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# ELECTRICAL ENERGY CONSUMPTION AND BUILDING CHARACTERISTICS OF OFFICE AND DRY GOODS RETAIL BUILDINGS IN THE PACIFIC NORTHWEST

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# Introduction

The commercial sector contains a diverse class of customers. It has been growing rapidly and is expected to continue to grow in the future. Reflecting this growth, the commercial sector's share of total Pacific Northwest electricity sales increased from 17 percent in 1975 to 22 percent in 1986. ___ 1987

Office and Dry Goods Retail consumers comprise two of the largest components of the commercial sector. Together, they account for 31 percent of the region's commercial buildings, 34 percent of the region's commercial floor space, and 37 percent of the commercial sector's electricity consumption (see Figure 1.1).

Until recently, reliable data on the building characteristics and electrical energy consumption of Office and Dry Goods Retail buildings in the Pacific Northwest have been unavailable. Yet information of this type would be invaluable to regional energy planners. For example, hourly end-use data can be used to evaluate the impact on regional electricity sales of changes in end-use equipment, e.g. adoption of new types of HVAC systems in large Office buildings, or utility policy, e.g. promotion of efficient lighting systems. In addition, regional forecasting models require estimates of regional building characteristics and end-use consumption.

This report presents estimates of building characteristics and end-use loads for Office and Dry Goods Retail buildings in the Bonneville Power Administration's (BPA) service area. These estimates are the result of recent research activities that have involved the integrated analysis of a variety of newly available regional commercial building data sets. The estimates presented in this report include:

- Physical characteristics of Office and Dry Goods Retail buildings in the region, including number of buildings and floor space by building size, age, location and utility type

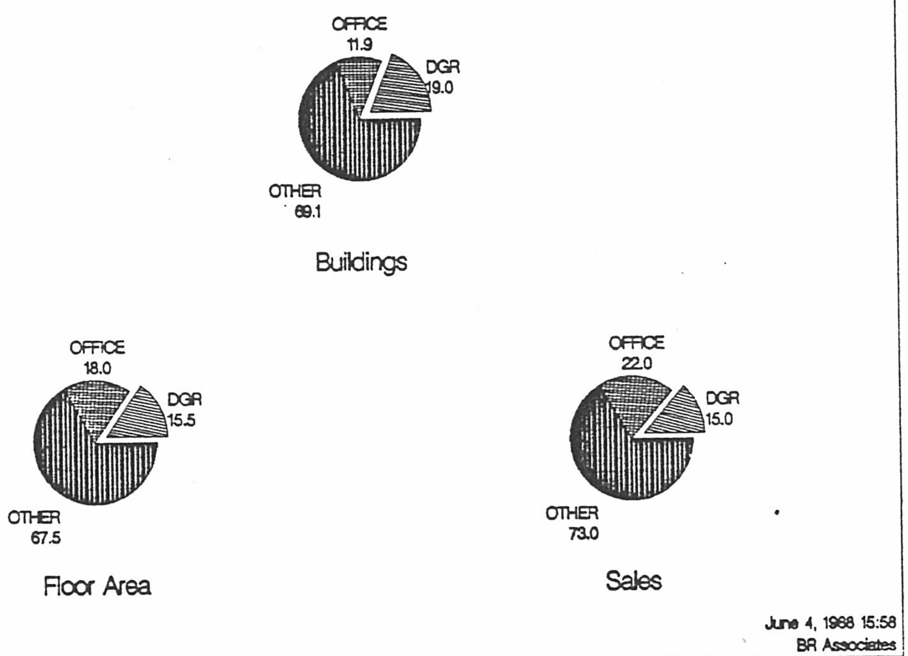
- o Recent construction activity and employment growth trends in the Office and Dry Goods Retails sectors

- o Regional hourly electricity consumption estimates for Offices and Dry Goods Retail buildings, including both total and end-use consumption

The report also describes the various data sources and the methodology used to develop these regional estimates.

FIGURE 1.1

Buildings, Floor Area, and Sales Shares in the Pacific Northwest Region




This effort represents the first time that a variety of regional commercial data sets have been combined in an integrated analysis. Many data sources were used in this effort. BPA has recently sponsored a number of studies to collect information on the region's commercial sector. One study, ELCAP (End-use Load and ~~Conservation~~ Assessment Project), has entailed the collection of building characteristics and hourly end-use loads data from 115 commercial buildings in the region. ELCAP provides the most detailed loads and characteristics data available in the region. A second study, PNNonRES (Pacific Northwest Non-Residential Energy Survey) is a two-stage survey collecting regional commercial building and energy consumption characteristics. The results of the first stage of PNNonRES are described in this report.

