single-pane. The insulation levels for the *Stock* vintage buildings are derived from NBECS, while those for the *Current* vintage are based on ASHRAE 90.1-1989 guidelines (see Table 4.F.3). The procedure used to derive the average amounts of insulation for the prototype buildings based on NBECS and the ASHRAE 90-75 Standard is described in Section 4.0. The resultant insulation levels are R-4 for the walls and R-12 for the roof.

Zone Conditions

The supermarket is divided into five zones : office, dry storage, bakery, deli, and general sales. The electricity intensities for lighting, equipment, and process loads vary by zone and are shown in Table 4.F.4. The hot water usage is assumed to be 50 Btu/employee per day.

Table 4.F.4 Zone descriptions for Supermarket Prototype

	Zones				
	Office	Dry Storage	Bakery	Deli	Sale
Floor Area (% total)	2	14	5	5	74
Wall Height (ft.)	10	20	20	20	20
Window/wall ratio	0	0	0	0	15
Ft^2/person	200	1000	250	250	80
Lights W/ft^2	2.5	1.5	2.5	2.5	2.5
Equip. W/ft^2	0.6	0.5	10.0	5.0	0.5
Freezer Case Btu/ft^2	-	-	-	-	5.2
Meat Case Btu/ft^2	-	-	-	-	14.1
Produce Case Btu/ft^2	-	-	-	-	11.3

Table 4.F.5a Hourly Load Profiles for 18 Hour Supermarket Prototypes

Zone	End-use(s)	Day type*	Hour of Day 1	2	3	4	5	6	7	8	9	10	11	12
1	People	All	0.00	0.00	0.00	0.00	0.00	0.30	0.40	0.50	0.70	0.70	0.70	0.70
2	People	All	0.00	0.00	0.00	0.00	0.00	0.10	0.10	0.50	0.70	0.80	0.80	0.80
3	People	All	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
4	People	All	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
5	People	All	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	Lights	All	0.60	0.60	0.60	0.60	0.60	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2	Lights	All	0.20	0.20	0.20	0.20	0.20	1.00	1.00	1.00	1.00	1.00	1.00	1.00
3	Lights	All	0.50	0.50	0.50	0.50	0.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00
4	Lights	All	0.10	0.10	0.10	0.10	0.10	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	Hot Water	All	0.00	0.00	0.00	0.00	0.00	0.55	0.55	0.55	0.55	0.55	0.55	0.55

Zone	End-use(s)	Day type*	Hour of Day 13	14	15	16	17	18	19	20	21	22	23	24
1	People	All	0.70	0.70	0.70	1.00	1.00	1.00	1.00	0.50	0.30	0.20	0.20	0.00
2	People	All	1.00	1.00	1.00	1.00	0.80	0.70	0.50	0.50	0.30	0.20	0.20	0.00
3	People	All	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
4	People	All	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00
5	People	All	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	Lights	All	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.60
2	Lights	All	1.00	1.00	1.00	1.00	1.00	1.00	0.20	0.20	0.20	0.20	0.20	0.20
3	Lights	All	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50
4	Lights	All	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	Hot Water	All	0.55	0.55	0.55	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.00

Table 4.F.5b Hourly Load Profiles for 24 Hour Supermarket Prototypes

Zone	End-use(s)	Day type*	Hour of Day 1	2	3	4	5	6	7	8	9	10	11	12
1	People	All	0.20	0.20	0.20	0.20	0.30	0.30	0.40	0.50	0.70	0.70	0.70	0.70
2	People	All	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.50	0.70	0.80	0.80	0.80
3	People	All	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
4	People	All	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
5	People	All	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	Lights	All	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2	Lights	All	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
3	Lights	All	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
4	Lights	All	0.10	0.10	0.10	0.10	0.10	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	Hot Water	All	0.30	0.30	0.30	0.30	0.30	0.55	0.55	0.55	0.55	0.55	0.55	0.55

Zone	End-use(s)	Day type*	Hour of Day 13	14	15	16	17	18	19	20	21	22	23	24
1	People	All	0.70	0.70	0.70	1.00	1.00	1.00	1.00	0.50	0.30	0.30	0.20	0.20
2	People	All	1.00	1.00	1.00	1.00	0.80	0.70	0.50	0.50	0.30	0.30	0.20	0.20
3	People	All	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
4	People	All	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00
5	People	All	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	Lights	All	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2	Lights	All	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
3	Lights	All	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
4	Lights	All	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	Hot Water	All	0.55	0.55	0.55	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30

* All = all days.

Schedules

The prototype has been simulated in the 13 cities using two operational schedules: 18 hours and 24 hours per day. The occupancy, equipment, hot water and process schedules are summarized in Table 4.F.5. The main difference between these two prototypes are their hours of operation; the 18-hour supermarket is closed between 12:00 a.m. and 5:00 a.m. The lighting schedule for the general sales area is assumed to be 100 percent during the occupied hours and 10% during the unoccupied hours.

Systems

The supermarket is simulated with five packaged air conditioning units, one for each zone. The old equipment is assumed to have refrigeration circuits all using timed defrost. A 100,000 Btu/hour heat reclaim coil on the produce case is used to supplement the sales area heating. The new equipment is assumed to have multiplexed meat and produce case circuits and freon defrost for the meat case. All of the meat and produce case capability is used for heat recovery. Gas is assumed for both space heating and domestic hot water. The heating and cooling set points are 72 F and 76 F, respectively.

Calibration

The prototype supermarket has been simulated using the DOE-2.1D program to estimate the thermal and electrical load of the building. The simulation results, where compared to monitoring study and the size of the heat reclaim coil, were increased to reflect the low fuel use found in the NBECS and monitoring study data.

Comparisons of the simulated electricity and fuel uses of the 18-hour and 24-hour prototype supermarkets in 13 cities with national NBECS consumption data are shown in Table 4.F.6.

Simulation Results

Table 4.F.7 provides information on annual energy intensities for heating, cooling, lighting, process, and equipment end uses for the finalized 18-hour and 24-hour supermarket prototypes. Note that the electrical loads for the refrigeration cases are included in the *Misc. Elec.* column.

Table 4.F.6.1 Comparision of prototype building energy use to NBECS for 18-hour supermarkets

Region	NBECS				City	DOE-2 Simulation		
	Total Electric * (kBtu/ft^2)	Total Fuel (kBtu/ft^2)	F/E Ratio Median	F/E Ratio Avg		Total Electric * (kBtu/ft^2)	Total Fuel (kBtu/ft^2)	F/E Ratio
U.S. Average	167.4	44.6	0.33	0.27	Boston	186.7	66.5	0.36
					New York	186.3	57.7	0.31
					Philadelphia	187.3	56.8	0.30
					Chicago	188.2	70.2	0.37
					Detroit	185.1	75.6	0.41
					St. Louis	190.4	54.4	0.29
					Miami	202.8	4.0	0.02
					New Orleans	195.7	16.5	0.08
					Houston	195.8	17.2	0.09
					Los Angeles	181.6	17.4	0.10
					San Diego	181.6	13.5	0.07
					San Francisco	179.2	34.2	0.19
					Phoenix	198.5	15.2	0.08

Table 4.F.6.2 Comparision of prototype building energy use to NBECS for 24-hour supermarkets

Region	NBECS				City	DOE-2 Simulation		
	Total Electric * (kBtu/ft^2)	Total Fuel (kBtu/ft^2)	F/E Ratio Median	F/E Ratio Avg		Total Electric * (kBtu/ft^2)	Total Fuel (kBtu/ft^2)	F/E Ratio
U.S. Average	167.4	44.6	0.33	0.27	Boston	195.3	66.8	0.34
					New York	195.3	57.6	0.29
					Philadelphia	195.9	57.1	0.29
					Detroit	193.7	76.4	0.39
					Chicago	196.8	70.9	0.36
					St. Louis	199.2	54.8	0.27
					New Orleans	204.8	15.6	0.08
					Houston	205.4	16.4	0.08
					Miami	212.9	3.7	0.02
					Los Angeles	191.4	15.0	0.08
					San Diego	190.4	11.0	0.06
					San Francisco	188.2	31.7	0.17
					Phoenix	210.1	14.6	0.07

* electricity kWh are converted to site Btus (1 kWh = 3413 Btu).

Table 4.F.7.1 Summary of annual end use intensities for prototype 18-hour supermarkets
(electricity in kWh/ft^2 and fuel in kBtu/ft^2)

City	Shell	Eqp	Heating Elec.	Heating Fuel	Cooling Elec.	Fan Elec.	DHW Elec.	DHW Fuel	Lighting Elec.	Misc. Elec.	Misc. Fuel	Total Elec.	Total Fuel	F/E Ratio
Northeast														
Boston	Stk	Old	0.00	66.0	1.01	6.52	0.00	0.5	18.36	28.82	0.0	54.70	66.5	0.36
Boston	Stk	New	0.00	19.4	1.13	6.52	0.00	0.5	18.36	26.70	0.0	52.71	19.9	0.11
Boston	Cur	New	0.00	6.2	1.11	4.30	0.00	0.5	18.36	26.66	0.0	50.42	6.8	0.04
New York	Stk	Old	0.00	57.1	1.29	5.87	0.00	0.5	18.36	29.07	0.0	54.59	57.7	0.31
New York	Stk	New	0.00	15.3	1.48	5.87	0.00	0.5	18.36	26.89	0.0	52.59	15.8	0.09
New York	Cur	New	0.00	5.0	1.41	4.06	0.00	0.5	18.36	26.85	0.0	50.69	5.5	0.03
Philadelphia	Stk	Old	0.00	56.3	1.44	5.92	0.00	0.5	18.36	29.15	0.0	54.88	56.8	0.30
Philadelphia	Stk	New	0.00	15.4	1.64	5.92	0.00	0.5	18.36	26.95	0.0	52.89	15.9	0.09
Philadelphia	Cur	New	0.00	5.2	1.54	4.08	0.00	0.5	18.36	26.91	0.0	50.89	5.7	0.03
North Central														
Chicago	Stk	Old	0.00	69.7	1.37	6.63	0.00	0.5	18.36	28.77	0.0	55.14	70.2	0.37
Chicago	Stk	New	0.00	25.0	1.57	6.63	0.00	0.5	18.36	26.66	0.0	53.21	25.5	0.14
Chicago	Cur	New	0.00	8.2	1.43	4.33	0.00	0.5	18.36	26.62	0.0	50.75	8.7	0.05
Detroit	Stk	Old	0.00	75.1	0.94	6.21	0.00	0.5	18.36	28.71	0.0	54.23	75.6	0.41
Detroit	Stk	New	0.00	27.2	1.04	6.21	0.00	0.5	18.36	26.58	0.0	52.18	27.8	0.16
Detroit	Cur	New	0.00	9.2	1.04	4.18	0.00	0.5	18.36	26.56	0.0	50.13	9.7	0.06
St. Louis	Stk	Old	0.00	53.8	1.92	6.14	0.00	0.5	18.36	29.37	0.0	55.79	54.4	0.29
St. Louis	Stk	New	0.00	16.3	2.22	6.14	0.00	0.5	18.36	27.13	0.0	53.85	16.8	0.09
St. Louis	Cur	New	0.00	6.1	1.96	4.16	0.00	0.5	18.36	27.10	0.0	51.60	6.6	0.04
South														
Miami	Stk	Old	0.00	3.5	4.84	4.57	0.00	0.5	18.36	31.64	0.0	59.42	4.0	0.02
Miami	Stk	New	0.00	1.7	5.80	4.57	0.00	0.5	18.36	28.80	0.0	57.54	2.2	0.01
Miami	Cur	New	0.00	1.7	5.31	3.95	0.00	0.5	18.36	28.83	0.0	56.46	2.2	0.01
New Orleans	Stk	Old	0.00	16.0	2.98	5.11	0.00	0.5	18.36	30.90	0.0	57.34	16.5	0.08
New Orleans	Stk	New	0.00	2.8	3.54	5.11	0.00	0.5	18.36	28.33	0.0	55.35	3.3	0.02
New Orleans	Cur	New	0.00	2.0	3.10	3.88	0.00	0.5	18.36	28.35	0.0	53.68	2.5	0.01
Houston	Stk	Old	0.00	16.7	3.14	4.99	0.00	0.5	18.36	30.87	0.0	57.37	17.2	0.09
Houston	Stk	New	0.00	3.0	3.74	4.99	0.00	0.5	18.36	28.31	0.0	55.41	3.5	0.02
Houston	Cur	New	0.00	2.1	3.23	3.79	0.00	0.5	18.36	28.32	0.0	53.71	2.6	0.01
West														
Los Angeles	Stk	Old	0.00	16.9	0.90	4.45	0.00	0.5	18.36	29.49	0.0	53.21	17.4	0.10
Los Angeles	Stk	New	0.00	2.1	0.95	4.45	0.00	0.5	18.36	27.24	0.0	50.98	2.6	0.01
Los Angeles	Cur	New	0.00	1.8	1.02	3.72	0.00	0.5	18.36	27.24	0.0	50.34	2.3	0.01
San Diego	Stk	Old	0.00	13.0	1.09	4.23	0.00	0.5	18.36	29.52	0.0	53.21	13.5	0.07
San Diego	Stk	New	0.00	1.9	1.17	4.23	0.00	0.5	18.36	27.23	0.0	50.98	2.4	0.01
San Diego	Cur	New	0.00	1.7	1.21	3.58	0.00	0.5	18.36	27.24	0.0	50.40	2.2	0.01
San Francisco	Stk	Old	0.00	33.7	0.45	4.58	0.00	0.5	18.36	29.10	0.0	52.51	34.2	0.19
San Francisco	Stk	New	0.00	3.2	0.46	4.58	0.00	0.5	18.36	27.01	0.0	50.42	3.7	0.02
San Francisco	Cur	New	0.00	2.0	0.53	3.57	0.00	0.5	18.36	27.01	0.0	49.49	2.5	0.01
Phoenix	Stk	Old	0.00	14.7	5.40	5.77	0.00	0.5	18.36	28.62	0.0	58.16	15.2	0.08
Phoenix	Stk	New	0.00	2.8	5.97	5.77	0.00	0.5	18.36	26.46	0.0	56.55	3.3	0.02
Phoenix	Cur	New	0.00	1.9	4.59	3.82	0.00	0.5	18.36	26.47	0.0	53.24	2.4	0.01

Table 4.F.7.2 Summary of annual end use intensities for prototype 24-hour supermarkets
(electricity in kWh/ft^2 and fuel in kBtu/ft^2)

City	Shell	Eqp	Heating Elec.	Heating Fuel	Cooling Elec.	Fan Elec.	DHW Elec.	DHW Fuel	Lighting Elec.	Misc. Elec.	Misc. Fuel	Total Elec.	Total Fuel	F/E Ratio
Northeast														
Boston	Stk	Old	0.00	66.2	1.10	5.97	0.00	0.6	20.59	29.58	0.0	57.22	66.8	0.34
Boston	Stk	New	0.00	16.3	1.10	5.97	0.00	0.6	20.59	30.17	0.0	57.84	16.9	0.09
Boston	Cur	New	0.00	4.1	1.06	3.75	0.00	0.6	20.59	30.19	0.0	55.58	4.7	0.02
New York	Stk	Old	0.00	56.9	1.43	5.43	0.00	0.6	20.59	29.78	0.0	57.22	57.6	0.29
New York	Stk	New	0.00	12.2	1.43	5.43	0.00	0.6	20.59	30.35	0.0	57.81	12.8	0.07
New York	Cur	New	0.00	3.1	1.35	3.57	0.00	0.6	20.59	30.37	0.0	55.87	3.8	0.02
Philadelphia	Stk	Old	0.00	56.4	1.58	5.38	0.00	0.6	20.59	29.83	0.0	57.40	57.1	0.29
Philadelphia	Stk	New	0.00	12.6	1.58	5.38	0.00	0.6	20.59	30.39	0.0	57.95	13.2	0.07
Philadelphia	Cur	New	0.00	3.3	1.46	3.57	0.00	0.6	20.59	30.42	0.0	56.05	3.9	0.02
North Central														
Chicago	Stk	Old	0.00	70.3	1.52	6.08	0.00	0.6	20.59	29.48	0.0	57.66	70.9	0.36
Chicago	Stk	New	0.00	22.0	1.52	6.08	0.00	0.6	20.59	30.07	0.0	58.25	22.6	0.11
Chicago	Cur	New	0.00	5.9	1.36	3.79	0.00	0.6	20.59	30.09	0.0	55.82	6.5	0.03
Detroit	Stk	Old	0.00	75.8	1.02	5.68	0.00	0.6	20.59	29.46	0.0	56.75	76.4	0.39
Detroit	Stk	New	0.00	24.0	1.02	5.68	0.00	0.6	20.59	30.05	0.0	57.34	24.6	0.13
Detroit	Cur	New	0.00	6.5	1.01	3.66	0.00	0.6	20.59	30.07	0.0	55.32	7.2	0.04
St. Louis	Stk	Old	0.00	54.1	2.13	5.61	0.00	0.6	20.59	30.02	0.0	58.37	54.8	0.27
St. Louis	Stk	New	0.00	13.8	2.13	5.61	0.00	0.6	20.59	30.56	0.0	58.89	14.5	0.07
St. Louis	Cur	New	0.00	4.3	1.83	3.60	0.00	0.6	20.59	30.58	0.0	56.61	5.0	0.03
South														
Miami	Stk	Old	0.00	3.0	5.59	4.21	0.00	0.6	20.59	32.01	0.0	62.38	3.7	0.02
Miami	Stk	New	0.00	1.6	5.59	4.21	0.00	0.6	20.59	32.32	0.0	62.70	2.3	0.01
Miami	Cur	New	0.00	1.6	5.05	3.56	0.00	0.6	20.59	32.36	0.0	61.56	2.3	0.01
New Orleans	Stk	Old	0.00	14.9	3.39	4.57	0.00	0.6	20.59	31.46	0.0	60.01	15.6	0.08
New Orleans	Stk	New	0.00	2.2	3.39	4.57	0.00	0.6	20.59	31.85	0.0	60.39	2.8	0.01
New Orleans	Cur	New	0.00	1.7	2.89	3.36	0.00	0.6	20.59	31.91	0.0	58.75	2.3	0.01
Houston	Stk	Old	0.00	15.8	3.59	4.57	0.00	0.6	20.59	31.44	0.0	60.18	16.4	0.08
Houston	Stk	New	0.00	2.3	3.59	4.57	0.00	0.6	20.59	31.84	0.0	60.59	2.9	0.01
Houston	Cur	New	0.00	1.7	3.01	3.35	0.00	0.6	20.59	31.89	0.0	58.83	2.3	0.01
West														
Los Angeles	Stk	Old	0.00	14.4	0.94	4.19	0.00	0.6	20.59	30.35	0.0	56.08	15.0	0.08
Los Angeles	Stk	New	0.00	1.6	0.94	4.19	0.00	0.6	20.59	30.86	0.0	56.58	2.3	0.01
Los Angeles	Cur	New	0.00	1.6	1.00	3.43	0.00	0.6	20.59	30.88	0.0	55.90	2.3	0.01
San Diego	Stk	Old	0.00	10.4	1.14	3.68	0.00	0.6	20.59	30.38	0.0	55.79	11.0	0.06
San Diego	Stk	New	0.00	1.6	1.14	3.68	0.00	0.6	20.59	30.88	0.0	56.28	2.3	0.01
San Diego	Cur	New	0.00	1.6	1.19	3.37	0.00	0.6	20.59	30.90	0.0	56.05	2.3	0.01
San Francisco	Stk	Old	0.00	31.1	0.46	4.13	0.00	0.6	20.59	29.96	0.0	55.14	31.7	0.17
San Francisco	Stk	New	0.00	1.9	0.46	4.13	0.00	0.6	20.59	30.53	0.0	55.73	2.5	0.01
San Francisco	Cur	New	0.00	1.6	0.53	3.27	0.00	0.6	20.59	30.54	0.0	54.91	2.3	0.01
Phoenix	Stk	Old	0.00	14.0	5.97	5.86	0.00	0.6	20.59	29.15	0.0	61.56	14.6	0.07
Phoenix	Stk	New	0.00	1.9	5.97	5.86	0.00	0.6	20.59	29.72	0.0	62.14	2.5	0.01
Phoenix	Cur	New	0.00	1.6	4.48	3.84	0.00	0.6	20.59	29.76	0.0	58.66	2.3	0.01

4.G APARTMENT

The apartment prototypes have been developed to represent larger multifamily buildings with more than five units. Since residential buildings typically have small to moderate end-use intensities, smaller "garden apartments" would not have thermal and electrical load levels sufficient for cogeneration applications.

Existing Data Sources

The development of apartment prototypes was greatly simplified by previous GRI-funded analysis at LBL that used essentially the same methodology as this project to produce 16 prototypical multifamily buildings to represent the U.S. multifamily stock (Ritschard et al. 1989). The general building descriptions for these prototypes were based on the 1980-82 RECS (Residential Energy Consumption Survey) data, which is a companion survey to NBECS for the residential stock (EIA 1983). More detailed building characteristics were then added based on review of existing studies of residential end-use consumption patterns, engineering judgement, and architectural experience to produce complete DOE-2 input files which were used to generate detailed hourly load files.

The 16 prototypical buildings from the completed GRI study were estimated to represent at least 53.3% of the entire multifamily building stock, including from three to five vintages for each of the four U.S. census regions. The buildings range from small 4-unit uninsulated brick buildings with single-pipe steam heating systems, representing the pre-1940's stock in older eastern cities, to larger multistory buildings with insulated ceilings and walls, double-pane windows, and central forced-air HVAC systems, representing current construction practices (Ritschard et al. 1989). Table 4.G.1 summarizes the 16 prototype multifamily buildings from this earlier GRI study.

For each census region, there are from three to five prototypes representing different vintages and building sizes. Two of the larger prototypes for each census region (*Prototypes 3,4,7,8,11,13, 15 and 16* from Table 4.G.1) were selected as the basis for the market prototypes, one to represent the *Stock*, and the other *Current* vintage.

Statistical Data

Since the existing GRI multifamily prototypes were developed from analysis of the RECS data, there was no need to repeat the data search through RECS to define average multifamily building characteristics. Similarly, comparisons of the prototype buildings' energy intensities and thermal/electric ratios to RECS were unnecessary since those prototypes had already been "calibrated" in earlier projects (Ritschard et al. 1989).

Building Prototype

The prototype apartment buildings for each market area are based on the respective regional prototypes from the GRI/MF study, modified for different building sizes as determined from Dodge Detailed Building Start data.

Table 4.G.1 Summary of Existing GRI Multifamily Building Prototypes

Census region	Proto-type no.	Year built	Pop.‡ (%)	No. of units	No. of floors	Flr area /unit (ft^2)	Wall type	Windows /unit† (ft^2)	Conservation (R) ceil	(R) wall	(No.) panes	HVAC system	DHW config.
North-east	1	pre-1940's	10.6	2-4	2	1143	Wood	123	0	0	2	Steam	common
	2	1950-1959	2.2	2-4	2	1357	Brick	172	7	0	2	Air	indiv.
	3	pre-1940's	4.7	>5	3-5	675	Brick	62	0	0	1	Steam	common
	4	1980's	0.3	>5	3-5	920	Brick	129	30	13	2	Air	indiv.
North Central	5	pre-1940's	6.6	2-4	2	1130	Brick	103	0	0	2	Steam	common
	6	1960-1969	2.3	2-4	2	968	Brick	65	7	7	2	Air	common
	7	1970-1979	5.0	>5	2-5	954	Brick	77	19	11	2	Basebd	indiv.
	8	1980's	0.3	2-9	2	1050	Wood	88	30	13	2	Air	indiv.
South	9	pre-1940's	2.4	2-4	2	863	Wood	83	0	0	1	Air	indiv.
	10	1960-1969	2.4	2-4	2	893	Brick	57	0	0	1	Air	indiv.
	11	1960-1969	3.2	>5	2-5	947	Brick	34	0	0	1	Air	indiv.
	12	1970-1979	3.7	>5	2-5	1022	Brick	37	3	0	1	Air	indiv.
	13	1980's	0.5	>5	2-5	968	Brick	48	21	12	2	Air	indiv.
West	14	pre-1940's	2.6	2-4	2	679	Wood	112	0	0	1	Air	indiv.
	15	1970-1979	4.7	>5	2-5	960	Wood	65	6	3	1	Air	indiv.
	16	1980's	1.8	>5	2-5	955	Wood	49	23	13	2	Air	indiv.

‡ percentage of total multifamily building stock represented by prototype.
† window area includes sliding glass doors.
Source: Zwack and Bernstein 1987.

Size

County-level Dodge Detailed Building Start data was used to determine average apartment building sizes by market area. The average building size was calculated using the Dodge data for all apartment buildings built between 1966 and 1988, but ignoring those smaller than 10,000 ft^2 to eliminate "garden apartments". The number of apartment units and floors for the selected prototype buildings were then adjusted to match as closely as possible the average building sizes by market area based on Dodge. The selected numbers of apartment units per building are shown in the top part of Table 4.G.3.

Table 4.G.3 Building Descriptions for Apartment Prototypes

Building Parameter	North-east	North Central	South	West
Stock vintage				
Floor Area/unit (ft^2)	675	954	947	960
No. of units/no. flrs	Bos: 36/6	Chi: 36/6	Mia: 48/6	LA,SF: 40/4
	NY: 160/10	Det: 18/3	NO: 30/5	SD,Phx: 30/5
	Phi: 42/7	StL: 36/6	Hou: 18/3	
Current vintage				
Floor Area/unit (ft^2)	920	1050	968	955
No. of units/no. flrs	Bos: 18/3	Chi: 36/6	Mia,NO: 30/5	LA,SF: 30/3
	NY: 72/9	Det: 18/3	Hou: 18/3	SD, Phx: 18/3
	Phi: 30/5	StL: 40/4		
Shell characteristics				
Stock vintage:				
Ceiling R-value	0	19	0	6
Wall R-value	0	11	0	3
Window glass	1-pane	2-pane	1-pane	1-pane
Window/wall ratio	0.189	0.222	0.106	0.188
Current vintage:				
Ceiling R-value	30	30	21	23
Wall R-value	13	13	12	13
Window glass	2-pane	2-pane	2-pane	2-pane
Window/wall ratio	0.380	0.242	0.138	0.142
Operational characteristics				
Lights W/ft^2	2.74	2.74	2.74	2.74
Equip W/unit	427	427	427	427
Stock vintage:				
Ft^2/person	540	440	440	440
Hot Water Btu/unit	Bos: 1364	Det,Chi: 2307	Mia: 1442	SF: 2062
	NY,Phi: 1270	StL: 2131	NO,Hou: 1776	Los,SD: 1868
				Phx: 1607
Current vintage:				
Ft^2/person	440	420	430	440
Hot Water Btu/unit	Bos: 2255	Det,Chi: 2645	Mia: 1334	SF: 2047
	NY,Phi: 2100	StL: 2443	NO,Hou: 1643	Los,SD: 1854
				Phx: 1594
System Types	Four-pipe fan coil for heating, direct expansion for cooling.			
Heat Sched	70 F day, 64 F 8 hour night setback			
Cool Sched	78 F all hours			
Heating plant	gas furnace	gas furnace	gas furnace	gas furnace
Cooling plant	electric	electric	electric	electric
Hot water plant	gas boiler	gas boiler	gas boiler	gas boiler

Shell Characteristics

The prototype building characteristics are based on the GRI/MF study and summarized in lower half of Table 4.G.3.

Zone conditions

The zoning of the apartment prototypes uses the same building-block approach as described in the GRI/MF study (Ritschard et al. 1989). Six types of apartment units are distinguished - ground, middle, or top floor, and end-or mid-unit. *End-units* refer to the apartments in the corners that have adjoining apartments only on one side, and, hence, have twice as much exterior wall area as the interior *mid-unit* apartments. Similarly, a distinction is made between ground floors with heat flows to either the ground or an unconditioned basement and an interior ceiling, middle floors with interior floors and ceilings, and top floors with an interior floor but an exterior roof. Lastly, all the prototype apartments have been modeled with a conditioned central corridor/lobby area that is mechanically ventilated to supply fresh air to the apartment units. The apartments in the Northeast and North Central regions are assumed to have unconditioned basements, but those in the South and West regions are assumed to have slab-on-grade construction.

The prototype buildings are assumed to be rectangular in plan, with double-loaded central corridors and apartments on both sides. The number of apartments by type is based on the number of apartments and floors assumed for each prototype. Each floor is assumed to have the same number of apartments. For each floor, there are four corner end-units, with the rest being mid-unit apartments. For example, the large *Stock* vintage New York prototype apartment with 160 units has been modeled with 10 floors (1 ground, 8 middle, and 1 top floor), each with 4 end- and 12 mid-units.

Schedules

The zone schedules for occupancy, lighting, aggregate electricity, and hot water are based on the earlier GRI study. These are shown in Table 4.G.5. In the DOE-2 simulations, the hourly schedules are multiply by the end-use loads shown in Table 4.G.3 to produce the hourly load by end-use and zone.

Systems

Although the apartment prototypes are considered to have central heating and cooling systems (e.g. four-pipe fan coil and direct-expansion chillers), they have been simulated with single-zone residential systems with a forced-air furnace and an electric air conditioner. This was done to take advantage of the ability of the DOE-2 Residential

Table 4.G.5 Hourly Load Profiles for Apartment Prototypes

End-use(s)	Day type*	Hour of Day 1	2	3	4	5	6	7	8
People	All	0.38	0.35	0.33	0.33	0.33	0.41	0.60	0.92
Electric	All	0.07	0.06	0.06	0.05	0.05	0.07	0.09	0.10
Hot Water	WD	0.11	0.11	0.11	0.11	0.11	0.11	1.00	1.00
Hot Water	WEH	0.19	0.19	0.19	0.19	0.19	0.19	0.39	0.58
End-use(s)	Day type*	9	10	11	12	13	14	15	16
People	All	0.88	0.94	0.92	0.72	0.70	0.47	0.44	0.49
Electric	All	0.10	0.09	0.08	0.08	0.07	0.07	0.07	0.07
Hot Water	WD	0.87	0.87	0.87	0.61	0.61	0.49	0.49	0.49
Hot Water	WEH	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
End-use(s)	Day type*	17	18	19	20	21	22	23	24
People	All	0.89	1.00	1.00	0.81	0.78	0.86	0.69	0.42
Electric	All	0.08	0.07	0.11	0.11	0.11	0.11	0.10	0.08
Hot Water	WD	0.49	0.84	0.84	0.84	0.84	0.68	0.68	0.11
Hot Water	WEH	0.77	0.77	0.77	0.77	0.77	0.58	0.39	0.19

* WD = weekdays, WEH = weekends and holidays, All = all days.

system to simulate natural ventilation through operable windows. The substitution of individual for central systems does not affect the data base output since it consists of systems loads, and not plant energy usage.

Calibration

The apartment prototypes are based on those from an earlier GRI study, which in an earlier study had been compared to and found in good agreement with various measured data of multifamily building energy usage (Ritschard et al. 1989). Therefore, it was not surprising that these modified apartment prototypes also compared well with measured consumption from the RECS data base.

We have simulated the prototype apartment buildings with DOE-2.1D to estimate their fuel and electricity uses in four test cities (Boston, St. Louis, Houston, and San Francisco). Table 4.G.6 compares the results to regional average fuel and electricity uses from the 1984 RECS data base.

Table 4.G.6 Comparison of prototype building energy use to RECS for apartments

Region	RECS				City	DOE-2 Simulation		
	Total Electric * (kBtu/ft^2)	Total Fuel (kBtu/ft^2)	F/E Ratio Median	Avg		Total Electric * (kBtu/ft^2)	Total Fuel (kBtu/ft^2)	F/E Ratio
Northeast	21.1	141.1	12.20	6.69	Boston	19.4	101.4	5.24
					New York	16.3	42.2	2.58
					Philadelphia	20.1	79.7	3.96
North Central	16.7	104.0	9.10	6.23	Chicago	16.5	43.8	2.66
					Detroit	16.5	58.3	3.54
					St. Louis	18.3	35.0	1.91
South	36.3	39.6	2.50	1.09	Miami	19.4	11.0	0.57
					New Orleans	17.2	39.7	2.31
					Houston	19.6	53.6	2.73
West	21.1	42.5	3.50	2.01	Los Angeles	13.3	40.0	3.00
					San Diego	13.9	36.3	2.61
					San Francisco	12.8	65.3	5.09
					Phoenix	26.4	31.7	1.20

* electricity kWh are converted to site Btus (1 kWh = 3413 Btu).

Simulation Results

Table 4.G.7 provides information on the calculated annual energy intensities for heating, cooling, lighting, and equipment end uses for the finalized apartment prototypes.

Table 4.G.7 Summary of annual end use intensities for prototype apartments
(electricity in kWh/ft^2 and fuel in kBtu/ft^2)

City	Shell	Eqp	Heating Elec.	Heating Fuel	Cooling Elec.	Fan Elec.	DHW Elec.	DHW Fuel	Lighting Elec.	Misc. Elec.	Misc. Fuel	Total Elec.	Total Fuel	F/E Ratio
Northeast														
Boston	Stk	Old	0.00	89.8	0.84	0.69	0.00	11.7	0.84	3.30	0.0	5.68	101.4	5.24
Boston	Stk	New	0.00	89.8	0.84	0.69	0.00	11.7	0.84	3.30	0.0	5.68	101.4	5.24
Boston	Cur	New	0.00	38.3	2.06	0.38	0.00	14.5	0.86	2.48	0.0	5.77	52.8	2.68
New York	Stk	Old	0.00	31.4	0.36	0.29	0.00	10.8	0.84	3.30	0.0	4.78	42.2	2.58
New York	Stk	New	0.00	31.4	0.36	0.29	0.00	10.8	0.84	3.30	0.0	4.78	42.2	2.58
New York	Cur	New	0.00	17.9	0.97	0.25	0.00	13.5	0.86	2.48	0.0	4.54	31.4	2.02
Philadelphia	Stk	Old	0.00	68.8	1.10	0.66	0.00	10.8	0.84	3.30	0.0	5.89	79.7	3.96
Philadelphia	Stk	New	0.00	68.8	1.10	0.66	0.00	10.8	0.84	3.30	0.0	5.89	79.7	3.96
Philadelphia	Cur	New	0.00	24.9	1.94	0.32	0.00	13.5	0.86	2.48	0.0	5.60	38.4	2.01
North Central														
Chicago	Stk	Old	0.00	29.5	1.25	0.32	0.00	14.3	0.86	2.40	0.0	4.83	43.8	2.66
Chicago	Stk	New	0.00	29.5	1.25	0.32	0.00	14.3	0.86	2.40	0.0	4.83	43.8	2.66
Chicago	Cur	New	0.00	25.7	1.23	0.28	0.00	15.0	0.87	2.19	0.0	4.57	40.7	2.61
Detroit	Stk	Old	0.00	44.0	1.22	0.35	0.00	14.3	0.86	2.40	0.0	4.83	58.3	3.54
Detroit	Stk	New	0.00	44.0	1.22	0.35	0.00	14.3	0.86	2.40	0.0	4.83	58.3	3.54
Detroit	Cur	New	0.00	37.7	1.22	0.30	0.00	15.0	0.87	2.19	0.0	4.57	52.7	3.37
St. Louis	Stk	Old	0.00	21.8	1.79	0.33	0.00	13.2	0.86	2.40	0.0	5.36	35.0	1.91
St. Louis	Stk	New	0.00	21.8	1.79	0.33	0.00	13.2	0.86	2.40	0.0	5.36	35.0	1.91
St. Louis	Cur	New	0.00	18.3	1.75	0.26	0.00	13.9	0.87	2.19	0.0	5.07	32.2	1.86
South														
Miami	Stk	Old	0.00	2.6	2.25	0.32	0.00	8.4	0.86	2.25	0.0	5.68	11.0	0.57
Miami	Stk	New	0.00	2.6	2.25	0.32	0.00	8.4	0.86	2.25	0.0	5.68	11.0	0.57
Miami	Cur	New	0.00	0.4	3.42	0.32	0.00	8.2	0.86	2.36	0.0	6.97	8.6	0.36
New Orleans	Stk	Old	0.00	29.3	1.47	0.45	0.00	10.3	0.86	2.25	0.0	5.04	39.7	2.31
New Orleans	Stk	New	0.00	29.3	1.47	0.45	0.00	10.3	0.86	2.25	0.0	5.04	39.7	2.31
New Orleans	Cur	New	0.00	22.1	1.64	0.31	0.00	10.1	0.86	2.36	0.0	5.16	32.1	1.82
Houston	Stk	Old	0.00	43.3	2.06	0.57	0.00	10.3	0.86	2.25	0.0	5.74	53.6	2.73
Houston	Stk	New	0.00	43.3	2.06	0.57	0.00	10.3	0.86	2.25	0.0	5.74	53.6	2.73
Houston	Cur	New	0.00	35.8	1.88	0.35	0.00	10.1	0.86	2.36	0.0	5.45	45.8	2.46
West														
Los Angeles	Stk	Old	0.00	28.4	0.26	0.41	0.00	11.5	0.86	2.38	0.0	3.90	40.0	3.00
Los Angeles	Stk	New	0.00	28.4	0.26	0.41	0.00	11.5	0.86	2.38	0.0	3.90	40.0	3.00
Los Angeles	Cur	New	0.00	17.0	0.37	0.24	0.00	11.5	0.86	2.39	0.0	3.87	28.5	2.16
San Diego	Stk	Old	0.00	24.8	0.41	0.42	0.00	11.5	0.86	2.38	0.0	4.07	36.3	2.61
San Diego	Stk	New	0.00	24.8	0.41	0.42	0.00	11.5	0.86	2.38	0.0	4.07	36.3	2.61
San Diego	Cur	New	0.00	14.6	0.58	0.26	0.00	11.5	0.86	2.39	0.0	4.07	26.0	1.87
San Francisco	Stk	Old	0.00	52.6	0.13	0.38	0.00	12.7	0.86	2.38	0.0	3.75	65.3	5.09
San Francisco	Stk	New	0.00	52.6	0.13	0.38	0.00	12.7	0.86	2.38	0.0	3.75	65.3	5.09
San Francisco	Cur	New	0.00	32.4	0.14	0.26	0.00	12.7	0.86	2.39	0.0	3.66	45.1	3.61
Phoenix	Stk	Old	0.00	21.8	3.83	0.67	0.00	9.9	0.86	2.38	0.0	7.74	31.7	1.20
Phoenix	Stk	New	0.00	21.8	3.83	0.67	0.00	9.9	0.86	2.38	0.0	7.74	31.7	1.20
Phoenix	Cur	New	0.00	7.2	4.41	0.43	0.00	9.9	0.86	2.39	0.0	8.09	17.1	0.62

4.H LARGE RETAIL

In the U. S., there is a trend toward increased centralization of retail services. The sizes of department stores, warehouse retailers, and shopping malls are all increasing, while groceries and food shops are being replaced by larger and larger supermarkets. This section will give the prototype description for only the large retail store; supermarkets are covered earlier in Section 4.F.

To attract customers, retail store managers are careful to maintain environmental comfort within their stores. Hence, these stores have fairly high usage of gas and electricity to provide comfort and increase visual appeal. Cogeneration can be justified in large retail stores because (1) there are coincidental demands for thermal load and electricity for most of the year, and (2) they have fairly long hours of operations. This potential for cogeneration may be even more lucrative if cooling loads are also met through gas-absorption cycles.

Existing Data Sources

The project reviewed five earlier studies of the physical and operational characteristics, and energy use, of large retail stores. The major characteristics of these prototypes are highlighted in Table 4.H.1. Three of the studies are regional in scope: MEOS summarizes building characteristics for Michigan, LBL for southern California, and ConEd for the Northeast. The EPRI prototype description is derived from NBECS, covers all retail rather than large retail stores, and has no regional variations. The PNL study is an actual retail store modeled using DOE-2.1B.

There are many similarities in the building characteristics from these five studies. The prototypical floor area for the ConEd, MEOS, and PNL studies are above 100,000 ft^2. The floor area for the LBL study is smaller because the prototype represents a wider spectrum of medium to large retail buildings. The EPRI study covers all retail stores in the U.S. and so has a much smaller average size. With the exception of the ConEd study for the New York area, all other prototype stores are 1 to 2 story buildings. The wall and roof insulations of all five prototypes agree within a factor of two, while the percentage of exterior glass vary from 5 to 25. The hours of operation are usually from 9 to 8 on weekdays, and from 11 to 5 on the weekends. The cooling set points are from 72 F to 78 F, typically with a setup to 80 - 85 F during the off-hours. The heating set points are 70 F to 72 F with a setback to 55 - 62 F during the off-hours. The lighting intensities are in the range of 1.4 to 3.4 W/ft^2. The PNL prototype has a lighting intensity of 3.4 W/ft^2 based on an actual audit of the building. This level of intensity is high and probably represents the higher extreme of lighting intensity for large retail stores. The equipment loads in these studies vary widely from 0.1 to 0.75 W/ft^2.

The heating and cooling equipment, and distribution systems of large retail buildings do not vary significantly. Most systems are constant-volume with either central or

Table 4.H.1 Summary of Existing Studies of Large Retail Stores

Report : (see Table 2.3 for coding)	ConEd	EPRI	MEOS	PNL	LBL
Geometry and U-values:					
Floor Area (ft^2)	149,000	25,000	105,800	164,200	67,628
Number of Stories	7	1	2	2	N/A
Percent of Glass in Wall (%)	14	25	6	〈5	8
Wall U-value ($Btu/ft^2 \cdot hr \cdot F$)	0.20	0.10	0.208	.214-.312	0.209
Roof U-value ($Btu/ft^2 \cdot hr \cdot F$)	0.010	0.070	0.120	.065-.111	0.032
Operating Conditions:					
Cooling Temperature Setpoint (F)	74/80	78/85	72/85	78	75
Heating Temperature Setpoint (F)	72/60	70/55	70/62	72/55	71
Standard Day Schedule	N/A	11-18	9-21	10-22	10-21
HVAC Equipment:					
Air Handling System Type	N/A	PSZ	Central	CVVT	PSZ SZRH
Cooling Plant Type	N/A	N/A	DX	Hermetic Centrifugal	N/A
Economizer?	N/A	N/A	N	Y	N/A
Percent Outside Air (annualized)	N/A	15	20	N/A	17
Heating Plant Type*	N/A	Electric	Gas Steam Boiler	Electric	N/A
Internal Loads (peak):					
Occupants (ft^2/person)	N/A	100	135	82	466
Lighting (Watts/ft^2)	1.40	2.00	1.89	3.4	1.65
Equipment/Misc (Watts/ft^2)	0.10	0.50	0.75	N/A	0.28

package cooling units. Newer buildings tend to take advantage of more efficient VAV air handling systems with central heating and cooling plants and economizer cycles. Gas or fuel boilers are used wherever available.