Seattle City Light has also conducted several commercial data collection efforts. SCL monitored total hourly consumption for approximately 500 buildings in its service area during 1984 - 1986. The resulting loads data base, supplemented with building characteristics for the monitored sites, is known as the SCLCDB (Seattle City Light Commercial Data Base). This is a large random sample of SCL's commercial customers that provides highly reliable estimates of total electrical load shape for the SCL service area. SCL has also been conducting a small scale end-use monitoring project of its own, entitled CHEUS (Commercial Hourly End Use Study). Since this study also provides hourly end use data, the four Office or Dry Goods Retails buildings being monitored were used in our analysis to supplement the ELCAP sample.

In addition, F.W. Dodge data on new commercial construction were collected for use in conjunction with PNNonRES, and employment data for the commercial sector have been gathered from federal and state government sources.

Data from these data sets have been assembled into an integrated SAS data base on BPA's IBM mainframe computer. This data base was used to develop the information presented in this report; it is also available for additional applications in commercial sector research and analysis. → We need [illegible] documentation

Since the analysis entailed the use of a variety of data sets, it was important to develop certain basic definitions that could be applied across data sets. First, analysis has been limited to the Pacific Northwest Region as defined by the Northwest Power Act. This area includes all of Washington, Oregon and Idaho, Western Montana, and small parts of Wyoming, California, Utah and Nevada.

Second, the definition of a building as commercial, Office or Dry Goods Retail is based on the economic activity of that building (e.g. Retail), rather than the functional use of the building (e.g. Storage). The primary advantage of categorizing buildings according to economic activity is that there exists an abundance of other data, such as employment data, which are also categorized by economic activity. The availability of such data enables one to relate information by building type to other economic measures and to use economic data to develop estimates and forecasts of floor area by building type.

The Standard Industrial Classification (SIC) system is used as the basis for defining building types by economic activity. The SIC system classifies firms and non-profit and government organizations according to the type of economic activity in which they are involved. BPA has adopted a method for assigning these SIC codes into business types such as Office, Dry Goods Retail, Grocery, etc. The Office category includes banks, health professionals' offices, and government and other business offices. The Dry Goods Retail category includes such economic activities as department stores, hardware stores, apparel stores, auto dealers, and other miscellaneous retail.

In some portions of the analysis, Offices and Dry Goods Retail buildings were further divided into Small and Large categories based on building floor area. Office buildings containing more than 30,000 square feet are classified as Large,

- We need to begin [illegible] ELCAP data sets so we know which set has been used for specific analyses while smaller buildings are classified as Small. Similarly, Dry Goods Retail buildings larger than 20,000 square feet are classified as Large, while others are classified as Small. These categories correspond to those used within BPA.

## 1.1 ORGANIZATION OF REPORT

This report describes the data sets and methodology used to derive regional estimates for Office and Dry Good Retail buildings, and presents the analysis results. Chapter Two focuses on regional building stock characteristics. Chapter Three focuses on estimation of regional energy consumption for Offices and Dry Goods Retail buildings.

# 2

# Regional Building Stock and Employment Estimates

This chapter presents information on building stock, construction activity and employment for the Pacific Northwest's commercial sector as a whole, and for Office and Dry Goods Retail buildings in particular. It includes descriptions of the data sources and methodology used, and it presents the principal findings from the data.

Section 2.1 describes the methodology used to obtain regional building stock, construction and employment estimates. It includes a discussion of PNNonRES (from which the building stock estimates are derived), and briefly explains the data sources and methodology used to obtain estimates of regional Office and Dry Goods Retail construction activity and employment.

Section 2.2 presents the regional building stock and floor space estimates, aggregated by location, vintage and utility type.

Section 2.3 presents estimates of new construction activity for the time period 1980 to 1984.

Section 2.4 describes trends in regional Office and Dry Goods Retail employment.

## 2.1 METHODOLOGY

Three types of regional estimates are presented in this chapter. Estimates of regional building stock and floor space were developed from the first stage of the

Pacific Northwest Non-Residential Energy Survey (PNNonRES), estimates of new construction activity were derived from F.W. Dodge data, and estimates of employment trends were derived from the U.S. Bureau of Economic Analysis' (BEA) Regional Economic Information System. The methodology used to evelop each of these sets of estimates is described below.