Statistical Data

The statistical data in NBECS on large retail stores represent a fairly small number of observations (61). Table 4.H.2 summarizes the weighted average statistics for large retail building in the four U.S. Census Regions. Analysis of the statistical significance of these characteristics is out of the scope of this study. However, the data can be used in conjunction with other data sources to define prototypical buildings for the 13 cities of interest. Since the four Census Regions include large geographical areas of the country (see Fig. 2.1), the NBECS data search has been narrowed to the SMSA's so that the resultant characteristics will reflect only the urban building stock. Due to inherent limitations in the NBECS data set, it is impossible to distinguish building differences from city to city within a region.

The NBECS buildings have fairly uniform floor areas of 110,000 to 140,000 ft^2 in 2 to 3 floors. The average number of employees are 115 to 221 per store. NBECS does not provide information on the numbers of customers, nor their hourly, daily, or seasonal variations. Sporadic information from other sources has been used in combination with engineering judgement to estimate the average floor area per person. The reported operational hours for all NBECS large retail stores are about 11 to 13 hours.

The percentages of glass on the exterior wall area are fairly small, varying from 20 to 30 per cent. In almost all cases, the glazings are regular single-pane, although a few buildings have reflective glazing. Buildings in all four census regions have some wall and ceiling insulation. 50 to 75% of the roofs are insulated, but only 11 to 40% of the walls. *Stock* vintage prototypes have been simulated with the insulation levels shown in Table 4.H.2, while the *New* vintage prototypes are assumed to follow ASHRAE 90.1-1989 Standards (see Section 4.0). Large retail stores in all regions have gas or fuel heating and electric cooling equipment. The median fuel/electric ratio for the four regions varies from 0.47 in the West to 0.61 in the North Central region. The end-use intensity of the NBECS large retail buildings are in the range of 47 to 96 kBtu/ft^2 (site energy). These intensities have been used to calibrate the prototype retail stores.

Prototype Buildings

The data discussed above has been used to develop 26 prototype for large retail stores shown in Table 4.H.3, two for each city of interest representing *Stock* and *Current* building vintages. The sizes and characteristics of the buildings are widely different as discussed below.

Table 4.H.2 NBECS Statistics for Large Retail (SMSA only)

Parameter	Region Northeast	North Central	South	West
Average Floor Area (x1000 ft^2)	113	138	143	131
Median Fuel/elec ratio	0.54	0.61	0.59	0.47
Average No. Floors	2	3	2	2
Average No. Employees	115	187	221	135
Average Hours Wkday	11	12	12	13
Average Hours Wkend	6	7	7	11
Average Total kBtu/ft^2	59.9	96.3	83.3	47.9
Average Elec kBtu/ft^2	35.4	69.2	63.2	35.9
Average Fuel kBtu/ft^2	26.3	30.5	20.3	13.2
Glass covers <25%	76	67	56	48
Glass covers 25-50%	21	32	43	36
Glass covers 50-75%	2	1	0	15
Glass covers >75%	2	0	0	1
Average glass area (%)	20	21	24	30
% Conservation glass	35	44	41	56
% Wall insulation	11	40	33	33
% Roof/ceiling insulation	75	52	73	67
% Heating setback	83	91	89	67
% Cooling setup	87	93	92	76
% Central heating	94	82	91	93
% Heating system uses furnaces/boilers	47	67	36	44
% Boilers present	27	38	26	27
% Electricity fires boilers	1	0	1	1
% Heat provided by other system	59	40	56	61
% Forced air fans	86	74	88	85
% Heat distributed from baseboards	8	30	16	4
% Electric baseboards	5	8	13	4
% Hot water baseboards	3	14	0	0
% Steam baseboards	0	19	3	0
% Heat fr. radiators/convectors	13	31	9	14
% Heating panels	0	4	0	0
% Other heat distribution	5	20	1	5
% Central air-conditioning	86	36	91	83

Table 4.H.3 Building Descriptions for Large Retail Prototypes

Building Parameter	North-east	North Central	South	West
Floor Areas (1000 ft^2)				
Stock vintage	Bos: 81 NY: 140 Phi: 105	Chi: 103 Det: 86 StL: 88	Mia: 95 NO: 88 Hou: 78	LA: 72 SF: 27 SD: 63 Phx: 79
Current vintage	Bos: 69 NY: 106 Phi: 123	Chi: 94 Det: 91 StL: 89	Mia: 118 NO: 103 Hou: 91	LA: 74 SF: 76 SD: 74 Phx: 66
No. of floors	2	3	2	2
Shell characteristics				
Stock vintage:				
Ceiling R-value	9.0	6.2	7.9	6.7
Wall R-value	1.0	1.6	1.00	1.00
Window glass	1-pane	1-pane	1-pane	1-pane
Current vintage:	ASHRAE-90.1 (see Table 4.1)			
Window shad. coeff	0.50	0.50	0.50	0.50
Window/wall ratio	0.20	0.21	0.24	0.30
Internal loads				
Ft^2/person	135	100	100	135
Lights W/ft^2 (*Stock*)	2.1	2.1	2.1	2.1
Lights W/ft^2 (*New*)	1.8	1.8	1.8	1.8
Equip W/ft^2	.30	.30	.30	.30
Hot Water Btu/hr./person	20	20	20	20
Process Btu/ft^2	N/A	N/A	N/A	N/A
Process W/ft^2	N/A	N/A	N/A	N/A
System Type	One system for each floor; all air single zone			
Old equipment	Reheat, Constant volume for all regions, cooling tower			
New equipment	Variable-air-volume for all regions, cooling tower and economizer			
Heat Schedule	72 F day, 60 F night			
Cool Schedule	75 F day, 85 F night			
Heating plant	gas boiler	gas boiler	gas boiler	gas boiler
Chiller type	hermetic centrif.	hermetic centrif.	hermetic centrif.	hermetic centrif.
Hot water plant	gas boiler	gas boiler	gas boiler	gas boiler

Size

The size of the prototype large retail store varies significantly from less than 27,000 in the San Francisco to 140,000 ft^2 in New York, based on analysis of the detailed Dodge Building Start data. The majority of stores are in the range of 60,000 to 100,000 ft^2. Although the prototype floor areas vary by a factor of five (only two, excluding San Francisco), the average number of floors are fairly constant in the range of 2 to 3. As shown on Table 4.H.3, the variations in size between the *Stock* and *Current* vintage buildings are fairly insignificant, except for San Francisco.

Shell Characteristics

The building shell is lightweight concrete with an average window/wall ratio of 0.20 for all cities. The glazing is assumed to be single pane in all 13 cities. The insulation levels for the *Stock* vintage buildings are derived from NBECS, while those for the *Current* vintage are based on ASHRAE 90.1-1989 guidelines (see Table 4.H.3). The procedure used to derive the average amounts of insulation for the prototype buildings based on NBECS and the ASHRAE 90-75 Standard is described in Section 4.0. The lighting intensity is assumed constant at 2.1 W/ft^2 for *Stock* and 1.8 W/ft^2 for *Current* vintage retail stores. A uniform equipment energy intensity of 0.30 W/ft^2 is assumed for all vintages and geographical regions. The hot water usage has been estimated as 20 Btu/person per day, estimated as follows: (1) 10% of the occupancy is staff with a usage of 135 Btu/person per day, and (2) 90% are customers with a usage of 5 Btu/person per day. Peak power usages for elevators and escalators are 21 kW.

Large retail stores have three modes of occupancy: peak sales period, normal weekday operation, normal weekend operation. During the peak sale periods, the peak time occupancy of the entire store may increase so that the average occupancy is around 20 to 50 ft^2 per person. In normal daily operation, average occupancy is around 100 to 120 ft^2 per person. The prototypes are modeled with average weekday occupancy densities. For weekends, the same occupancy density is assumed, but with shorter hours of operation. Although we are aware of the existence of peak sales periods (e.g., Christmas), no attempt has been made to incorporate these periods into the prototype modeling.

Zone Conditions

The prototype retail stores are assumed to be rectangular in shape with aspect ratios (length to width) of 0.5. Because of the assumed low window/wall ratio, each floor of the building has been simulated as a single zone, so that the prototype stores have two to three zones. The walls heights are taken to be 15 ft.

Since there is no differentiation by zone, Table 4.H.4 for the large retail prototype is not presented.

Schedules

The occupancy, equipment, hot water and elevator (plus escalator) schedules are summarized in Table 4.H.5.

Table 4.H.5. Occupancy and equipment schedules for large retail stores

Zone	Parameter	Day type*	Hour of Day 1	2	3	4	5	6	7	8
Bldg	People,Hot Water	WD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	" "	WEH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bldg	Lights	WD	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
	"	WEH	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Bldg	Equipment,	WD	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
	Elevators	WEH	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Zone	Parameter	Day type*	Hour of Day 9	10	11	12	13	14	15	16
Bldg	People,Hot Water	WD	0.33	0.67	1.00	1.00	1.00	1.00	1.00	1.00
	" "	WEH	0.00	0.00	0.33	0.67	1.00	1.00	1.00	1.00
Bldg	Lights	WD	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
	"	WEH	0.20	0.20	0.90	0.90	0.90	0.90	0.90	0.90
Bldg	Equipment,	WD	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Elevators	WEH	0.17	0.17	1.00	1.00	1.00	1.00	1.00	1.00
Zone	Parameter	Day type*	Hour of Day 17	18	19	20	21	22	23	24
Bldg	People,Hot Water	WD	1.00	1.00	1.00	1.00	1.00	0.50	0.00	0.00
	" "	WEH	1.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00
Bldg	Lights	WD	0.90	0.90	0.90	0.90	0.20	0.20	0.20	0.20
	"	WEH	0.90	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Bldg	Equipment,	WD	1.00	1.00	1.00	1.00	0.17	0.17	0.17	0.17
	Elevators	WEH	1.00	0.17	0.17	0.17	0.17	0.17	0.17	0.17

* WD = weekdays, WEH = weekends and holidays

For all but the West region, the prototype stores are assumed to be open from 8 a.m. to 6 p.m. on weekdays and from 10 a.m. to 6 p.m. on weekends and holidays. In the West, the stores are assumed to stay open until 9 p.m. on weekdays. 100% occupancy is assumed from 11 a.m. to 6 p.m. on weekdays and from 1 p.m. to 5 p.m. on weekends. For the transition hours of 9 a.m., 10 a.m., and 7 p.m. (10 p.m. in the West) assumed from the day schedule to night schedule. The domestic hot water schedules are assumed to closely follow those for occupancy.

The lighting schedule is assumed to be 90 percent of the peak lighting intensity for hours 9 a.m. to 9 p.m. during the normal weekday operations and 20% for hours 10 p.m. to 8 a.m. For weekends and holidays lighting schedule is 90 per cent during hours 11 a.m. to 5 p.m. and 20% for hours 6 p.m. to 10 a.m. Equipment, escalators, and elevator schedules, like lighting, are also simple square waves, 100 per cent for 9 a.m. to 9 p.m. of weekdays and 17 per cent for all other hours. For weekends and holidays, equipment schedule is 100% from 11 a.m. to 5 p.m. and 17% for other hours.

Systems

Large retail stores in all regions are heated with gas. The cooling is with central centrifugal chillers and cooling towers. The systems are all Single-zone Reheat (SZRH), with Constant-air Volume for the *Old*, and Variable-air Volume for the *New* systems. One system for each floor is considered.

Calibration

The prototype buildings have been simulated using DOE-2.1D to estimate their heating and cooling loads. Systematic sensitivity analyses was not done for large retail stores on the assumption that the sensitivity results for large offices would also apply to retail stores. Set points and operating hours where adjusted in order bring the prototype energy intensities closer to that of NBECS.

The simulated total electricity and fuel use of the prototypical large retail stores in 13 cities and comparison with NBECS consumption data are shown in Table 4.H.6. The results indicate a good comparison between the simulations and NBECS data on thermal and electric energy intensities and fuel/electric ratios.

Simulation Results

Table 4.H.7 provides information on annual energy intensities for heating, cooling, lighting, and equipment end uses for three types of large retail stores in the 13 cities.

Table 4.H.6 Comparision of prototype building energy use to NBECS for large retail stores

Region	NBECS				City	DOE-2 Simulation		
	Total Electric * (kBtu/ft^2)	Total Fuel (kBtu/ft^2)	F/E Ratio Median	F/E Ratio Avg		Total Electric * (kBtu/ft^2)	Total Fuel (kBtu/ft^2)	F/E Ratio
Northeast	35.4	26.3	0.74	0.74	Boston	62.7	34.3	0.55
					New York	62.7	26.1	0.42
					Philadelphia	63.9	28.6	0.45
North Central	69.2	30.5	0.44	0.44	Chicago	55.7	35.6	0.64
					Detroit	54.2	37.4	0.69
					St. Louis	57.7	31.1	0.54
South	63.2	20.3	0.32	0.32	Miami	62.9	2.2	0.04
					New Orleans	60.9	10.5	0.17
					Houston	61.8	11.9	0.19
West	35.9	13.2	0.37	0.37	Los Angeles	73.2	20.6	0.28
					San Diego	70.6	12.5	0.18
					San Francisco	74.6	46.0	0.62
					Phoenix	80.2	21.0	0.26

* electricity kWh are converted to site Btus (1 kWh = 3413 Btu).

4.I SECONDARY SCHOOL

Cogeneration systems are potentially feasible in secondary schools for the following reasons:

1. Secondary schools require substantial process heat for the kitchen and showers during normal operating hours when electricity is also required. During the winter in Northern cities, space heating requirements make the thermal demands of a school even higher.
2. Historically, secondary schools have not been air-conditioned since they are not used during the summer. However, with the increasing trend towards summertime activities in the secondary schools, air-conditioning is becoming more and more required. This demand can be met with combined cogeneration/absorption cooling systems.
3. The existence of a heated swimming pool makes cogeneration even more attractive for a secondary school. However, since such heated pool are not typical, the secondary school prototypes have been simulated without this optional thermal load.

Table 4.H.7 Summary of annual end use intensities for prototype large retail stores

(electricity in kWh/ft^2 and fuel in kBtu/ft^2)

City	Shell	Eqp	Heating Elec.	Heating Fuel	Cooling Elec.	Fan Elec.	DHW Elec.	DHW Fuel	Lighting Elec.	Misc. Elec.	Misc. Fuel	Total Elec.	Total Fuel	F/E Ratio
Northeast														
Boston	Stk	Old	0.29	33.5	3.28	3.28	0.00	0.8	9.28	2.24	0.0	18.37	34.3	0.55
Boston	Stk	New	0.16	18.4	1.63	2.00	0.00	0.8	9.28	2.25	0.0	15.32	19.2	0.37
Boston	Cur	New	0.13	14.5	1.53	1.85	0.00	0.8	7.95	2.25	0.0	13.71	15.3	0.33
New York	Stk	Old	0.23	25.4	3.43	3.17	0.00	0.8	9.28	2.26	0.0	18.37	26.1	0.42
New York	Stk	New	0.11	12.5	1.98	2.04	0.00	0.8	9.28	2.27	0.0	15.68	13.2	0.25
New York	Cur	New	0.09	10.3	1.85	1.88	0.00	0.8	7.95	2.26	0.0	14.03	11.1	0.23
Philadelphia	Stk	Old	0.25	27.8	3.64	3.29	0.00	0.8	9.28	2.26	0.0	18.72	28.6	0.45
Philadelphia	Stk	New	0.12	14.2	2.17	2.12	0.00	0.8	9.28	2.25	0.0	15.94	15.0	0.28
Philadelphia	Cur	New	0.09	9.6	2.00	1.91	0.00	0.8	7.95	2.26	0.0	14.21	10.4	0.21
North Central														
Chicago	Stk	Old	0.28	34.8	2.98	2.89	0.00	0.8	8.01	2.16	0.0	16.32	35.6	0.64
Chicago	Stk	New	0.17	21.3	1.72	1.83	0.00	0.8	8.01	2.13	0.0	13.86	22.1	0.47
Chicago	Cur	New	0.14	17.0	1.62	1.69	0.00	0.8	6.86	2.14	0.0	12.45	17.8	0.42
Detroit	Stk	Old	0.28	36.5	2.69	2.75	0.00	0.8	8.01	2.15	0.0	15.88	37.4	0.69
Detroit	Stk	New	0.18	23.3	1.45	1.67	0.00	0.8	8.00	2.15	0.0	13.45	24.1	0.52
Detroit	Cur	New	0.15	18.2	1.37	1.55	0.00	0.8	6.86	2.14	0.0	12.07	19.0	0.46
St. Louis	Stk	Old	0.25	30.3	3.50	3.00	0.00	0.8	8.00	2.16	0.0	16.91	31.1	0.54
St. Louis	Stk	New	0.15	18.2	2.35	2.03	0.00	0.8	8.00	2.15	0.0	14.68	19.0	0.38
St. Louis	Cur	New	0.12	14.0	2.19	1.84	0.00	0.8	6.86	2.15	0.0	13.16	14.8	0.33
South														
Miami	Stk	Old	0.01	1.4	5.40	2.90	0.00	0.8	8.17	1.95	0.0	18.43	2.2	0.04
Miami	Stk	New	0.00	0.3	5.19	2.72	0.00	0.8	8.17	1.97	0.0	18.05	1.1	0.02
Miami	Cur	New	0.00	0.2	4.83	2.47	0.00	0.8	7.01	1.95	0.0	16.26	1.0	0.02
New Orleans	Stk	Old	0.09	9.7	4.67	2.96	0.00	0.8	8.17	1.95	0.0	17.84	10.5	0.17
New Orleans	Stk	New	0.03	3.4	3.99	2.36	0.00	0.8	8.17	1.98	0.0	16.53	4.2	0.08
New Orleans	Cur	New	0.02	2.5	3.72	2.15	0.00	0.8	7.01	1.95	0.0	14.85	3.4	0.07
Houston	Stk	Old	0.10	11.1	4.82	3.07	0.00	0.8	8.17	1.95	0.0	18.11	11.9	0.19
Houston	Stk	New	0.04	4.1	4.09	2.42	0.00	0.8	8.17	1.95	0.0	16.67	5.0	0.09
Houston	Cur	New	0.03	3.0	3.80	2.20	0.00	0.8	7.01	1.93	0.0	14.97	3.9	0.08
West														
Los Angeles	Stk	Old	0.19	19.8	4.67	4.19	0.00	0.9	9.95	2.45	0.0	21.45	20.6	0.28
Los Angeles	Stk	New	0.04	3.7	2.77	2.53	0.00	0.9	9.95	2.44	0.0	17.73	4.6	0.08
Los Angeles	Cur	New	0.03	3.3	2.56	2.32	0.00	0.9	8.53	2.44	0.0	15.88	4.1	0.08
San Diego	Stk	Old	0.12	11.6	4.32	3.84	0.00	0.9	9.95	2.46	0.0	20.69	12.5	0.18
San Diego	Stk	New	0.02	1.9	2.86	2.58	0.00	0.9	9.95	2.43	0.0	17.84	2.8	0.05
San Diego	Cur	New	0.01	1.4	2.62	2.36	0.00	0.9	8.53	2.45	0.0	15.97	2.3	0.04
San Francisco	Stk	Old	0.40	45.1	4.49	4.58	0.00	0.9	9.95	2.44	0.0	21.86	46.0	0.62
San Francisco	Stk	New	0.17	18.4	1.68	2.50	0.00	0.9	9.95	2.43	0.0	16.73	19.2	0.34
San Francisco	Cur	New	0.06	6.2	1.38	1.97	0.00	0.9	8.53	2.45	0.0	14.39	7.0	0.14
Phoenix	Stk	Old	0.19	20.1	5.99	4.92	0.00	0.9	9.95	2.45	0.0	23.50	21.0	0.26
Phoenix	Stk	New	0.06	6.2	4.57	3.67	0.00	0.9	9.95	2.44	0.0	20.69	7.0	0.10
Phoenix	Cur	New	0.04	4.7	4.22	3.35	0.00	0.9	8.53	2.44	0.0	18.58	5.6	0.09

Existing Data Sources

The project reviewed the secondary school building characteristics documented in six earlier studies. These characteristics are summarized in Table 4.I.1. Three of these studies are regional in scope: NEU3 summarizes building characteristics for New England, MEOS for Michigan, and ConEd for New York. The PNL study represents an actual school modeled with DOE-2. The EPRI prototype description is derived from NBECS and represents a national average. The LBL study summarizes building characteristics from various sources to produce a "typical" school building. The review indicates that the building characteristics in the LBL study adequately describe average characteristics of secondary schools in all regions of the country.

Most of the building characteristics described in these studies are fairly similar. The floor areas range from 47,000 to over 230,000 ft^2, with three in the range of 120,000 - 170,000 ft^2. Except for the ConEd study, the prototypes are all from one to three stories high. The amounts of wall insulation agree within 50%. In addition, the amounts of roof insulation are also fairly uniform, except for the ConEd and LBL studies. The ConEd prototype has a very poorly insulated roof (U = .128), while the LBL building has a very high insulated roof (U = .0175). The percentages of exterior glass are mainly in the range of 20 to 25, although the LBL building has 50% glass on exterior walls. The operational schedules are usually from 8 to 4; the cooling set point is 78 F, some with night time setup; and the heating set points are 70 F to 72 F, some with a night time setback of 62 F. The lighting intensities are also quite uniform, from 1.62 to 2.28 W/ft^2, although the NEU3 study has a intensity of only 0.93 W/ft^2. This seems very low for a typical school that has more than 50% class area. The equipment load in these studies vary from 0.46 to 1.10 W/ft^2.

Table 4.I.1 shows a wide variation in the heating and cooling systems of these studies. Most schools, at least in the northern and western parts of the country, do not have air conditioning. Even in those cases where air conditioning is available, it is used only for a few spaces, mainly offices. This condition, however, may change as schools are used more in the summer, particularly for those in the south and west. There is more consistency in the heating systems. All but the PNL study indicate the schools use fossil fuel (mainly gas) with boilers as their main heating systems.

Statistical Data

The statistical data from NBECS differ widely from the information reported in the other studies. The NBECS data are shown in Table 4.I.2 for the four NBECS geographical regions, again limited to only schools in the urban areas. The NBECS secondary schools are in general much smaller than those summarized in Table 4.I.1, with average floor areas varying from 28,000 to 81,000 ft^2. The average number of floors, however, is similar, varying from 2 in the South and West to 3 in Northeast and North Central

Table 4.I.1 Summary of Existing Studies of Secondary Schools

Report: (see Table 2.3 for coding)	ConEd	EPRI	MEOS	NEU3	PNL	Carroll
Geometry and U-values:						
Floor Area (ft^2)	237,110	67,600	47,299	171,800	123,666	125,330
Number of Stories	6	1	1	3	2	3
Percent of Glass in Wall (%)	20	19	22	25	N/A	~50
Wall U-value ($Btu/ft^2 \cdot hr \cdot F$)	0.20	0.20	0.217	0.32	0.27-0.33	N/A
Roof U-value ($Btu/ft^2 \cdot hr \cdot F$)	0.128	0.070	0.062	0.077	.047-.108	0.0175
Operating Conditions:						
Cooling Setpoint (F)	78/90	78/82	N/A	N/A	78	78
Heating Setpoint (F)	70/63	72/68	70/62	N/A	72/62	72/58
Standard Day Schedule	N/A	9-15	8-16	7-16	N/A	8-16
HVAC Equipment:						
Air Handling System Type	PSZ	Central	Central	CV	VAV	Unit Ventilators
Cooling Plant Type	DX	Open Centrifugal	None	Chiller	DX	Chiller
Economizer	N/A	N/A	N/A	N	Y	Y
% Outside Air (annualized)	N/A	13	30	20	N/A	N/A
Heating Plant Type	N/A	Gas Hot Water Boiler	Gas Steam Boiler	Oil Steam Boiler	Electric Baseboard	Boiler
Internal Loads (peak):						
Occupants (ft^2/person)	N/A	82	65	166	57	134
Lighting (Watts/ft^2)	1.70	2.28	1.62	0.93	2.1	1.82
Equipment/Misc (Watts/ft^2)	1.10	0.65	0.46	N/A	N/A	N/A

Table 4.I.2 NBECS Statistics for Secondary School (SMSA only)

Parameter	Region Northeast	North Central	South	West
Average Floor Area (x1000 sf)	49.6	81.1	29.9	26.7
Median Fuel/elec ratio	3.77	4.34	0.85	3.30
Average No. Floors	3	3	2	2
Average No. Employees	52	66	26	24
Average Hours Wkday	9	12	9	8
Average Hours Wkend	3	2	1	2
Average Total kBtu/sf	157.8	124.8	53.9	68.6
Average Elec kBtu/sf	32.7	24.7	20.2	19.1
Average Fuel kBtu/sf	125.1	100.1	33.7	49.5
Glass covers <25%	33	20	54	51
Glass covers 25-50%	37	53	29	32
Glass covers 50-75%	26	26	11	17
Glass covers >75%	5	1	7	0
Average glass area (%)	38	39	30	29
% Conservation glass	53	54	19	35
% Wall insulation	51	19	24	30
% Roof/ceiling insulation	48	62	61	49
% Heating setback	97	94	99	100
% Cooling setup	34	79	99	45
% Central heating	92	97	66	98
% Heating system uses furnaces/boilers	87	84	51	71
% Boilers present	64	52	21	13
% Electricity fires boilers	1	0	1	0
% Heat provided by other system	7	20	26	29
% Forced air fans	45	80	45	94
% Heat distributed from baseboards	44	35	7	3
% Electric baseboards	9	4	1	0
% Hot water baseboards	32	30	2	3
% Steam baseboards	4	8	5	0
% Heat fr. radiators/convectors	80	67	28	24
% Heating panels	16	7	3	2
% Other heat distribution	5	6	9	14
% Central air-conditioning	29	51	57	46

regions. The reported operational hours for most NBECS school buildings is 9, with longer hours of operation in the Northeast region. This variation in the hours of operation is not considered significant.

NBECS also reports the average percent glass area to be in the range of 30 - 40%. Most of the buildings (50-60%) in all four regions have some ceiling or wall insulation. The frequency of wall insulation varies significantly from ~20% in the North Central to over 50% in the Northeast region. This amount of variation in wall insulation levels between two regions with similar winter heating requirements is surprising. Secondary schools in all regions are heated predominantly with gas or fuel; however, only buildings in the Northeast and North Central regions have boilers. The saturation of air conditioning systems is about 30% in the Northeast, and 45 - 57% in the other regions. The energy intensity of the NBECS secondary schools are in the range of 54 to 158 kBtu/ft^2 (site energy). Buildings in the West and South regions use almost three times less fuel, which is mainly used for heating. Electricity use intensities are fairly constant, in the range of 20 to 32 kBtu/ft^2. These End-use Intensities are used to calibrate the prototype secondary school buildings for the 13 cities.

Prototype Buildings

Based on review of the above data, 25 prototype secondary school buildings have been developed (two vintages per city). These are shown in Table 4.I.3, with the differences in building size and characteristics discussed below.

Size

The total square footages of the prototype secondary schools are derived from the National Center of Educational Statistics (NCES) data base, which lists every public and private school in the country. Since the NCES data base does not record the actual building size, the following equation has been used to estimate square footage based on a school's enrollment :

$$\text{Area}(\text{ft}^2) = \text{Enrollment} \cdot 135.7 + 35415 \qquad (1)$$

This equation is based on regression analyses comparing floor areas to enrollment for several hundred secondary schools in Minnesota, with a R^2 of .77 (personal communication, Carroll 1990). A statistical search was made by county for the 20 market areas, and average secondary school floor areas calculated for each of the 13 cities comprising the market areas. These are shown on the top part of Table 4.I.3. It should be noted that the same size has been used for both the *Stock* and *Current* vintage buildings.

Table 4.I.3 Building Descriptions for Secondary School Prototypes

Building Parameter	North-east	North Central	South	West
Floor Areas (1000 ft^2)‡				
Stock Vintage	Bos: 177 NY: 208 Phi: 196	Chi: 218 Det: 195 StL: 170	Mia: 224 NO: 173 Hou: 205	LA: 242 SF: 194 SD: 212 Phx: 198
Current Vintage	Bos: 177 NY: 208 Phi: 196	Chi: 218 Det: 195 StL: 170	Mia: 224 NO: 173 Hou: 205	LA: 242 SF: 194 SD: 212 Phx: 198
No. of floors	3	3	3	3
Shell characteristics				
Stock Vintage:				
Ceiling R-value	5.8	7.4	6.1	4.9
Wall R-value	1.5	1.0	1.0	1.0
Window glass	1-pane	1-pane	1-pane	1-pane
Current Vintage:	ASHRAE-90.1 (see Table 4.1)			
Window shad. coeff	0.85	0.85	0.85	0.85
Window/wall ratio	0.38	0.39	0.30	0.29
Internal loads				
Ft^2/person	See Table 4.I.4 †			
Lights W/ft^2	See Table 4.I.4 †			
Equip W/ft^2	See Table 4.I.4 †			
Hot Water Btu/person.hr	210	210	210	210
Process Hot Water	142	142	142	142
System Type	Unitary ventilation systems			
Old Equipment	no cooling			
New Equipment	Packaged Multi-zone			
Heat Sched	75 F day, 65 F night (7:00-9:00 p.m.)			
Cool Sched	78 F day, 85 F night (7:00-9:00 p.m.)			
Heating plant	gas boiler	gas boiler	gas boiler	gas boiler
Chiller type for *New* Vintage	hermetic centrif.	hermetic centrif.	hermetic centrif.	hermetic centrif.
Hot water plant	gas boiler	gas boiler	gas boiler	gas boiler

† constant for all cities but varies by building zone, numbers are approximate since zone peaks may not be coincident.

‡ Source: NCES

Shell Characteristics

The secondary schools were modeled as concrete block buildings with built-up roofs. The total window/wall ratio varies from 0.38 in the Northeast region to 0.29 in the West. The windows are assumed to be single pane for all four regions. The insulation levels for the *Stock* vintage buildings are derived from NBECS, while those for the *Current* vintage are based on ASHRAE 90.1-1989 guidelines. The procedure used to derive the average amounts of insulation for the prototype buildings based on NBECS and the ASHRAE 90-75 Standard is described in Section 4.0.

The lighting intensities by zone are summarized in Table 4.I.4. These vary from 0.65 W/ft^2 in the gymnasium to 2.2 W/ft^2 in the classrooms. These lighting intensity have been assumed to be the same for all regions. A uniform equipment energy intensity of 0.5 W/ft^2 has been assumed for all building zones except the kitchen. The domestic hot water usage is assumed to be 210 Btu/person per hour, plus a process hot water use of 142 kBtu/hour·ft^2 in the kitchen during meal hours.

Table 4.I.4. Zone descriptions for Secondary School Prototype

	Zones					
	Music,Lib., Home-making	Class-rooms	Gym	Audit-orium	Kitchen	Dining
Floor Area (% total)	13	60	13	8	2	4
Wall Height	10	10	32	32	10	10
Window/wall ratio	55	30	8	0	0	30
Ft^2/person	100	90	180	100	300	20
Lights W/ft^2	1.5	2.2	0.65	0.80	1.7	1.7
Equip. W/ft^2	0.5	0.5	0.5	0.5	50	15
Process Btu/ft^2					142	

Zone Conditions

The physical layout and proportions of the classrooms, offices, and other spaces are adopted from the LBL study (Webster et al. 1985), but the total wall areas, floor areas, and window/wall ratios have been adjusted for each city to incorporate the results from the other studies. The building is simulated with six zones: 1) music room, library, and home making classes; 2) classrooms; 3) gymnasium; 4) auditorium; 5) kitchen; and 6) dining room. The characteristics of these zones are summarized in Table 4.I.4. The walls height is assumed to be 10 ft. in all zones except the gym and auditorium, where it is assumed to be 30 ft. The internal loads and occupancy intensities are also summarized in Table 4.I.4.

Schedules

The schedules for occupancy, equipment, and hot water are given in Table 4.I.5. The classrooms are occupied from 7:00 a.m. until 3:00 p.m. on weekdays with partial occupancy in the evenings from 7:00 p.m. until 10:00 p.m. and on Saturdays from 10:00 a.m. until 1:00 p.m. During the summer the classrooms are 50 percent occupied from 10:00 a.m. until 3:00 p.m. to simulate summer sessions. The lighting in the classrooms tracks the occupancy with 90 percent of peak during the day and approximately 70 percent during the evenings and summer.

The gym, auditorium, kitchen, and dining rooms are occupied only during weekdays of regular sessions, starting between 8:00 a.m. and 10:00 a.m. and trailing off around 4:00 p.m.

The same schedule as the lighting is used for equipment schedules in all zones except the kitchen. The kitchen has its own equipment schedule which takes into account meal preparation and cleanup.

Systems

In most older schools, the classrooms are typically heated, but not air conditioned. In the newer schools, particularly in the South and West regions, the classrooms have packaged heat pump units that provide both heating and cooling. The prototype schools have been modeled with gas heating for all regions, with boiler in the Northeast and North Central and furnaces in South and West regions. For schools with *Old* equipment, only a few office areas are assumed to be air-conditioned with packaged rooftop units that are basically single-zone constant volume systems. Schools with *New* equipment are assumed to be conditioned with packaged multi-zone systems.

Calibration

The prototype buildings have been simulated using DOE-2.1D to estimate their heating and cooling loads. Initial simulations of the secondary school prototype showed good agreement when compared with the NBECS electric intensities but much lower fuel intensities. Therefore, we increased the heating set points, evening operating hours, and hot water intensities. Total fuel intensities are still somewhat low but we feel that the current prototype is reasonable for the types of schools we are considering.

The simulated total electricity and fuel use of the prototypical secondary schools in 13 cities and comparison with NBECS consumption data are shown in Table 4.I.6.

Table 4.I.5 Hourly Load Profiles for Secondary School Prototypes

Zone	End-use(s)	Day type*	Hour of Day 1	2	3	4	5	6	7	8	9	10	11	12
Class	People	WD	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.90	0.90	0.90	0.90	0.80
"	"	Sat	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.10	0.10
"	"	Sun,Hol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
"	"	Sum WD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.50	0.50
"	Light	WD	0.10	0.10	0.10	0.10	0.10	0.10	0.20	0.95	0.95	0.95	0.95	0.95
"	"	Sat	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.30	0.30	0.30
"	"	Sun,Hol	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
"	"	Sum WD	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.75	0.75	0.75
Gym	People	WD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00
"	"	WEH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
"	Light	WD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.90	0.90	0.90	0.90	0.90
"	"	WEH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Auditorium	People	WD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.75	0.75	0.20
"	"	WEH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
"	Light	WD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.90	0.90	0.90
"	"	WEH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kitchen	People	WD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.70	1.00	1.00
"	"	WEH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
"	Light	WD	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.70	1.00	1.00
"	"	WEH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
"	Equip	WD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.30	0.40
"	"	WEH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dining	People	WD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00
"	"	WEH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
"	Light	WD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	1.00	1.00
"	"	WEH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Building	Hot Water	WD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.30	0.55	0.60	0.70
"	"	WEH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
"	"	Sum WD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.30

* WD = weekdays, WEH = weekends and holidays, Sum WD = summer weekdays.

Table 4.I.5 Hourly Load Profiles for Secondary School Prototypes (continued)

Zone	End-use(s)	Day type*	Hour of Day 13	14	15	16	17	18	19	20	21	22	23	24
Class	People	WD	0.80	0.80	0.80	0.45	0.15	0.05	0.33	0.33	0.33	0.00	0.00	0.00
"	"	Sat	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
"	"	Sun,Hol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
"	"	Sum WD	0.50	0.50	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
"	Light	WD	0.80	0.80	0.80	0.80	0.30	0.20	0.66	0.66	0.66	0.10	0.10	0.10
"	"	Sat	0.30	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
"	"	Sun,Hol	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
"	"	Sum WD	0.75	0.75	0.75	0.30	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Gym	People	WD	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
"	"	WEH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
"	Light	WD	0.90	0.90	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
"	"	WEH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Auditorium	People	WD	0.75	0.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
"	"	WEH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
"	Light	WD	0.90	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
"	"	WEH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kitchen	People	WD	1.00	1.00	1.00	1.00	0.70	0.70	0.00	0.00	0.00	0.00	0.00	0.00
"	"	WEH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
"	Light	WD	1.00	1.00	1.00	1.00	1.00	1.00	0.10	0.10	0.10	0.10	0.10	0.10
"	"	WEH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
"	Equip	WD	0.80	0.95	0.55	0.35	0.20	0.10	0.00	0.00	0.00	0.00	0.00	0.00
"	"	WEH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dining	People	WD	1.00	0.20	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
"	"	WEH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
"	Light	WD	1.00	0.40	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
"	"	WEH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Building	Hot Water	WD	0.75	0.80	0.60	0.60	0.50	0.50	0.15	0.20	0.20	0.20	0.00	0.00
"	"	WEH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
"	"	Sum WD	0.30	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

* WD = weekdays, WEH = weekends and holidays, Sum WD = summer weekdays.

Table 4.I.6 Comparison of prototype building energy use to NBECS for secondary schools

Region	NBECS				City	DOE-2 Simulation		
	Total Electric * (kBtu/ft^2)	Total Fuel (kBtu/ft^2)	F/E Ratio Median	F/E Ratio Avg		Total Electric * (kBtu/ft^2)	Total Fuel (kBtu/ft^2)	F/E Ratio
Northeast	32.7	125.1	3.77	3.83	Boston	24.8	66.9	2.69
					New York	24.3	57.7	2.37
					Philadelphia	24.2	56.9	2.35
North Central	24.7	100.0	4.34	4.05	Chicago	24.9	70.0	2.81
					Detroit	24.9	74.4	2.98
					St. Louis	24.3	56.6	2.33
South	20.2	33.0	0.85	1.63	Miami	22.1	7.6	0.35
					New Orleans	22.7	19.5	0.86
					Houston	22.7	19.1	0.84
West	19.1	49.5	3.30	2.59	Los Angeles	22.6	19.3	0.85
					San Diego	22.5	16.5	0.74
					San Francisco	23.2	32.5	1.40
					Phoenix	22.6	17.7	0.78

* electricity kWh are converted to site Btus (1 kWh = 3413 Btu).

Simulation Results

Table 4.I.7 provides information on annual energy intensities for heating, cooling, lighting, and equipment end uses for the finalized of secondary school prototypes in the 13 cities.

Table 4.I.7 Summary of annual end use intensities for prototype secondary schools
(electricity in kWh/ft^2 and fuel in kBtu/ft^2)

			Heating		Cooling	Fan	DHW		Lighting	Misc.		Total	Total	F/E
City	Shell	Eqp	Elec.	Fuel	Elec.	Elec.	Elec.	Fuel	Elec.	Elec.	Fuel	Elec.	Fuel	Ratio
Northeast														
Boston	Stk	Old	0.57	60.8	0.00	0.31	0.00	6.1	4.54	1.85	0.0	7.27	66.9	2.69
Boston	Stk	New	0.00	46.6	0.72	1.79	0.00	6.1	4.54	1.86	0.0	8.91	52.8	1.74
Boston	Cur	New	0.00	35.0	0.72	1.54	0.00	6.1	4.54	1.87	0.0	8.67	41.2	1.39
New York	Stk	Old	0.47	51.5	0.00	0.25	0.00	6.1	4.54	1.86	0.0	7.12	57.7	2.37
New York	Stk	New	0.00	38.8	0.93	1.64	0.00	6.1	4.54	1.86	0.0	8.97	44.9	1.47
New York	Cur	New	0.00	29.4	0.93	1.45	0.00	6.1	4.54	1.87	0.0	8.79	35.6	1.19
Philadelphia	Stk	Old	0.46	50.7	0.00	0.24	0.00	6.1	4.54	1.85	0.0	7.09	56.9	2.35
Philadelphia	Stk	New	0.00	38.3	1.10	1.67	0.00	6.1	4.54	1.86	0.0	9.17	44.5	1.42
Philadelphia	Cur	New	0.00	29.0	1.09	1.46	0.00	6.1	4.54	1.85	0.0	8.94	35.1	1.15
North Central														
Chicago	Stk	Old	0.58	63.8	0.00	0.31	0.00	6.1	4.54	1.87	0.0	7.30	70.0	2.81
Chicago	Stk	New	0.00	47.5	0.92	1.83	0.00	6.1	4.54	1.88	0.0	9.17	53.6	1.72
Chicago	Cur	New	0.00	34.8	0.89	1.49	0.00	6.1	4.54	1.84	0.0	8.76	41.0	1.37
Detroit	Stk	Old	0.60	68.3	0.00	0.30	0.00	6.1	4.54	1.86	0.0	7.30	74.4	2.98
Detroit	Stk	New	0.00	47.5	0.68	1.71	0.00	6.1	4.54	1.86	0.0	8.79	53.7	1.79
Detroit	Cur	New	0.00	35.6	0.64	1.39	0.00	6.1	4.54	1.87	0.0	8.44	41.8	1.45
St. Louis	Stk	Old	0.45	50.5	0.00	0.27	0.00	6.1	4.54	1.86	0.0	7.12	56.6	2.33
St. Louis	Stk	New	0.00	39.6	1.48	1.81	0.00	6.1	4.54	1.87	0.0	9.70	45.7	1.38
St. Louis	Cur	New	0.00	30.3	1.45	1.58	0.00	6.1	4.54	1.86	0.0	9.43	36.5	1.13
South														
Miami	Stk	Old	0.02	1.5	0.00	0.05	0.00	6.1	4.54	1.87	0.0	6.48	7.6	0.35
Miami	Stk	New	0.00	3.8	4.21	1.53	0.00	6.1	4.54	1.85	0.0	12.13	9.9	0.24
Miami	Cur	New	0.00	3.3	4.13	1.44	0.00	6.1	4.54	1.87	0.0	11.98	9.5	0.23
New Orleans	Stk	Old	0.13	13.3	0.00	0.11	0.00	6.1	4.54	1.87	0.0	6.65	19.5	0.86
New Orleans	Stk	New	0.00	14.9	2.52	1.53	0.00	6.1	4.54	1.87	0.0	10.46	21.1	0.59
New Orleans	Cur	New	0.00	11.4	2.45	1.38	0.00	6.1	4.54	1.86	0.0	10.23	17.5	0.50
Houston	Stk	Old	0.13	12.9	0.00	0.11	0.00	6.1	4.54	1.87	0.0	6.65	19.1	0.84
Houston	Stk	New	0.00	14.1	2.75	1.52	0.00	6.1	4.54	1.86	0.0	10.67	20.2	0.55
Houston	Cur	New	0.00	10.8	2.68	1.38	0.00	6.1	4.54	1.86	0.0	10.46	16.9	0.47
West														
Los Angeles	Stk	Old	0.13	13.1	0.00	0.09	0.00	6.1	4.54	1.86	0.0	6.62	19.3	0.85
Los Angeles	Stk	New	0.00	15.2	1.08	1.38	0.00	6.1	4.54	1.85	0.0	8.85	21.3	0.71
Los Angeles	Cur	New	0.00	11.5	1.09	1.28	0.00	6.1	4.54	1.85	0.0	8.76	17.6	0.59
San Diego	Stk	Old	0.11	10.4	0.00	0.08	0.00	6.1	4.54	1.86	0.0	6.59	16.5	0.74
San Diego	Stk	New	0.00	13.7	1.34	1.48	0.00	6.1	4.54	1.87	0.0	9.23	19.9	0.63
San Diego	Cur	New	0.00	10.3	1.34	1.37	0.00	6.1	4.54	1.86	0.0	9.11	16.4	0.53
San Francisco	Stk	Old	0.25	26.3	0.00	0.14	0.00	6.1	4.54	1.87	0.0	6.80	32.5	1.40
San Francisco	Stk	New	0.00	23.8	0.49	1.33	0.00	6.1	4.54	1.87	0.0	8.23	29.9	1.07
San Francisco	Cur	New	0.00	16.7	0.52	1.22	0.00	6.1	4.54	1.87	0.0	8.15	22.9	0.82
Phoenix	Stk	Old	0.12	11.6	0.00	0.11	0.00	6.1	4.54	1.85	0.0	6.62	17.7	0.78
Phoenix	Stk	New	0.00	15.4	2.88	1.80	0.00	6.1	4.54	1.86	0.0	11.08	21.6	0.57
Phoenix	Cur	New	0.00	10.2	2.53	1.50	0.00	6.1	4.54	1.86	0.0	10.43	16.3	0.46

4.J SMALL HOTEL/MOTEL

Small hotels and motels are similar to large hotels, except that they generally lack a large lobby/conference area and do not have full-service kitchens and restaurants. Although the thermal needs of the small hotels/motels are not as great as those for large hotels, there are still significant concurrent needs for both electricity and thermal energy that make them moderately attractive candidates for cogeneration applications. The thermal energy is used primarily for space heating, hot water, laundry, and, in some cases, a heated pool. The electricity is used for lighting, air conditioning, and miscellaneous appliances and equipment.

Existing Data Sources

Three of the engineering studies reviewed developed prototype buildings for small hotel/motels (EPRI, MEOS and SCE1). The characteristics of these prototypes are shown in Table 4.J.1. The EPRI prototype is a national average based on NBECS data with no regional variation. The MEOS prototype has been developed for the North Central region, while the SCE1 prototype is for southern California.

The EPRI and MEOS prototypes both have three stories with total floor areas of 60,00, and 17,000 ft^2. The SCE1 prototype has ten stories and is more representative of a mid-size hotel rather than a motel. Because of its similarity to large hotels, the SCE1 prototype has not been used for defining the small hotel/motel prototype. The wall and roof insulations of the EPRI and MEOS prototypes agree within a factor of less than two. The percentage of exterior glass varies from 12 to 17%. Although small hotels/motels have a 24-hour operating schedule, there is generally minimal room occupancy during the day as compared to the night. The cooling set points in the two prototypes are 75 F, with a daytime set-up of 78 F for the EPRI study. The heating set points are 70 F to 72 F, with a night set-back to 65 F for the EPRI study. The prototypes assume lighting intensities in the range of 1.1 to 1.2 W/ft^2, and equipment wattages of 1.0 or 0.58 W/ft^2.

The most significant variation between the two prototypes is in the HVAC equipment and distribution systems. The EPRI study assumes that the building has a water loop heat pump for both heating and cooling. The MEOS study assumes that air conditioning is provided by a packaged direct-expansion unit, and heating by a hot water unit with a central electric boiler.

Statistical Data

We have obtained the NBECS statistical data for all small hotels/motels in the range of 1 to 3 stories. These data are summarized in Table 4.J.2 for four geographical regions. Note that the data reflect characteristics of small hotels/motels in the Standard Metropolitan Statistical Area (SMSA's). The variations in the average floor areas for

Table 4.J.1 Summary of Existing Studies of Small Hotels

Report: (see Table 2.3 for coding)	EPRI	MEOS	SCE1
Geometry and U-values:			
Floor Area (ft^2)	60,000	17,280	54,650
Number of Stories	3	3	10
Percent of Glass in Wall (%)	12	17	19
Wall U-value ($Btu/ft^2 \cdot hr \cdot F$)	0.10	0.184	0.30
Roof U-value ($Btu/ft^2 \cdot hr \cdot F$)	0.070	0.064	0.126
Operating Conditions:			
Cooling Setpoint (F)	75/78	75	71
Heating Setpoint (F)	70/65	72	73
Standard Day Schedule	20-7	24hr	24hr
HVAC Equipment:			
Air Handling System Type	N/A	Package	Package
Cooling Plant Type	Water Loop Heatpump	Direct Expansion	Direct Expansion
Economizer	No	No	No
% Outside Air (annualized)	7	20	25
Heating Plant Type	Water Loop Heatpump	Electric Hot Water Boiler	Electric Resistance
Internal Loads (peak):			
Occupants (ft^2/person)	357	144	251
Lighting (Watts/ft^2)	1.20	1.09	1.87
Equipment/Misc (Watts/ft^2)	1.00 *	0.58	N/A

three of the four regions (all but North Central) are fairly small: 9,500 to 14,800 ft^2 in 2 floors. In design of our prototype, we use other sources of information for the prototypical floor area. Also, we would like to emphasize that variation in the sizes of the small hotels/motels do not significantly affect their energy use intensity, provided that the same services are offered. The average floor area per occupant obtained from the NBECS data base does not include the guests. In our analysis, we assume a peak occupancy of two guests per room. Similarly, the reported operational hours for all NBECS small hotel/motel buildings only reflects the working hours of the hotel staff. For all practical purposes, small hotels/motels operate 24 hours a day, however, with varying schedules.

NBECS also reports a wide range of the average glass area: 23 -56%. Excluding Northeast region, the range is only 23 - 32%. Small hotels/motels in all geographical areas have some level of insulation in walls and ceilings. Insulation level is highest in

Northeast region and gets gradually smaller in the North Central, South, and West regions. The majority of small hotels/motels in the northern part of the country are equipped with boilers, while less than 20% of small hotels/motels in the south and west have them. Central air-conditioning is mainly present in South and West and in the North, central heating is more popular. NBECS data for small hotels/motels show very high energy use intensities and significant regional variations. Ignoring the statistical variations of the data because of the small sample size, the high electricity use in the South and West can be explained by extensive use of air conditioning. The high thermal use in the West can be explained by an unusual energy sink such as a heated pool.

Prototype Buildings

Using the data discussed above and the Dodge database, 26 prototype small hotel/motel buildings (13 for *Stock* vintage, 13 for *Current* vintage) have been developed for each city of interest (Table 4.J.3). The major differences between these prototypes are their sizes and the HVAC equipment. The size and characteristics of the buildings are discussed below.

Size

The size of our prototype small hotel/motel buildings for the *Stock* and the *Current* vintages varies from 20,000 in the New York NY to 46,000 ft^2 in the Phoenix AZ. Although the average floor areas vary by over a factor of two, all prototypes have been modeled with two floors based on the *Dodge Project Detail* data.

Shell Characteristics

The small hotel/motel buildings are modeled as slab-on-grade with wood frame construction and the total window/wall ratio for the rooms is assumed to be 0.56, 0.23, 0.32, and 0.23 for the Northeast, North Central, South, and West regions, respectively. For the *Stock* vintage, the windows are assumed to be single pane throughout the country. However, the window shading coefficients are assumed to be 0.6 in Northeast and North Central and 0.4 in South and West. The ceilings are generally insulated in all regions, but the wall have minimal insulation. For the *Current* vintage, the prototype shell conditions are based on ASHRAE 90.1-1989 standards.

Zone Conditions

The small hotels/motels are simulated with three major zones: guest rooms (90% of the total area); laundry (5% of the total area); and lobby (5% of the total area). The wall heights for all zones are 8 feet. All the internal loads and schedules are summarized in

Table 4.J.2 NBECS Statistics for Small Hotels (1-3 stories, SMSA only)

	Region			
Parameter	Northeast	North Central	South	West
Average Floor Area (x1000 sf)	12.5	33.9	14.8	9.5
Median Fuel/elec ratio	2.30	1.53	0.53	1.89
Average No. Floors	2	2	2	2
Average No. Employees	10	31	31	9
Average Hours Wkday	16	24	22	22
Average Hours Wkend	14	24	21	22
Average Total kBtu/sf	161.2	285.1	338.1	1257.9
Average Elec kBtu/sf	55.1	80.0	235.7	192.7
Average Fuel kBtu/sf	106.1	205.2	102.5	1065.3
Glass covers <25%	0	73	60	57
Glass covers 25-50%	26	19	13	43
Glass covers 50-75%	74	0	13	1
Glass covers >75%	0	8	13	0
Average glass area (%)	56	23	32	24
% Conservation glass	15	55	35	19
% Wall insulation	85	55	33	33
% Roof/ceiling insulation	94	55	46	40
% Heating setback	37	100	77	76
% Cooling setup	100	90	97	21
% Central heating	95	59	60	55
% Heating system uses furnaces/boilers	95	55	19	24
% Boilers present	100	85	20	6
% Electricity fires boilers	0	0	0	0
% Heat provided by other system	0	6	43	30
% Forced air fans	10	14	40	38
% Heat distributed from baseboards	100	6	13	25
% Electric baseboards	15	4	13	25
% Hot water baseboards	85	2	0	0
% Steam baseboards	0	0	0	0
% Heat fr. radiators/convectors	10	56	10	0
% Heating panels	5	16	26	39
% Other heat distribution	0	17	25	13
% Central air-conditioning	10	19	57	0

Table 4.J.3 Building Descriptions for Small Hotel/Motel Prototypes

Building Parameter	North-east	North Central	South	West
Floor Area (1000 ft^2)				
Stock vintage	Bos: 40 NY: 31 Phi: 27	Chi: 35 Det: 36 StL: 34	Mia: 33 NO: 21 Hou: 31	LA: 27 SFO: 34 SD: 26 Phx: 46
Current vintage	Bos: 28 NY: 20 Phi: 34	Chi: 37 Det: 46 StL: 40	Mia: 28 NO: 31 Hou: 29	LA: 29 SFO: 34 SD: 36 Phx: 45
No. of floors	2	2	2	2
Shell characteristics:				
Stock vintage:				
Ceiling R-value	13.7	12.1	9.0	8.0
Wall R-value	2.6	2.2	1.0	1.0
Window glass	1-pane	1-pane	1-pane	1-pane
Current vintage:	ASHRAE-90.1 (see Table 4.1)			
Window shad. coeff	0.6	0.6	0.4	0.4
Window/wall ratio	0.56	0.23	0.32	0.23
Ft^2/person	† (see Table 4.J.4 for zone variations)			
Lights W/ft^2	† (see Table 4.J.4 for zone variations)			
Equip W/ft^2	† (see Table 4.J.4 for zone variations)			
Hot Water Btu/person·hour	1,420			
System Type	*Old*: 2 systems: packaged single-zone for lobby/offices; central gas and window-AC in rooms in South and West (no AC in Northeast and North Central) *New*: 2 systems: packaged single-zone VAV for lobby/offices; for rooms, central gas and window-AC in North Central and Northeast, heat pumps in the West and South			
Heat Sched	72 F			
Cool Sched	76 F			
Heating plant	gas furnace	gas furnace	gas furnace	gas furnace
Chiller	packaged dir-exp.	packaged dir-exp.	packaged dir-exp.	packaged dir-exp.
Hot water plant	gas boiler	gas boiler	gas boiler	gas boiler

† constant for all cities but varies by building zone, numbers are approximate since zone peaks may not be coincident.

Table 4.J.4.

Table 4.J.4 Zone descriptions for Small Hotel/Motel Prototype

	Guest Rooms	Lobby	Laundry
Floor Area (% total)	90	5	5
Wall Height (ft)	8	8	8
Ft^2/person	100	200	400
Lights W/ft^2	1.0	1.5	1.7
Equipment W/ft^2	0.6	0.0	3.0
Process Btu/bldg ft^2	0	0	16

The lighting intensities are assumed to be the same for all regions and varies from 1 W/ft^2 in guest rooms to 1.7 W/ft^2 in the laundry. Similarly, equipment energy intensities are assumed constant between the prototypes but vary from 0.6 W/ft^2 in the guest rooms to 3.0 W/ft^2 in the laundry. The hot water usage is 34,000 Btu/person per day. Peak power usages for process load (mainly in the laundry) is approximately 16 Btu/hour·ft^2. The schedules and intensities by building zone are summarized in Table 4.J.4.

Schedules

The occupancy, equipment, and hot water schedules are summarized in Table 4.J.5. The guest rooms have 90% occupancy during the night and 20% during the day. The equipment in guest rooms have the same schedules as the occupancy. The lights are mainly on during the evening and early morning hours. Lights energy use is assumed 90% of the installed intensity during the peak hours, 10% during the night, and about 25% during most daytime hours. The hot water usage in the guest rooms peaks to 60% in the early morning hours, levels off to about 40% during the day, and decreases to about 20% during the late night hours.

The lights in the lobby area are assumed to be always on, but its occupancy peaks at 60% during the early morning hours and 80% during the evening hours. During the night, the lobby occupancy is about 10%.

The laundry area is occupied between 7:00 a.m. and 5:00 p.m. with a maximum occupancy of 90%. Its lighting and equipment schedules follow those for occupancy.

The weekend operational schedules are slightly different than those during the weekdays, as shown in Table 4.J.5. The basic differences are the lower level of occupancy and the later start of normal operation on weekends and holidays.

Table 4.J.5 Hourly End-use Load Profiles for Small Hotels/Motels

Zone	End-use(s)	Day type*	Hour of Day 1.00	2	3	4	5	6	7	8
Rooms	People	WD	0.90	0.90	0.90	0.90	0.90	0.90	0.70	0.40
	"	WEH	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
	Lights	WD	0.20	0.15	0.10	0.10	0.10	0.20	0.40	0.50
	"	WEH	0.30	0.30	0.20	0.20	0.20	0.20	0.30	0.40
	Hot Water	WD	0.21	0.20	0.20	0.20	0.22	0.20	0.51	0.61
	"	WEH	0.30	0.25	0.22	0.22	0.25	0.31	0.51	0.55
Lobby	People	WD	0.10	0.10	0.10	0.10	0.10	0.20	0.40	0.60
	"	WEH	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
	Lights	All	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Laundry	People	WD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20
	"	WEH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Lights	WD	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.90
	"	WEH	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
	Equipment	WD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.80

Zone	End-use(s)	Day type*	Hour of Day 9	10	11	12	13	14	15	16
Rooms	People	WD	0.40	0.20	0.20	0.20	0.20	0.20	0.20	0.30
	"	WEH	0.50	0.50	0.50	0.30	0.30	0.20	0.20	0.20
	Lights	WD	0.40	0.40	0.25	0.25	0.25	0.25	0.25	0.25
	"	WEH	0.40	0.30	0.30	0.30	0.30	0.20	0.20	0.20
	Hot Water	WD	0.59	0.48	0.42	0.48	0.45	0.40	0.35	0.35
	"	WEH	0.52	0.57	0.51	0.51	0.45	0.42	0.35	0.32
Lobby	People	WD	0.60	0.40	0.20	0.20	0.20	0.20	0.20	0.30
	"	WEH	0.40	0.40	0.30	0.30	0.30	0.30	0.30	0.40
	Lights	All	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Laundry	People	WD	0.90	0.90	0.90	0.70	0.90	0.90	0.90	0.90
	"	WEH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Lights	WD	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
	"	WEH	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
	Equipment	WD	0.80	0.80	0.80	0.80	0.50	0.50	0.80	0.80
	"	WEH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Zone	End-use(s)	Day type*	Hour of Day 17	18	19	20	21	22	23	24
Rooms	People	WD	0.50	0.50	0.50	0.70	0.70	0.80	0.90	0.90
	"	WEH	0.30	0.40	0.40	0.60	0.60	0.70	0.70	0.70
	Lights	WD	0.25	0.25	0.60	0.80	0.90	0.80	0.60	0.30
	"	WEH	0.20	0.20	0.50	0.70	0.80	0.50	0.50	0.30
	Hot Water	WD	0.33	0.45	0.60	0.65	0.55	0.50	0.48	0.20
	"	WEH	0.32	0.42	0.52	0.52	0.43	0.52	0.43	0.25
Lobby	People	WD	0.60	0.80	0.80	0.70	0.50	0.30	0.30	0.10
	"	WEH	0.40	0.50	0.50	0.40	0.40	0.30	0.30	0.10
	Lights	All	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Laundry	People	WD	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	"	WEH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Lights	WD	0.90	0.10	0.10	0.10	0.10	0.10	0.10	0.10
	"	WEH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Equipment	WD	0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	"	WEH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

* WD = weekdays, WEH = weekends and holidays, All = all days.

Systems

The small hotels/motels are simulated differently for each region. The *Old* system is modeled with gas heating in all regions, no air conditioning in the rooms for the Northeast and North Central regions, and window air-conditioning units for the South and West regions. The lobby/office area is served with a single-zone package air conditioning unit. The *New* system is modeled with gas heating and window air conditioning units in the Northeast and North Central regions, and electric heat pumps in the South and West regions. The lobby/office area is served with a variable-air-volume system. Gas boilers are assumed for space heating as well as for meeting process or service hot water loads.

Calibration

We have simulated the prototype buildings to estimate the heating and cooling load of buildings. The prototype building and system characteristics have been adjusted so that the simulation results generally agree with the NBECS consumption data.

The simulated total electricity and fuel use of the prototypical small hotel/motel in 13 cities and comparison with NBECS consumption data are shown in Table 4.J.6.

Table 4.J.6 Comparison of prototype building energy use to NBECS for small hotels

Region	NBECS				City	DOE-2 Simulation		
	Total Electric * ($kBtu/ft^2$)	Total Fuel ($kBtu/ft^2$)	F/E Ratio Median	F/E Ratio Avg		Total Electric * ($kBtu/ft^2$)	Total Fuel ($kBtu/ft^2$)	F/E Ratio
Northeast	55.1	106.1	2.30	1.93	Boston	26.7	167.2	6.26
					New York	25.8	146.6	5.68
					Philadelphia	25.7	143.8	5.59
North Central	80.0	205.2	1.53	2.56	Chicago	26.1	160.9	6.17
					Detroit	25.9	170.8	6.59
					St. Louis	25.3	130.0	5.15
South	235.7	102.5	0.53	0.43	Miami	76.4	27.8	0.36
					New Orleans	51.6	63.2	1.23
					Houston	55.6	64.1	1.15
West	192.7	1065.3	1.89	5.53	Los Angeles	23.7	70.7	2.98
					San Diego	25.0	59.2	2.37
					San Francisco	21.4	112.9	5.29
					Phoenix	56.6	61.8	1.09

* electricity kWh are converted to site Btus (1 kWh = 3413 Btu).

The NBECS fuel use intensity for the West region is very high. This could be due to a very high thermal load (such as a heated pool) in one of the limited samples of small hotels present in the NBECS data base. Therefore, we have chosen not to use the NBECS fuel intensities in the West region.

Simulation Results

Table 4.J.7 provides information on annual energy intensities for heating, cooling, lighting, and equipment end uses for the finalized small hotel/motel prototype buildings.

4.K PRISON

Similar to hospitals, prisons are also prime candidates for cogeneration because they are large and have high demands for both heat and electricity. Prison operations and load demands, however, fluctuate with the time of day, so that there may not be concurrency in the thermal and electric loads. In order to correctly predict the hourly fluctuations in load demands, a prototypical building must account for the variety of usage patterns, schedules, and equipment types typically found in a prison.

Existing Data Sources

Because of the small market sector and the absence of available statistical data, the prison prototype was developed almost entirely from review of building plans and DOE-2 input files for four prison buildings from an unrelated energy analysis project in Connecticut and discussions with the principal investigator for that project (A. Tuluca 1989). Table 4.K.1 lists the characteristics of the four prison buildings that were modeled.

Statistical Data

A search through the NBECS data for penitentiaries showed only six observations. This data is presented in Table 4.K.2, but because of the small sample size, the data from the table was used only as a reference in developing the prototype buildings.

Prototype Buildings

A single average prison prototype was developed and used for all 20 market areas, although the size of the prototype was varied based on data from the Dodge Building Start Data 1966-1988. Since cogeneration is most applicable to large buildings with relatively constant loads, the prototype is that of a large penitentiary, rather than a smaller

Table 4.J.7 Summary of annual end use intensities for prototype small hotels

(electricity in kWh/ft^2 and fuel in kBtu/ft^2)

City	Shell	Eqp	Heating Elec.	Heating Fuel	Cooling Elec.	Fan Elec.	DHW Elec.	DHW Fuel	Lighting Elec.	Misc. Elec.	Misc. Fuel	Total Elec.	Total Fuel	F/E Ratio
Northeast														
Boston	Stk	Old	1.12	145.4	0.14	0.96	0.00	18.2	3.65	1.95	3.6	7.82	167.2	6.26
Boston	Stk	New	1.12	145.4	0.14	0.96	0.00	18.2	3.65	1.95	3.6	7.82	167.2	6.26
Boston	Cur	New	1.07	137.6	3.51	1.14	0.00	18.2	3.65	1.95	3.6	11.34	159.3	4.12
New York	Stk	Old	0.93	124.8	0.20	0.81	0.00	18.2	3.65	1.95	3.6	7.56	146.6	5.68
New York	Stk	New	0.93	124.8	0.20	0.81	0.00	18.2	3.65	1.95	3.6	7.56	146.6	5.68
New York	Cur	New	0.89	118.8	4.66	1.05	0.00	18.2	3.65	1.95	3.6	12.22	140.6	3.38
Philadelphia	Stk	Old	0.91	122.0	0.24	0.79	0.00	18.2	3.65	1.95	3.6	7.53	143.8	5.59
Philadelphia	Stk	New	0.91	122.0	0.24	0.79	0.00	18.2	3.65	1.95	3.6	7.53	143.8	5.59
Philadelphia	Cur	New	0.87	115.2	5.12	1.03	0.00	18.2	3.65	1.95	3.6	12.63	137.0	3.18
North Central														
Chicago	Stk	Old	1.03	139.1	0.20	0.80	0.00	18.2	3.65	1.95	3.6	7.65	160.9	6.17
Chicago	Stk	New	1.03	139.1	0.20	0.80	0.00	18.2	3.65	1.95	3.6	7.65	160.9	6.17
Chicago	Cur	New	0.90	119.3	3.30	0.80	0.00	18.2	3.65	1.95	3.6	10.61	141.2	3.90
Detroit	Stk	Old	1.09	149.0	0.13	0.77	0.00	18.2	3.65	1.95	3.6	7.59	170.8	6.59
Detroit	Stk	New	1.09	149.0	0.13	0.77	0.00	18.2	3.65	1.95	3.6	7.59	170.8	6.59
Detroit	Cur	New	0.95	128.9	1.72	0.77	0.00	18.2	3.65	1.95	3.6	9.05	150.7	4.88
St. Louis	Stk	Old	0.80	108.2	0.30	0.69	0.00	18.2	3.65	1.95	3.6	7.41	130.0	5.15
St. Louis	Stk	New	0.80	108.2	0.30	0.69	0.00	18.2	3.65	1.95	3.6	7.41	130.0	5.15
St. Louis	Cur	New	0.70	93.8	5.17	0.74	0.00	18.2	3.65	1.95	3.6	12.22	115.6	2.77
South														
Miami	Stk	Old	0.00	6.0	16.19	0.59	0.00	18.2	3.65	1.95	3.6	22.38	27.8	0.36
Miami	Stk	New	0.00	6.0	16.19	0.59	0.00	18.2	3.65	1.95	3.6	22.38	27.8	0.36
Miami	Cur	New	0.99	0.7	16.14	0.60	0.00	18.2	3.65	1.95	3.6	23.32	22.5	0.28
New Orleans	Stk	Old	0.00	41.4	8.92	0.58	0.00	18.2	3.65	1.95	3.6	15.12	63.2	1.23
New Orleans	Stk	New	0.00	41.4	8.92	0.58	0.00	18.2	3.65	1.95	3.6	15.12	63.2	1.23
New Orleans	Cur	New	6.33	2.0	8.49	0.51	0.00	18.2	3.65	1.95	3.6	20.95	23.8	0.33
Houston	Stk	Old	0.00	42.3	10.08	0.60	0.00	18.2	3.65	1.95	3.6	16.29	64.1	1.15
Houston	Stk	New	0.00	42.3	10.08	0.60	0.00	18.2	3.65	1.95	3.6	16.29	64.1	1.15
Houston	Cur	New	6.53	2.1	9.52	0.53	0.00	18.2	3.65	1.95	3.6	22.18	23.9	0.32
West														
Los Angeles	Stk	Old	0.00	48.9	0.74	0.59	0.00	18.2	3.65	1.95	3.6	6.94	70.7	2.98
Los Angeles	Stk	New	0.00	48.9	0.74	0.59	0.00	18.2	3.65	1.95	3.6	6.94	70.7	2.98
Los Angeles	Cur	New	7.22	1.9	0.74	0.51	0.00	18.2	3.65	1.95	3.6	14.09	23.7	0.49
San Diego	Stk	Old	0.00	37.5	1.18	0.54	0.00	18.2	3.65	1.95	3.6	7.32	59.2	2.37
San Diego	Stk	New	0.00	37.5	1.18	0.54	0.00	18.2	3.65	1.95	3.6	7.32	59.2	2.37
San Diego	Cur	New	5.47	1.3	1.21	0.48	0.00	18.2	3.65	1.95	3.6	12.77	23.1	0.53
San Francisco	Stk	Old	0.00	91.1	0.14	0.51	0.00	18.2	3.65	1.95	3.6	6.27	112.9	5.29
San Francisco	Stk	New	0.00	91.1	0.14	0.51	0.00	18.2	3.65	1.95	3.6	6.27	112.9	5.29
San Francisco	Cur	New	13.26	3.7	0.12	0.45	0.00	18.2	3.65	1.95	3.6	19.43	25.5	0.38
Phoenix	Stk	Old	0.00	40.0	10.24	0.75	0.00	18.2	3.65	1.95	3.6	16.58	61.8	1.09
Phoenix	Stk	New	0.00	40.0	10.24	0.75	0.00	18.2	3.65	1.95	3.6	16.58	61.8	1.09
Phoenix	Cur	New	5.79	1.6	9.17	0.61	0.00	18.2	3.65	1.95	3.6	21.18	23.4	0.32

Table 4.K.1 Summary of Building Characteristics for 3 Prisons

	Prison 1	Prison 2	Prison 3
Building-level characteristics:			
Total area (ft^2)	368,300	156,500	90,900
No. of floors	3	3	2
Wall U-value (Btu/ft^2·hr·F)	0.055	0.055	0.078
Roof U-value (Btu/ft^2·hr·F)	0.071	0.071	0.031
Glazing type	single	single	single
HVAC Equipment:	Packaged Multizone	Packaged Multizone	Packaged Multizone
Heating Plant	Gas boiler	Gas boiler	Gas boiler
Cooling Type	Herm.-Centrif.	Herm.-Centrif.	Herm.-Centrif.
Hot Water Plant	Gas boiler	Gas boiler	Gas boiler
Hot Water (kBtu)	6500	3173	1272
Process Elec (kBtu)	141	245	-

Zone:	Housing	Dining	Kitchen	Gym	Admin	Shop	Laundry
Zone-level characteristics for Prison 1							
Floor Area	34%	2%	5%	4%	25%	26%	1%
Wall Height (ft)	13	10	10	28	11	11	10
Occupants (ft^2/per)	124	25	608	676	626	225	175
Lighting (W/ft^2)	2.0	2.0	2.0	2.25	2.0	3.5	3.5
Equipment (W/ft^2)	0.0	0.0	4.0	0.0	1.0	1.0	3.8
Cooling Set point (F)	76	76	76	76	76	76	76
Heating Set point (F) *	74	70/9	70/9	74/10	70/9	74	74/9
Zone-level characteristics for Prison 2							
Floor Area	46%	-	10%	1%	32%	7%	1%
Wall Height (ft)	13	-	10	10	10	10	8.5
Occupants (ft^2/per)	75	-	313	364	67	553	84
Lighting (W/ft^2)	2.0	-	2.0	2.0	2.0	3.5	3.5
Equipment (W/ft^2)	-	0.0	4.0	1.0	1.0	1.0	
Cooling Set point (F)	76	-	85/15	76	76/9	76/9	76
Heating Set point (F) *	74	-	74/15	70/9	70/9	74/9	74
Zone-level characteristics for Prison 3							
Floor Area	78%	3%	-	12%	6%	-	-
Wall Height (ft)	8	10	-	22	10	-	-
Occupants (ft^2/per)	292	57	-	676	195	-	-
Lighting (W/ft^2)	1.6	2.0	-	1.3	2.0	-	-
Equipment (W/ft^2)	1.5	1.0	-	0.2	1.0	-	-
Cooling Set point (F)	76	76	-	76	76	-	-
Heating Set point (F) *	74	70/9	-	70/9	74/10	70/9	74

* number after slash indicates the number of hours heated, the remainder being set back hours.

Table 4.K.2 NBECS Results for Prisons (Penitentiaries)

Parameter	National Average
Average Floor Area (x1000 ft^2)	317
Median Fuel/elec ratio	5.40
Average No. Floors	6
Average No. Employees	531
Average Hours Wkday	22
Average Hours Wkend	22
Average Total kBtu/ft^2	200
Average Elect kBtu/ft^2	44
Average Fuel kBtu/ft^2	156
Glass covers <25%	86
Glass covers 25-50%	14
Glass covers 50-75%	0
Glass covers >75%	0
Average glass area (%)	16
% Conservation glass	1
% Wall insulation	0
% Roof/ceiling insulation	100
% Heating setback	100
% Cooling setup	100
% Central heating	100
% Heating system uses furnaces/boilers	100
% Boilers present	0
% Electricity fires boilers	0
% Heat provided by other system	0
% Forced air fans	74
% Heat distributed from baseboards	60
% Electric baseboards	44
% Hot water baseboards	16
% Steam baseboards	1
% Heat fr. radiators/convectors	100
% Heating panels	18
% Other heat distribution	41
% Central air-conditioning	19

police station or county jail.

The review of the building plans and DOE-2 input files showed the following characteristics about prisons: 1. they are squat and spread-out, with no more than three stories, 2. they are of very massive construction, with thick concrete walls and floors, 3. the housing areas , i.e., cells, have 100% outside air because of constant occupancy and presence of toilets and washbasin, 4. the administrative areas are similar to typical offices, and 5. they generally have packaged HVAC systems with terminal reheat.

Size

The total square footage of the prototype prison has been varied by market area based on the information from Dodge Building Start Data for 1966-1988. These are given at the top of Table 4.K.3.

Shell Characteristics

Because there is practically no statistical data on prison construction characteristics, engineering judgement has been used in determining the shell characteristics of the prototype prisons. The *Stock* vintage prisons are assumed to have minimal amounts of insulation - R-12 in the ceiling and R-3 in the walls - and single-glazed windows. The *Current* vintage prisons are assumed to be insulated to ASHRAE 90.1-1989 Standards as described in Section 4.0. The building shell characteristics are summarized in the top half of Table 4.K.3.

Zone conditions

The operational characteristics of the prototype prisons are based on review of the four input files from SWA, and summarized in the lower half of Table 4.K.3. The prison can be divided into six general areas by usage: housing, administration/public, gym, kitchen/dining, shops, and laundry. Circulation space has been apportioned to the six zones, and unconditioned spaces such as mechanical spaces have been ignored. The characteristics of each zone are given in Table 4.K.4 and summarized below.

(1) The housing areas are the prisoner cells and have low occupant heat gains from sedentary prisoners.

(2) The administrative/public area includes the lobby, offices, conference rooms, and guard stations. There are low occupant heat gains, and a small electrical load from office equipment.

(3) The kitchen/dining area has significant electrical and source loads from cooking, and moderate occupant heat gains averaging between the cookers and the eaters.

Table 4.K.3 Building Descriptions for Prison Prototypes

Building Parameter	North-east	North Central	South	West
Floor Areas (1000 ft^2)				
Stock vintage	Bos: 158 NY: 230 Phi: 234	Chi: 320 Det: 133 StL: 90	Mia: 159 NO: 108 Hou: 272 Phx: 165	LA: 326 SF: 216 SD: 206
Current vintage	Bos: * NY: 260 Phi: 237	Chi: * Det: 600 StL: 215	Mia: 329 NO: * Hou: 115 Phx: 317	LA: 252 SF: 515 SD: 200
No. of floors	3	3	3	3
Shell characteristics				
Stock vintage :				
Ceiling R-value	12.0	12.0	12.0	12.0
Wall R-value	3.0	3.0	3.0	3.0
Window glass	1-pane	1-pane	1-pane	1-pane
Current vintage :	ASHRAE-90.1 (see Table 4.1)			
Window shad. coeff	0.6	0.6	0.4	0.4
Window/wall ratio	0.178 for building † (see Table 4.K.4 for zone variations)			
Wall Area (% total)	† (see Table 4.K.4 for zone variations)			
Ft^2/person	~ 175 † (see Table 4.K.4 for zone variations)			
Lights W/ft^2	~ 2.4 † (see Table 4.K.4 for zone variations)			
Equip W/ft^2	~ 0.68 † (see Table 4.K.4 for zone variations)			
Hot Water Btu/ft^2	17.5			
Process Btu/ft^2	2.15			
Process W/ft^2	0.24			
System Type	6 systems of 3 types; single-zone for housing and dining, packaged single-zone for gym, shop, and laundry. For administration and public areas, *Old* equipment is constant-air-volume, *New* equipment is variable-air-volume.			
Heat Sched	† (see Table 4.K.4 for zone variations)			
Cool Sched	† (see Table 4.K.4 for zone variations)			
Heating plant	gas boiler	gas boiler	gas boiler	gas boiler
Chiller type	hermetic centrif.	hermetic centrif.	hermetic centrif.	hermetic centrif.
Hot water plant	gas boiler	gas boiler	gas boiler	gas boiler

* no building in market area

Table 4.K.4 Zone descriptions for Prison Prototypes

	Zones						
	Housing	Din/Kit	Gym	Adm/Pub	Shop	Laundry	Bldg
Floor Area (% total)	35	7	5	25	25	2	100
Wall Height	10	10	25	10	15	10	-
Window/wall ratio	10	5	0	10	0	0	6
Ft^2/person	125	300	500	200	200	200	~ 175
Occup. Schedule †	H	D	G	A	A	A	-
Lights W/ft^2	2.0	2.0	2.0	2.0	3.5	3.5	~ 2.4
Light Schedule †	H	D	G	A	A	A	-
Equip. W/ft^2	-	2.0	-	1.0	1.0	2.0	~ 0.68
Equip. Schedule †	-	D	-	A	A	A	-
Process Btu/bldg ft^2	-	1.8,0.3 *	-	-	-	0.05 *	-
Process W/bldg ft^2	-	-	-	-	-		0.25 ‡
Process Schedule †	-	C,D	-	-	-	A	-
System Types **							
Old equip.	SZRH	SZRH	PSZ	RHFS	PSZ	PSZ	-
New equip.	"	"	"	VAV	"	"	-
Heat Sched			always on				-
Cool Sched (Cool locs)			always on				-
Cool Sched (Warm locs)			summer only				-
Set points ††	7/24	7/10	7/10	5/10	5/10	5/10	-
Min-outside-air	0.50	0.50	0.25	0.25	0.50	0.5	-

† code for hourly loads schedules: H=housing, D=dining, C=cooking, A=admin, G=gym (see Table 4.K.5).
†† Set point numbers refer to days per week and number of hours per day.
* kitchen source is due to cooking and meals, laundry source is due to washing.
** code for system types: SZRH = Single-zone Reheat, PSZ = Packaged Single-zone, RHFS = Reheat-Fan, VAV = Variable-air Volume.
‡ miscellaneous electricity is from freezer.

Gas cooking consumption is counted as a building-resource.

(4) The gym has moderate occupant heat gains averaging players and spectators, and no electrical or source loads.

(5) The shop has moderate equipment loads and high people heat gains from workers.

(6) The laundry is small in area but has high people heat gains, as well as electrical loads from washers and gas source loads from dryers.

In addition to the above, there are additional electrical loads due to large freezers, which are counted as a building resource but do not contribute to the building loads since they are located in the unconditioned mechanical spaces.

The assumed floor areas, wall heights, and window/wall ratios are estimated from review of the floor plans from the Connecticut project, and shown in the first three rows of Table 4.K.4. The amount of wall per zone is calculated using the following rules and observations:

1. Housing is assumed to be two-storied, with a wall height of 10 ft. and cells about 12 ft. deep opening onto a larger dayroom or corridor area. As a result, typical prison housing areas have depths ranging from 50 to 70 ft., and relatively large amounts of wall area. A typical depth of 60 ft. has been assumed, which produces a wall length of (floor area/60). ⅓ of the wall perimeter is modeled as interior wall attached to other zones, so the amount of exterior wall is : (perimeter · 0.666 · 10ft · 2).
2. Administration and lobby areas are assumed to be two-storied, with a wall height also of 10 ft., and a more compact layout compared to the housing blocks. The area has been modeled with an aspect ratio of 2:1, and ½ of the wall area as interior walls attached to other zones. The amount of exterior wall is then : (perimeter · 0.50 · 10ft · 2).
3. Shops, dining, and gym areas are the most compact and assumed to be single-storied, with varying wall heights as indicated in Table 4.K.4. The areas have been modeled as square, i.e., aspect ratios of 1:1, with ½ of the wall area as interior walls attached to other zones. The amount of exterior wall is then : (perimeter · 0.50 · wall height).

Schedules

The zone schedules for various activities are modified from the four prisons input files developed by SWA, which were developed in consultation with correction officials in Connecticut. These schedules are shown in Table 4.K.5. In the DOE-2 simulations, the hourly schedules are multiply by the end-use loads shown in Table 4.K.4 to produce the hourly load by end-use and zone.

Systems

The system types modeled for each zone are listed in table 4.K.4. Prisons with *New* equipment are assumed to have Variable-Air-Volume instead of Reheat-Fan systems in the administration and public areas. Heating is assumed to be available at all hours for all locations. Cooling and fan schedules, however, vary depending on location.

Table 4.K.5 Hourly Load Profiles for Prisons

Hourly profile	End-use(s)	Day type *	1	2	3	4	5	6	7	8
H (Housing)	People	WD	1.00	1.00	1.00	1.00	1.00	0.90	0.65	0.65
	People	WEH	1.00	1.00	1.00	1.00	1.00	0.90	0.40	0.40
	Lights	All	0.50	0.50	0.50	0.50	0.50	0.50	1.00	1.00
D (Dining)	People,Eqp.	All	0.00	0.00	0.00	0.00	0.00	0.15	1.00	1.00
A (Adminis.)	People	WD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
	People	WEH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Lights	WD	0.05	0.05	0.05	0.05	0.05	0.05	0.05	1.00
	Lights	WEH	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
C (Cooking)	Gas Cook	All	0.20	0.20	0.20	0.20	0.20	0.80	0.80	0.80
G (Gym)	People,Lights	WD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	People,Lights	WEH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HW	Hot Water	All	0.00	0.00	0.00	0.00	0.00	0.0	0.38	0.38
EQ	Equipment	All	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00

Hourly profile	End-use(s)	Day type *	9	10	11	12	13	14	15	16
H (Housing)	People	WD	0.90	0.90	0.90	0.65	0.65	0.90	0.90	0.90
	People	WEH	0.70	0.70	0.70	0.40	0.40	0.70	0.70	0.70
	Lights	All	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
D (Dining)	People	All	0.15	0.15	0.15	1.00	1.00	0.15	0.15	0.15
	Lights	All	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
C (Cooking)	Gas Cook	All	0.80	0.80	0.80	0.80	0.50	0.50	0.80	0.80
A (Adminis)	People	WD	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	People	WEH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G (Gym)	People,Lights	WD	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	People,Lights	WEH	0.00	0.00	1.00	1.00	1.00	1.00	1.00	0.00
HW	Hot Water	WD	0.92	0.92	0.77	0.77	0.50	0.92	0.92	0.92
	Hot Water	WEH	0.38	0.38	0.23	0.23	0.23	0.23	0.23	0.23
EQ	Equipment	All	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Hourly profile	End-use(s)	Day type *	17	18	19	20	21	22	23	24
H (Housing)	People	All	0.90	0.65	0.65	0.90	1.00	1.00	1.00	1.00
	Lights	All	1.00	1.00	1.00	1.00	1.00	1.00	0.50	0.50
D (Dining)	People	All	0.15	1.00	1.00	0.15	0.00	0.00	0.00	0.00
C (Cooking)	Gas Cook	All	0.80	0.50	0.50	0.50	0.20	0.20	0.20	0.20
A (Adminis)	People	All	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Lights	WD	0.20	0.20	0.20	0.05	0.05	0.05	0.05	0.05
	Lights	WEH	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
G (Gym)	People,Lights	WD	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
	People,Lights	WEH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HW	Hot Water	All	0.23	0.23	0.38	0.38	0.30	0.00	0.00	0.00
EQ	Equipment	All	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00

* WD = weekdays, WEH = weekends and holidays, All = all days.

They are always on for the warm locations, but only during the summer for the colder locations. The zone controls are listed in Table 4.K.4 and summarized below:

(1) Housing is assumed to have single-zone reheat systems with 50% outside air. The 50% value is an average between the cells, assumed to have 100% outside air, and the dayrooms, assumed to have no outside air. The systems and fans are on 24 hours a day, with heating at 74, cooling at 78.

(2) Administrative/public is assumed to be a reheat fan system with a minimum 25% outside air and typical office hours, i.e., heating at 70 and cooling at 78 from 7 to 5 during work days.

(3) Kitchen/dining is assumed to have a single-zone reheat system with 100% outside air. Heating is at 74 and cooling at 78 from 6 to 8 every day.

(4) Gym is assumed to have a packaged single-zone system with 25% outside air. Set points are the same as for kitchen/dining, but the hours of operation start at 8 a.m.

(5) Shop and Laundry are assumed to have a packaged single-zone system with 100% outside air. Operations are the same as for Administration/public, i.e., five working days, ten hours per day, but the heating set point is at 74.

Calibration

Calibration of the prison prototypes is difficult due to the lack of measured data on their energy use intensities. NBECS is the only available data source, but its reliability is doubtful since it is based on a small sample of six buildings.

We simulated the prototype prisons to estimate their fuel and electricity uses in the thirteen Market Locations and compared the results to the nation-wide average energy use from NBECS (see Table 4.K.6). The DOE-2 calculated electricity intensities match almost exactly those from the small NBECS sample, while the fuel intensities are from 30-50% lower, depending on climate. Because of the large uncertainties in the small NBECS sample, this discrepancy is not deemed large enough to warrant modifications to the input assumptions.

Simulation Results

Table 4.K.7 provides information on the calculated annual energy intensities for heating, cooling, lighting, and equipment end uses for the finalized prison prototypes.

Table 4.K.6 Comparison of prototype building energy use to NBECS for prisons

Region	NBECS				City	DOE-2 Simulation		
	Total Electric * ($kBtu/ft^2$)	Total Fuel ($kBtu/ft^2$)	F/E Ratio Median	F/E Ratio Avg		Total Electric * ($kBtu/ft^2$)	Total Fuel ($kBtu/ft^2$)	F/E Ratio
U.S. Average	65.5	181.5	5.40	2.77	Boston	63.8	117.8	1.85
					New York	65.3	110.9	1.70
					Philadelphia	65.9	111.0	1.69
					Chicago	65.3	124.0	1.90
					Detroit	63.9	124.8	1.95
					St. Louis	69.3	113.8	1.64
					Miami	82.4	81.4	0.99
					New Orleans	75.9	86.4	1.14
					Houston	75.7	86.5	1.14
					Los Angeles	63.2	86.1	1.36
					San Diego	64.2	84.6	1.32
					San Francisco	58.8	89.6	1.52
					Phoenix	75.6	87.4	1.16

* electricity kWh are converted to site Btus (1 kWh = 3413 Btu).

Table 4.K.7 Summary of annual end use intensities for prototype prisons
(electricity in kWh/ft^2 and fuel in kBtu/ft^2)

			Heating		Cooling	Fan	DHW		Lighting	Misc.		Total	Total	F/E
City	Shell	Eqp	Elec.	Fuel	Elec.	Elec.	Elec.	Fuel	Elec.	Elec.	Fuel	Elec.	Fuel	Ratio
Northeast														
Boston	Stk	Old	0.18	38.5	1.49	3.73	0.00	70.2	11.75	1.54	9.1	18.69	117.8	1.85
Boston	Stk	New	0.09	29.1	1.40	3.57	0.00	70.2	11.75	1.53	9.1	18.34	108.5	1.73
Boston	Cur	New	0.06	18.5	1.46	3.29	0.00	70.2	11.75	1.55	9.1	18.11	97.8	1.58
New York	Stk	Old	0.15	31.6	2.02	3.72	0.00	70.2	11.75	1.49	9.1	19.13	110.9	1.70
New York	Stk	New	0.06	23.0	1.92	3.57	0.00	70.2	11.75	1.48	9.1	18.78	102.3	1.60
New York	Cur	New	0.04	15.2	1.97	3.35	0.00	70.2	11.75	1.50	9.1	18.61	94.5	1.49
Philadelphia	Stk	Old	0.15	31.7	2.17	3.74	0.00	70.2	11.75	1.50	9.1	19.31	111.0	1.69
Philadelphia	Stk	New	0.06	23.4	2.08	3.59	0.00	70.2	11.75	1.51	9.1	18.99	102.8	1.59
Philadelphia	Cur	New	0.04	15.8	2.14	3.38	0.00	70.2	11.75	1.50	9.1	18.81	95.1	1.48
North Central														
Chicago	Stk	Old	0.20	44.7	1.88	3.83	0.00	70.2	11.75	1.47	9.1	19.13	124.0	1.90
Chicago	Stk	New	0.11	35.4	1.81	3.68	0.00	70.2	11.75	1.46	9.1	18.81	114.7	1.79
Chicago	Cur	New	0.07	22.7	1.88	3.35	0.00	70.2	11.75	1.47	9.1	18.52	102.0	1.61
Detroit	Stk	Old	0.20	45.5	1.53	3.68	0.00	70.2	11.75	1.56	9.1	18.72	124.8	1.95
Detroit	Stk	New	0.10	36.0	1.46	3.53	0.00	70.2	11.75	1.56	9.1	18.40	115.3	1.84
Detroit	Cur	New	0.07	23.4	1.50	3.23	0.00	70.2	11.75	1.44	9.1	17.99	102.8	1.67
St. Louis	Stk	Old	0.16	34.5	2.82	3.92	0.00	70.2	11.75	1.65	9.1	20.30	113.8	1.64
St. Louis	Stk	New	0.07	26.3	2.74	3.78	0.00	70.2	11.75	1.64	9.1	19.98	105.6	1.55
St. Louis	Cur	New	0.05	17.6	2.71	3.49	0.00	70.2	11.75	1.48	9.1	19.48	96.9	1.46
South														
Miami	Stk	Old	0.02	2.0	6.84	3.99	0.00	70.2	11.75	1.54	9.1	24.14	81.4	0.99
Miami	Stk	New	0.00	0.3	6.72	3.92	0.00	70.2	11.75	1.55	9.1	23.94	79.6	0.98
Miami	Cur	New	0.00	0.3	6.66	4.01	0.00	70.2	11.75	1.46	9.1	23.88	79.7	0.98
New Orleans	Stk	Old	0.04	7.1	4.91	3.94	0.00	70.2	11.75	1.60	9.1	22.24	86.4	1.14
New Orleans	Stk	New	0.00	2.9	4.76	3.83	0.00	70.2	11.75	1.61	9.1	21.95	82.2	1.10
New Orleans	Cur	New	0.00	2.5	4.76	3.77	0.00	70.2	11.75	1.61	9.1	21.89	81.9	1.10
Houston	Stk	Old	0.04	7.2	4.97	3.94	0.00	70.2	11.75	1.48	9.1	22.18	86.5	1.14
Houston	Stk	New	0.00	2.9	4.84	3.84	0.00	70.2	11.75	1.49	9.1	21.92	82.2	1.10
Houston	Cur	New	0.00	2.6	4.88	3.79	0.00	70.2	11.75	1.58	9.1	22.00	81.9	1.09
West														
Los Angeles	Stk	Old	0.04	6.8	1.68	3.59	0.00	70.2	11.75	1.46	9.1	18.52	86.1	1.36
Los Angeles	Stk	New	0.00	2.1	1.49	3.44	0.00	70.2	11.75	1.46	9.1	18.14	81.4	1.31
Los Angeles	Cur	New	0.00	1.9	1.51	3.46	0.00	70.2	11.75	1.48	9.1	18.20	81.3	1.31
San Diego	Stk	Old	0.03	5.2	2.01	3.50	0.00	70.2	11.75	1.52	9.1	18.81	84.6	1.32
San Diego	Stk	New	0.00	1.4	1.90	3.39	0.00	70.2	11.75	1.51	9.1	18.55	80.7	1.28
San Diego	Cur	New	0.00	1.3	1.91	3.42	0.00	70.2	11.75	1.50	9.1	18.58	80.6	1.27
San Francisco	Stk	Old	0.05	10.3	0.72	3.21	0.00	70.2	11.75	1.50	9.1	17.23	89.6	1.52
San Francisco	Stk	New	0.00	4.4	0.60	3.06	0.00	70.2	11.75	1.50	9.1	16.91	83.8	1.45
San Francisco	Cur	New	0.00	3.1	0.64	3.03	0.00	70.2	11.75	1.43	9.1	16.85	82.4	1.43
Phoenix	Stk	Old	0.05	8.1	4.46	4.35	0.00	70.2	11.75	1.54	9.1	22.15	87.4	1.16
Phoenix	Stk	New	0.00	3.4	4.34	4.24	0.00	70.2	11.75	1.53	9.1	21.86	82.7	1.11
Phoenix	Cur	New	0.00	2.5	4.17	3.97	0.00	70.2	11.75	1.47	9.1	21.36	81.8	1.12

5. DATA BASE OUTPUT

The outputs from the DOE-2.1D simulations provide a wealth of information about the energy use patterns of various commercial buildings of different vintages in the 13 representative cities. These results have been processed into two different formats suited to their particular use: (1) four-dimensional ‘‘demand-duration’’ bins of thermal loads, air conditioning electric demand, non-air conditioning electric demand, and utility rate period that are used in HBI’s Market Assessment Model, and (2) electronic files of hourly end-use loads along with a small computer program that allows users to manipulate this detailed data.

In addition to the above formats, this section of the report presents summary tables of the total annual and peak energy uses by fuel type for all 481 prototypes. Moreover, the annual energy uses disaggregated by end-use and fuel type have already been presented in various tables in Section 4.

5.A SUMMARY RESULTS

Tables 5.A.1 through 5.A.3 show the simulated total annual energy uses for the 481 prototypes for heating and hot water, air-conditioning, and non-air-conditioning electricity, respectively. To facilitate comparisons across prototypes and vintages, the values have been normalized by ft^2 of floor area. Tables 5.A.4 through 5.A.6 show the simulated peak building loads for the 481 prototypes disaggregated by the the same three end-uses. Note that these peak end-use loads are not necessarily coincident.

5.B BINNED LOADS FOR MARKET ASSESSMENT MODEL

For use in HBI’s Market Assessment Model, the results from the DOE-2 hourly simulations must be compressed into a compact format that captures the concurrency of the various demands (heating, cooling, hot water, and electricity) in different rate periods without overloading the program with numbers. After discussions between LBL and HBI, a four-dimensional binned format has been selected as the most appropriate.

The bin technique is frequently used in simplified building loads calculations, such as the ASHRAE TC 4.7 method (ASHRAE 1985). Each bin contains the number of hours for which certain variables (temperatures and humidity ratios for ASHRAE loads calculations, end-use demands for the cogeneration model) are within the range defined for that bin. Given the resolution of each bin, all the hours in a bin are considered to be equivalent. Therefore, calculations (i.e., building loads, or, in this case, energy uses) are done for a single hour using the average for that bin and then multiplied by the number of hours to derive the total contribution of that bin.

Table 5.A.1 Total Heating/Hot Water Consumption for Prototype Buildings (kBtu/ft^2)

Bldg	Vintage		North Central			North East			South			West			
Type	Shell	Eqp	Bos	NY	Phi	Chi	Det	StL	Mia	Hou	NO	LA	SD	SF	Phx
Hospital	Stock	Old	166.7	153.6	148.4	166.8	168.7	142.5	79.3	101.3	100.1	84.5	76.9	105.4	76.2
	Stock	New	144.0	130.2	125.7	146.5	148.2	123.9	55.0	74.6	73.0	59.7	54.7	74.7	61.9
	Current	New	133.9	121.4	116.4	134.7	136.7	115.0	54.8	71.8	70.4	57.8	53.5	69.8	59.2
Large Hotel	Stock	Old	155.2	133.4	131.2	158.8	168.4	128.3	17.2	47.2	46.3	51.6	42.5	88.0	43.7
	Stock	New	123.8	107.6	105.7	128.3	135.8	103.6	16.4	40.3	39.8	45.2	38.2	72.9	37.9
	Current	New	114.7	100.1	98.3	121.0	128.2	98.1	16.5	39.7	39.2	44.4	37.5	70.0	37.2
Sit-down Restaurant	Average	Old	169.1	162.8	156.1	180.2	191.2	142.9	65.0	84.9	84.0	74.1	68.0	90.1	75.6
	Average	New	169.1	162.8	156.1	180.2	191.2	142.9	65.0	84.9	84.0	74.1	68.0	90.1	75.6
Fast-food Restaurant	Average	Old	266.7	231.3	227.3	271.4	288.9	215.0	44.5	88.1	86.1	83.2	69.1	148.8	80.6
	Average	New	266.7	231.3	227.3	271.4	288.9	215.0	44.5	88.1	86.1	83.2	69.1	148.8	80.6
24-hr Large Office	Stock	Old	80.8	60.0	61.7	68.7	73.6	57.9	30.5	45.7	36.6	38.3	43.0	44.7	46.1
	Stock	New	49.3	34.9	35.5	40.3	44.3	33.2	8.6	18.8	15.2	16.7	17.4	22.2	19.4
	Current	New	42.3	33.5	33.3	36.5	45.3	35.1	8.8	17.0	13.7	15.9	16.7	22.5	18.7
12-hr Large Office	Stock	Old	79.0	56.3	61.3	64.4	72.8	57.8	33.8	45.2	39.6	45.8	48.0	51.1	46.9
	Stock	New	50.8	34.5	37.3	40.0	46.0	34.4	10.3	20.4	17.4	21.4	21.7	27.6	21.6
	Current	New	42.3	32.5	34.3	34.7	47.0	35.6	10.2	17.5	15.0	20.1	20.1	27.4	20.3
24-hr Supermarket	Stock	Old	66.8	57.6	57.1	70.9	76.4	54.8	3.7	16.4	15.6	15.0	11.1	31.7	14.6
	Stock	New	16.9	12.9	13.2	22.6	24.6	14.5	2.3	2.9	2.8	2.3	2.3	2.5	2.5
	Current	New	4.7	3.8	3.9	6.5	7.2	5.0	2.3	2.3	2.3	2.3	2.3	2.3	2.3
Apartment	Stock	Old	101.4	42.2	79.7	43.8	58.3	35.0	11.0	53.6	39.6	40.0	36.3	65.3	31.7
	Stock	New	101.4	42.2	79.7	43.8	58.3	35.0	11.0	53.6	39.6	40.0	36.3	65.3	31.7
	Current	New	52.8	31.4	38.4	40.7	52.7	32.2	8.6	45.8	32.1	28.5	26.0	45.1	17.1
Prison	Stock	Old	108.7	101.8	101.9	114.9	115.8	104.7	72.3	77.4	77.3	77.0	75.5	80.6	78.3
	Stock	New	99.4	93.2	93.7	105.6	106.2	96.5	70.5	73.2	73.1	72.3	71.6	74.7	73.6
	Current	New	88.7	85.4	86.0	92.9	93.7	87.8	70.6	72.8	72.8	72.2	71.5	73.3	72.7
Large Retail	Stock	Old	34.3	26.1	28.6	35.6	37.3	31.1	2.2	11.9	10.5	20.6	12.5	46.0	21.0
	Stock	New	19.2	13.2	15.0	22.1	24.1	19.0	1.1	5.0	4.2	4.6	2.8	19.2	7.1
	Current	New	15.3	11.1	10.4	17.8	19.0	14.8	1.0	3.9	3.4	4.1	2.3	7.1	5.6
18-hr Supermarket	Stock	Old	66.5	57.7	56.8	70.2	75.6	54.4	4.0	17.2	16.5	17.4	13.5	34.2	15.2
	Stock	New	19.9	15.8	15.9	25.5	27.8	16.8	2.2	3.5	3.3	2.6	2.4	3.7	3.3
	Current	New	6.8	5.5	5.7	8.7	9.7	6.7	2.2	2.6	2.5	2.3	2.2	2.5	2.4
Secondary School	Stock	Old	66.9	57.7	56.9	70.0	74.4	56.6	7.6	19.1	19.5	19.3	16.5	32.4	17.7
	Stock	New	52.8	44.9	44.5	53.6	53.6	45.7	9.9	20.2	21.1	21.3	19.9	29.9	21.6
	Current	New	41.2	35.6	35.1	41.0	41.8	36.5	9.5	16.9	17.5	17.6	16.4	22.9	16.3
Small Hotel/ Motel	Stock	Old	163.6	143.0	140.2	157.3	167.2	126.4	24.2	60.5	59.6	67.1	55.6	109.3	58.2
	Stock	New	163.6	143.0	140.2	157.3	167.2	126.4	24.2	60.5	59.6	67.1	55.6	109.3	58.2
	Current	New	155.7	137.0	133.3	137.5	147.1	112.0	24.2	54.4	53.2	58.5	48.5	90.8	50.4

Table 5.A.2 Total A/C Consumption for Prototype Buildings (kWh/ft^2)

Bldg Type	Vintage Shell	Eqp	North Central Bos	NY	Phi	North East Chi	Det	StL	South Mia	Hou	NO	West LA	SD	SF	Phx
Hospital	Stock	Old	3.7	4.8	5.3	4.8	4.1	6.1	14.6	11.3	11.1	5.4	6.1	2.8	8.0
	Stock	New	3.4	4.3	4.8	4.3	3.6	5.8	13.3	10.2	10.0	4.7	5.4	2.3	7.7
	Current	New	3.6	4.5	4.7	4.3	3.5	6.1	13.2	10.1	9.9	4.7	5.4	2.4	7.5
Large Hotel	Stock	Old	1.6	2.2	2.4	2.3	1.6	3.6	8.6	6.3	5.9	1.4	1.6	0.5	4.7
	Stock	New	2.1	2.6	2.8	2.6	2.0	4.0	8.6	6.6	6.3	2.1	2.4	1.0	5.0
	Current	New	2.1	2.6	2.8	2.7	2.0	4.0	8.6	6.6	6.2	2.1	2.4	1.0	5.0
Sit-down Restaurant	Average	Old	4.4	6.0	6.6	5.8	4.4	8.1	20.7	14.3	13.8	4.4	4.9	1.6	14.3
	Average	New	3.4	4.8	5.3	4.7	3.5	6.7	17.2	11.8	11.3	3.0	3.5	1.0	11.6
Fast-food Restaurant	Average	Old	4.6	6.2	7.1	6.3	4.4	9.6	26.1	17.5	16.7	3.8	4.2	1.6	18.9
	Average	New	3.9	5.2	6.0	5.3	3.7	8.1	21.7	14.6	14.0	3.0	3.5	1.3	15.8
24-hr Large Office	Stock	Old	8.1	7.4	8.1	8.6	8.2	9.2	13.1	12.0	10.8	8.6	9.5	7.2	11.8
	Stock	New	3.1	3.4	3.7	3.5	3.2	4.6	10.4	8.2	7.6	4.6	5.5	2.2	7.3
	Current	New	2.8	3.2	3.5	3.3	3.1	4.5	9.6	7.4	6.8	4.2	5.0	2.0	6.7
12-hr Large Office	Stock	Old	6.2	5.2	5.9	6.1	6.1	6.8	10.4	9.1	8.4	6.7	7.4	5.5	9.2
	Stock	New	2.3	2.3	2.7	2.5	2.4	3.4	7.8	6.0	5.6	3.5	4.1	1.6	5.6
	Current	New	2.0	2.2	2.5	2.3	2.4	3.3	7.2	5.2	4.9	3.2	3.7	1.5	5.1
24-hr Supermarket	Stock	Old	1.1	1.4	1.6	1.5	1.0	2.1	5.6	3.6	3.4	0.9	1.1	0.5	6.0
	Stock	New	1.1	1.4	1.6	1.5	1.0	2.1	5.6	3.6	3.4	0.9	1.1	0.5	6.0
	Current	New	1.1	1.4	1.5	1.4	1.0	1.8	5.0	3.0	2.9	1.0	1.2	0.5	4.5
Apartment	Stock	Old	0.8	0.4	1.1	1.2	1.2	1.8	2.2	2.1	1.5	0.3	0.4	0.1	3.8
	Stock	New	0.8	0.4	1.1	1.2	1.2	1.8	2.2	2.1	1.5	0.3	0.4	0.1	3.8
	Current	New	2.1	1.0	1.9	1.2	1.2	1.8	3.4	1.9	1.6	0.4	0.6	0.1	4.4
Prison	Stock	Old	1.5	2.0	2.2	1.9	1.5	2.8	6.8	5.0	4.9	1.7	2.0	0.7	4.5
	Stock	New	1.4	1.9	2.1	1.8	1.5	2.7	6.7	4.8	4.8	1.5	1.9	0.6	4.3
	Current	New	1.5	2.0	2.1	1.9	1.5	2.7	6.7	4.9	4.8	1.5	1.9	0.6	4.2
Large Retail	Stock	Old	3.3	3.4	3.6	3.0	2.7	3.5	5.4	4.8	4.7	4.7	4.3	4.5	6.0
	Stock	New	1.6	2.0	2.2	1.7	1.4	2.4	5.2	4.1	4.0	2.8	2.9	1.7	4.6
	Current	New	1.5	1.9	2.0	1.6	1.4	2.2	4.8	3.8	3.7	2.6	2.6	1.4	4.2
18-hr Supermarket	Stock	Old	1.0	1.3	1.4	1.4	0.9	1.9	4.8	3.1	3.0	0.9	1.1	0.5	5.4
	Stock	New	1.1	1.5	1.6	1.6	1.0	2.2	5.8	3.7	3.5	0.9	1.2	0.5	6.0
	Current	New	1.1	1.4	1.5	1.4	1.0	2.0	5.3	3.2	3.1	1.0	1.2	0.5	4.6
Secondary School	Stock	Old	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Stock	New	0.7	0.9	1.1	0.9	0.7	1.5	4.2	2.8	2.5	1.1	1.3	0.5	2.9
	Current	New	0.7	0.9	1.1	0.9	0.6	1.4	4.1	2.7	2.5	1.1	1.3	0.5	2.5
Small Hotel/ Motel	Stock	Old	0.1	0.2	0.2	0.2	0.1	0.3	16.2	10.1	8.9	0.7	1.2	0.1	10.2
	Stock	New	0.1	0.2	0.2	0.2	0.1	0.3	16.2	10.1	8.9	0.7	1.2	0.1	10.2
	Current	New	3.5	4.7	5.1	3.3	1.7	5.2	16.1	9.5	8.5	0.7	1.2	0.1	9.2

Table 5.A.3 Total Non-A/C Consumption for Prototype Buildings (kWh/ft^2)

Bldg	Vintage		North Central			North East			South			West			
Type	Shell	Eqp	Bos	NY	Phi	Chi	Det	StL	Mia	Hou	NO	LA	SD	SF	Phx
Hospital	Stock	Old	24.8	24.7	24.7	24.9	24.7	24.7	24.3	24.5	24.4	24.1	24.1	23.9	24.3
	Stock	New	23.8	23.7	23.7	23.9	23.7	23.8	23.2	23.4	23.3	23.1	23.1	22.8	23.6
	Current	New	23.7	23.5	23.5	23.7	23.5	23.6	23.2	23.3	23.2	23.0	23.1	22.8	23.4
Large Hotel	Stock	Old	12.4	12.1	12.1	12.4	12.4	12.2	11.4	11.6	11.6	11.2	11.2	11.3	11.4
	Stock	New	11.7	11.5	11.6	11.8	11.8	11.8	11.0	11.3	11.3	10.9	10.8	10.9	11.2
	Current	New	11.6	11.4	11.5	11.8	11.7	11.7	11.0	11.2	11.2	10.9	10.8	10.8	11.1
Sit-down Restaurant	Average	Old	36.5	40.5	39.0	39.6	39.4	37.2	38.8	39.4	39.8	39.1	36.2	34.1	37.2
	Average	New	36.5	40.5	39.0	39.6	39.4	37.2	38.8	39.5	39.8	39.1	36.2	34.1	37.2
Fast-food Restaurant	Average	Old	37.2	37.2	37.3	37.1	36.9	37.1	37.2	37.3	37.2	37.7	37.2	37.3	38.3
	Average	New	37.2	37.2	37.3	37.1	36.9	37.1	37.2	37.3	37.2	37.7	37.2	37.3	38.2
24-hr Large Office	Stock	Old	30.4	28.8	29.5	31.0	30.8	30.8	32.5	32.7	31.4	30.6	31.7	30.0	33.9
	Stock	New	25.2	24.6	24.9	26.0	25.9	26.1	27.7	27.6	27.0	26.1	26.7	25.6	28.1
	Current	New	23.3	22.9	23.2	23.5	23.7	24.0	24.6	24.2	23.6	23.0	23.6	22.7	24.9
12-hr Large Office	Stock	Old	19.4	17.6	18.4	19.1	19.5	19.4	21.6	21.3	20.5	19.2	20.0	18.4	21.5
	Stock	New	15.1	14.3	14.7	15.3	15.5	15.5	17.3	17.0	16.6	15.2	15.7	14.7	16.7
	Current	New	13.7	13.2	13.6	13.6	14.3	14.3	15.1	14.6	14.2	13.3	13.7	13.0	14.7
24-hr Supermarket	Stock	Old	56.1	55.8	55.8	56.1	55.7	56.2	56.8	56.6	56.6	55.1	54.6	54.7	55.6
	Stock	New	56.7	56.4	56.4	56.7	56.3	56.8	57.1	57.0	57.0	55.6	55.1	55.3	56.2
	Current	New	54.5	54.5	54.6	54.5	54.3	54.8	56.5	55.8	55.9	54.9	54.9	54.4	54.2
Apartment	Stock	Old	4.8	4.4	4.8	3.6	3.6	3.6	3.4	3.7	3.6	3.6	3.7	3.6	3.9
	Stock	New	4.8	4.4	4.8	3.6	3.6	3.6	3.4	3.7	3.6	3.6	3.7	3.6	3.9
	Current	New	3.7	3.6	3.7	3.3	3.4	3.3	3.6	3.6	3.5	3.5	3.5	3.5	3.7
Prison	Stock	Old	17.2	17.1	17.1	17.3	17.2	17.5	17.3	17.2	17.3	16.8	16.8	16.5	17.7
	Stock	New	16.9	16.9	16.9	17.0	16.9	17.2	17.2	17.1	17.2	16.6	16.6	16.3	17.5
	Current	New	16.6	16.6	16.7	16.6	16.5	16.8	17.2	17.1	17.1	16.7	16.7	16.2	17.2
Large Retail	Stock	Old	15.1	14.9	15.1	13.3	13.2	13.4	13.0	13.3	13.2	16.8	16.4	17.4	17.5
	Stock	New	13.7	13.7	13.8	12.1	12.0	12.3	12.9	12.6	12.5	15.0	15.0	15.1	16.1
	Current	New	12.2	12.2	12.2	10.8	10.7	11.0	11.4	11.2	11.1	13.3	13.3	13.0	14.4
18-hr Supermarket	Stock	Old	53.7	53.3	53.4	53.8	53.3	53.9	54.6	54.2	54.4	52.3	52.1	52.1	52.8
	Stock	New	51.6	51.1	51.2	51.6	51.1	51.6	51.7	51.7	51.8	50.0	49.8	50.0	50.6
	Current	New	49.3	49.3	49.4	49.3	49.1	49.6	51.2	50.5	50.6	49.3	49.2	49.0	48.6
Secondary School	Stock	Old	7.3	7.1	7.1	7.3	7.3	7.1	6.5	6.7	6.7	6.6	6.6	6.8	6.6
	Stock	New	8.2	8.0	8.1	8.3	8.1	8.2	7.9	7.9	7.9	7.8	7.9	7.7	8.2
	Current	New	8.0	7.9	7.8	7.9	7.8	8.0	7.9	7.8	7.8	7.7	7.8	7.6	7.9
Small Hotel/ Motel	Stock	Old	7.7	7.4	7.3	7.4	7.5	7.1	6.2	6.2	6.2	6.2	6.1	6.1	6.3
	Stock	New	7.7	7.4	7.3	7.4	7.5	7.1	6.2	6.2	6.2	6.2	6.1	6.1	6.3
	Current	New	7.8	7.6	7.5	7.3	7.3	7.0	6.2	6.1	6.1	6.1	6.1	6.1	6.2

Table 5.A.4 Peak Heating/Hot Water Load for Prototype Buildings (Btu/ft^2·hr)

Bldg	Vintage		North Central			North East			South			West			
Type	Shell	Eqp	Bos	NY	Phi	Chi	Det	StL	Mia	Hou	NO	LA	SD	SF	Phx
Hospital	Stock	Old	0.51	0.42	0.42	0.54	0.48	0.44	0.22	0.30	0.29	0.19	0.18	0.23	0.26
	Stock	New	0.51	0.42	0.42	0.54	0.48	0.44	0.20	0.29	0.29	0.17	0.16	0.21	0.25
	Current	New	0.48	0.40	0.40	0.51	0.45	0.42	0.20	0.28	0.28	0.16	0.15	0.20	0.24
Large Hotel	Stock	Old	0.62	0.51	0.49	0.63	0.58	0.55	0.23	0.34	0.32	0.20	0.19	0.26	0.29
	Stock	New	0.51	0.42	0.40	0.52	0.48	0.46	0.20	0.28	0.27	0.18	0.16	0.22	0.25
	Current	New	0.48	0.40	0.38	0.50	0.46	0.44	0.21	0.28	0.27	0.17	0.16	0.21	0.25
Sit-down Restaurant	Average	Old	0.72	0.62	0.60	0.76	0.69	0.61	0.28	0.42	0.43	0.26	0.22	0.30	0.35
	Average	New	0.72	0.62	0.60	0.76	0.69	0.61	0.28	0.42	0.43	0.26	0.22	0.30	0.35
Fast-food Restaurant	Average	Old	1.18	0.98	0.96	1.16	1.12	1.07	0.42	0.66	0.65	0.44	0.37	0.53	0.66
	Average	New	1.18	0.98	0.96	1.16	1.12	1.07	0.42	0.66	0.65	0.44	0.37	0.53	0.66
24-hr Large Office	Stock	Old	0.45	0.39	0.41	0.44	0.43	0.39	0.29	0.35	0.31	0.24	0.26	0.30	0.35
	Stock	New	0.25	0.21	0.23	0.25	0.24	0.25	0.19	0.25	0.22	0.15	0.17	0.21	0.24
	Current	New	0.22	0.20	0.22	0.23	0.24	0.25	0.18	0.22	0.20	0.14	0.16	0.20	0.23
12-hr Large Office	Stock	Old	0.37	0.30	0.33	0.35	0.36	0.35	0.29	0.33	0.29	0.24	0.26	0.29	0.34
	Stock	New	0.20	0.16	0.18	0.19	0.20	0.20	0.19	0.22	0.20	0.16	0.17	0.18	0.24
	Current	New	0.18	0.15	0.17	0.17	0.20	0.20	0.18	0.18	0.17	0.15	0.16	0.17	0.22
24-hr Supermarket	Stock	Old	0.29	0.22	0.21	0.29	0.27	0.24	0.09	0.14	0.14	0.09	0.08	0.11	0.13
	Stock	New	0.21	0.14	0.13	0.21	0.19	0.16	0.01	0.06	0.06	0.01	0.00	0.03	0.05
	Current	New	0.10	0.07	0.06	0.10	0.09	0.08	0.00	0.02	0.02	0.00	0.00	0.00	0.01
Apartment	Stock	Old	0.23	0.10	0.18	0.14	0.20	0.13	0.08	0.19	0.14	0.11	0.12	0.12	0.14
	Stock	New	0.23	0.10	0.18	0.14	0.20	0.13	0.08	0.19	0.14	0.11	0.12	0.12	0.14
	Current	New	0.21	0.09	0.14	0.13	0.19	0.11	0.07	0.15	0.11	0.11	0.13	0.11	0.14
Prison	Stock	Old	0.27	0.25	0.25	0.28	0.27	0.27	0.18	0.20	0.21	0.18	0.18	0.19	0.21
	Stock	New	0.25	0.22	0.22	0.25	0.24	0.24	0.16	0.18	0.19	0.16	0.16	0.17	0.19
	Current	New	0.23	0.21	0.21	0.24	0.22	0.22	0.16	0.18	0.18	0.16	0.16	0.17	0.18
Large Retail	Stock	Old	0.31	0.28	0.29	0.36	0.34	0.37	0.17	0.23	0.22	0.18	0.17	0.27	0.25
	Stock	New	0.19	0.17	0.17	0.25	0.23	0.24	0.11	0.17	0.17	0.13	0.12	0.21	0.19
	Current	New	0.18	0.16	0.15	0.23	0.22	0.22	0.10	0.16	0.15	0.12	0.11	0.14	0.18
18-hr Supermarket	Stock	Old	0.31	0.24	0.23	0.31	0.29	0.26	0.12	0.16	0.16	0.12	0.11	0.14	0.17
	Stock	New	0.25	0.19	0.18	0.26	0.23	0.21	0.06	0.10	0.11	0.06	0.05	0.08	0.10
	Current	New	0.14	0.12	0.11	0.15	0.13	0.13	0.04	0.07	0.07	0.04	0.02	0.05	0.06
Secondary School	Stock	Old	0.88	0.75	0.74	0.92	0.86	0.84	0.33	0.52	0.51	0.38	0.37	0.48	0.50
	Stock	New	0.33	0.30	0.30	0.37	0.34	0.34	0.16	0.22	0.22	0.18	0.18	0.20	0.25
	Current	New	0.30	0.27	0.27	0.32	0.30	0.31	0.14	0.20	0.20	0.17	0.16	0.19	0.21
Small Hotel/ Motel	Stock	Old	1.28	1.07	1.06	1.19	1.09	1.03	0.03	0.04	0.05	0.04	0.03	0.04	0.04
	Stock	New	1.28	1.07	1.06	1.19	1.09	1.03	0.03	0.04	0.05	0.04	0.03	0.04	0.04
	Current	New	0.63	0.53	0.52	0.55	0.51	0.48	0.03	0.04	0.04	0.03	0.03	0.04	0.04

Table 5.A.5 Peak A/C Load for Prototype Buildings (W/ft^2·hr)

Bldg	Vintage		North Central			North East			South			West			
Type	Shell	Eqp	Bos	NY	Phi	Chi	Det	StL	Mia	Hou	NO	LA	SD	SF	Phx
Hospital	Stock	Old	2.5	3.1	3.1	3.0	2.9	2.9	3.1	3.4	3.4	2.1	2.4	1.4	2.6
	Stock	New	2.6	3.0	3.1	3.0	2.9	2.9	3.0	3.3	3.3	2.0	2.4	1.3	2.6
	Current	New	2.8	3.0	3.0	2.9	2.8	3.1	2.9	3.2	3.3	2.0	2.3	1.3	2.5
Large Hotel	Stock	Old	2.4	2.4	2.6	2.5	2.4	3.1	2.7	2.9	2.9	1.5	1.5	0.9	2.1
	Stock	New	2.4	2.3	2.5	2.4	2.3	3.0	2.6	2.8	2.8	1.4	1.5	0.8	2.1
	Current	New	2.3	2.3	2.5	2.4	2.3	2.9	2.6	2.8	2.8	1.4	1.5	0.8	2.1
Sit-down Restaurant	Average	Old	5.8	5.6	6.3	6.1	4.9	6.1	6.3	7.2	6.9	6.0	3.6	2.8	7.5
	Average	New	4.9	4.7	5.2	5.1	4.1	5.1	5.3	6.0	5.8	5.0	3.0	2.3	6.3
Fast-food Restaurant	Average	Old	8.1	7.8	8.5	8.7	7.2	9.0	8.9	9.5	9.7	8.5	5.3	4.6	11.2
	Average	New	6.8	6.5	7.1	7.3	6.0	7.5	7.4	7.9	8.1	7.1	4.4	3.8	9.4
24-hr Large Office	Stock	Old	1.8	1.7	1.8	2.0	1.9	2.1	2.2	2.3	2.1	1.5	1.7	1.2	2.1
	Stock	New	1.8	1.8	1.8	2.0	2.0	2.1	2.2	2.3	2.1	1.4	1.6	1.1	2.2
	Current	New	1.7	1.7	1.8	1.9	1.9	2.1	2.0	2.1	1.9	1.2	1.5	1.0	2.0
12-hr Large Office	Stock	Old	1.4	1.2	1.3	1.4	1.4	1.5	1.7	1.8	1.7	1.1	1.3	0.9	1.7
	Stock	New	1.2	1.1	1.3	1.3	1.4	1.4	1.6	1.6	1.4	1.0	1.1	0.7	1.7
	Current	New	1.1	1.1	1.2	1.2	1.4	1.4	1.5	1.4	1.3	0.9	1.0	0.6	1.6
24-hr Supermarket	Stock	Old	1.9	1.8	2.0	2.2	1.6	2.2	2.4	2.6	2.3	2.2	1.7	1.2	3.7
	Stock	New	1.9	1.8	2.0	2.2	1.6	2.2	2.4	2.6	2.3	2.2	1.7	1.2	3.7
	Current	New	1.5	1.4	1.5	1.6	1.2	1.7	2.0	2.0	1.8	1.8	1.3	1.0	2.7
Apartment	Stock	Old	1.4	0.5	1.3	0.9	1.3	0.9	0.7	1.4	0.9	1.0	1.1	0.6	1.6
	Stock	New	1.4	0.5	1.3	0.9	1.3	0.9	0.7	1.4	0.9	1.0	1.1	0.6	1.6
	Current	New	1.6	0.6	1.1	0.9	1.2	0.8	0.9	0.9	0.7	0.7	1.0	0.5	2.0
Prison	Stock	Old	1.9	2.3	2.3	2.1	2.3	2.4	2.6	2.8	2.7	1.5	1.6	0.9	2.8
	Stock	New	1.9	2.3	2.3	2.1	2.3	2.4	2.6	2.8	2.7	1.5	1.6	0.9	2.8
	Current	New	1.8	2.2	2.2	2.1	2.2	2.2	2.6	2.7	2.7	1.5	1.7	0.9	2.6
Large Retail	Stock	Old	1.7	1.7	1.8	2.0	2.0	2.2	2.3	2.3	2.3	1.5	1.5	1.4	2.1
	Stock	New	1.7	1.7	1.8	2.0	2.0	2.2	2.3	2.4	2.3	1.6	1.5	1.4	2.1
	Current	New	1.6	1.7	1.6	1.9	1.9	2.1	2.2	2.2	2.2	1.5	1.4	1.1	1.9
18-hr Supermarket	Stock	Old	1.8	1.7	1.9	2.1	1.5	2.1	2.4	2.5	2.2	2.0	1.5	1.2	3.7
	Stock	New	2.0	1.8	2.1	2.3	1.7	2.3	2.5	2.7	2.4	2.3	1.7	1.3	3.7
	Current	New	1.6	1.5	1.6	1.7	1.3	1.8	2.2	2.1	1.9	1.9	1.4	1.1	2.7
Secondary School	Stock	Old	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Stock	New	2.9	2.8	3.0	2.6	1.9	3.4	3.2	3.4	2.9	2.1	3.0	1.7	3.9
	Current	New	2.7	2.7	2.8	2.4	1.8	3.2	3.1	3.3	2.7	2.0	2.9	1.6	3.0
Small Hotel/ Motel	Stock	Old	0.3	0.3	0.3	0.3	0.2	0.3	4.5	5.0	4.4	3.9	4.2	1.8	5.8
	Stock	New	0.3	0.3	0.3	0.3	0.2	0.3	4.5	5.0	4.4	3.9	4.2	1.8	5.8
	Current	New	5.3	4.8	5.1	3.9	3.0	3.8	4.5	4.5	4.0	3.6	3.9	1.5	5.1

Table 5.A.6 Peak Non-A/C Load for Prototype Buildings (W/ft²·hr)

Bldg Type	Vintage Shell	Vintage Eqp	North Central Bos	North Central NY	North Central Phi	North East Chi	North East Det	North East StL	South Mia	South Hou	South NO	West LA	West SD	West SF	West Phx
Hospital	Stock	Old	4.1	4.0	4.0	4.1	4.1	3.7	3.6	4.0	4.0	3.9	3.9	3.6	4.0
	Stock	New	4.0	3.9	3.9	4.0	4.0	3.6	3.5	3.9	3.9	3.8	3.8	3.5	3.9
	Current	New	4.0	3.9	3.9	4.0	3.9	3.6	3.5	3.9	3.9	3.8	3.8	3.5	3.9
Large Hotel	Stock	Old	2.3	2.2	2.2	2.3	2.3	2.2	2.0	2.1	2.1	2.0	2.0	2.0	2.0
	Stock	New	2.2	2.1	2.1	2.2	2.1	2.1	2.0	2.0	2.0	2.0	2.0	2.0	2.0
	Current	New	2.1	2.1	2.1	2.2	2.1	2.1	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Sit-down Restaurant	Average	Old	5.9	6.4	6.2	6.2	6.2	5.9	6.1	6.2	6.3	6.2	5.8	5.5	6.0
	Average	New	5.9	6.4	6.2	6.2	6.2	5.9	6.1	6.2	6.3	6.2	5.8	5.5	6.0
Fast-food Restaurant	Average	Old	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.3	6.2	6.2	6.4
	Average	New	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.3	6.2	6.2	6.4
24-hr Large Office	Stock	Old	4.6	4.4	4.5	4.7	4.7	4.6	4.8	4.8	4.7	4.6	4.7	4.5	5.0
	Stock	New	4.2	4.1	4.1	4.4	4.3	4.3	4.5	4.5	4.4	4.2	4.3	4.0	4.8
	Current	New	3.9	3.8	3.9	4.0	3.9	4.0	4.0	4.0	3.8	3.7	3.8	3.6	4.3
12-hr Large Office	Stock	Old	3.9	3.6	3.8	3.9	3.9	3.9	4.1	4.1	4.0	4.0	4.1	3.9	4.3
	Stock	New	3.5	3.3	3.4	3.6	3.6	3.6	3.8	3.8	3.6	3.5	3.5	3.4	4.0
	Current	New	3.2	3.1	3.2	3.2	3.3	3.3	3.3	3.2	3.1	3.0	3.1	3.0	3.5
24-hr Supermarket	Stock	Old	7.4	7.4	7.4	7.5	7.4	7.4	7.3	7.3	7.4	7.1	7.0	7.0	7.2
	Stock	New	7.4	7.4	7.4	7.5	7.4	7.4	7.3	7.4	7.4	7.1	7.1	7.0	7.3
	Current	New	7.2	7.2	7.2	7.3	7.2	7.2	7.2	7.3	7.3	7.0	7.0	6.9	7.0
Apartment	Stock	Old	0.8	0.7	0.7	0.6	0.6	0.6	0.5	0.6	0.6	0.6	0.6	0.6	0.6
	Stock	New	0.8	0.7	0.7	0.6	0.6	0.6	0.5	0.6	0.6	0.6	0.6	0.6	0.6
	Current	New	0.6	0.6	0.6	0.5	0.6	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Prison	Stock	Old	3.7	3.6	3.7	3.7	3.7	3.8	3.7	3.6	3.7	3.6	3.6	3.6	3.7
	Stock	New	3.6	3.6	3.6	3.6	3.6	3.7	3.7	3.6	3.7	3.6	3.6	3.5	3.7
	Current	New	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.7	3.7	3.6	3.6	3.5	3.6
Large Retail	Stock	Old	3.4	3.3	3.4	3.6	3.5	3.6	3.3	3.4	3.4	3.4	3.3	3.5	3.6
	Stock	New	3.2	3.2	3.2	3.3	3.3	3.4	3.3	3.3	3.3	3.3	3.2	3.4	3.5
	Current	New	2.8	2.8	2.8	3.0	2.9	3.0	2.9	2.9	2.9	3.0	2.9	2.9	3.1
18-hr Supermarket	Stock	Old	7.5	7.4	7.4	7.5	7.4	7.5	7.3	7.4	7.5	7.1	7.2	7.0	7.2
	Stock	New	7.5	7.4	7.4	7.5	7.4	7.5	7.3	7.4	7.4	7.2	7.1	7.1	7.2
	Current	New	7.2	7.2	7.3	7.3	7.2	7.3	7.3	7.3	7.3	7.0	7.1	6.9	7.0
Secondary School	Stock	Old	3.1	3.1	3.1	3.1	3.1	3.1	2.8	3.0	3.0	2.9	2.8	2.9	3.0
	Stock	New	3.6	3.5	3.5	3.6	3.5	3.6	3.4	3.4	3.4	3.4	3.4	3.4	3.5
	Current	New	3.5	3.4	3.4	3.4	3.4	3.5	3.4	3.4	3.4	3.3	3.3	3.3	3.4
Small Hotel/ Motel	Stock	Old	1.9	1.8	1.8	1.9	1.8	1.8	1.5	1.5	1.4	1.5	1.4	1.4	1.5
	Stock	New	1.9	1.8	1.8	1.9	1.8	1.8	1.5	1.5	1.4	1.5	1.4	1.4	1.5
	Current	New	1.9	1.8	1.8	1.8	1.8	1.8	1.5	1.4	1.4	1.4	1.4	1.4	1.5

The concurrency of different energy demands can be distinguished by using multi-dimensional bins, with each representing a combination of individual end-use demand conditions. Similarly, different energy pricing rate periods can also be treated as another dimension. The total number of bins is the cumulative product of the number of bins in each dimension. Increasing the number of bins improves calculational accuracy, but at the cost of data size and calculational time.

The hourly building energy demands have been aggregated by the following four parameters: (1) rate periods (1 to 5 depending on utility district and building type), and three levels of (2) heating and hot water demand (HHW) in Btu/ft^2, (3) air-conditioning electricity demand (AC) in w/ft^2, and (4) non-air-conditioning electricity demand (NAC) in w/ft^2. The HHW, AC, and NAC demands are equally divided into three divisions based on the peak demand for each parameter. The total number of binned values per rate period is 27 (3 HHW x 3 AC x 3 NAC).

Tables 5.B.1 and 5.B.2 show sample binned tables for a Hospital prototype of Current vintage with New equipment in Boston (Market Area 19) and a Fast-food Restaurant of Average vintage with New equipment in San Francisco (Market Area 16) as transmitted to HBI for the Market Assessment Model. The first part of each binned table has a seven line identifier for the building prototype giving the location, utility district, total building floor area, and the shell and equipment vintages. The first line immediately following the identifier lines gives the number of rate periods and a code number for the customer rate type (4 and 2 for the hospital in Table 5.B.1 and 2 and 1 for the fast-foods restaurant in Table 5.B.2, respectively)

The following lines comprise the main contents of the binned tables. The binned data are given in nested fashion, nine per line, in the order of HHW, AC, NAC, and Rate Period. For example, the first row is for the bins HHW 1 to 3, nested within AC 1 to 3, all for NAC 1 and Rate Period 1. In other words, the nine cells in the first row are for the following demand levels, all within Rate Period 1 :

Bin cell	1	2	3	4	5	6	7	8	9
NAC	1	1	1	1	1	1	1	1	1
AC	1	1	1	2	2	2	3	3	3
HHW	1	2	3	1	2	3	1	2	3

For each cell, the table shows four numbers: the number of hours within the bin, and the average demand levels for NAC, AC, and HHW. For example, the first Cell (1,1,1,1) in the upper left corner of Table 5.B.1 outlined in bold is for the condition NAC=1, AC=1, and HHW=1 in Rate Period 1. The cell numbers indicate that there are 59 hours in the bin period, with average demands of 970.4 kW for NAC, 194.0 kW for AC, and 14.39 kBtu/hr for HHW. As a second example, Cell (3,2,1,2) is outlined in bold on the sixth column of fourth row. This cell is for the condition NAC=3, AC=2, and HHW=1 in Rate

Table 5.B.1 Sample Binned Output for a Prototypical Hospital of Current Vintage and New Equipment in Boston

```
*******************************************************************
*  FILE NAME:         hosboscn.dta                                *
*  CITY:              Boston / Boston_Edison                      *
*  BUILDING TYPE:     Hospital                                    *
*  BUILDING AREA:     347087                                      *
*  BUILDING VINT:     Current                                     *
*  EQUIPMENT TYPE:    New                                         *
*  PERIODS/YEAR:      4                                           *
*******************************************************************
4 2
     59      59      59      59      59      59      59      59      60  RATE=1 NHRS
  970.4  1110.7  1132.9   840.1  1183.8  1313.1   841.1  1187.7  1311.1   NAC1  AVGNAC
  194.0   178.3    84.2   317.5   289.6   285.6   553.7   563.7   538.9         AVGAC
 14.390  18.150  29.140  12.280  14.490  18.540  12.060  13.810  17.600         AVGHHW
     59      59      59      59      59      59      59      59      60  RATE=1 NHRS
 1325.2  1326.5  1325.8  1325.8  1326.1  1325.7  1327.4  1326.2  1326.4   NAC2  AVGNAC
  208.9   189.3   111.6   319.7   296.3   305.1   564.9   474.7   487.6         AVGAC
 18.090  19.660  32.600  17.310  18.020  20.280  17.200  17.530  19.980         AVGHHW
     59      59      60      59      59      60      59      59      60  RATE=1 NHRS
 1335.3  1335.0  1342.1  1336.2  1336.4  1330.3  1340.2  1331.2  1331.0   NAC3  AVGNAC
  167.0   155.3   127.2   350.3   347.3   348.6   667.1   673.1   646.2         AVGAC
 16.820  21.620  28.290  12.790  16.490  18.660  14.620  17.670  19.420         AVGHHW
     50      50      50      50      50      50      50      50      50  RATE=2 NHRS
  659.9   660.1   660.0   659.6   660.1   660.0   659.7   659.5   660.1   NAC1  AVGNAC
  222.5    84.8     0.0   324.4   326.7   324.2   493.6   455.6   491.8         AVGAC
  6.990  22.880  46.670   5.730   7.320  10.530   5.530   7.010  10.370         AVGHHW
     50      50      50      50      50      50      50      50      50  RATE=2 NHRS
  671.9   687.4   699.2   664.9   673.1   696.1   663.5   667.7   763.8   NAC2  AVGNAC
  157.1   146.6   120.8   182.9   184.4   181.3   274.5   238.4   378.4         AVGAC
 11.780  18.600  24.900   8.550  13.260  20.230   8.000  11.340  19.080         AVGHHW
     50      50      50      50      50      50      50      50      52  RATE=2 NHRS
  942.7   987.7   886.7   818.7  1152.7   871.9   829.8  1022.0  1048.7   NAC3  AVGNAC
  152.8   119.4    20.8   215.9   209.8   197.2   444.7   397.1   348.4         AVGAC
 21.240  32.350  52.110  14.690  22.610  29.630  11.090  18.190  23.620         AVGHHW
    116     116     117     116     116     117     116     116     118  RATE=3 NHRS
 1200.4  1075.7  1003.8  1068.3  1296.2  1310.0  1006.5  1263.5  1297.5   NAC1  AVGNAC
    0.0     0.0     0.0   131.4     3.3     0.0   333.0   295.0   272.6         AVGAC
 33.720  50.020  74.300  21.740  41.480  66.970  13.310  17.150  19.710         AVGHHW
    116     116     117     116     116     117     116     116     118  RATE=3 NHRS
 1324.6  1324.6  1324.6  1325.2  1325.0  1325.0  1326.1  1326.6  1326.5   NAC2  AVGNAC
    0.0     0.0     0.0     0.0     0.0     0.0   327.7   198.1     0.0         AVGAC
 44.430  58.200  76.500  44.420  61.620  79.700  18.060  26.310  70.930         AVGHHW
    116     116     117     116     116     117     117     117     117  RATE=3 NHRS
 1332.3  1344.0  1372.8  1342.5  1352.1  1341.5  1335.0  1332.5  1341.0   NAC3  AVGNAC
    0.0     0.0     0.0   111.3    95.1    17.2   322.4   231.4   166.8         AVGAC
 42.890  74.710 110.930  23.290  30.270  57.770  14.890  19.850  25.720         AVGHHW
     98      98      99      98      98      99      99      99      99  RATE=4 NHRS
  660.0   660.0   660.0   660.0   660.0   660.0   659.9   660.0   660.0   NAC1  AVGNAC
    0.0     0.0     0.0     0.0     0.0     0.0   134.1     0.0     0.0         AVGAC
 48.620  64.360  74.440  41.070  55.470  71.030  27.690  53.520  69.130         AVGHHW
     98      98      99      98      98      99      99      99      99  RATE=4 NHRS
  728.0   729.1   713.6   693.9   703.9   707.7   664.8   668.8   686.8   NAC2  AVGNAC
    0.0     0.0     0.0   134.1    74.2     0.0   243.1   195.6   173.4         AVGAC
 59.620  85.110 103.670  21.300  42.860 105.760   8.460  11.830  19.680         AVGHHW
     98      98     100      98      98     100      98      98     100  RATE=4 NHRS
  938.7   805.3   844.2   834.6   829.2   836.6   895.3  1004.8   901.1   NAC3  AVGNAC
    0.0     0.0     0.0     1.3     0.0     0.0   251.0   183.2   131.4         AVGAC
 54.670  75.300  98.980  46.150  64.270 104.290  16.370  25.370  37.430         AVGHHW
 1368.8   988.0  64.149
 1357.6   687.3  78.147
 1381.3   708.5 158.026
 1364.9   567.5 168.237
```

Table 5.B.2 Sample Binned Output for a Prototypical Fast-foods Restaurant of Average Vintage and New Equipment in San Francisco

```
*******************************************************************
*  FILE NAME:        ffdsfosn.dta                                 *
*  CITY:             San_Francisco / PG&E                         *
*  BUILDING TYPE:    Fast_Food_Restaurant                         *
*  BUILDING AREA:    2500                                         *
*  BUILDING VINT:    Average                                      *
*  EQUIPMENT TYPE:   New                                          *
*  PERIODS/YEAR:     2                                            *
*******************************************************************
2 1
     163      163      164      163      163      164      163      163      165  RATE=1 NHRS
     4.2      4.2      4.2      4.2      4.2      6.2      9.9     10.7     10.7   NAC1  AVGNAC
     0.2      0.2      0.2      0.2      0.2      0.2      0.2      0.2      0.2         AVGAC
   0.000    0.000    0.000    0.000    0.000    0.010    0.030    0.030    0.030         AVGHHW
     163      163      164      163      163      164      163      163      165  RATE=1 NHRS
    11.2     11.1     12.6     11.2     11.2     11.3     10.7     11.4     12.6   NAC2  AVGNAC
     0.2      0.2      0.2      0.2      0.2      0.2      2.5      0.9      2.4         AVGAC
   0.030    0.040    0.100    0.030    0.030    0.040    0.030    0.050    0.100         AVGHHW
     163      163      165      163      163      165      163      163      165  RATE=1 NHRS
    12.8     13.0     13.6     14.0     13.8     15.0     13.6     14.4     14.9   NAC3  AVGNAC
     0.2      0.2      0.2      0.2      0.2      0.2      1.8      0.8      1.6         AVGAC
   0.090    0.100    0.130    0.140    0.150    0.190    0.140    0.170    0.190         AVGHHW
     160      160      162      160      160      162      161      161      162  RATE=2 NHRS
     4.2      4.2      4.2      4.2      4.2      6.2      9.9     10.7     10.7   NAC1  AVGNAC
     0.2      0.2      0.2      0.2      0.2      0.2      0.2      0.2      0.2         AVGAC
   0.000    0.000    0.000    0.000    0.000    0.010    0.030    0.030    0.030         AVGHHW
     160      160      162      160      160      162      161      161      162  RATE=2 NHRS
    10.7     11.1     11.1     11.2     11.2     11.2     11.5     12.6     12.6   NAC2  AVGNAC
     0.2      0.2      0.2      0.2      0.2      0.2      0.3      0.2      0.3         AVGAC
   0.030    0.030    0.040    0.030    0.030    0.040    0.060    0.100    0.100         AVGHHW
     160      160      162      160      160      162      161      161      162  RATE=2 NHRS
    12.8     13.0     13.2     13.7     13.9     14.1     14.4     14.6     15.6   NAC3  AVGNAC
     0.2      0.2      0.2      0.2      0.2      0.2      0.2      0.2      0.2         AVGAC
   0.090    0.100    0.120    0.130    0.140    0.160    0.170    0.180    0.200         AVGHHW
    15.6      9.6  0.200
    15.6      3.6  0.200
```

Period 2. The cell numbers indicate that there are 50 hours in the bin period, with average demands of 660.0 kW for NAC, 324.2 kW for AC, and 14.39 kBtu/hr for HHW.

Following the bin tables, the last lines of the files give the peak demands of the same three parameters by rate period, arranged in the order of NAC, AC, and HHW, with a separate line for each rate period. For example, Table 5.B.1 indicate the peak demands during Rate Period 1 to be 1368.8 kWh for Non-Air-Conditioning (NAC), 988.0 kWh for Air-Conditioning (AC), and 64.149 kBtu/hr for Heating and Hot Water (HHW).

5.C END-USE HOURLY LOADS

The hourly data, as well as the DOE-2.1D input files, are stored as individual ASCII character files on three standard 12-inch reels of ½ inch magnetic tape. The tape is written with a fixed record length of 80, a block factor of 100, and a density of 6250 BPI. Since the data will be written in ASCII, the tapes have no subdirectory structure or file names. To assist users, each tape includes a short file TAPE.LIS giving the names for all the files on that tape. The first line of each file on the tape also has the name for that file. The first magnetic tape contains the DOE-2 input files, followed by the start of the detailed hourly files. The other two tapes contain the rest of the hourly files.

Each data file has a unique file name identifying the building type, location, vintage, and equipment, followed by the extension .DAT. Table 5.1 shows the naming scheme for the file names using three letter codes for building type and location, and single letter codes for shell and equipment vintages. For example, HOSCHICN.DAT indicates that the file is for a hospital (HOS) in Chicago (CHI) of current construction (C) and new equipment (N).

Table 5.C.1. Naming scheme for DOE-2 hourly files

Prototype		Location		Shell Vintage *	Equipment Vintage ‡
HOS	(Hospital)	SDG	(San Diego)	S (Stock)	O (Old)
LHT	(Large Hotel)	CHI	(Chicago)	C (Current)	N (New)
SIT	(24-hr Sitdown Restaurant)	LAX	(Los Angeles)	A (Average)	
FFD	(Fast Foods Restaurant)	MIA	(Miami)		
LO2	(24-hr Large office)	SFO	(San Francisco)		
LO1	(12-hr Large office)	NYC	(New York)		
SM2	(24-hr Supermarket)	PHX	(Phoenix)		
APT	(Apartment)	DET	(Detroit)		
PRI	(Prison)	HOU	(Houston)		
LRT	(Large Retail)	PHL	(Philadelphia)		
SM1	(18-hr Supermarket)	NEW	New Orleans)		
SSC	(Secondary school)	BOS	(Boston)		
SHT	(Small Hotel/Motel)	STL	(St. Louis)		

* For building types with envelope-dominant loads, two shell vintages (**Stock** and **Current**) are defined, using 1980 as the cutoff year; for buildings with process-dominant loads, a **Average** vintage is defined that is an average of all buildings of that type.

‡ **Old** refers to pre-1980s, and **New** to post-1980s equipment.

Description of Hourly Loads File Structure

The hourly files have been stored in a straightforward and consistent format to minimize the need for detailed instructions or lengthy computer set-up time, at the expense of some increase in file size. At the beginning of each file there are six lines of building description giving the building type, location, shell and equipment vintages, floor area, volume, total and peak electricity and fuel usages. These serve to identify the file, and are used to convert the energy uses per square foot to that for the whole building. More information about the prototype buildings and their market size are found in the User's Guide and, of course, this report.

The six descriptive lines in each file are followed by a blank line, a following line identifying the hourly parameters, and then 8760 lines of hourly values. The 12 hourly parameters are :

IM,ID,IHR,IDTYP,DBT,HUMRAT,HL,CL,LCL,HWL,NACE,ACE

where

IM	= Month of year (1-12)
ID	= Day of Month
IHR	= Hour of Day
IDTYP	= Day Type (1=Weekday, 2=Weekend, 3= Holiday)
DBT	= Ambient Dry Bulb Temperature (°F)
HUMRAT	= Ambient Humidity Ratio (x 10000)
HL	= Heating Load per floor area (Btu/ft^2)
CL	= Cooling Load per floor area (Btu/ft^2)
LCL	= Latent Cooling Load per floor area (Btu/ft^2)
HWL	= Hot Water Load per floor area (Btu/ft^2)
NACE	= Non-air Conditioning Electricity per floor area (w/ft^2) (includes fans, lighting, and miscellaneous electrical equipment)
ACE	= Air Conditioning Electricity per floor area (w/ft^2) (includes chiller, plant and auxiliary pumps; note that the Coefficient-of-Performance (COP) relative to the Cooling Load (CL) varies hourly depending on the ambient conditions and the load factor)

Table 5.C.2 shows sample excerpts from the hourly file for a current vintage hospital with new equipment in Chicago (HOSCHICN.DAT). Table 5.C.3 shows additional information about the prototype building that will be given in the User's Guide.

Data-processing Program

A short data-processing program, *binread*, has been written to allow users to extract summary data from the hourly files and to provide a framework for further analysis of the data. The Fortran listing for *binread* appears in Chapter 8 and is included in the first data tape. Since this type of analysis is of interest only to researchers, *binread* is a functional utility program without an elaborate user front end. Table 5.C.4

Table 5.C.2 Sample Excerpt of Hourly Data File for a Prototypical Hospital of Current Vintage and New Equipment in Chicago

Prototype Name	hoschicn.dat	Building Type	Hospital
Location	Chicago	Weather tape	chicagotmy
Shell vintage	Current	Equipment vintage	New
Floor area (SF)	363884	Volume (CF)	3638840
Total Elec (MWh)	10185.18	Peak Elec (kW)	2282.85
Total Fuel (MBtu)	51954.80		

IM	ID	IHR	IDTYP	DBT	HUMRAT	HL	CL	LCL	HWL	NACE	ACE
(typical winter day)											
1	1	1	1	34	31	15.2264	0.0000	0.0000	1.2168	1.6991	0.0000
1	1	2	1	34	34	15.5465	0.0000	0.0000	1.2168	1.6991	0.0000
1	1	3	1	34	34	15.7363	0.0000	0.0000	1.2168	1.6991	0.0000
1	1	4	1	34	34	15.8877	0.0000	0.0000	1.6900	1.6991	0.0000
1	1	5	1	33	35	16.3632	0.0000	0.0000	1.6900	1.6991	0.0000
1	1	6	1	34	34	15.3112	0.0000	0.0000	4.3940	2.0454	0.0000
1	1	7	1	36	41	14.4469	0.0000	0.0000	6.7600	2.0454	0.0000
1	1	8	1	37	43	12.0198	0.0000	0.0000	5.8136	3.4948	0.0000
1	1	9	1	39	43	10.8388	0.0000	0.0000	5.4080	3.4913	0.0000
1	1	10	1	39	47	10.3079	0.0000	0.0000	4.6644	3.4913	0.0000
1	1	11	1	39	47	9.9612	0.0000	0.0000	4.6644	3.4913	0.0000
1	1	12	1	40	49	9.2190	0.0000	0.0000	4.9348	3.5001	0.0000
1	1	13	1	41	51	8.5727	0.0000	0.0000	4.9348	3.4405	0.0000
1	1	14	1	40	49	8.8340	0.0000	0.0000	3.8532	3.4405	0.0000
1	1	15	1	40	49	8.5497	0.0000	0.0000	4.6644	3.4913	0.0000
1	1	16	1	41	51	8.0011	0.0000	0.0000	5.6784	3.4913	0.0000
1	1	17	1	40	49	8.4569	0.0000	0.0000	4.9348	3.4913	0.0000
1	1	18	1	40	49	8.5462	0.0000	0.0000	4.4616	3.5163	0.0000
1	1	19	1	40	49	8.4619	0.0000	0.0000	3.3800	3.5145	0.0000
1	1	20	1	36	46	12.5118	0.0000	0.0000	3.2448	2.2373	0.0000
1	1	21	1	36	41	12.9781	0.0000	0.0000	3.1096	2.1690	0.0000
1	1	22	1	35	44	13.6755	0.0000	0.0000	2.8392	2.1690	0.0000
1	1	23	1	34	42	14.6882	0.0000	0.0000	2.9068	1.6991	0.0000
1	1	24	1	34	37	14.9926	0.0000	0.0000	2.2308	1.6991	0.0000
(typical summer day)											
7	1	1	7	77	152	0.3613	20.4094	9.3118	1.2168	1.6971	1.5340
7	1	2	7	76	139	0.3774	17.6654	7.2465	1.2168	1.6968	1.3357
7	1	3	7	75	141	0.3930	17.3595	7.5385	1.6900	1.6962	1.2855
7	1	4	7	75	133	0.4037	15.9235	6.3478	1.6900	1.6958	1.1894
7	1	5	7	74	143	0.4401	17.7694	8.3627	4.3940	2.0428	1.2988
7	1	6	7	75	141	0.4500	17.8872	8.0482	6.7600	2.0430	1.3217
7	1	7	7	78	150	0.3425	22.2788	9.7904	5.8136	3.4971	1.5896
7	1	8	7	85	158	0.3302	27.2494	11.3299	5.4080	3.4964	1.8989
7	1	9	7	90	155	0.3203	29.5615	11.0946	4.6644	3.4989	2.1153
7	1	10	7	94	146	0.3098	30.5383	9.8994	4.6644	3.5015	2.2135
7	1	11	7	95	144	0.3032	31.1787	9.7219	4.9348	3.5134	2.2637
7	1	12	7	97	139	0.2957	31.4688	8.9934	4.9348	3.4557	2.2880
7	1	13	7	96	142	0.2903	31.8721	9.5384	3.8532	3.4574	2.3176
7	1	14	7	99	135	0.2809	32.2994	8.5184	4.6644	3.5092	2.3499
7	1	15	7	99	135	0.2777	32.8539	8.5964	5.6784	3.5135	2.3916
7	1	16	7	98	137	0.2777	33.0426	8.9272	4.9348	3.5167	2.4091
7	1	17	7	98	138	0.2777	33.5433	9.1274	4.4616	3.5454	2.4460
7	1	18	7	92	134	0.2777	30.4384	8.3825	3.3800	3.5453	2.2364
7	1	19	7	87	154	0.2778	29.6409	11.0960	3.2448	2.2484	2.1270
7	1	20	7	85	159	0.2983	28.3868	11.4596	3.1096	2.1767	2.0589
7	1	21	7	83	155	0.3059	26.2454	10.6062	2.8392	2.1751	1.9220
7	1	22	7	81	160	0.3183	25.3994	11.1655	2.9068	1.7024	1.8457
7	1	23	7	79	148	0.3277	21.9563	9.0448	2.2308	1.7007	1.6547
7	1	24	7	78	142	0.3353	20.0707	7.9064	1.2168	1.6997	1.5226

IM - Month, ID - Day, IHR - Hour, IDTYP- Day Type, DBT - Temp (F), HUMRAT - Humidity Ratio x 10000, HL - Heating, CL - Cooling, LCL - Latent Cool., HWL - Hot Water, NACE - Non-A/C Elec, ACE - A/C Elec.

Table 5.C.3. Building Description for Prototype HOSCHICN

Prototype Name : HOSCHICN	
Location	Chicago
Building Type	Hospital
Building Size	area 363884 ft^2, vol 3638840 ft^3
No. of floors	6
Shell Characteristics :	
Vintage	Current (post-1980)
Construction	Concrete frame
Roof Insulation	R-19
Wall Insulation	R-12
Window/Wall Ratio	0.178
Window Panes	1
Shading Coefficient	0.60
Operational Characteristics :	
Average Hot Water Intensity	6.76 Btu/hr·ft^2
Peak Lighting Intensity	3.0 W/ft^2
Peak Equipment Intensity	0.5 W/ft^2, 1.5 W/ft^2 in clinic
Peak Gas Cooking Load	3.59 Therms/hr
Peak Elec Cooking Load	14.78 kW
Equipment Characteristics :	
Vintage	New (post-1980)
System Types	Four-pipe Fan Coil (patient areas), Variable-air-volume (lobby and core areas), Single-zone Reheat (kitchen), Reheat-fan (clinic).
Plant Type	Hot-Water Boiler, Hermetic Centrifugal Chiller, Cooling Tower

Table 5.C.4. Output Tables from Data-processing Program

1.	Monthly building loads and electricity consumptions by end-use.
2.	Peak monthly building loads with coincident temperatures and humidity ratios, and peak monthly electricity use by end-use.
3.	Heating and cooling loads binned by 5°F drybulb temperature.
4.	Cooling and latent cooling loads binned by 5°F drybulb temperature and 0.002 humidity ratio.
5.	Annual building loads and electricity consumptions by end-use binned by hour of day.
6.	Ambient temperatures and humidity ratios binned by temperature, humidity ratio, and hour of day.

Table 5.C.5 Total Monthly Building Loads and Electric Consumption per ft^2 for Prototype Current Hospital with New Equipment in Chicago

Monthly Building Loads (per SqFt)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Heating Load (kBtu)	14201.	12453.	9588.	3934.	1405.	386.	290.	296.	546.	1914.	6502.	12916.	64430.
Hot Water Load (kBtu)	2787.	2517.	2787.	2697.	2787.	2697.	2787.	2787.	2697.	2787.	2697.	2787.	32816.
Cooling Load (kBtu)	0.	6.	116.	1187.	4998.	9594.	12668.	12630.	7256.	2648.	585.	94.	51782.
Lat Cool Load (kBtu)	0.	0.	6.	59.	1412.	2464.	4000.	4377.	2066.	442.	63.	34.	14924.
A/C Electricity (kWh)	0.	3.	28.	165.	451.	744.	943.	947.	600.	303.	95.	12.	4289.
Non A/C Elec (kWh)	2033.	1834.	2012.	1948.	2006.	1938.	2003.	2004.	1938.	2009.	1947.	2027.	23700.
Total Elec (kWh)	2034.	1837.	2040.	2113.	2457.	2682.	2946.	2951.	2538.	2312.	2042.	2040.	27990.

Table 5.C.6 Peak Monthly Building Loads per ft^2 for Prototype Current Hospital with New Equipment in Chicago

Peak Building Loads (per SqFt)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Heating Load (kBtu/hr)													
Load	42.0	36.7	31.0	18.8	9.6	3.9	1.4	2.4	4.9	12.8	25.3	32.5	42.0
Temp	-8	0	7	27	41	54	55	51	48	34	19	5	-8
Hot Water Load (kBtu/hr)													
Load	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8
Cooling Load (kBtu/hr)													
Load	0.0	1.4	6.7	13.2	31.3	36.0	34.8	36.4	35.3	17.1	9.9	6.6	36.4
Temp	48	53	64	77	89	91	90	88	85	77	73	61	88
HRx1000	6	5	10	9	16	18	16	18	19	10	7	10	18
Lat Cool Load (kBtu/hr)													
Load	0.0	0.0	2.4	3.9	13.1	15.6	15.4	17.0	17.8	5.3	3.0	3.2	17.8
Temp	0	0	62	67	89	91	80	86	85	64	62	59	85
HRx1000	0	0	9	11	16	18	18	19	19	11	10	10	19
A/C Electricity (kW)	0.2	0.4	0.6	1.0	2.3	2.7	2.6	2.7	2.6	1.2	0.8	0.6	2.7
Non A/C Elec (kW)	3.7	3.7	3.6	3.6	3.6	3.6	3.6	3.6	3.5	3.6	3.6	3.7	3.7
Total Elec (kW)	3.7	3.9	4.1	4.5	5.8	6.2	6.1	6.3	6.1	4.7	4.2	4.1	6.3

Table 5.C.7 Heating and Cooling Loads per ft^2 for Prototype Current Hospital with New Equipment in Chicago, Binned by Outdoor Temperature

Building Loads By 5 Degree Temperature Bins (per SqFt)

Temp (F) L	Temp (F) U	Heating Hours	Heat Load (kBtu)	Heat Rate (kBtu/hr)	Cooling Hours	Cool Load (kBtu)	Cool Rate (kBtu/hr)
-10	-5	8	325.33	40.67	0	0.00	0.00
-5	0	16	603.07	37.69	0	0.00	0.00
0	4	56	1881.76	33.60	0	0.00	0.00
5	9	101	3061.13	30.31	0	0.00	0.00
10	14	168	4540.14	27.02	0	0.00	0.00
15	19	260	6219.39	23.92	0	0.00	0.00
20	24	289	6125.02	21.19	0	0.00	0.00
25	29	563	10268.18	18.24	0	0.00	0.00
30	34	743	10921.25	14.70	0	0.00	0.00
35	39	794	9241.27	11.64	0	0.00	0.00
40	44	621	4860.15	7.83	2	0.00	0.00
45	49	506	2267.78	4.48	204	37.82	0.19
50	54	534	1432.96	2.68	534	630.69	1.18
55	59	660	991.20	1.50	660	1982.52	3.00
60	64	695	563.50	0.81	695	3827.30	5.51
65	69	771	416.97	0.54	771	7556.16	9.80
70	74	707	290.91	0.41	707	9734.15	13.77
75	79	568	202.00	0.36	568	10373.69	18.26
80	84	379	121.57	0.32	379	8647.14	22.82
85	89	238	71.83	0.30	238	6429.13	27.01
90	94	72	21.12	0.29	72	2214.38	30.76
95	99	11	3.17	0.29	11	349.32	31.76
Total		8760	64429.65	7.35	4841	51782.43	10.70

Table 5.C.8 Building Loads and Electricity Consumptions per Square Foot for Prototype Current Hospital with New Equipment in Chicago, Binned by Hour of Day

Hour	Heating Load (kBtu)	HotWater Load (kBtu)	Cooling Load (kBtu)	LatCool Load (kBtu)	Air Cond Elec (kW)	Non-A/C Elec (kW)	Total Elec (kW)
1	3319.	444.	1499.	546.	135.	630.	765.
2	3434.	444.	1421.	542.	130.	631.	761.
3	3555.	544.	1337.	515.	124.	632.	755.
4	3667.	617.	1287.	511.	120.	633.	753.
5	3688.	1185.	1317.	532.	121.	706.	827.
6	3606.	2101.	1363.	540.	125.	759.	884.
7	3376.	2269.	1659.	597.	143.	1061.	1205.
8	2875.	2037.	1934.	626.	162.	1283.	1445.
9	2608.	1818.	2240.	673.	182.	1281.	1464.
10	2362.	1703.	2504.	705.	201.	1281.	1482.
11	2173.	1759.	2704.	708.	216.	1282.	1497.
12	2010.	1801.	2821.	697.	224.	1270.	1494.
13	1900.	1574.	2960.	689.	233.	1261.	1494.
14	1818.	1577.	3077.	696.	240.	1271.	1511.
15	1758.	1915.	3114.	679.	243.	1279.	1522.
16	1779.	1916.	3091.	685.	241.	1279.	1520.
17	1866.	1702.	2971.	681.	234.	1285.	1519.
18	1998.	1401.	2800.	681.	222.	1289.	1511.
19	2150.	1205.	2371.	639.	195.	1019.	1214.
20	2591.	1156.	2140.	615.	179.	809.	989.
21	2752.	1078.	2013.	636.	170.	800.	969.
22	2885.	1051.	1840.	605.	158.	700.	858.
23	3065.	919.	1720.	577.	150.	629.	779.
24	3197.	601.	1600.	551.	142.	630.	772.
Total	64430.	32816.	51782.	14924.	4289.	23700.	27990.

Table 5.C.9 Cooling Loads per ft^2 for Prototype Current Hospital with New Equipment in Chicago, Binned by Outdoor Temp and Humidity Ratio

Cooling Loads (kBtu) Binned vs. Temperature and Humidity (per SqFt)

T/H.R.	.001	.003	.005	.007	.009	.011	.013	.015	.017	.019	.021	All
97.5	0.	0.	0.	0.	0.	0.	254.	95.	0.	0.	0.	349.
92.5	0.	0.	0.	0.	84.	29.	548.	1068.	414.	72.	0.	2214.
87.5	0.	0.	0.	259.	245.	861.	943.	2401.	1549.	171.	0.	6429.
82.5	0.	0.	60.	391.	759.	1301.	1586.	2364.	1864.	322.	0.	8647.
77.5	0.	12.	256.	369.	1351.	2076.	1816.	2614.	1778.	101.	0.	10374.
72.5	0.	119.	507.	868.	1486.	1716.	2534.	1990.	514.	0.	0.	9734.
67.5	0.	150.	562.	865.	1377.	1993.	1997.	612.	0.	0.	0.	7556.
62.5	6.	245.	438.	1101.	1062.	946.	29.	0.	0.	0.	0.	3827.
57.5	0.	196.	467.	656.	624.	38.	0.	0.	0.	0.	0.	1983.
52.5	0.	123.	228.	247.	33.	0.	0.	0.	0.	0.	0.	631.
47.5	1.	12.	15.	10.	0.	0.	0.	0.	0.	0.	0.	38.
Total	7.	857.	2534.	4765.	7021.	8959.	9708.	11144.	6119.	666.	0.	51782.

Latent Cool Loads (kBtu) Binned vs. Temperature and Humidity (per SqFt)

T/H.R.	.001	.003	.005	.007	.009	.011	.013	.015	.017	.019	.021	All
97.5	0.	0.	0.	0.	0.	0.	66.	29.	0.	0.	0.	95.
92.5	0.	0.	0.	0.	4.	5.	150.	351.	167.	31.	0.	710.
87.5	0.	0.	0.	0.	22.	161.	268.	857.	655.	82.	0.	2044.
82.5	0.	0.	0.	0.	64.	258.	482.	927.	853.	165.	0.	2749.
77.5	0.	0.	0.	0.	111.	460.	625.	1141.	890.	56.	0.	3285.
72.5	0.	0.	0.	1.	157.	457.	1040.	996.	275.	0.	0.	2926.
67.5	0.	0.	0.	1.	193.	730.	968.	322.	0.	0.	0.	2214.
62.5	0.	0.	0.	5.	220.	425.	16.	0.	0.	0.	0.	665.
57.5	0.	0.	0.	11.	188.	19.	0.	0.	0.	0.	0.	219.
52.5	0.	0.	0.	8.	9.	0.	0.	0.	0.	0.	0.	17.
47.5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
Total	0.	0.	0.	27.	968.	2515.	3615.	4624.	2840.	335.	0.	14924.

Air-cond. Elec (kWh) Binned vs. Temperature and Humidity (per SqFt)

T/H.R.	.001	.003	.005	.007	.009	.011	.013	.015	.017	.019	.021	All
97.5	0.	0.	0.	0.	0.	0.	18.	7.	0.	0.	0.	25.
92.5	0.	0.	0.	0.	6.	2.	39.	77.	31.	5.	0.	160.
87.5	0.	0.	0.	19.	18.	62.	67.	172.	113.	13.	0.	462.
82.5	0.	0.	4.	28.	55.	95.	115.	170.	135.	24.	0.	625.
77.5	0.	1.	18.	27.	99.	151.	134.	193.	130.	7.	0.	760.
72.5	0.	9.	37.	66.	115.	129.	187.	149.	38.	0.	0.	730.
67.5	0.	12.	46.	71.	117.	160.	152.	45.	0.	0.	0.	604.
62.5	1.	25.	47.	118.	106.	83.	2.	0.	0.	0.	0.	381.
57.5	0.	29.	76.	109.	79.	4.	0.	0.	0.	0.	0.	296.
52.5	0.	38.	73.	75.	7.	0.	0.	0.	0.	0.	0.	192.
47.5	1.	16.	20.	11.	0.	0.	0.	0.	0.	0.	0.	47.
Total	3.	133.	321.	524.	601.	685.	714.	813.	446.	49.	0.	4289.

Table 5.C.10 Ambient Hours in Chicago, Binned by Outdoor Temperature and Hour of Day

Ambient Hours Binned vs. Hour and Temperature

T/Hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
97.5	0	0	0	0	0	0	0	0	0	0	1	1	2	2	2	1	2	0	0	0	0	0	0	0	11
92.5	0	0	0	0	0	0	0	0	1	1	3	7	12	15	13	11	7	2	0	0	0	0	0	0	72
87.5	0	0	0	0	0	0	0	1	4	15	25	25	28	26	26	27	22	23	12	3	1	0	0	0	238
82.5	1	0	0	0	0	0	1	9	23	29	27	33	27	31	32	31	30	25	25	23	14	9	6	3	379
77.5	18	16	9	6	6	9	20	35	33	34	30	24	32	26	29	28	28	28	28	27	28	28	27	19	568
72.5	30	25	32	31	24	30	35	35	31	26	26	29	23	23	24	26	28	28	27	34	33	35	35	37	707
67.5	38	41	37	38	44	40	38	29	30	27	29	30	26	27	23	23	20	28	37	33	32	30	33	38	771
62.5	32	33	34	31	35	35	32	25	29	29	24	20	25	23	28	29	27	28	21	23	33	34	33	32	695
57.5	33	36	40	40	36	26	22	28	25	19	23	24	23	24	23	19	26	19	27	31	28	29	29	30	660
52.5	27	22	18	21	20	30	31	24	21	24	23	25	23	24	18	20	20	24	19	18	19	20	21	22	534
47.5	20	21	22	24	25	24	19	23	29	26	19	18	16	14	19	17	17	18	25	22	24	23	21	20	506
42.5	26	28	29	28	28	26	25	27	14	19	23	23	25	31	29	31	30	28	25	24	23	26	25	28	621
37.5	39	39	35	34	35	32	33	26	30	32	32	32	34	32	29	30	30	31	31	35	36	36	37	34	794
32.5	27	27	31	31	29	31	27	30	30	28	32	33	29	27	31	32	35	34	34	34	36	33	31	31	743
27.5	32	32	32	33	31	26	28	25	25	22	15	12	15	17	15	16	15	21	21	21	22	27	30	30	563
22.5	12	15	13	14	16	20	19	13	11	9	14	14	10	8	12	9	9	8	11	11	10	8	10	13	289
17.5	13	12	12	11	9	12	10	11	10	10	10	6	11	12	8	9	11	10	9	13	12	13	13	13	260
12.5	7	8	10	11	15	10	12	13	8	7	4	6	3	1	3	4	4	6	7	6	7	7	4	5	168
7.5	6	6	5	5	5	8	6	3	6	7	4	2	1	2	1	1	3	3	4	4	5	2	6	6	101
2.5	2	2	4	5	5	3	4	7	4	0	1	1	0	0	0	1	1	1	2	3	2	4	2	2	56
-2.5	2	2	1	0	0	2	2	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	2	2	16
-7.5	0	0	1	2	2	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8

Table 5.C.11 Ambient Hours in Chicago, Binned by Outdoor Temperature and Humidity Ratio

T/H.R.	.001	.003	.005	.007	.009	.011	.013	.015	.017	.019	.021	All
97.5	0	0	0	0	0	0	8	3	0	0	0	11
92.5	0	0	0	0	4	1	19	34	12	2	0	72
87.5	0	0	0	14	12	38	36	84	49	5	0	238
82.5	0	0	4	25	42	67	71	92	67	11	0	379
77.5	0	1	20	29	95	124	96	124	75	4	0	568
72.5	0	12	49	82	133	132	164	111	24	0	0	707
67.5	0	20	75	114	171	195	158	38	0	0	0	771
62.5	1	48	92	234	197	120	3	0	0	0	0	695
57.5	0	64	173	251	166	6	0	0	0	0	0	660
52.5	0	106	211	201	16	0	0	0	0	0	0	534
47.5	7	156	250	93	0	0	0	0	0	0	0	506
42.5	23	317	279	2	0	0	0	0	0	0	0	621
37.5	24	612	158	0	0	0	0	0	0	0	0	794
32.5	103	635	5	0	0	0	0	0	0	0	0	743
27.5	205	358	0	0	0	0	0	0	0	0	0	563
22.5	240	49	0	0	0	0	0	0	0	0	0	289
17.5	260	0	0	0	0	0	0	0	0	0	0	260
12.5	168	0	0	0	0	0	0	0	0	0	0	168
7.5	101	0	0	0	0	0	0	0	0	0	0	101
2.5	56	0	0	0	0	0	0	0	0	0	0	56
-2.5	16	0	0	0	0	0	0	0	0	0	0	16
-7.5	8	0	0	0	0	0	0	0	0	0	0	8

gives a list of the output tables that can be produced by *binread*. A one-line command file (COMMAND.TMP) permits users to select the output tables to be generated and to display either building totals or per square foot values. Tables 5.C.5 through 5.C.11 show samples output tables for the prototype Current hospital building with New equipment in Chicago.

User's Guide

The data tapes are accompanied by a short 12-page User's Guide that lists the contents of the tapes, describe its purpose and use, the structure for the hourly and DOE-2 input files, how to compose the DOE-2.1D input files and use the Data-processing program, and sample outputs. The guide will assume that interested users are familiar with the DOE-2 program and building loads analysis, and concentrate only on the mechanics of data processing.

The User's Guide will also contain short descriptions of the prototype buildings and their market sector size abridged from the Summary Results Report. For detailed information of the simulation and analysis methodology, users should refer to the larger summary report.

5.D DOE-2 INPUT FILES

As explained in Section 3.D, the DOE-2.1D input files utilize the new ''Input Macro'' feature that allows partial inputs to be composed into final input files based on specified commands. This feature reduces errors and increases consistency by keeping repetitive input information in separate files, which are imported into the final input files originally containing only those inputs that are unique to it. With this input procedure there are four common ''Include Files'' describing the location and output reports (LOC.INC, LDSRPT.INC, SYSRPT.INC, and PLTRPT.INC), and four common prototype files for each of the thirteen building types : *.CONF (configuration), *.LDS (loads), *.SYS (systems), and *.PLT (plant). Lastly, there are short input files for each DOE-2 simulation following the nomenclature in Table 5.C.1, except with the extension *.INP instead of *.DAT.

For example, the DOE-2.1D input for the data file HOSCHICN.DAT can be created from HOSCHICN.INP, which imports data from LOC.INC, LDSRPT.INC, SYSRPT.INC, PLTRPT.INC., HOS.LDS, HOS.SYS, and HOS.PLT.

6. MARKET SECTOR SIZE ANALYSIS

This chapter describes the second major task of this project, which is to estimate the numbers and total floor area represented by each of the 481 prototypical buildings described and analyzed in Chapter 4. These market size estimates are used in the Commercial Cogeneration Assessment Model (CCAM) developed by HBI, in conjunction with the four-dimensional bins of prototypical energy use characteristics described in Chapter 5, to project the potential for cogeneration in commercial buildings in the 13 representative cities. More detail on how the LBL market data are used in the CCAM is available in the final project report from Hagler, Bailly, Inc. (HBI 1991).

6.A DESCRIPTION OF DATA SOURCES

To estimate market sector sizes, the project team relied on a subset of the data used to define the prototypical buildings, i.e., the statistical data bases listed in Table 2.1. These include : two sets of county-level data from Dodge (Building Stock 1989, and Building Starts 1989), the NBECS (Non-residential Buildings Energy Consumption Survey 1983), RECS (Residential Energy Consumption Survey 1984), AHA (American Hospital Association 1988), and NCES (National Educational Association 1988) data bases, the Statistical Abstract of the United States (Department of Commerce 1989), and 1980 census populations and projections (Rand McNally 1990). Brief descriptions of these data sources are given in Appendix 8.A.

Since no single data source provides all the necessary data, different methods have been used to estimate market sizes depending on the building type and vintage. The output of this effort are the estimated building count and total floor area for each Project Building Type disaggregated by three vintages/equipment combinations : (1) Current, i.e., post-1981, construction, (2) Stock, i.e., pre-1981, construction with original equipment, and (3) Stock construction with new equipment.

The rest of this section will describe how the market size estimates for each Market Area have been derived by building type, vintage, and if necessary, hours of operation. This is followed by brief descriptions of how the estimated market sizes for new versus old equipment, growth and demolition rates, and the ratios of public versus private ownership have been determined.

6.B ESTIMATES OF BUILDING SECTOR SIZES

1. Hotels, Large Retail, Large Offices, and Apartments

The two Dodge data sets are the primary data sources for estimating market sector sizes for these prototypes, supplemented by NBECS or RECS data on floor area distributions for pre-1965 buildings.

The Dodge Building Start data has been processed to derive the *number of buildings*, *total floor area*, and *average floor area* by Project Building Type, Market Area, and two vintages (1967-1981, 1981-1988). There are two instances where the mapping between counties and Market Areas is not distinct. Data for Cook County (Illinois) are divided equally between the two Chicago Market Areas (People's and Northern Illinois Gas). Likewise, the data for Queens County (New York) are divided equally between the two New York Market Areas (Brooklyn Union Gas and Consolidated Edison).

In all cases, the Project Building Types are subsets of their respective Dodge Requested Building Category based on building size, e.g., Large Offices > 60,000 ft^2 or Large Retail Stores > 20,000 ft^2. Since the requested Buildings Start data are binned by floor area (see sample data in Table 2.A.5), it is a straightforward procedure to calculate the percentage of the total Dodge Requested Building Category floor area that fall within the specified building size criteria. Results for the same sample market area as in Table 2.A.5 is shown in Table 6.1. For example, the total stock of office and banks built in the sample market area from 1967 to 1980 is 106 million ft^2 or 3778 buildings (from Table 2.A.5). Of these, 31.7 million ft^2, or 3436 buildings, are below 60,000 ft^2 in size and outside the scope of this study. The remaining office buildings larger than 60,000 ft^2 have a total square footage of 74.3 million ft^2, making up 70.1% of the total office square footage (Table 6.1).

The total floor area of Current buildings (1981-1988) is based entirely on the analysis of Dodge Start data mentioned above, with demolitions ignored since the average age of such buildings is less than 6 years. The procedure for estimating the floor area of Stock buildings (pre-1981) is more complex, and involves combining the estimated floor areas for 1967-1981 buildings to that for the pre-1967 buildings. For the 1967-1981 building stock, the Dodge Building Start Data is used in the same way as mentioned earlier. However, this stock has been reduced by a demolition rate of 0.0156 per year based on Dodge's demolition equation and assuming equal amounts of construction from years 9 to 24 (Dodge 1989).

The floor areas for the pre-1967 buildings are estimated using the Dodge Building Stock data in conjunction with NBECS. This other Dodge data base gives the estimated total building stock in each Dodge Requested Building Category by county and year starting from 1970. The Dodge Building Stock data for 1970 are first backcast to 1967 based on the growth trends of the following five years. These estimated 1967 floor areas are then multiplied by the percent distributions of the Project Building Type within each Building Category derived by averaging the percent distributions from the Dodge Building Start as illustrated by Table 6.1 and those from either the 1983 NBECS or the 1984 RECS surveys (Table 6.2). The reason for averaging the percent distributions from the two data sources is that the Dodge Building Start data is geographically specific but covers only post-1967 buildings, while the NBECS and RECS surveys cover all building

Table 6.1 Partial list of percent representation of Project Building Types within Requested Building Types for a sample Market Area
(based on Dodge Building Start data from 1966-1980)

Project Building Type	Requested Dodge Building Category	Percent representation (%)
Large Apartment > 10K	% of all apartments	75.9
Large Hotel	% of all hotels	71.9
Small hotel/Motel	% of all hotels	28.1
Large Office > 60K	% of all offices	70.1
Large Retail > 20K	% of all stores	61.0
Restaurants	% of all stores	9.2

Table 6.2 Percent representation of Project Building Types within Requested Building Types
(based on NBECS and RECS data for pre-1965 vintage buildings)

Region	Project Building Type	Requested Bldg. Category	Percent Repr. (%)
Northeast	Large Office > 60K	% of all offices	57.7
	Large Retail > 20K	% of all stores	54.2
	Large Hotel	% of all hotels	70.1
	Small hotel/Motel	% of all hotels	29.9
	Large Apartment > 5 units	% of all apartments	26.0
North Central	Large Office > 60K	% of all offices	47.3
	Large Retail > 20K	% of all stores	44.8
	Large Hotel	% of all hotels	67.5
	Small hotel/Motel	% of all hotels	32.5
	Large Apartment > 5 units	% of all apartments	18.3
South	Large Office > 60K	% of all offices	53.7
	Large Retail > 20K	% of all stores	46.1
	Large Hotel	% of all hotels	29.9
	Small hotel/Motel	% of all hotels	70.1
	Large Apartment > 5 units	% of all apartments	46.3
West	Large Office > 60K	% of all offices	49.7
	Large Retail > 20K	% of all stores	42.8
	Large Hotel	% of all hotels	14.5
	Small hotel/Motel	% of all hotels	85.5
	Large Apartment > 5 units	% of all apartments	34.3

vintages but lack geographical precision.

For the pre-1967 buildings, cumulative demolition rates of 0.260, 0.265, 0.258, and 0.260 are used for the Northeast, North Central, West, and South regions, respectively, based on Dodge estimates of annual demolition rates for pre-1967 buildings (Dodge 1989), multiplied by the 23 years since 1967.

The estimated square footages of Large Hotels, Large Offices, and Apartments by Market Area and the two vintages (Current and Stock) are given in Tables 6.4.1 through 6.4.5. The building counts per Market Area are calculated by dividing these square footages by the average building sizes from the Dodge Building Start data. The average sizes for the 1967-1981 buildings are used for the Stock, and those for the 1981-1988 buildings for the Current vintage buildings. For cities with more than one Market Area, the same average building size has been used for both areas.

The breakdown between 12 hour and 24 hour offices is based solely on an engineering estimate of 80% to 20%.

2. Extended-hour Sit-down and Fast-food Restaurants

The two Dodge data bases are also the primarily source for estimating the market sector size for restaurants. The Dodge Building Start data for Food Sales has been processed to derive the number and total floor area of new construction from 1967 to 1988 by Market Area. Buildings over 20,000 ft^2 have been eliminated as either data errors or non-restaurant buildings.

There is very little publicly available information that can be used to distinguish sit-down from fast-food restaurants, or to separate extended-hour from other sit-down restaurants. The Statistical Abstract (Department of Commerce 1990) indicates that, for the entire nation, there are equal numbers of the two restaurant types (126,514 full-service to 126,125 limited-menu restaurants). For this study, it has been assumed that each Market Area has the same number of sit-down to fast-food restaurants, and that fast-food restaurant average 2,500 ft^2 in size. The remaining square footages are all assumed to be sit-down restaurants. Of these sit-down restaurants, ⅓ are estimated to be extended-hour operations that serve three meals and are open at least 18 hours per day. The estimated market sector sizes for fast-food and extended-hour sit-down restaurants are shown in Tables 6.4.6 or 6.4.7.

3. Hospitals and Schools

For the hospital and secondary schools, the Dodge Requested Building Start data base has been processed in a similar fashion as before to derive the floor area of Current vintage buildings. However, for the floor area of Stock vintage buildings, the AHA and NES data bases have been used in place of the Dodge Requested Building Stock data. Since these two data base are comprehensive and current, there is no need to account for demolitions. The building counts in the AHA and NCES data bases have been converted to total square footages using algorithms that correlate bed counts or enrollment to building size (see Sections 4.A and 4.I). Because the AHA data are stored by Zip code, it is impossible in three instances to distinguish between Market Areas within one city (Detroit, Philadelphia, and New Orleans). For those areas, the city-level data are evenly divided between their two respective Market Areas. The floor areas of Stock buildings are derived by subtracting the floor areas of Current buildings calculated earlier from the total floor area based on the AHA or NES data. The building counts are then calculated by dividing these total square footages by the average building sizes from the same AHA and NES data sets. The resultant market sizes are shown in Tables 6.4.8 and 6.4.9.

4. Supermarkets

The Dodge data bases lump supermarkets in with other stores. In the NBECS data base, it is possible to distinguish supermarkets by the "Building Activity" identifier, but the sample size is too small and unreliable for estimating the number of supermarkets at the regional level, let alone Market Areas.

Due to this scarcity of data, it has been judged better to estimate the number of supermarkets based on a simple correlation of supermarkets to the population of each Market Area. The Statistical Abstract indicates that, for the entire nation, there is 0.00011 supermarkets per person (Table 6.3).

Table 6.3 Population and Number of Supermarkets in the U.S.

Year	U.S. Population	No. of Supermarkets	Supermarkets/ person
1980	227,757,000	26,321	0.0001156
1984	237,001,000	26,947	0.0001137
1986	241,613,000	27,005	0.0001118

The number of Stock supermarkets (pre-1981) is estimated by multiplying the Market Area population in 1980 by the above ratio (.00011) and then eliminating the demolished buildings using the average Dodge demolition rates for Stores from 1980 to 1988. The number of Current supermarkets (post-1981) is estimated by multiplying the estimated Market Area population for December 1988 by the same ratio, and then subtracting the number of Stock supermarkets just calculated. The total square footage is calculated by multiplying the number of supermarkets by an average size of 21,000 ft^2 based on the NBECS data (see Section 4.F).

The estimated total number of supermarkets by Market Area is shown in Table 6.4.10. The breakdown of 18 hour and 24 hour supermarkets is based solely on an engineering estimate of 75% to 25% and not indicated in the tables.

5. Prisons

Estimated building counts and square footages of prisons have been derived using the Dodge Building Start data and information from the Department of Justice and the American Correctional Association. Prisons differ by their operations, e.g., short-term jails, penitentiaries, rehabilitation centers, etc., as well as jurisdiction, e.g., federal, state, and local. For this study, the primary buildings of interest are the larger long-term penitentiaries with substantial electrical and thermal demands. The small jails that have load shapes and end-use intensities similar to police stations should not be included in the study.

The total number of prisons and inmate population in the Market Areas has been pieced together from various sources. The *Census of Jails, 1978* (Dept. of Justice 1981) identifies all county jails in the country and gives the number of inmates. This data has been used to derive the number of prisons and inmates in local jails for the 31 counties of interest (See Table 2.A.9). To eliminate the smaller jails, only those with more than 100 inmates are included in the market size estimates.

More than half of the nation's inmates are incarcerated in state and federal penitentiaries that do not appear in the above census. Since these are often located away from major urban centers, it is impossible to estimate their distribution in the Market Areas by demographic statistics such as population, crime rate, etc. The *1989 Directory of Juvenile and Adult Correctional Departments* (American Correctional Association 1988) lists all the state and federal penitentiaries throughout the nation, their inmate population and year of construction. This document has been used to determine the number and total number of inmates in state and federal penitentiaries located within the Market Area counties (see Table 2.A.8).

Based on review of the three available prison input files, a rough estimate of 350 ft^2 per inmate has been used to convert the number of inmates to estimated square footage of prisons in the Market Areas.

The number and floor area of Current vintage prisons has been derived independently from the Dodge Building Start data, omitting those with floor areas less than 50,000 ft^2. This number is then from the estimated total building count and floor area to produce the number and floor area of Stock vintage prisons. Table 6.4.11 gives the resultant estimates of prison building stock for the 20 Market Areas.

Table 6.4.1 Market Sector Sizes for Large Retail

Market	Stock Vintage (pre-1981) No. Bldgs	Stock Vintage (pre-1981) Area (1000ft^2)	Current Vintage (1981-1988) No. Bldgs	Current Vintage (1981-1988) Area (1000ft^2)	Total No. Bldgs	Total Area (1000ft^2)
Boston	644	52194	71	4955	715	57149
New York 1	272	38021	24	2640	296	40661
New York 2	744	104078	5	553	749	104631
Philadelphia 1	362	38225	36	4480	398	42705
Philadelphia 2	311	32840	36	4512	347	37352
Chicago 1	508	52428	72	6788	580	59216
Chicago 2	508	52428	72	6788	580	59216
Detroit 1	402	34681	51	4705	453	39386
Detroit 2	229	19798	61	5603	290	25401
St. Louis	392	34484	27	2482	419	36966
Miami 1	300	28670	123	14497	423	43167
Miami 2	228	21699	127	15080	355	36779
New Orleans 1	158	13941	24	2508	182	16449
New Orleans 2	97	8535	39	4064	136	12599
Houston	714	55937	241	21904	955	77841
Los Angeles 1	1857	133547	361	26885	2218	160432
Los Angeles 2	594	42762	142	10577	736	53339
San Diego	512	32239	193	14446	705	46685
San Francisco	2479	66289	145	10976	2624	77265
Phoenix	452	35662	264	17413	716	53075

Table 6.4.2 Market Sector Sizes for Large Office

Market	Stock Vintage (pre-1981) No. Bldgs	Stock Vintage (pre-1981) Area (1000ft^2)	Current Vintage (1981-1988) No. Bldgs	Current Vintage (1981-1988) Area (1000ft^2)	Total No. Bldgs	Total Area (1000ft^2)
Boston	295	55037	78	15397	373	70434
New York 1	208	116347	129	54182	337	170529
New York 2	236	131498	6	2786	242	134284
Philadelphia 1	105	28574	36	7411	141	35985
Philadelphia 2	194	52662	52	10699	246	63361
Chicago 1	215	75629	73	25693	288	101322
Chicago 2	215	75629	73	25693	288	101322
Detroit 1	198	44782	31	4773	229	49555
Detroit 2	97	21993	125	18769	222	40762
St. Louis	159	51200	159	31425	318	82625
Miami 1	200	29992	118	18876	318	48868
Miami 2	57	8674	62	9922	119	18596
New Orleans 1	68	18857	19	6760	87	25617
New Orleans 2	22	6050	6	2138	28	8188
Houston	431	87998	280	70899	711	158897
Los Angeles 1	893	175385	488	96185	1381	271570
Los Angeles 2	156	30879	161	31744	317	62623
San Diego	144	21457	156	22742	300	44199
San Francisco	328	87498	262	52054	590	139552
Phoenix	119	19327	172	24363	291	43690

Table 6.4.3 Market Sector Sizes for Apartment

Market	Stock Vintage (pre-1981)		Current Vintage (1981-1988)		Total	
	No. Bldgs	Area (1000ft^2)	No. Bldgs	Area (1000ft^2)	No. Bldgs	Area (1000ft^2)
Boston	4983	111593	810	15224	5793	126817
New York 1	4612	527867	914	61025	5526	588892
New York 2	5230	598632	170	11414	5400	610046
Philadelphia 1	1834	63015	349	10717	2183	73732
Philadelphia 2	2520	86546	195	5986	2715	92532
Chicago 1	5947	241007	640	23684	6587	264691
Chicago 2	5947	241007	640	23684	6587	264691
Detroit 1	3742	89630	503	10770	4245	100400
Detroit 2	1914	45853	901	19270	2815	65123
St. Louis	2579	102755	525	22037	3104	124792
Miami 1	5092	235499	2440	66802	7532	302301
Miami 2	4654	215239	2351	64390	7005	279629
New Orleans 1	1984	44827	204	4553	2188	49380
New Orleans 2	847	19134	163	3630	1010	22764
Houston	11569	179501	2756	45106	14325	224607
Los Angeles 1	20282	556444	6659	168661	26941	725105
Los Angeles 2	3243	88996	1436	36374	4679	125370
San Diego	4776	109645	3123	57670	7899	167315
San Francisco	6864	196525	1668	47054	8532	243579
Phoenix	2508	47740	4325	67103	6833	114843

Table 6.4.4 Market Sector Sizes for Large Hotel

Market	Stock Vintage (pre-1981)		Current Vintage (1981-1988)		Total	
	No. Bldgs	Area (1000ft^2)	No. Bldgs	Area (1000ft^2)	No. Bldgs	Area (1000ft^2)
Boston	36	5253	10	1390	46	6643
New York 1	14	6914	14	7140	28	14054
New York 2	31	15284	0	275	31	15559
Philadelphia 1	12	3010	6	1263	18	4273
Philadelphia 2	23	5695	9	1726	32	7421
Chicago 1	15	8174	13	2831	28	11005
Chicago 2	15	8174	13	2831	28	11005
Detroit 1	17	4794	7	1606	24	6400
Detroit 2	6	1896	11	2254	17	4150
St. Louis	31	6784	23	6501	54	13285
Miami 1	77	13379	16	3158	93	16537
Miami 2	27	4777	19	3811	46	8588
New Orleans 1	20	6790	7	2713	27	9503
New Orleans 2	2	884	3	1370	5	2254
Houston	48	12017	20	5241	68	17258
Los Angeles 1	64	13505	66	13420	130	26925
Los Angeles 2	22	4697	37	7677	59	12374
San Diego	20	2429	28	6952	48	9381
San Francisco	32	11954	40	8847	72	20801
Phoenix	20	3653	27	4977	47	8630

Table 6.4.5 Market Sector Sizes for Small Hotel/Motel

Market	Stock Vintage (pre-1981)		Current Vintage (1981-1988)		Total	
	No. Bldgs	Area (1000ft^2)	No. Bldgs	Area (1000ft^2)	No. Bldgs	Area (1000ft^2)
Boston	48	1964	32	911	80	2875
New York 1	17	553	9	191	26	744
New York 2	253	7906	3	73	256	7979
Philadelphia 1	27	752	19	683	46	1435
Philadelphia 2	0	8	2	74	2	82
Chicago 1	40	1394	18	665	58	2059
Chicago 2	40	1394	18	665	58	2059
Detroit 1	25	931	29	1349	54	2280
Detroit 2	16	610	38	1783	54	2393
St. Louis	38	1338	9	356	47	1694
Miami 1	170	5674	28	801	198	6475
Miami 2	100	3332	21	624	121	3956
New Orleans 1	53	1117	11	343	64	1460
New Orleans 2	11	254	16	522	27	776
Houston	108	3408	45	1321	153	4729
Los Angeles 1	357	9603	237	6880	594	16483
Los Angeles 2	132	3567	154	4456	286	8023
San Diego	147	3775	134	4782	281	8557
San Francisco	145	4970	83	2790	228	7760
Phoenix	116	5430	64	2947	180	8377

Table 6.4.6 Market Sector Sizes for Extended-hour Sitdown Restaurants

Market	Stock Vintage (pre-1981)		Current Vintage (1981-1988)		Total	
	No. Bldgs	Area (1000ft^2)	No. Bldgs	Area (1000ft^2)	No. Bldgs	Area (1000ft^2)
Boston	490	2214	27	123	517	2337
New York 1	345	1218	7	30	352	1248
New York 2	1610	4039	3	11	1613	4050
Philadelphia 1	221	1223	13	78	234	1301
Philadelphia 2	345	1211	8	28	353	1239
Chicago 1	577	2030	47	168	624	2198
Chicago 2	577	2030	47	168	624	2198
Detroit 1	461	1622	30	106	491	1728
Detroit 2	185	843	21	99	206	942
St. Louis	346	1217	9	34	355	1251
Miami 1	367	1290	40	144	407	1434
Miami 2	197	1092	34	188	231	1280
New Orleans 1	116	529	8	40	124	569
New Orleans 2	78	280	13	48	91	328
Houston	705	1769	105	263	810	2032
Los Angeles 1	1617	5672	133	469	1750	6141
Los Angeles 2	390	2152	52	288	442	2440
San Diego	313	1419	43	198	356	1617
San Francisco	430	3230	25	191	455	3421
Phoenix	331	1501	76	344	407	1845

Table 6.4.7 Market Sector Sizes for Fastfood Restaurants

Market	Stock Vintage (pre-1981) No. Bldgs	Stock Vintage (pre-1981) Area (1000ft^2)	Current Vintage (1981-1988) No. Bldgs	Current Vintage (1981-1988) Area (1000ft^2)	Total No. Bldgs	Total Area (1000ft^2)
Boston	1473	3682	81	202	1554	3884
New York 1	1040	2600	23	57	1063	2657
New York 2	4838	12095	11	27	4849	12122
Philadelphia 1	665	1662	41	102	706	1764
Philadelphia 2	1036	2590	24	60	1060	2650
Chicago 1	1736	4340	143	357	1879	4697
Chicago 2	1736	4340	143	357	1879	4697
Detroit 1	1387	3467	90	225	1477	3692
Detroit 2	558	1395	65	162	623	1557
St. Louis	1040	2600	28	70	1068	2670
Miami 1	1103	2757	122	305	1225	3062
Miami 2	593	1482	102	255	695	1737
New Orleans 1	350	875	25	62	375	937
New Orleans 2	237	592	40	100	277	692
Houston	2118	5295	315	787	2433	6082
Los Angeles 1	4857	12142	401	1002	5258	13144
Los Angeles 2	1172	2930	157	392	1329	3322
San Diego	943	2357	131	327	1074	2684
San Francisco	1290	3225	76	190	1366	3415
Phoenix	997	2492	229	572	1226	3064

Table 6.4.8 Market Sector Sizes for Hospitals

Market	Stock Vintage (pre-1980) No. Bldgs	Stock Vintage (pre-1980) Area (1000 ft^2)	Current Vintage (1981-1988) No. Bldgs	Current Vintage (1981-1988) Area (1000 ft^2)	Total No. Bldgs	Total Area (1000 ft^2)
Boston	54	18636	9	3245	63	21882
New York 1	25	9575	5	2033	30	11608
New York 2	72	27905	8	2954	80	30860
Philadelphia 1	23	7487	5	1761	29	9249
Philadelphia 2	43	14026	10	3145	53	17171
Chicago 1	36	12981	6	2208	42	15189
Chicago 2	36	12981	6	2208	42	15189
Detroit 1	47	15518	5	1633	52	17151
Detroit 2	10	3243	2	728	12	3972
St. Louis	33	12183	7	2664	40	14847
Miami 1	31	9641	7	2221	38	11863
Miami 2	13	4211	5	1437	18	5648
New Orleans 1	15	4477	3	986	18	5463
New Orleans 2	5	1575	3	1001	9	2577
Houston	38	9653	36	9037	74	18690
Los Angeles 1	122	31551	19	4793	141	36344
Los Angeles 2	20	4996	4	1089	24	6086
San Diego	24	6280	14	3683	38	9963
San Francisco	54	15220	8	2128	62	17349
Phoenix	25	6466	12	3022	37	9488

Table 6.4.9 Market Sector Sizes for Secondary Schools

Market	Stock Vintage (pre-1980) No. Bldgs	Stock Vintage (pre-1980) Area (1000 ft^2)	Current Vintage (1981-1988) No. Bldgs	Current Vintage (1981-1988) Area (1000 ft^2)	Total No. Bldgs	Total Area (1000 ft^2)
Boston	197	34885	8	1411	205	36297
New York 1	38	7914	6	1172	44	9087
New York 2	107	22309	7	1407	114	23716
Philadelphia 1	10	1979	1	294	12	2274
Philadelphia 2	25	4947	5	954	30	5901
Chicago 1	75	16478	4	792	79	17271
Chicago 2	75	16478	4	792	79	17271
Detroit 1	76	14781	2	453	78	15235
Detroit 2	38	7358	1	242	39	7600
St. Louis	59	10032	8	1418	67	11451
Miami 1	63	14009	8	1747	70	15756
Miami 2	10	2128	7	1632	17	3761
New Orleans 1	9	1530	8	1419	17	2950
New Orleans 2	12	2051	3	538	15	2590
Houston	24	5019	33	6730	57	11749
Los Angeles 1	241	58420	11	2707	252	61127
Los Angeles 2	111	26775	8	2051	119	28827
San Diego	52	11107	13	2747	65	13855
San Francisco	218	42256	6	1137	224	43394
Phoenix	35	6996	19	3724	54	10720

Table 6.4.10 Market Sector Sizes for Supermarkets

Market	Stock Vintage (pre-1981) No. Bldgs	Stock Vintage (pre-1981) Area (1000ft^2)	Current Vintage (1981-1988) No. Bldgs	Current Vintage (1981-1988) Area (1000ft^2)	Total No. Bldgs	Total Area (1000ft^2)
Boston	200	4200	16	336	216	4536
New York 1	352	7392	44	924	396	8316
New York 2	440	9240	52	1092	492	10332
Philadelphia 1	164	3444	24	504	188	3948
Philadelphia 2	168	3528	8	168	176	3696
Chicago 1	264	5544	20	420	284	5964
Chicago 2	264	5544	20	420	284	5964
Detroit 1	232	4872	0	0	232	4872
Detroit 2	100	2100	8	168	108	2268
St. Louis	172	3612	24	504	196	4116
Miami 1	164	3444	36	756	200	4200
Miami 2	104	2184	24	504	128	2688
New Orleans 1	52	1092	0	0	52	1092
New Orleans 2	40	840	4	84	44	924
Houston	240	5040	56	1176	296	6216
Los Angeles 1	760	15960	192	4032	952	19992
Los Angeles 2	200	4200	48	1008	248	5208
San Diego	192	4032	68	1428	260	5460
San Francisco	304	6384	60	1260	364	7644
Phoenix	152	3192	68	1428	220	4620

Table 6.4.11 Market Sector Sizes for Prisons

Market	Stock Vintage (pre-1981) No. Bldgs	Stock Vintage (pre-1981) Area (1000ft^2)	Current Vintage (1981-1988) No. Bldgs	Current Vintage (1981-1988) Area (1000ft^2)	Total No. Bldgs	Total Area (1000ft^2)
Boston	6	948	0	0	6	948
New York 1	10	2296	4	1069	14	3365
New York 2	10	2296	0	0	10	2296
Philadelphia 1	6	1347	2	360	8	1707
Philadelphia 2	6	1459	1	350	7	1809
Chicago 1	5	1599	0	0	5	1599
Chicago 2	5	1599	0	0	5	1599
Detroit 1	5	733	1	600	6	1333
Detroit 2	2	196	0	0	2	196
St. Louis	5	451	1	215	6	666
Miami 1	4	672	2	588	6	1260
Miami 2	3	442	1	400	4	842
New Orleans 1	4	508	0	0	4	508
New Orleans 2	2	140	0	0	2	140
Houston	3	815	1	115	4	930
Los Angeles 1	8	3111	6	1433	14	4544
Los Angeles 2	4	798	1	330	5	1128
San Diego	3	617	1	200	4	817
San Francisco	10	2163	2	1003	12	3166
Phoenix	6	991	1	317	7	1308

6.C ESTIMATES OF MARKET SIZES BY EQUIPMENT VINTAGE

In addition to the building counts and total square footages by shell vintage, the cogeneration market assessment model also requires estimates of the number of Stock ,i.e., pre-1981, buildings with new equipment and equipment replacement and retrofit rates for both Stock and Current, i.e., post-1981, buildings.

Due to the lack of any statistical data on such equipment characteristics, very rough engineering estimates have been devised based on basic principles and assumed average equipment lives of 25 years for central systems and 15 years for packaged systems. These lifetimes are based on information from ASHRAE and GRI (see Table 6.5).

Assuming that only equipment replaced since 1981 constitutes new equipment of higher energy efficiency, the fraction of Stock buildings with new equipment is estimated as (9 years)/(Estimated Equipment Life). Therefore, 36% (9/25) of the Stock vintage of the following building types with central systems are assumed to have new equipment: large offices, large retail, apartments, large hotels, and prisons. Similarly, 60% (9/15) of the Stock vintage of the following building types with packaged systems are assumed to have new equipment: restaurants, supermarkets, and small hotel/motels.

The annual equipment replacement rate for all buildings is assumed to be 1/(Equipment life). Therefore, it is 0.040 for large offices, large retail, apartments, large hotels, and prisons, but 0.067 for restaurants, supermarkets, and small hotel/motels. The equipment retrofit rate for all buildings is assumed to be half of the replacement rate.

Table 6.5 Summary of Selected Equipment Service/Replacement Life Estimates

Equipment Type	*Appliance Magazine* Life Expectancy Low	Avg	High	ASHRAE * Equip. Service Life (Median)	Easton Replacement Estimate * Point	Range
Boilers						
Gas	13	17	22	Steel 25/30	20	20-25
Oil	12	15	19	Cast iron 35/30	20	20-25
Warm Air Furnaces						
Gas	13	16	20	18	18	15-20
Oil	12	15	19	18	17	15-20
Electric	15	18	22	-	20	20-25
Unit Heaters	10	13	17	13	13	10-15
Packaged Chillers						
Reciprocating		N.A.		20	20	18-23
Centrifugal		N.A.		23	23	20-25
Absorption		N.A.		23	23	20-25
Air Conditioners						
Room	8	11	14	10	11	10-15
Unitary (Resid.)	9	12	15	15	14	11-16
Unitary (Comm.)	-	N.A.	-	15	12	10-15

source: Easton Consultants 1990. "Replacement Market for Selected Commercial Energy Service", Gas Research Institute Report GRI-89.0204.02.

6.D ESTIMATES OF BUILDING GROWTH AND DEMOLITION RATES

Changes in the size of the market sector over time are estimated using growth rates for Current vintage, and demolition rates for Stock vintage buildings. These rates are based on the Dodge Building Stock data which give the projected floor areas of new buildings as well as the total building stock annually to the year 1998 (Dodge 1989a). Within this time frame, it is safe to assume that all demolitions are of Stock, i.e., pre-1981, buildings. The growth rates for Current buildings are calculated by averaging the projected annual new buildings floor area from 1989 to 1998, and then dividing by the 1989 total building floor area. The demolition rates for Stock buildings are calculated as the differences between the projected total building floor area for 1998 and the sum of the total floor area for 1989 plus the total floor areas of projected new construction from 1989 to 1998.

Since the Dodge Building Stock data are disaggregated only by 20 Dodge Major Building Categories, rates for some of the Project Building Types are based on their respective categories. For example, the growth and demolition rates for prisons are based on those for all public buildings, those for restaurants and large retail are based on those for all stores, and those for secondary schools are based on those for all educational buildings. These growth and demolition rates are given in Tables 6.6 and 6.7.

Table 6.6 Yearly Growth Rates for Current Vintage Buildings (% of 1981-1988 bldg. pop.)

Market Area	Building Type: Hos-pital	Sec. School	Large Retail	Large Office	Apart-ments	Large Hotel	S. Hotel/ Motel	Restau-rants	Pri-sons
Boston	13.2	23.2	9.1	12.0	6.1	8.5	8.5	9.1	14.9
New York 1	23.5	21.3	19.0	12.1	17.6	20.2	20.2	19.0	29.8
New York 2	22.3	17.0	18.2	20.2	18.0	15.2	15.2	18.2	24.4
Philadelphia 1	19.6	42.2	15.3	20.1	19.0	21.9	21.9	15.3	26.2
Philadelphia 2	13.4	32.1	28.1	20.2	11.9	12.1	12.1	28.1	26.2
Chicago 1	10.0	23.8	23.1	12.4	13.1	14.5	14.5	23.1	16.2
Chicago 2	10.0	23.8	23.1	12.4	13.1	14.5	14.5	23.1	16.2
Detroit 1	11.7	11.2	17.9	18.8	17.1	14.5	14.5	17.9	60.4
Detroit 2	17.4	31.3	16.2	16.9	17.3	15.3	15.3	16.2	20.0
St. Louis	14.0	25.7	13.3	11.4	13.0	8.7	8.7	13.3	12.5
Miami 1	8.8	22.5	10.7	6.6	9.6	6.0	6.0	10.7	21.3
Miami 2	11.7	28.3	12.1	9.7	14.5	6.7	6.7	12.1	17.1
New Orleans 1	12.6	13.4	6.2	4.2	7.5	3.1	3.1	6.2	14.0
New Orleans 2	11.1	12.8	10.6	3.9	9.8	11.5	11.5	10.6	20.2
Houston	20.1	15.8	6.7	7.4	5.3	5.7	5.7	6.7	24.7
Los Angeles 1	15.1	25.2	14.6	8.6	12.8	13.6	13.6	14.6	40.5
Los Angeles 2	17.5	27.1	20.5	11.4	13.3	12.4	12.4	20.5	26.4
San Diego	17.4	31.3	15.2	9.1	11.1	11.9	11.9	15.2	20.0
San Francisco	14.6	17.8	14.0	4.3	12.8	9.6	9.6	14.0	14.8
Phoenix	13.9	20.7	12.9	7.4	7.5	10.6	10.6	12.9	15.8

Table 6.7 Yearly Demolition Rates for Stock Vintage Buildings (% of pre-1981 bldg. pop.)

Market Area	Building Type: Hos-pital	Second School	Large Retail	Large Office	Apart-ments	Large Hotel	S. Hotel/ Motel	Restau-rants	Pri-sons
Boston	0.9	0.8	1.0	0.9	0.8	0.7	0.7	1.0	0.5
New York 1	1.0	1.2	1.3	1.2	0.5	1.9	1.9	1.3	0.8
New York 2	1.0	1.1	1.3	1.2	0.5	1.5	1.5	1.3	0.8
Philadelphia 1	0.7	1.5	0.5	1.1	0.3	1.1	1.1	0.5	0.5
Philadelphia 2	0.2	1.3	0.8	0.8	0.4	1.0	1.0	0.8	0.5
Chicago 1	0.8	0.9	0.9	0.9	0.8	0.7	0.7	0.9	0.3
Chicago 2	0.8	0.9	0.9	0.9	0.8	0.7	0.7	0.9	0.3
Detroit 1	0.8	1.0	1.0	1.0	0.8	0.8	0.8	1.0	0.7
Detroit 2	0.6	0.9	0.8	0.7	0.2	0.6	0.6	0.8	0.2
St. Louis	0.8	0.9	1.0	1.0	0.4	0.8	0.8	1.0	0.3
Miami 1	0.7	0.9	0.8	0.8	0.2	0.9	0.9	0.8	0.3
Miami 2	0.7	0.7	0.5	0.8	0.1	0.8	0.8	0.5	0.2
New Orleans 1	0.8	1.0	1.0	0.9	0.5	0.6	0.6	1.0	0.5
New Orleans 2	0.4	0.9	0.9	0.8	0.3	0.4	0.4	0.9	0.4
Houston	0.3	1.1	0.7	1.8	0.6	1.5	1.5	0.7	3.1
Los Angeles 1	0.8	1.0	0.9	0.9	0.4	0.7	0.7	0.9	0.4
Los Angeles 2	0.7	0.9	0.7	0.7	0.2	0.3	0.3	0.7	0.4
San Diego	0.7	0.9	0.7	0.8	0.2	0.7	0.7	0.7	0.7
San Francisco	0.8	1.0	0.9	0.8	0.4	0.7	0.7	0.9	0.7
Phoenix	0.7	0.8	0.6	0.7	0.2	0.6	0.6	0.6	0.4

These rates are expressed as percentages of the existing 1981-1988 or the pre-1981 building floor areas that are shown in Tables 6.4.1 through 6.4.11.

6.E ESTIMATES OF PUBLIC VERSUS PRIVATE OWNERSHIP

The only data sources on building ownership are the NBECS and RECS survey tapes. Unfortunately, statistical searches through the NBECS data produced results that are highly questionable and counter-intuitive. According to NBECS, only 1% of the total commercial building floor area is publicly-owned, including only 0.3% of the large offices, 0.7% of the hospitals, and none of the hotels or food sales. Although the percentages for the hotels and food sales are plausible, those for the offices and hospitals are not in view of the numerous government institutions and veteran's hospitals. Even more questionable is the NBECS figure that all of the "Public Order" buildings are privately-owned!

The percentage of public ownership of apartment buildings is based on RECS. Because of its questionable nature, NBECS data on commercial building ownership has not been used in this project. Instead, the following rough engineering estimates have been devised: 1) assume that 10% of hospitals are publicly-owned Veteran's Hospitals, 2) assume that 15% of large offices belong to government organizations, 3) assume that 20% of secondary schools are private, 4) assume that all restaurants, supermarkets, and hotels are private, and 5) assume that all prisons are publicly-owned. These estimates are summarized in Table 6.8.

Table 6.8 Estimated Percentages of Public and Private Ownership by Building Type

Building Type	Percent Public	Percent Private
Hospital	10	90
Large Hotel	0	100
Restaurant	0	100
Large Office	15	85
Supermarket	0	100
Prison	100	0
Apartment	12	88
Large Retail	0	100
Secondary School/College	80	20
Small Hotel/Motel	0	100

6.F RELATIONSHIP OF REPRESENTATIVE MARKETS TO ENTIRE COMMERCIAL MARKET

Although a detailed characterization of the commercial building stock of the entire country is beyond the scope of this project, an attempt has been made to estimate what portion of the total commercial and multifamily building stock is represented by the 481 prototype buildings. Table 6.9 compares the building population represented by the prototypes to national totals in terms of building count, while Table 6.10 compares the same populations in terms of total floor area.

For major building categories, such as hospitals, offices, retail, etc., NBECS and RECS statistics are used to estimate their total number and square footage across the nation and then only in the metropolitan areas. These statistics are shown in Columns A and B of Tables 6.9 and 6.10. For the smaller subsectors such as the restaurants, supermarkets, and prisons, the NBECS sampling sizes are too small to be statistically reliable. For these, supplementary data sources are used to derive the total numbers of buildings in the nation. These numbers appear in the appropriate rows of Column A of the two tables, with the sources indicated in the footnotes.

The estimated numbers and total floor areas by major building type in the 31 counties are taken from the Dodge Building Stock data base, and shown in Column C of Tables 6.9 and 6.10. The estimated numbers and total floor areas of buildings represented by the prototypes within these market areas are derived by summing the last two columns of Tables 6.4.1 through 6.A.11, and shown in Column D of Tables 6.9 and 6.10.

The building population represented by the prototypes are then compared to national totals by dividing Column D by Column A, with the results shown in Column E of Tables 6.9 and 6.10. For example, Table 6.9 indicates that the 78 large office prototypes represent in terms of building counts only 1.2% of the national office stock. However, Table 6.10 indicates that, in terms of floor area, the same prototypes represent some 20.2% of all offices in the nation. Furthermore, the following rows indicate that for large offices above 50,000 ft^2, the prototypes represent 23.6% by building count and 27.3% by floor area of the national total. Of the entire commercial building stock of the nation, the 481 prototypes represent 1.9 of the total building count and 7.6% of the total floor area.

The percentages shown in Column E of Tables 6.9 and 6.10 are very conservative, because they disregard the high probability that the prototypes are also representative of buildings in cities outside the 20 selected market areas. As discussed in Chapters 2 and 4, the limitations in the available data made it impossible to differentiate most building characteristics at the city level. Except for the building size and number of floors, which are based on county-level Dodge data, all other building characteristics, as well the calibration procedure, have been based on regional numbers from the NBECS and

Table 6.9 Number of Buildings in Representative Markets Compared to Entire Commercial Building Sector

(note: numbers in bold are additive, others are subsector data)

Building Type	Building Counts (x 1000) (NBECS or RECS) ‡ Nation (A)	SMSA (B)	Market Areas (Dodge) (C)	Bldg. pop. represented by prototypes (D)	Percent Representation Criteria 1 (E)	Criteria 2 * (F)
Educational	**176.9**	**117.2**	**55.7**	**-**	**0.9**	**15.7**
Sec. school	40.0	*27.7*	-	1.6	4.0	69.2
Food sales/service	**380.4**	**220.6**	**-**	**-**	**12.4**	**100.0**
Fast foods	*126.1* †	-	-	31.4	24.9	100.0
Ext-hr. sitdown	*126.5* †	-	-	10.4	8.2	100.0
Supermarkets	*27.0* †	-	-	5.3	19.6	100.0
Health care	**60.5**	**40.4**	**25.4**	**-**	**1.5**	**7.9**
Hospital	9.4	*4.8*	-	0.9	9.6	50.0
Retail	**1070.7**	**617.7**	**224.3**	**-**	**1.3**	**2.0**
Large Retail	26.7	*21.3*	-	13.9	52.0	79.8
Office	**575.1**	**359.8**	**199.9**	**-**	**1.2**	**5.0**
Large office	28.8	*24.8*	-	6.8	23.6	100.0
Public	**38.6**	**17.3**	**11.8**	**-**	**0.3**	**1.6**
Prisons	*0.6* **	-	-	0.1	16.7	100.0
Lodging	**106.4**	**49.1**	**9.6**	**-**	**0.9**	**46.1**
Large Hotel	8.2	*7.2*	-	0.9	11.0	88.0
Small Hotel	98.2	*41.9*	-	2.8	2.9	42.7
Other Commercial	**1303.3**	**684.8**	**126.2**	**-**	**0.0**	**0.0**
Total Commercial	**3911.8**	**2106.8**	**-**	**74.1**	**1.9**	**10.4**
Multifamily	**4666.0**	**-**	**1404.7**	**-**	**2.8**	**28.8**
Large Apartment	*1343.1*	-	-	132.0	9.8	100.0

* Numbers in italics on Columns A and B indicate building population represented by prototypes under second criteria (see text).

‡ 1984 RECS for apartments, 1983 NBECS for all other building types.

† number of buildings based on *Statistical Abstract of the United States 1989* (U.S. Dept. of Justice).

** number of buildings based on *Census of Jails 1978* (U.S. Government Printing Office).

Table 6.10 Total Building Floor Areas in Representative Markets Compared to Entire Commercial Building Sector

(note: numbers in bold are additive, others are subsector data)

Building Type	Building Floor areas (x 10^6 ft^2) (NBECS or RECS) ‡ Nation (A)	SMSA (B)	Market Areas (Dodge) (C)	Bldg. pop. represented by prototypes (D)	Percent Representation Criteria 1 (E)	Criteria 2 (F)
Educational	**6143**	**4290**	**1256**	**-**	**5.5**	**22.3**
Sec. school	2041	*1375*	-	340	16.6	67.3
Food sales/service	**2053**	**1302**	**-**	**-**	**11.1**	**51.0**
Fast foods	*313* †	-	-	78	24.9 †	100.0
Ext-hr. sitdown	*476* †	-	-	39	8.2 †	100.0
Supermarkets	*571* †	-	-	112	19.6 †	100.0
Health care	**2277**	**1691**	**585**	**-**	**12.3**	**41.1**
Hospital	1432	*937*	-	280	19.5	65.4
Retail	**10196**	**6606**	**2328**	**-**	**10.6**	**28.0**
Large Retail	4124	*2863*	-	1080	26.2	69.4
Office	**8268**	**6851**	**2985**	**-**	**20.2**	**50.8**
Large office	4505	4205	-	1671	37.1	93.3
Public	**715**	**494**	**151**	**-**	**4.2**	**17.8**
Prisons	*128* †	-	-	30	23.4 †	100.0
Lodging	**2228**	**1604**	**389**	**-**	**14.2**	**72.0**
Large Hotel	1161	*1067*	-	226	19.5	91.9
Small Hotel	1067	*537*	-	90	8.4	50.3
Other Commercial	**17872**	**12484**	**-**	**-**	**0.0**	**0.0**
All Commercial	**51979**	**35325**	**-**	**3946**	**7.6**	**24.0**
Multifamily	**22484**	**-**	**9527**	**-**	**20.3**	**48.7**
Large Apartment	10942	-	-	4566	41.7	100.0

* Numbers in italics on Columns A and B indicate building floor area represented by prototypes under second criteria (see text).

‡ 1984 RECS for apartments, 1983 NBECS for all other building types.

† assume buildings are of uniform size across nation; hence, the percent representation by floor area is the same as by building count.

RECS data bases. Therefore, except for these two gross building characteristics, the 481 prototypes are, in essence, regional prototypes equally appropriate for all buildings in those census regions. Since the 20 market areas span all four U.S. census regions, the prototypes can be regarded as covering the entire nation for their respective building subsector, with the only limitation that the larger prototypes (hotels, hospitals, secondary schools, and retail) are appropriate only for urban sites.

If this more relaxed criteria is used, the number of buildings represented by the prototypes is either the entire national stock for that subsector (Column A) or that portion of the national stock in the metropolitan areas (Column B). These numbers and total floor areas are indicated by italics on Tables 6.9 and 6.10. The last column on the two tables (Column F) gives the estimated percentage of buildings represented by the prototypes using this criteria. For the entire commercial building stock, the percent represented by the 481 prototypes rises to 10% by count and 24% by floor area.

7. REFERENCES

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APPENDIX 8.A DESCRIPTION OF DATA SOURCES

For this discussion, the data have been divided into four major categories : statistical data bases, engineering studies, existing building characteristics, and existing building prototypes. In general, the statistical data bases were useful only for defining the size of the building stock in each city and general characteristics such as average floor areas or numbers of floors. The two EIA energy surveys and all the other data sources were used to develop physical characteristics and operating conditions for the prototypical buildings. The data sources are listed in alphabetical order using the acronyms that appear in Table 2.2. These same acronyms are also used in Chapter 4. Table 2.3 cross-references these acronyms to the reference list in Section 7.

SURVEY DATA OR STATISTICAL DATA BASES

1. **ACA : American Correctional Association 1988**. The ACA published the *1989 Directory of Juvenile and Adult Correctional Departments* that listed all state and federal penitentiaries in the U.S, with information on their year of construction and numbers of inmates (designed and actual) and staff. *This document was used to derive the number of penitentiaries and their total inmate count for the 20 Market Areas* (Table 8.A.1). Based on review of available prison plans, a ratio of 350 ft^2 per inmate was used to estimate the total square footage of the prisons by Market Area. The ACA data had no additional information that could be used for developing prototype descriptions.

2. **AHA : American Hospital Association 1987**. The AHA data base lists all the hospitals in the U.S, with relevant information on their address, Zip code, and bed count. LBL has the AHA data base on its computer and did a data search by 3-digit Zip code to find the number of hospitals and their bed counts for the 20 Market Areas (see Table 8.A.2). An algorithm previously developed by one of the research team (Bill Carroll) was used to estimate hospital floor areas from the bed count (see Section 4.A). *The AHA data base was used to derive the average building size and total floor area for hospitals in the 20 Market Areas.* Although the AHA data base was comprehensive, it had no additional information that could be used for developing prototype descriptions.

3. **CEC2 : California Energy Commission** (Akbari et al. 1989). This data source is comprised of CEC's 1986 on-site survey data of 375 buildings in the Southern California Edison (SCE) service district. The data covers 88 offices, 78 retail, 69 food store, 20 warehouses, 12 health, 80 restaurants, and 21 miscellaneous buildings. Since LBL has been analyzing this data on a separate project jointly sponsored by

Table 8.A.1 Prison and inmate data for state and federal penitentiaries in 1988

Census Region	Market area	No. of Jails		No. of inmates	
		State	Federal	State	Federal
North-east	Boston	3	0	1701	0
	New York 1	10	1	5076	407
	New York 2	3	0	5599	0
	Philadelphia 1	2	0	2992	0
	Philadelphia 2	4	0	2669	0
North Central	Chicago	7	1	5649	363
	Detroit 1	3	0	1127	0
	Detroit 2	0	0	0	0
	St. Louis	2	0	1086	0
South	Miami 1	2	0	1356	0
	Miami 2	1	0	463	0
	New Orleans 1	1	0	300	0
	New Orleans 2	1	0	130	0
	Houston	0	0	0	0
West	Los Angeles 1	0	2	0	1166
	Los Angeles 2	1	0	859	0
	San Diego	1	1	2700	559
	San Francisco	1	1	2700	335
	Phoenix	6	1	2384	509

Table 8.A.2 Hospital stock in the 20 market areas from the AHA data base

Census region	Market area	Inventory by building size (1000 ft^2)								Total
		<50	<80	<140	<250	<370	<485	<600	>600	
North-east	Boston	0	6	12	21	25	13	11	15	103
	New York 1	0	0	0	2	1	1	2	0	6
	NY (Queens)	0	0	1	5	9	9	5	16	45
	New York 2	0	7	6	11	16	3	4	24	71
	Philadelphia	2	2	8	18	19	9	6	8	72
North Central	Chicago	0	2	14	33	27	16	18	20	130
	Detroit	0	7	12	22	11	16	3	14	85
	St Louis	0	1	6	10	6	2	4	9	38
South	Miami	0	3	9	16	17	8	6	6	65
	New Orleans	0	2	5	11	6	2	4	3	33
	Houston	2	11	17	24	10	5	3	9	81
West	Los Angeles 1	1	11	40	41	21	15	5	11	145
	Los Angeles 2	1	5	18	26	13	7	3	4	77
	San Diego	0	0	9	14	6	2	3	2	36
	San Francisco	2	7	18	22	26	16	5	6	102
	Phoenix	3	4	9	10	6	5	1	4	42

CEC and SCE, the staff has utilized the End Use Intensities (EUI's) and ten building prototypes developed by that project. *This regional information has been used to develop building and system prototypes for the Los Angeles and San Diego metropolitan areas.* Chapter 4 will also discuss how these CEC2 prototypes have been used in this project for comparison purposes.

4. **Census : Bureau of the Census 1989**. The *Statistical Abstract* has population data by county from the 1980 census and estimates and projections for subsequent years (1984, 1988, and 1993). *These were used to estimate the building stock for supermarket and restaurants, for which there is an absence of true building stock data at the county level.* Some of the census data are taken from the *1990 Commercial Atlas and Marketing Guide* (McNally 1990), but still referred to as census data. Table 8.A.3 shows the populations for the twenty market areas derived by adding up county-level data. In the two instances where a county falls into two market areas (Queens County in New York, and Cook county in Illinois), the county population has been divided by two.

5. **CJ: Census of Jails** (U.S. Department of Justice 1981). This document in four volumes lists by state all county and city jails in the U.S, with information on their year of construction and their number of inmates and staff. *This information has been used to estimate the number and square footage of county jails for the 20 Market Areas* (Table 8.A.4). To eliminate smaller jails, only those with more than 100 inmates have been included in the market size estimates.

6. **Dodge : F.W. Dodge Building Stock/Forecast Data** (Dodge, F.W. 1989a and 1989b). The Dodge data base consists of two separate sets of data : (1) building stock estimates, and (2) construction starts. *Since it is the only available source of county-level information, Dodge was used extensively in this project to (1) estimate market characteristics such as the total square footage and to (2) derive average building sizes by building type, vintage, and Market Area.* Since the Dodge data base is proprietary, the project requested data searches from Dodge/DRI through GRI's subscription for the counties and building types of interest.

   The first Dodge data set, called the summary *Dodge Construction Potentials (DCP)* (Dodge 1989a), give estimates of the total building stock by Major Building Category and county from 1970 through 1998. The data utilize various sources to derive estimated floor areas by building type and county for the best benchmark years (for methodology, see Dodge 1989c). These estimates are then backcast to the base year of 1970. Estimates of the building stock for subsequent historical years are then computed by adding new building square footage from the Dodge Construction Start data base (see following paragraph), and subtracting the

Table 8.A.3 Populations of the 20 Representative Market Areas

Census Region	Market Area	Populations 1980 census	est. 12/31/1989	proj. 1993
NORTH-EAST	Boston	2,017,176	2,022,600	2,028,700
	New York 1	3,528,719	3,670,750	3,751,150
	New York 2	4,409,517	4,552,350	4,649,850
	Philadelphia 1	1,677,611	1,796,200	1,860,800
	Philadelphia 2	1,688,210	1,642,900	1,615,300
NORTH CENTRAL	Chicago 1	2,626,814	2,638,000	2,628,950
	Chicago 2	2,626,814	2,638,000	2,628,950
	Detroit 1	2,337,843	2,155,900	2,102,500
	Detroit 2	1,011,793	1,053,300	1,074,800
	St. Louis	1,717,271	1,800,400	1,846,800
SOUTH	Miami 1	1,625,611	1,850,400	1,987,000
	Miami 2	1,018,257	1,214,300	1,330,600
	New Orleans 1	557,927	546,500	533,000
	New Orleans 2	454,592	470,700	473,600
	Houston	2,409,544	2,740,100	2,897,000
WEST	Los Angeles 1	7,477,421	8,704,700	9,441,100
	Los Angeles 2	1,932,921	2,273,700	2,477,100
	San Diego	1,861,846	2,382,000	2,690,100
	San Francisco	3,028,013	3,385,700	3,586,800
	Phoenix	1,509,265	2,057,600	2,385,300

source: Rand McNally, *1990 Commercial Atlas and Marketing Guide*, Chicago IL. 1990.

Table 8.A.4 Number of jails and inmates in county institutions in 1978

Census Region	Market area	No. of jails <100 inmates	No. of jails >100 inmates	No. of inmates <100 inmates	No. of inmates >100 inmates
North-east	Boston	0	3	0	1010
	New York	3	10	198	5805
	Philadelphia 1	1	4	20	859
	Philadelphia 2	0	3	0	2175
North Central	Chicago	0	4	0	3991
	Detroit 1	7	3	37	1518
	Detroit 2	2	2	4	560
	St. Louis	6	4	69	1032
South	Miami 1	1	3	90	1377
	Miami 2	3	2	149	800
	New Orleans 1	0	3	0	1152
	New Orleans 2	0	1	0	270
	Houston	2	3	13	2330
West	Los Angeles 1	11	7	383	8311
	Los Angeles 2	4	3	48	1423
	San Diego	7	2	527	1204
	San Francisco	7	8	429	3147
	Phoenix	10	3	136	1199
National totals		3493		158394	

estimated demolitions. Algorithms are used to account for the lag time between building starts and completions based on the project size, and for demolitions. For pre-1970 buildings, annual demolition rates by Region are used based on analysis of NBECS data. For post-1970 buildings, an exponential equation is used based on the year of construction that assumes 50% of all buildings will be demolished after 45 years and 90% after 60 years. Projections for year beyond 1989 incorporate results from Dodge's Regional Construction Market Forecast (Dodge 1989c). For this project, these estimated building stock figures from 1970 to 1998 were acquired for the 31 counties of interest (Table 1.B.1). A sample of this building stock data is shown in Figure 8.1. Chapter 6 discusses how these data are used, along with other data sources, to estimate the building stock and growth rates by building type, vintage, and Market Area.

The other Dodge data base, called the *Dodge Project Detail* (Dodge 1989b), is a detailed record of actual building permits granted from 1966 to the present. For each record, the data base has the construction start date, geographical location, type of construction (new, addition, or alteration), ownership, type of structure, type of framing (wood, steel, reinforced concrete, etc.), square footage, and number of stories of the project.

For this project, a data search was requested from Dodge for the same 31 counties of interest (see Table 1.B.1). The requested data are aggregated by Market Area, 13 Requested Building Categories (see Table 8.A.5 on previous page), and three vintages (1967-73, 1974-80, and 1981-88). For each Requested Building Category and vintage, the data give the number of projects and total square footage separated into from 7 to 15 bins by floor area (see sample in Table 8.A.6). The binned format makes it possible to further disaggregate the data by building size variations or to eliminate portions that are too small for cogeneration applications. This information is used to calculate the total building stock and average size by building type, vintage, and location. In addition, the information on the structure code, framing type and number of stories were used, in conjunction with NBECS and other data bases, to develop the prototype descriptions for this study.

7. **ICP : Institutional Conservation Program** (Carroll W.L., Kammerud, R.C., Birdsall, B.E. et al. 1987). The ICP program has provided about $660 million in matching grants for energy conservation in hospitals, schools, and colleges since its inception in 1979 and has reached some 50% of all hospitals and 10% of all schools and colleges. The program has kept records on the pre- and post-retrofit building energy use of all these buildings, the cost and estimated energy savings of installed retrofits. Since LBL conducted a multi-year technical evaluation of the ICP program (Carroll et al. 1987), we have a copy of this data base, which includes 3773 hospitals, 17508 schools, and 7051 colleges. *Staff experience from previous*

Figure 8.1 Sample of Dodge Building Stock Data Base

Building Stock (Inventory) - Thousands of Square Feet

COUNTY	STRUCTURE	1970	1972	1974	1976	1978	1980	1982	1984	1986	1988	1990	1992	1994	1996
SAMPLE COUNTY 1	STORES	33941	35534	43088	48256	52403	59564	65726	67738	75651	84214	89911	95545	101752	106941
SAMPLE COUNTY 1	WAREHOUSE	6571	9000	12877	17420	23014	30333	37101	43184	57457	70282	79364	88334	97671	105270
SAMPLE COUNTY 1	OFFICES	32821	34882	39937	43276	45519	48858	56319	64065	74966	86094	90879	96722	103182	109241
SAMPLE COUNTY 1	EDUCATION	24211	26106	28214	30569	32530	33670	35886	36882	38641	41838	43683	45617	47798	50061
SAMPLE COUNTY 1	HEALTH	5816	6164	7205	7716	8195	9503	10860	13379	15778	17884	19746	21773	23894	26019
SAMPLE COUNTY 1	PUBLIC	694	1059	1912	2723	3254	3399	3915	4129	5500	5891	6393	6932	7503	8073
SAMPLE COUNTY 1	AMUSEMENT	8816	9818	10678	11130	11763	12600	13266	14025	15207	16516	17296	18163	19039	19719
SAMPLE COUNTY 1	MISC. NR	280	735	1316	2564	3411	4717	5749	6245	7142	7931	8586	9264	9956	10562
SAMPLE COUNTY 1	MULTIFAM	51404	60957	84534	95608	99674	118298	142037	164251	216943	274077	303423	338451	370123	393602
SAMPLE COUNTY 1	HOTEL	5348	5374	6729	8959	9466	10290	11310	12251	14180	18042	19489	21123	22982	24693
SAMPLE COUNTY 1	DORM	3818	4002	4006	3973	3904	3864	3798	3800	3799	3760	3732	3709	3689	3670
SAMPLE COUNTY 2	STORES	216901	222672	233914	242257	250644	256802	266019	269289	279910	291651	300414	309335	319448	327255
SAMPLE COUNTY 2	WAREHOUSE	72626	91245	111508	129978	147435	177620	193606	203147	222304	248694	268630	287746	307731	324663
SAMPLE COUNTY 2	OFFICES	249281	262437	275691	286862	294648	303552	320685	342726	373856	401110	418706	433827	451490	468634
SAMPLE COUNTY 2	EDUCATION	143720	145300	145558	146829	146519	144896	143839	142568	141117	141365	141753	141957	142503	143181
SAMPLE COUNTY 2	HEALTH	44682	49741	53833	56338	60033	61725	63239	65259	67951	71151	74359	78023	81908	85807
SAMPLE COUNTY 2	PUBLIC	4671	7137	9864	12446	14180	14443	14594	16768	16988	18028	18574	19172	19805	20425
SAMPLE COUNTY 2	AMUSEMENT	58019	58845	61313	61489	62685	63685	64309	64396	64992	65817	66513	67430	68383	68973
SAMPLE COUNTY 2	MISC. NR	2042	4951	7546	10065	12790	14869	17327	18724	21681	24481	27057	29346	31680	33652
SAMPLE COUNTY 2	MULTIFAM	849105	894329	945988	965008	984239	1024907	1070362	1083986	1131160	1206798	1238736	1278264	1313437	1336126
SAMPLE COUNTY 2	HOTEL	18331	19867	23762	24657	27239	27733	29415	32986	38610	44629	48106	51882	56289	60363
SAMPLE COUNTY 2	DORM	4432	4888	5506	5599	5647	5758	5994	6249	6475	6590	6731	6892	7066	7243
SAMPLE COUNTY 3	STORES	47629	52191	57853	63122	70015	76247	79250	80399	83811	90159	94731	98738	103164	106690
SAMPLE COUNTY 3	WAREHOUSE	5000	11855	25966	39261	59323	74314	82399	87759	97521	112536	124173	135348	146994	156950
SAMPLE COUNTY 3	OFFICES	47592	51305	56172	60166	65526	71999	80882	89696	96005	109788	114311	119998	126507	132827
SAMPLE COUNTY 3	EDUCATION	35050	36433	38964	40648	41648	42022	41587	41411	42366	44063	45037	46078	47295	48569
SAMPLE COUNTY 3	HEALTH	6922	7877	10143	10560	10727	11077	11573	12487	13356	14814	15832	16977	18183	19393
SAMPLE COUNTY 3	PUBLIC	973	1492	2205	2699	3257	3295	3666	3688	4160	4907	5142	5400	5674	5947
SAMPLE COUNTY 3	AMUSEMENT	12476	13132	14294	14983	15705	16472	17190	17684	18066	18842	19374	19993	20620	21088
SAMPLE COUNTY 3	MISC. NR	283	884	1389	1983	3304	3526	4254	4773	5215	5675	6101	6548	7004	7387
SAMPLE COUNTY 3	MULTIFAM	103058	134907	167317	190949	212236	229768	244437	253224	273569	309326	326958	348012	367111	380897
SAMPLE COUNTY 3	HOTEL	1327	2601	5023	6410	6997	8169	9128	11435	16502	20643	23296	26154	29447	32505
SAMPLE COUNTY 3	DORM	3094	3060	3651	3617	3558	3677	3818	3956	3998	4035	4079	4133	4195	4259
SAMPLE COUNTY 4	STORES	37881	41252	45665	48807	54156	60218	64289	67486	71636	80571	85753	90981	96723	101404
SAMPLE COUNTY 4	WAREHOUSE	4609	6908	10915	14720	18080	24032	28490	32483	38449	44907	50415	55715	61257	66017
SAMPLE COUNTY 4	OFFICES	43833	45356	48618	50693	53258	58111	64672	74056	83065	91287	96088	101181	107025	112716
SAMPLE COUNTY 4	EDUCATION	30286	31411	32288	34928	37100	37425	37419	38381	41977	46354	48804	51379	54281	57302
SAMPLE COUNTY 4	HEALTH	6886	8320	9874	11127	11633	11895	12820	13542	14955	18369	19864	21542	23310	25088
SAMPLE COUNTY 4	PUBLIC	2889	3608	3741	4912	5493	5852	5831	6304	6300	6429	6565	6718	6882	7044

Table 8.A.5 Requested Dodge Building Categories

Dodge code	Dodge structure description	Requested Bldg. Category	Project Building Type
070 071 078	Apartments 3 or 4 units Apartments 5 or more (1-3 stories) Apartments 5 or more (4 stories & over)	Apartments	Large Apartments
042 043 045 046 047 048 049	Junior High schools Senior High schools Vocational schools Community schools College/universities Special schools Schools - educational & science bldgs	Second. School/ College	Second. School/ College
093 095	Hospitals Hospitals & other health treatment bldgs	Hospital	Hospital
093 095	Hospitals Hospitals & other health treatment bldgs	Hospital additions	Hospital
069	Hotel/Motels (4 stories & over)	Large Hotel	Large Hotel
072	Hotel/Motels (1-3 stories)	Small Hotel/Motel	Small Hotel/Motel
073	Hotel/Motels (no. stories unknown)	Misc Hotel/Motel	Large Hotel or Sm. Hotel/Motel
005	Offices	Offices	Large Offices
006 007	Banks/financial Offices and Banks/financial	Banks	Large Offices
050	Detention	Prisons	Prisons
101	Shopping centers	Shopping centers	Large Retail & Supermarkets
001 004	Stores Stores and Other Mercantile Bldgs	Stores	Large Retail & Supermarkets
002	Food/beverage service	Food stores	Restaurants

Table 8.A.6 Output for a Sample Market Area from requested Dodge Building Start Data
(Total floor areas in 1,000 ft^2)

Area range (ft^2)			1966-1973 No. of. Proj.	1966-1973 Total floor area	1974-1980 No. of. Proj.	1974-1980 Total floor area	1981-1988 No. of. Proj.	1981-1988 Total floor area
Building Type: Offices								
0	-	20,000	1085	5332.8	1385	7919.0	1881	11501.4
20,001	-	40,000	85	2405.5	205	6011.7	328	9670.6
40,001	-	60,000	44	2178.2	72	3523.0	155	7879.8
60,001	-	80,000	27	1842.1	61	4360.5	104	7449.0
80,001	-	100,000	19	1838.6	31	2894.7	80	7394.8
100,001	-	200,000	46	6686.2	62	8397.0	136	19465.0
200,001	-	300,000	25	6202.6	17	4178.4	55	13978.8
300,001	-	400,000	13	4530.4	6	2162.7	31	11276.3
400,001	-	500,000	10	4515.0	4	1725.1	11	5017.9
500,001	-	600,000	2	1056.2	1	587.0	8	4389.0
600,001	-	700,000	5	3358.0	3	2080.0	4	2644.5
700,001	-	800,000	0	0.0	1	800.0	5	3783.0
800,001	-	900,000	0	0.0	0	0.0	5	4321.2
900,001	-	1,000,000	0	0.0	0	0.0	1	1000.0
1,000,000	and	above	6	13897.1	2	3066.4	9	15073.0
Building Type: Banks								
0	-	10,000	177	962.5	268	1284.6	140	605.0
10,001	-	20,000	29	344.8	53	709.9	13	170.5
20,001	-	30,000	12	289.5	10	267.0	3	86.1
30,001	-	40,000	2	71.5	3	100.5	0	0.0
40,001	-	50,000	3	130.0	1	48.0	0	0.0
50,001	-	60,000	0	0.0	2	109.0	0	0.0
60,000	and	above	0	0.0	1	210.0	3	392.0
Building Type: Shopping Centers								
0	-	50,000	94	1611.3	243	3854.5	729	10465.8
50,001	-	100,000	16	1100.2	28	1885.6	65	4487.0
100,001	-	150,000	5	594.2	11	1316.0	14	1732.3
150,001	-	200,000	2	330.0	6	992.5	8	1458.6
200,001	-	250,000	4	938.1	1	210.0	2	447.0
250,001	-	300,000	3	853.2	2	565.0	2	581.5
300,001	-	350,000	0	0.0	0	0.0	1	350.0
350,001	-	400,000	0	0.0	0	0.0	1	400.0
400,000	and	above	5	3826.8	4	1846.0	4	2384.5
Building Type: Retail Stores								
0	-	20,000	1793	8933.6	1926	9771.1	1554	8474.7
20,001	-	40,000	169	4752.4	172	4827.2	151	4482.8
40,001	-	60,000	33	1636.3	31	1533.1	46	2223.3
60,001	-	80,000	16	1135.0	21	1501.4	17	1207.6
80,001	-	100,000	20	1892.7	9	818.1	18	1659.1
100,001	-	120,000	15	1654.9	7	764.2	6	670.9
120,001	-	140,000	4	514.9	6	792.2	9	1184.0
140,001	-	160,000	8	1212.2	8	1223.0	9	1361.1
160,000	and	above	25	6932.9	17	3895.1	8	2255.6

analysis of this data was very useful for developing average building characteristics for secondary schools and hospitals. In addition, the ICP energy use data was used as an additional source to NBECS for calibrating the resultant prototype buildings (see Figure 8.2). However, this data must be interpreted with care because the sampling was not statistically balanced.

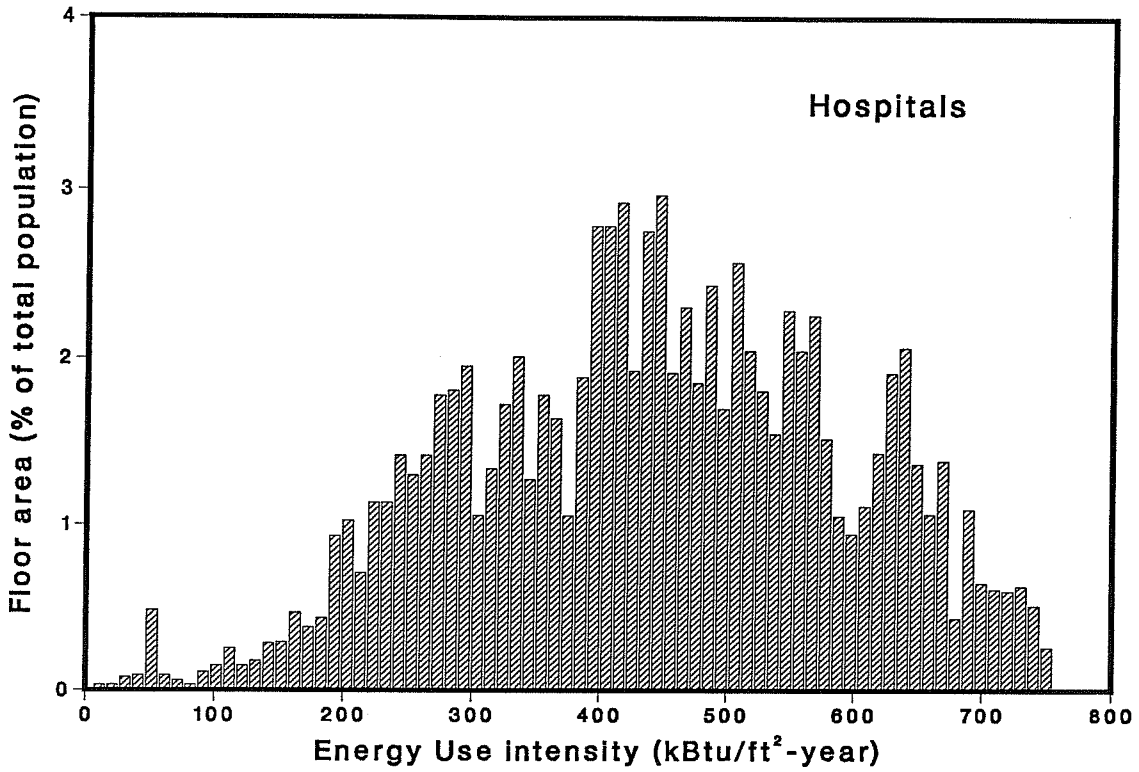
8. **NCES : National Center of Educational Statistics 1986**. The NCES data base lists all the schools in the U.S., with relevant information on their address, Zip code, and enrollment. LBL has the NCES data base on its computer and did a data search by county to find the number of schools and their enrollments for the 20 Market Areas (see Table 8.A.7). An algorithm previously developed by one of the research team (Bill Carroll) was used to estimate school floor areas from the enrollment figures (see Section 4.I). *The NCES data base was used to derive the average building size and total floor area for schools in the 20 Market areas.* The NCES data was similar to the AHA data base in that it provided no additional information that could be used for developing prototype descriptions.

9. **NBECS : Nonresidential Building Energy Consumption Survey** (Energy Information Administration 1979, 1983). The NBECS data base contains survey information on over 6000 commercial buildings that were selected specifically for developing sector-wide estimates of key commercial building types. LBL has both the 1979 and 1983 NBECS data in its computer system. *The NBECS data was used extensively for both defining the physical and operational characteristics, and for calibrating the energy uses, of all the prototypical buildings except the apartments.* Because these data have been used extensively in this project, their major features and limitations of this data set should be clarified.

   NBECS was designed to provide a statistical basis for analyzing commercial building characteristics and energy use by four major geographical regions (*Northeast, North Central, South*, and *West*) and 14 major building types. These geographical regions are shown in Figure 8.3. Although the NBECS data have sufficient information to permit finer disaggregations by location or building use, the sampling methodology is such that *these finer subset are not necessarily statistically representative.* NBECS also has indicators on each building record to identify whether the building is located in a metropolitan or suburban area.

   The objective of this project is to develop prototype buildings for 13 major metropolitan areas. In the absence of any city-specific statistical building data base, NBECS was used to obtain this information. Table 8.A.8 shows the number of buildings in the NBECS data base in metropolitan and suburban areas for the four regions of the country. The total number of valid buildings in the data base is 6,345 of which 4,474 are in the metropolitan areas. Note that almost half of the building

Figure 8.2 Distribution of End-Use Intensities from the ICP Data Base



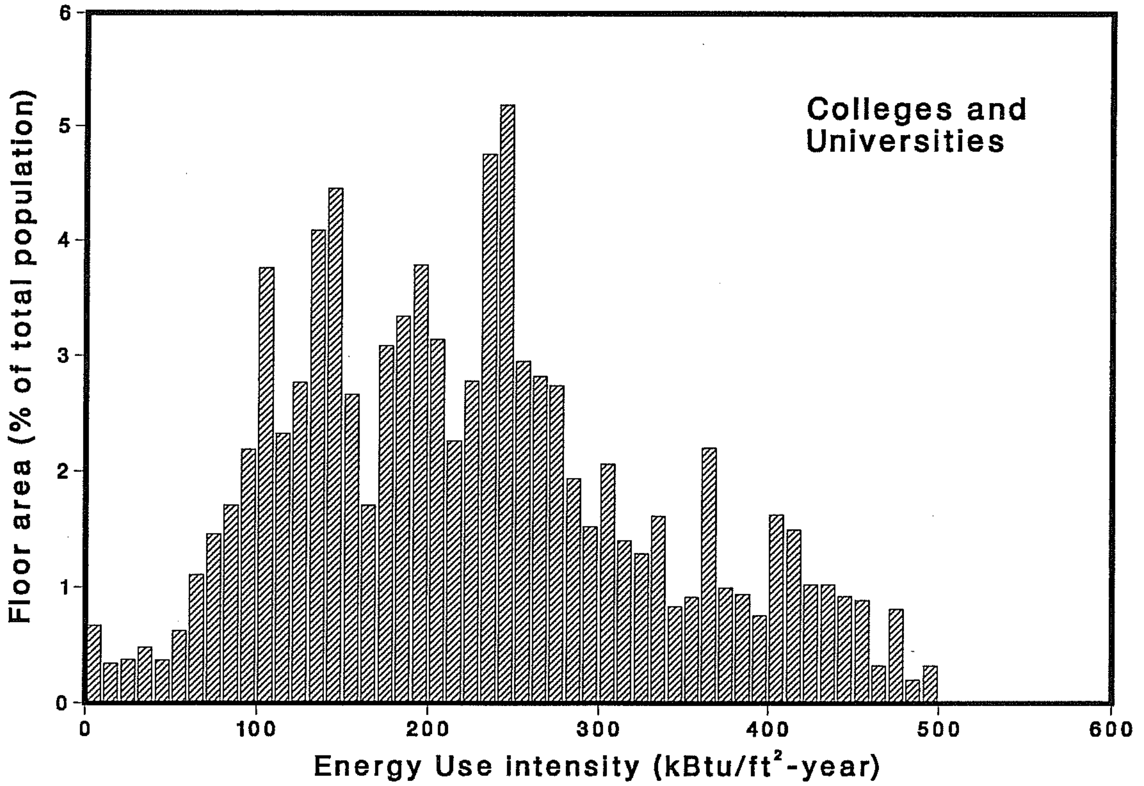


Table 8.A.7 Secondary school stock in the 20 market areas based on NCES data base

Census Region	Market area	Inventory by building size (1000 ft^2) <50	<75	<100	<135	<170	<240	>240	Total
North-east	Boston	5	19	29	36	55	83	52	279
	New York 1	0	6	4	19	28	41	71	169
	New York 2	0	6	16	16	21	29	41	129
	Philadelphia 1	0	2	0	7	9	19	11	48
	Philadelphia 2	0	4	7	8	14	12	20	65
North Central	Chicago	5	25	11	19	17	51	118	246
	Detroit 1	1	9	11	18	14	17	36	106
	Detroit 2	1	3	2	7	11	20	17	61
	St Louis	0	13	12	24	10	13	25	97
South	Miami 1	1	1	1	2	9	19	51	84
	Miami 2	1	7	4	5	1	5	18	41
	New Orleans 1	2	5	1	8	8	10	1	35
	New Orleans 2	1	0	2	2	1	6	6	18
	Houston	4	14	13	9	8	21	55	124
West	Los Angeles 1	3	22	9	11	19	46	186	296
	Los Angeles 2	1	6	7	9	15	18	88	144
	San Diego	5	9	2	4	8	24	38	90
	San Francisco	27	34	12	11	19	63	99	265
	Phoenix	5	8	10	4	8	15	34	84

Figure 8.3 NBECS Geographical Regions

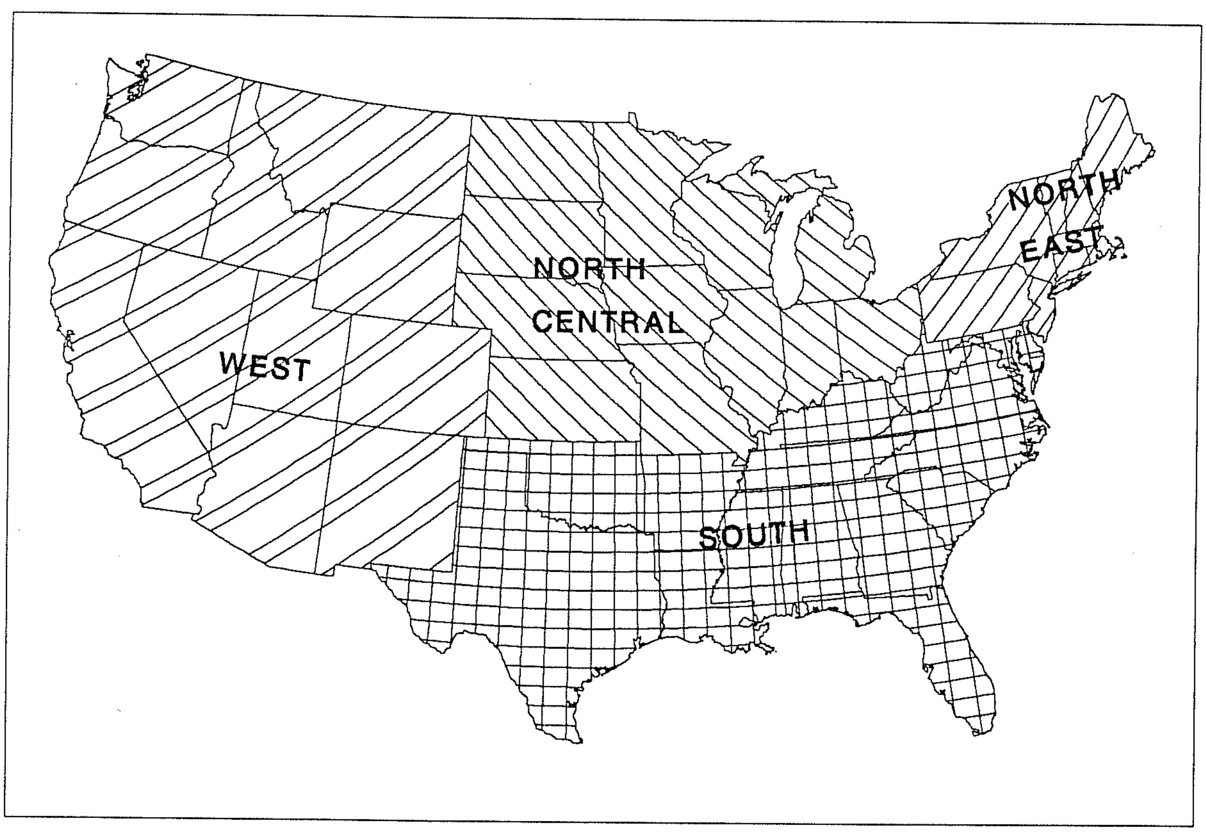


Table 8.A.8 Number of actual observations in 1983 NBECS and 1984 RECS data bases by primary building activity or housing type

Building activity	Region Northeast	N. Central	South	West	Total U.S.
1983 NBECS					
Hospital	39	40	35	18	132
Sit-down Restaurant	17	17	15	12	61
Fast-Foods Restaurant	6	7	11	4	28
Large Office	158	142	147	89	536
Supermarket	3	15	11	3	32
Large Retail	12	20	17	12	61
Shopping Center	31	33	33	29	126
Second. School/College	78	80	44	28	230
Small Hotel/Motel	6	4	19	8	37
Ref. Warehouse	3	2	5	2	12
Medium Office	84	103	77	71	335
Laundry	5	5	9	5	24
Health Club *	7	14	8	7	36
Clinic/Nursing Home	11	14	7	2	34
Primary School	52	55	30	21	158
Small Retail	64	78	70	50	262
Small Office	82	99	100	77	358
Nonref. Warehouse	34	47	38	53	172
Prison	1	0	1	1	3
Others	392	517	540	388	1837
Total 1983 NBECS	1085	1292	1217	880	4474
1984 RECS					
Mobile Home	47	69	147	99	362
Single-family	695	901	1290	787	3673
Multifamily 2-4 Units	278	173	138	158	747
Multifamily >5 units	257	154	218	200	829
Total 1984 RECS	1277	1297	1793	1244	5611

* building activity described as "gymnasium or other recreational activity".

Table 8.A.9 Estimated total number of buildings represented by 1983 NBECS and 1984 RECS data bases by primary building activity or housing type

Building activity	Region Northeast	N. Central	South	West	Total U.S.
1983 NBECS(thousands of buildings)					
Hospital	1.1	2.0	1.2	0.5	4.8
Sit-down Restaurant	17.4	21.9	19.4	19.5	78.3
Fast-food Restaurant	6.9	9.7	16.3	2.7	35.6
Large Office	11.2	9.1	9.5	5.5	35.2
Supermarket	1.7	19.3	12.5	0.6	34.1
Large Retail	4.8	3.8	3.1	1.6	13.3
Shopping Center	3.8	5.4	9.0	7.4	25.6
Second. School/College	3.4	7.0	9.7	7.5	27.7
Small Hot/Motel	1.8	1.1	12.0	7.4	22.3
Ref. Warehouse	0.9	2.0	2.0	4.0	8.9
Medium Office	43.7	37.3	27.7	26.6	135.3
Laundry	5.8	7.4	12.8	6.6	32.7
Health Club *	7.9	5.3	4.7	4.5	22.4
Clinic/Nursing Home	5.0	7.0	4.1	3.3	19.3
Primary School	10.6	12.3	15.0	9.8	47.7
Small Retail	69.6	93.2	96.0	56.9	315.6
Small Office	89.9	108.7	136.8	83.3	418.7
NRef. Warehouse	16.8	27.3	22.7	21.4	88.2
Prison	1.0	< 0.1	< 0.1	< 0.1	1.0
Others	228.6	303.5	229.8	126.2	888.1
1983 NBECS Total	531.9	683.5	644.2	395.3	2254.8
1984 RECS (thousands of dwelling units)					
Mobile Home	659.6	1138.3	2305.9	1031.2	5135.0
Single-family	10857.0	14570.4	21797.1	10048.3	57272.8
Multifamily 2-4 Units	3215.5	2808.2	1693.5	2251.5	9968.8
Multifamily >5 units	3565.9	3100.1	3527.5	3237.5	13430.9
1984 RECS Total	18298.0	21617.0	29324.1	16568.5	85807.5

* building activity described as "gymnasium" or "other recreational activity".

in NBECS are of types other than those covered in this study. When buildings in NBECS are weighed accounting for their statistical weights, they represent the stock of commercial buildings in the country. Table 8.A.9 shows the estimated total number of buildings represented by NBECS in the four geographical regions.

To define building characteristics, only NBECS data for the metropolitan areas have been used. This assumes that the building samples in the metropolitan areas are statistically significant. Although this assumption is untested, any bias resulting from this assumption should be minimal given that:

i. About 80% of the buildings sample in NBECS are in the metropolitan areas,

ii. the NBECS data have been used to characterize buildings only by the four geographical regions, and

iii. the NBECS data have been supplemented and revised based on available region or city-specific data from other sources.

An example of the output from the NBECS for Large Office is shown in Table 4.E.2. The type of data obtained from the NBECS for each building include: average floor area, average number of building occupants, average number of floors, shell construction, percent glass cover, level of wall and ceiling insulation, hours of operation, heating and cooling systems, and heating and cooling temperature setting. In addition to the building characteristics, NBECS also provides average electricity and fuel consumption by building type which can be used to calibrate the prototype buildings to better represent the average energy use of the building stock. Summaries of the NBECS data for each building type are presented in the prototype descriptions in Chapter 4.

10. **RECS : Residential Energy Consumption Survey** (Energy Information Administration 1984). The RECS data base is the residential counterpart of NBECS and includes over 4000 residential buildings, of which 26% are multi-family. Like NBECS, RECS does not have county-level building stock information. However, it can be used to estimate apartment stock characteristics such as size, vintage distribution, insulation levels, and average energy use at the regional level. The total number of buildings in the RECS data base is 5611 of which 829 are multifamily buildings with more than 5 units, the only housing type of interest to this project (see bottom of Tables 8.A.9 and 8.A.10). For this study, the 1984 RECS data set has been used. *Information on the multifamily building stock has been obtained primarily from this data source.*

11. **SCE2 : Southern California Edison** (ADM Associates, Inc. 1986). This data source is comprised of SCE's 1983-1984 on-site surveys of 60 commercial buildings. SCE has completed the on-site survey of another 60 buildings in 1988. In

addition, SCE has conducted commercial sector mail surveys in 1982, 1983, and 1985 covering thousands of buildings. *The SCE data have been used in development of building and system prototypes for the Los Angeles and San Diego metropolitan areas.*

EXISTING ENGINEERING STUDIES

Literature review has been an integral part of the effort to develop regional building prototypes. The information from the following studies have been used, in conjunction with other sources of information and engineering calculations, in developing the final prototype descriptions. Although the number of existing studies on building energy use is impressive, the majority of them had been done by only a few interested utilities. Northeast Utilities (NEU), for example, had conducted numerous studies over several years to develop prototypical commercial and residential buildings for that part of the country.

1. **EPRI/PGE : Electric Power Research Institute and Pacific Gas and Electric** (Foster-Miller,Inc. 1989, "Supermarket Refrigeration Modeling and Field Demonstration"). This study conducted detailed end-use monitoring of energy use in a typical supermarket. *The hourly end-use load shapes from this study have been used to calibrate the DOE-2 simulations for the supermarket prototype.*

2. **NEU5 : Northeast Utilities Service** (XEnergy, Inc. 1987b, "End-use energy consumption survey for restaurants, warehouses, hotels/motels and miscellaneous buildings"). This study analyzed the energy consumption of the listed building types, but did not develop any building prototypes. The raw data for the study were from on-site audits of 262 hotel/motel, warehouse, restaurant, and miscellaneous buildings. *The EUI's from this study have been used to check the DOE-2 simulation results for restaurants and hotels for this area.*

3. **NYSEG : New York State Electric and Gas** (XEnergy, Inc. and Synergic Resources Corporation 1987c, " End-use energy consumption survey for office buildings, etc.") The NYSEG study used data from 3470 responses to a mail survey to estimate EUI's with a statistical/engineering technique for seven electricity end-uses. The data from this study were reviewed but not used in the project because they are for upstate New York rather than New York City.

4. **PGE : Pacific Gas and Electric** (McCollister, G. and Turiel, I. 1985, "Energy utilization intensities for major end-uses in the commercial sector, report to PG&E"). The PG&E study utilized 5540 responses from a mail survey to estimate average

EUI's for 9 business types and seven end-uses. The building types include office, restaurant, retail, food store, warehouse, school, health, hotel, and miscellaneous. The end-uses include heating, cooling, water heating, cooking, refrigeration, ventilation, and lighting. *The EUI's from this study have been used to check the DOE-2 simulation results for in California cities, particularly San Francisco.*

5. **SDGE : San Diego Gas and Electric** (McCollister, G. and Turiel, I. 1987, "Commercial energy utilization indices in SDG&Es service territory") The San Diego study utilized data obtained from 1000 responses to 1984 and 1986 mail and phone surveys to develop EUI's for 11 business types and by 11 electrical and 5 gas end-uses. The building types include large and small offices, restaurant, retail, food store, warehouse, school, college, health, hotel, and miscellaneous. *The EUI's from this study have been used to check the DOE-2 simulation results for in California cities, particularly San Diego.*

6. **WEP : Wisconsin Electric Power** (McMenamin, S. 1986, "Summary of commercial sector end-use data development"). The WEP study used data from customers requesting commercial audits and an on-site survey to estimate electric EUI's by commercial building type. *The EUI's from this study has been used to check the DOE-2 simulation results for the North Central region.*

EXISTING BUILDING CHARACTERIZATIONS

There are a few sporadic studies which have summarized information about buildings and their operational characteristics. These information by themselves are not sufficient to develop prototypes, but can be used to 1) customize existing prototypes by metropolitan areas and 2) cross-check consistency of building characteristics obtained from various sources.

1. **GRI4 : Gas Research Institute** (United Enertec, Inc. 1983, "Packaged Gas-fueled Cogeneration systems for Hospitals"). This study has summarized some incomplete information on building characteristics, energy use, and load shapes for hospitals based on analysis of data from 134 hospitals. *This information was reviewed in developing the hospital prototypes.*

2. **GRI5 : Gas Research Institute** (Science Applications International Corp. 1984, "Characterization of commercial and multi-family residential cogeneration markets and applications"). This study has collected information on building characteristics and measured load shapes for 10 building types including: hotel/motel, hospital, nursing home, supermarket, apartment building, shopping center, office, computer

facility, laundries, and restaurants. *This information was used in developing prototypes for hotel/motel, hospital, supermarket, apartment, office, and restaurant.*

3. **NEU4 : Northeast Utilities Service Company** (XEnergy, Inc. 1986a, "Retail buildings end-use energy consumption survey"). This study contains some statistical building characteristics on retail stores, food stores and personal services. The analysis on this study was based on audit information collected for 255 retail, food stores, and services. *This information was used in developing the prototype descriptions for retail and food stores.*

EXISTING BUILDING PROTOTYPES

These section lists and briefly discusses various prototypes which has been developed in a variety of previous studies. Table 2.2 shows the prototypes by building type and geographical location. Summaries and comparisons of the prototype descriptions are shown in Chapter 4 for each building type. *These information were used in conjunction with the regional data from NBECS to develop prototypes specific to each metropolitan area.*

1. **CEC1 : California Energy Commission 1988** (no report). In the course of developing building energy efficiency standards, the CEC developed in 1978-79 DOE-2 prototypes for 11 building types and two vintages (1974 and Title 24). The building types are: small and large offices, restaurant, retail store, food/liquor store, warehouse, school, college, health care, hotel/motel, and miscellaneous. Although LBL is quite familiar with these prototype buildings, there is no published reference and all information related to the prototypes have been through personal communications.

2. **CEC/SCE : Lawrence Berkeley Laboratory CEC/SCE Study** (Akbari, H. et al. 1989, "Integrated Estimation of Commercial Sector End-Use Load Shapes and Energy Use Intensities"). This study, done for the Southern California Edison (SCE) Company and the California Energy Commission (CEC), has developed a methodology to develop commercial end use load shapes and EUIs. The methodology includes development of DOE2 prototypical buildings from on-site surveys, performing DOE-2 simulation, and reconciling the simulation results against the measured whole-building hourly electricity consumptions. The prototypes developed in this study are: small office, large office, small retail, large retail, food store (supermarket), sit-down restaurant, fast-food restaurant, refrigerated warehouse, and non-refrigerated warehouse. The end uses included: indoor lighting, outdoor lighting, miscellaneous electric equipment, cooking, water heating,

ventilation, and cooling. *Information from this study has been used substantially to develop prototypes for Los Angeles and San Diego.*

3. **ConEd: Consolidated Edison Company of New York** (XEnergy, Inc. 1987c, "Study of energy end uses and conservation potential in selected segments of the commercial class"). DOE-2.1 prototypes were developed for 6 building types - offices, hotels, hospitals, retail, supermarkets, and schools - and 7 end-uses - heating, cooling, lighting, DHW, cooking, refrigeration, and others.

4. **EPRI : Electric Power Research Institute** (XEnergy, Inc. 1988, "TAG™ Technical Assessment Guide"). This study developed prototypes of two vintages (ASHRAE 90-75 and ASHRAE 90.1) for 9 building types : low- and high-rise offices, restaurants, retail, grocery, warehouse, school, health, and lodging. The prototypes are not city or regionally specific but have been simulated for El Paso, Lake Charles, Madison, Seattle, and Washington.

5. **FPL : Florida Power and Light** (Synergic Resources Corp., 1986a, "Cool Storage Market Assessment in Florida Power and Light's Service Area"). Prototype buildings were developed for 11 building types and 8 end-uses. The building types are : Large and small offices, retail, school, higher education, hospital, hotel, restaurant, civic center, movie, and church. The end-use estimates are based on a large on-site data collection effort involving about 1200 buildings.

6. **GRI1 : Gas Research Institute** (Briggs et al. 1989, "Analysis and Categorization of the Office Building Stock"). Building characteristics were defined and DOE-2 prototypes developed for 20 offices based on cluster analysis of U.S. office building stock. The prototype descriptions were reviewed, but not used directly in this project because of the differences in prototype methodology.

7. **GRI2 : Gas Research Institute** (Ritschard and Huang 1989, "U.S. Multifamily Building Prototype Specifications"). DOE-2 prototypes were developed for 16 multi-family prototypes in 4 U.S. census regions based on statistical analysis of Residential Energy Consumption Survey (RECS) originally done by Applied Management Sciences, Inc. (1987a).

8. **GRI3 : Gas Research Institute** (Chamberlain GARD 1990, "Simulation and analysis of integrated gas-fired desiccant dehumidification and mechanical and absorption cooling systems for commercial buildings", internal report). Fifteen DOE-2 prototypes for prototypical buildings - apartment, church, bar/lounge, health club, hospital, hotel; large, medium, and small offices; nursing home, retail,

restaurant, school, strip store, and warehouse - were defined based on DOE-2 input files from various sources (mostly PNL/ASHRAE/90, DOE/Oregon, etc.).

9. **MEOS : Michigan Energy Options Study** (Synergic Resources Corp. 1987a, no report). ADM-2 input files were developed for 10 building types - large and small offices, large and small retail, supermarket, fast foods restaurant, school, hospital, warehouse, and hotel/motel.

10. **NEU1 : Northeast Utilities Service Company** (Synergic Resources Corp. 1985, "New office buildings end-use energy consumption survey"). Prototype descriptions were developed for large, medium, and small *new* office buildings developed from an on-site survey of 18 large, 15 medium, and 28 small office buildings.

11. **NEU2 : Northeast Utilities Service Company** (Applied Management Sciences,Inc. 1987b, "End-use energy consumption survey for office buildings--conservation analysis"). This source provides prototype descriptions for large, medium and small *stock* office buildings developed from an on-site survey.

12. **NEU3 : Northeast Utilities Service Company** (Synergic Resources Corp. 1986b, "Education and health buildings end-use energy consumption survey"). ADM-2 prototypes were developed for 10 buildings types (primary school, secondary school, college dormitory, college classroom/administration building, college student center/dining, vocational/technical school, hospital, nursing home, large and small physician’s office) and 8 end uses (heating, cooling, ventilation, lighting, water heating, refrigeration, cooking, miscellaneous). The input data to this study are from 60 ICP buildings and supplementary on-site survey of 62 buildings.

13. **PNL : Pacific Northwest Laboratories 1983,** "Recommendations for energy conservation standards and guidelines for new commercial buildings". This report describes DOE-2 prototypes that were developed by PNL for ASHRAE Special Project 41 (SP-41) in support of commercial building energy standards. The building types covered include offices (small, medium, and large), retail (small, large), schools (elementary, high school), and a hospital. These prototypes were based on real buildings judged to be typical of that building type. The prototypes have been simulated for many climates.

14. **SCE1 : Southern California Edison** (Synergic Resources Corp. 1987b, "End-use data development: Initial load shape and technology data base"). ADM-2 prototypes have been developed for 13 building types, 8 end-uses, and 4 climate zones. The prototypes are: large office (2 equipment types), small office, fast foods

restaurant, large retail (2 equipment types), small retail, refrigerated and non-refrigerated warehouses, primary/secondary school, hospital, and hotel/motel. The primary source of data for development of these prototypes were SCE's 1983 mail survey.

15. **SWA : Steven Winter Associates** (Tuluca, A. 1989). This project entailed energy analysis of planned commercial buildings for a New England utility company. Among the buildings studied in 1989 were three penitentiaries in Connecticut, for which the project developed detailed DOE-2 input files. Although there are no assurances that these prisons are statistically representative, they provide the only information available to this project on the physical characteristics and operating schedules of prisons.

16. **UTA : Univ. of Texas at Austin** (Hunn, Akbari et al. 1985, "Technology Potential for Electric Energy Conservation and Peak Demand Reduction in Texas Buildings"). This report documents an assessment of conservation potentials in buildings for the Public Utility Commission of Texas. The commercial portion of the study includes three prototypical office, retail, and educational buildings based on SP-41 prototypes but modified for Texas. *These prototypes have been reviewed for development of prototypical information for metropolitan Houston.*

APPENDIX 8.B FORTRAN LISTING FOR BINNING PROGRAM

The following six pages is a print-out of the Fortran code for the *Binread* program for analyzing the detailed hourly loads files. A file with this source listing is also included on the first of the two magnetic tapes with the hourly loads data base. The program is written in Fortran-77 and should compile on any machine with a standard Fortran compiler.

A short description of this program and sample output tables are given in Section C of Chapter 5. To run the *Binread* program, the following files are required:

1. executable version of the *Binread* program.
2. HRLY.INP - input hourly file, i.e., any of the 481 files of the hourly loads data base.
3. COMMAND.TMP - input one-line command file with two numbers specifying the desired output format. The first number is either 1 for per square foot results, or 2 for building totals. The second number should be from 1 to 5 depending on the number of desired output tables, 1 for loads binned by hour of day, 2 for heating and cooling loads binned by temperature and humidity ratio, 3 for monthly totals and peak loads, 4 for the number of hours for ambient conditions binned by temperature, hour of day, and humidity ratio, and 5 for all tables.

The output from the *Binread* program is a file called HRLY.OUT with the requested tables.

FORTRAN SOURCE CODE FOR BINREAD PROGRAM FOR PROCESSING HOURLY DATA FILES

```
      PROGRAM BINREAD
C
C      This program analyzes a year's worth of hourly data
C
      OPEN (4,FILE='COMMAND.TMP',STATUS='OLD')
      OPEN (5,FILE='HRLY.INP',STATUS='OLD')
      OPEN (6,FILE='HRLY.OUT')
C
C     Read output selections
C     IF = format (2=total, 1=sqft),
C     IR = report selection (1 = hr of day bins, 2 = temp/hum. bins,
C          3= totals and pks 4 = air temp/hum. bins, 5 = all reports)
C
      READ(4,100) IF,IR
 100  FORMAT (2I2)
      WRITE(6,200)
 200  FORMAT ('1')
      CALL RDDATA (IF,IR,IP,MULT,HMULT)
      CALL WRDATA (IF,IR,IP,MULT,HMULT)
      END
C
      SUBROUTINE RDDATA (IF,IR,IP,MULT,HMULT)
      COMMON /BINS/ HBIN(25,30),HWBIN(25),ELBIN(25,2),IHHRS(30),
     $              CBIN(25,30,3),CBIN2(12,30,3),ICHRS(30),
     $              AIRBIN1(25,30),AIRBIN2(12,30),
     $              HMON(13,2),CMON(13,3),HPK(13,2),CPK(13,3),
     $              HPKT(13),CPKT(13,2),CPKHR(13,2),
     $              ELMON(13,2),ELPK(13,2)
      REAL HL,CL,LCL,HWL,NACE,ACE,CLOAD(3),HLOAD(2),ELEC(2),
     $     MULT,HMULT,
     $     HBIN(25,30),HWBIN(25),ELBIN(25,2),
     $     CBIN(25,30,3),CBIN2(12,30,3),
     $     HMON(13,2),CMON(13,3),HPK(13,2),CPK(13,3),
     $     ELMON(13,2),ELPK(13,2)
      INTEGER IAREA,IMON,IDAY,IH,IDBT,IHUMRAT,IT,IHUM,IP,
     $     AIRBIN1(25,30),AIRBIN2(12,30),IHHRS(30),ICHRS(30),
     $     HPKT(13),CPKT(13,2),CPKHR(13,2)
      CHARACTER*9 HEADER(10)
C
C      Initialize arrays
C
       DATA IHHRS,ICHRS/60 * 0/
       DATA HBIN/750 * 0.0/
       DATA CBIN,CBIN2/3330 * 0.0/
       DATA AIRBIN1,AIRBIN2/ 1110 * 0/
       DATA HMON,CMON,ELMON,HPK,CPK,ELPK/ 182 * 0.0/
       DATA HPKT,CPKT,CPKHR/ 65 * 0/
C
C     Read header
C
      DO 10 I=1,8
        READ(5,5001) HEADER
        IF (I.EQ.4) DECODE (9,5005,HEADER(3)) IAREA
5005    FORMAT(I9)
        IF (I.LE.7) WRITE(6,5001) HEADER
  10  CONTINUE
C
C    set format and multiplier flags depending on selection
C
      IF (IF.EQ.1) THEN
        IP = 1
        MULT = 1.
        HMULT = 1.
        IAREA = 1000.
      ELSE
        IF (IAREA.LT.100000) THEN
          IP = 1
          MULT = 1.
          HMULT = 1000.
        ELSE
          IP = 2
          MULT = 1000.
          HMULT = 1.
        ENDIF
        IAREA=IAREA/MULT
      ENDIF
C
C     WRITE(6,5005) IAREA
C
C     Read hourly data hour by hour
C
      DO 100 K=1,8760
        READ(5,5002) IMON,IDAY,IH,IDYTPE,IDBT,IHUMRAT,
     $                 HL,CL,LCL,HWL,NACE,ACE
```

```
C       WRITE(6,5002) IMON,IDAY,IH,IDYTPE,IDBT,IHUMRAT,
C    $                HL,CL,LCL,HWL,NACE,ACE
C
C   convert to KBtus and kWhs
C
        HLOAD(1)=HL*IAREA/1000.
        HLOAD(2)=HWL*IAREA/1000.
        CLOAD(1)=CL*IAREA/1000.
        CLOAD(2)=LCL*IAREA/1000.
        CLOAD(3)=ACE*IAREA/1000.
        ELEC(1)=NACE*IAREA/1000.
        ELEC(2)=CLOAD(3)+ELEC(1)
C
C     WRITE (6,5003) (HLOAD(I),I=1,2),(CLOAD(I),I=1,3),(ELEC(I),I=1,2)
C
C *******  Set temperature and humidity ratio bins
C
       IT = (IDBT + 30)/5
       IT = MAX0(IT,1)
       IT = MIN0(IT,29)
       IHUM = (IHUMRAT/20) + 1
       IHUM = MIN0(IHUM,11)
C
C  ********  heating bins by temperature and hour of day *********
C
          HBIN(IH,IT) = HBIN(IH,IT)+HLOAD(1)
          HBIN(25,IT) = HBIN(25,IT)+HLOAD(1)
          HBIN(IH,30) = HBIN(IH,30)+HLOAD(1)
          HBIN(25,30) = HBIN(25,30)+HLOAD(1)
C
C     WRITE (6,5004) IT,HBIN(25,IT)
C
C                ******** heating hours *****************
C
       IF (HLOAD(1).GT.0) THEN
           IHHRS(IT) = IHHRS(IT) +1
           IHHRS(30) = IHHRS(30) +1
       ENDIF
C
C               ********  hot water bins by hour of day *********
C
       HWBIN(IH) = HWBIN(IH)+HLOAD(2)
       HWBIN(25) = HWBIN(25)+HLOAD(2)
C
C                *******  heating and hot water load peaks *****
C
       DO 101 IVAR=1,2
         IF (HLOAD(IVAR).GT.HPK(IMON,IVAR)) THEN
            HPK(IMON,IVAR)=HLOAD(IVAR)
            IF (IVAR.EQ.1) HPKT(IMON)= IDBT
         ENDIF
         IF (HLOAD(IVAR).GT.HPK(13,IVAR)) THEN
            HPK(13,IVAR)=HLOAD(IVAR)
            IF (IVAR.EQ.1) HPKT(13)= IDBT
         ENDIF
C               *******  heating and hot water monthly totals ******
C
         HMON(IMON,IVAR) = HMON(IMON,IVAR) + HLOAD(IVAR)/HMULT
         HMON(13,IVAR) = HMON(13,IVAR) + HLOAD(IVAR)/HMULT
C
  101  CONTINUE
C
C  ******** cooling hours *****************
C
       IF (CLOAD(1).GT.0) THEN
          ICHRS(IT) = ICHRS(IT) +1
          ICHRS(30) = ICHRS(30) +1
       ENDIF
C
       DO 102 IVAR=1,3
C
C  ********  cooling bins by temperature and hour of day *********
C
          CBIN(IH,IT,IVAR) = CBIN(IH,IT,IVAR) + CLOAD(IVAR)
          CBIN(25,IT,IVAR) = CBIN(25,IT,IVAR) + CLOAD(IVAR)
          CBIN(IH,30,IVAR) = CBIN(IH,30,IVAR) + CLOAD(IVAR)
          CBIN(25,30,IVAR) = CBIN(25,30,IVAR) + CLOAD(IVAR)
C
C *******  cooling bins by temperature and humidity ratio ******
C
          CBIN2(IHUM,IT,IVAR) = CBIN2(IHUM,IT,IVAR) + CLOAD(IVAR)
          CBIN2(IHUM,30,IVAR) = CBIN2(IHUM,30,IVAR) + CLOAD(IVAR)
          CBIN2(12,IT,IVAR) = CBIN2(12,IT,IVAR) + CLOAD(IVAR)
          CBIN2(12,30,IVAR) = CBIN2(12,30,IVAR) + CLOAD(IVAR)
C
C ******* cooling load peaks  ************
C
        IF (CLOAD(IVAR).GT.CPK(IMON,IVAR)) THEN
           CPK(IMON,IVAR)=CLOAD(IVAR)
           IF (IVAR.LE.2) THEN
              CPKT(IMON,IVAR)= IDBT
              CPKHR(IMON,IVAR)=IHUMRAT/10
           ENDIF
        ENDIF
```

```
       IF (CLOAD(IVAR).GT.CPK(13,IVAR)) THEN
          CPK(13,IVAR)=CLOAD(IVAR)
          IF (IVAR.LE.2) THEN
             CPKT(13,IVAR)= IDBT
             CPKHR(13,IVAR)=IHUMRAT/10
          ENDIF
       ENDIF
C
C ******* cooling monthly totals  ****
C
      CMON(IMON,IVAR) = CMON(IMON,IVAR) + CLOAD(IVAR)
      CMON(13,IVAR) = CMON(13,IVAR) + CLOAD(IVAR)
C
 102  CONTINUE
C
C  ********  non-a/c elec bins by hour of day *********
C
         ELBIN(IH,1) = ELBIN(IH,1)+ELEC(1)
         ELBIN(25,1) = ELBIN(25,1)+ELEC(1)
C
C  ********   total elec bins by hour of day *********
C
         ELBIN(IH,2) = ELBIN(IH,2)+ELEC(2)
         ELBIN(25,2) = ELBIN(25,2)+ELEC(2)
C
         DO 103 I=1,2
C
C                *******  non-a/c and total elec peaks *****
C
         IF (ELEC(I).GT.ELPK(IMON,I)) THEN
            ELPK(IMON,I)=ELEC(I)
         ENDIF
         IF (ELEC(I).GT.ELPK(13,I)) THEN
            ELPK(13,I)=ELEC(I)
         ENDIF
C
C                *******  non-a/c and total monthly totals *****
C
         ELMON(IMON,I) = ELMON(IMON,I) + ELEC(I)
         ELMON(13,I) = ELMON(13,I) + ELEC(I)
C
 103    CONTINUE
C
C ************* weather bins **********************************
C
       AIRBIN1(IH,IT) = AIRBIN1(IH,IT) + 1
       AIRBIN1(25,IT) = AIRBIN1(25,IT) + 1
       AIRBIN2(IHUM,IT) = AIRBIN2(IHUM,IT) + 1
       AIRBIN2(12,IT) = AIRBIN2(12,IT) + 1
C
 100  CONTINUE
 5001 FORMAT(10A9)
 5002 FORMAT (I2,2I3,I2,I3,I4,6F8.4)
 5003 FORMAT (7F8.1)
C5004 FORMAT ('HBIN(25,',I3,') IS ',F8.1)
      RETURN
      END
C
      SUBROUTINE WRDATA (IF,IR,IP,MULT,HMULT)
      COMMON /BINS/ HBIN(25,30),HWBIN(25),ELBIN(25,2),IHHRS(30),
     $              CBIN(25,30,3),CBIN2(12,30,3),ICHRS(30),
     $              AIRBIN1(25,30),AIRBIN2(12,30),
     $              HMON(13,2),CMON(13,3),HPK(13,2),CPK(13,3),
     $              HPKT(13),CPKT(13,2),CPKHR(13,2),
     $              ELMON(13,2),ELPK(13,2)
      CHARACTER*7 LAB2(4)
      CHARACTER*9 LAB1(4,2)
      CHARACTER*10 LAB3(2)
      CHARACTER*15 LABEL(7)
      CHARACTER*17 CKEY(3)
      REAL  ITMID(30),IHRMID(12),HRATE,CRATE,MULT
      DATA CKEY /
     $    '    Cooling Loads', 'Latent Cool Loads',
     $    '   Air-cond. Elec'/
      DATA LABEL /'Heating Load', 'Hot Water Load',
     $             'Cooling Load', 'Lat Cool Load',
     $             'A/C Electricity', 'Non A/C Elec', 'Total Elec'/
      DATA LAB1 /'(kBtu)','(kWh)','(kBtu/hr)', '(kW)',
     $          '(MBtu)','(MWh)','(kBtu/hr)', '(MW)'/
      DATA LAB2 /'Load', 'Temp', 'HRx1000','Elec' /
      DATA LAB3 /'(per SqFt)', '(Totals)'/

C     DATA IOUT /30* 0/
C
C     ****** select print formats depending on units
C
      IF (IP.EQ.2) THEN
        ASSIGN 6109 TO IPR1
        ASSIGN 6110 TO IPR2
        ASSIGN 6113 TO IPR3
        ASSIGN 6114 TO IPR4
        ASSIGN 6116 TO IPR5
        ASSIGN 6117 TO IPR6
        ASSIGN 6126 TO IPR7
```

```
          ASSIGN 6127 TO IPR8
        ELSE
          ASSIGN 6009 TO IPR1
          ASSIGN 6010 TO IPR2
          ASSIGN 6013 TO IPR3
          ASSIGN 6014 TO IPR4
          ASSIGN 6016 TO IPR5
          ASSIGN 6017 TO IPR6
          ASSIGN 6026 TO IPR7
          ASSIGN 6027 TO IPR8
        ENDIF
C
C     ****** calculate bin mid-points (for label purposes only)
C
           ITMID(1) = -22.5
           DO 10 IT=2,30
             ITMID(IT) = ITMID(IT-1) + 5.
 10        CONTINUE
           IHRMID(1) = 0.001
           DO 20 IH=2,11
             IHRMID(IH) = IHRMID(IH-1) + 0.002
 20        CONTINUE
C
C    ****** write hour-of-day bins for HL,HWL,CL,LCL,ACE,NACE,TE
C
         IF (IR.EQ.1.OR.IR.EQ.5) THEN
           WRITE(6,6004) LAB3(IF),(LAB2(1),J=1,4),(LAB2(4),J=1,3),
     $                   (LAB1(1,IP),J=1,4),(LAB1(4,IP),J=1,3)
           DO 40 IH=1,24
                 WRITE(6,IPR1) IH,HBIN(IH,30),HWBIN(IH),
     $           (CBIN(IH,30,J),J=1,3),(ELBIN(IH,J),J=1,2)
40         CONTINUE
           WRITE(6,IPR2) HBIN(25,30),HWBIN(25),
     $           (CBIN(25,30,J),J=1,3),(ELBIN(25,J),J=1,2)
           WRITE(6,6007)
         ENDIF
C
         IF (IR.EQ.2.OR.IR.EQ.5) THEN
           WRITE(6,6008)
C
C  ***** heating and cooling loads and rates by temperature
C
           WRITE(6,6015) LAB3(IF),LAB1(1,IP),LAB1(1,IP)
C
C   calculate top and bottom of bins by integer addition,use
C   +2.4 for top bin to get correct cutoff
C
           DO 901 IT=1,29
             IHVAC=IHHRS(IT)+ICHRS(IT)
             IBINTOP=ITMID(IT)+2.49
             IBINBOT=ITMID(IT)-2.50
             IF (IHHRS(IT).EQ.0) THEN
                HRATE=0.0
              ELSE
                HRATE= (HBIN(25,IT)*MULT)/IHHRS(IT)
             ENDIF
             IF (ICHRS(IT).EQ.0) THEN
                CRATE=0.0
              ELSE
                CRATE= (CBIN(25,IT,1)*MULT)/ICHRS(IT)
             ENDIF
             IF (IHVAC.GT.0) WRITE (6,IPR5) IBINBOT,IBINTOP,
     $          IHHRS(IT),HBIN(25,IT),HRATE,
     $          ICHRS(IT),CBIN(25,IT,1),CRATE
 901 CONTINUE
          IF (IHHRS(30).EQ.0) THEN
                HRATE=0.0
             ELSE
                HRATE= (HBIN(25,30)*MULT)/IHHRS(30)
             ENDIF
          IF (ICHRS(30).EQ.0) THEN
                CRATE=0.0
             ELSE
                CRATE= (CBIN(25,30,1)*MULT)/ICHRS(30)
             ENDIF
          WRITE (6,IPR6)
     $          IHHRS(30),HBIN(25,30),HRATE,ICHRS(30),CBIN(25,30,1),CRATE
C
C    ****** write cooling temperature and humidity bins
C
             WRITE(6,6008)
             DO 50 IVAR=1,3
                IF (IVAR.EQ.3) THEN
                   ITMP=2
                ELSE
                   ITMP=1
                ENDIF
                WRITE(6,6011) CKEY(IVAR),LAB1(ITMP,IP),LAB3(IF)
                WRITE(6,6012) (IHRMID(IHUM),IHUM=1,11)
                DO 55 IT=29,1,-1
                   IF (CBIN(12,IT,1).GT.0) WRITE(6,IPR3)
     $                  ITMID(IT),(CBIN2(IHUM,IT,IVAR),IHUM=1,12)
 55             CONTINUE
                WRITE(6,IPR4) (CBIN2(IHUM,30,IVAR),IHUM=1,12)
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```
 50      CONTINUE
      ENDIF
C
C******** print total loads *************************
C
      IF (IR.EQ.3.OR.IR.EQ.5) THEN
      WRITE(6,6008)
      WRITE(6,6024) 'Monthly Building Loads',LAB3(IF)
      DO 902 I=1,2
        IF (IF.EQ.1)
     $     WRITE(6,6126) LABEL(I),LAB1(1,1),(HMON(IM,I),IM=1,13)
        IF (IF.EQ.2)
     $     WRITE(6,IPR7) LABEL(I),LAB1(1,2),(HMON(IM,I),IM=1,13)
 902  CONTINUE
      DO 903 I=1,2
        WRITE(6,6126)
     $    LABEL(I+2),LAB1(1,IP),(CMON(IM,I),IM=1,13)
 903  CONTINUE
      WRITE(6,6126) LABEL(5),LAB1(2,IP),(CMON(IM,3),IM=1,13)
      DO 904 I=1,2
        WRITE(6,6126)
     $    LABEL(I+5),LAB1(2,IP),(ELMON(IM,I),IM=1,13)
 904  CONTINUE
      WRITE(6,6025)
C
C******** print peak loads *************************
C
      WRITE(6,6024) 'Peak Building Loads',LAB3(IF)
      WRITE(6,IPR8)
     $   LABEL(1),LAB1(3,IP),LAB2(1),(HPK(IM,1)*MULT,IM=1,13)
      WRITE(6,6028) LAB2(2),(HPKT(IM),IM=1,13)
      WRITE(6,IPR8)
     $   LABEL(2),LAB1(3,IP),LAB2(1),(HPK(IM,2)*MULT,IM=1,13)
      DO 910 I=1,2
      WRITE(6,IPR8) LABEL(I+2),LAB1(3,IP),LAB2(1),
     $  (CPK(IM,I)*MULT,IM=1,13)
      WRITE(6,6028) LAB2(2),(CPKT(IM,I),IM=1,13)
      WRITE(6,6028) LAB2(3),(CPKHR(IM,I),IM=1,13)
910   CONTINUE
      WRITE(6,IPR8) LABEL(5),LAB1(4,IP),'          ',
     $  (CPK(IM,3)*MULT,IM=1,13)
      DO 911 I=1,2
      WRITE(6,IPR8)
     $  LABEL(I+5),LAB1(4,IP),'          ',(ELPK(IM,I)*MULT,IM=1,13)
911   CONTINUE
      WRITE(6,6025)
      ENDIF
C
C ******* print climate bins ******************************
C
      IF (IR.EQ.4.OR.IR.EQ.5) THEN
      WRITE(6,6008)
      WRITE(6,6018) 'Ambient Hours'
      WRITE(6,6019) (IH,IH=1,24)
      DO 1033 IT=29,1,-1
        IF (AIRBIN1(25,IT).GT.0)
     $      WRITE(6,6020) ITMID(IT),(AIRBIN1(IH,IT),IH=1,25)
 1033 CONTINUE
      WRITE(6,6021)
      WRITE(6,6011) 'Ambient Hours',' ',' '
      WRITE(6,6012) (IHRMID(IHUM),IHUM=1,11)
      DO 1037 IT=29,1,-1
        IF (AIRBIN1(25,IT).GT.0)
     $      WRITE(6,6022) ITMID(IT),(AIRBIN2(IHUM,IT),IHUM=1,12)
 1037 CONTINUE
      WRITE(6,6023)
      ENDIF
C
C ****** Formats **************************************************
C
 6004 FORMAT (2X,'Loads and Elec Consumption Binned vs. Hour of Day',
     $        1x,A//1X,'Hour',4X,'Heating  HotWater  Cooling  LatCool',
     $        ' Air Cond  Non-A/C   Total'/9x,7(2x,A6,1x)
     $        /7x,4(3x,A6),1X,3(3X,A6)/1X,70('_'))
 6005 FORMAT (2X,F5.1,4X,F10.0)
 6105 FORMAT (2X,F5.1,4X,F10.1)
 6006 FORMAT (2X,20('_')/2X,'Total ',4X,F10.0)
 6106 FORMAT (2X,20('_')/2X,'Total ',4X,F10.1)
 6007 FORMAT (/)
 6008 FORMAT ('1')
 6009 FORMAT (2X,I2,3X,7F9.0)
 6109 FORMAT (2X,I2,3X,7F9.1)
 6010 FORMAT (1X,70('_')/' Total',7F9.0)
 6110 FORMAT (1X,70('_')/' Total',7F9.1)
 6011 FORMAT (//1X,A24,1X,A,'Binned vs. Temperature and
Humidity',1X,A/)
 6012 FORMAT (' ',' T/H.R. ',11(3X,F4.3),3X'All'/' ',92('_'))
 6013 FORMAT (' ',F5.1,2X,11F7.0,F8.0)
 6113 FORMAT (' ',F5.1,2X,11F7.1,F8.1)
 6014 FORMAT (92('_')/' Total  ',11F7.0,F8.0)
 6114 FORMAT (92('_')/' Total  ',11F7.1,F8.1)
 6015 FORMAT (/6X,'Building Loads By 5 Degree Temperature Bins',1X,A//
     $     2X,' Temp (F) ',
     $     2X,' Heating  ','Heat Load ','Heat Rate ',
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     $     2X,' Cooling  ','Cool Load ','Cool Rate ',/
     $     2X,'   L    U ',
     $     2X,'  Hours   ',1X,A6,3X,'(kBtu/hr) ',
     $     2X,'  Hours   ',1X,A6,3X,'(kBtu/hr) ',/
     $     2X,2('_____'),2X,6('_____'),2X,6('_____'))
 6016 FORMAT (2X,2I5,2(I10,2F10.2,2X))
 6116 FORMAT (2X,2I5,2(I10,F10.2,F10.0,2X))
 6017 FORMAT (2X,2('_____'),2X,6('_____'),2X,6('_____')/
     $        5X,'Total',2X,2(I10,2F10.2,2X))
 6117 FORMAT (2X,2('_____'),2X,6('_____'),2X,6('_____')/
     $        5X,'Total',2X,2(I10,F10.2,F10.0,2X))
 6018 FORMAT (/20X,A,3X,'Binned vs. Hour and Temperature'/)
 6019 FORMAT (1X,'T/Hour',I3,23I4/' ',107('_'))
 6020 FORMAT (' ',F5.1,24I4,I6)
 6021 FORMAT (1X,107('_'))
 6022 FORMAT (' ',F5.1,2X,11I7,I8)
 6023 FORMAT (1X,92('_'))
 6024 FORMAT (/A,1X,A//9X,
     $  'Jan',4X,'Feb',4X,'Mar',4X,'Apr',4X,'May',4X,'Jun',4X,
     $  'Jul',4X,'Aug',4X,'Sep',4X,'Oct',4X,'Nov',4X,'Dec',5X,'Year'/
     $  102('_'))
 6025 FORMAT (102('_')//)
 6026 FORMAT (/A,1X,A/6X,12F7.2,F8.2)
 6126 FORMAT (/A,1X,A/6X,12F7.0,F8.0)
 6027 FORMAT (/A,1X,A/2X,A4,12F7.1,F8.1)
 6127 FORMAT (/A,1X,A/2X,A4,12F7.0,F8.0)
 6028 FORMAT (2X,A7,I3,11I7,I8)
      RETURN
      END
```