**Estimation of Building Stock and Floor Space**

Estimates of regional building stock and floor space were developed from the first stage of the Pacific Northwest Non-Residential Energy Survey (PNNonRES). This survey was designed to obtain information about the physical characteristics and energy consumption patterns of commercial buildings in the Pacific Northwest (BPA's service territory). Information was collected from a sample of the region's buildings, and was then used to generalize from that sample to the entire population of buildings in the region.

A two-stage sample design was used in PNNonRES to maximize the efficiency of the sample. The first stage involved selecting a sample of ZIP areas from all the ZIP areas in the region, listing all commercial buildings in those areas and collecting basic information about those buildings. In the second stage, a sample of buildings was selected from the list developed in the first stage, and more detailed information is collected for the buildings in that sample.

The results in this report are based on the information collected from buildings in the first stage sample. As background for these results, the following discussions address the sample design and data collection efforts for the first stage.

*First Stage Sample Design*

The first stage sample design for PNNonRES involved the use of three separate sampling frames: regional ZIP areas, regional hospital facilities, and regional post-secondary institutions.

The majority of buildings enumerated in the first stage were selected in a sample of ZIP areas. PPS (probability proportional to size) sampling was used to select ZIP areas from the 1415 total ZIP areas in the region (i.e. the probability of selecting a specific ZIP area was proportional to the number of non-residential buildings it contains). 66 ZIP areas were chosen in this manner. In addition, 7 ZIP areas in the central business districts of Seattle, Portland and Spokane were selected with certainty. In total, 73 ZIP areas were selected in the first stage. Each sampled ZIP area containing more than 300 buildings was then subdivided into subareas called segments. One of the segments was selected randomly, and only the buildings in that segment were enumerated. A total of 11,525 commercial buildings were included in this enumeration.

However, hospitals and higher education buildings are not adequately represented in a ZIP area sample, because these are few in number and spatially concentrated. As a result, it was necessary to develop separate lists of all hospitals and higher education campuses in the region. Separate samples of hospitals and campuses were selected from these lists, and the buildings comprising the sampled hospitals or located on the sampled campuses were enumerated by means of mail and phone surveys. 2076 buildings were enumerated in this way, resulting in a total first stage sample of 13,601 buildings.

*First Stage Data Collection*

Data collected in the first stage consisted of general physical and economic building characteristics. Each building selected from the ZIP area sample received a walk-by audit, during which the following information was collected:

- floor area
- number of tenants
- economic activity of each tenant (up to 18)
- vintage (pre-1980 or post-1980)
- development type (strip, mall, etc.)
- functional use of building

In addition, the ZIP area of each building provides information about that building's geographic location (state, East/West of Cascades, urban/rural) and about the type of utility serving that building (private, public generating, public non-generating).

During processing of the field data, a primary building type was assigned to each building, based on the economic activities of the tenants in that building. Tenants were grouped by economic activity, and the primary building type was defined as the economic activity accounting for the most floor space in the building. Thus, the economic activity of the firms or organizations occupying a building (e.g. Retail), rather than the actual use of the building (e.g. storage), determined the building type classification for that building.

The primary advantage of categorizing buildings according to economic activity is that there exists an abundance of other data, such as employment data, which are also categorized by economic activity. The availability of such data enables one to relate information by building type to other economic measures and to use economic data to develop estimates and forecasts of floor area by building type for years in which survey data is unavailable.

PNNonRES used the Standard Industrial Classification (SIC) system for defining its building types. The SIC system classifies firms and non-profit and government organizations according to the type of economic activity in which they are involved. Using the SIC system, the following 12 commercial building type categories were defined for use in the PNNonRES survey:

1. Warehouse
2. Dry Goods Retail (DGR)
3. Grocery
4. Restaurant
5. Office
6. Primary & Secondary Education
7. Higher Education
8. Hotel & Motel
9. Hospital
10. Other Health
11. Other Commercial
12. Unknown

### Estimation of New Construction Activity

Information on new construction activity in the region was obtained from the F.W. Dodge Company's *Construction Potentials* data series. F.W. Dodge collects information on all construction contracts awarded in the U.S. The type of information collected includes project value, location, size of project (in square feet of floor area), type of project, and the physical characteristics of the project.

As part of the PNNonRES project, F.W. Dodge construction data were purchased for the Pacific Northwest states for the years 1980-84. After the data were obtained, it was necessary to delete from the data set all counties that were not within the boundaries of the BPA service area, and to convert the F.W. Dodge project type designations to the PNNonRES building type categories. The resulting data set contained information on county-level construction activity by building type for all counties in the region.

### Estimation of Employment Trends

Employment estimates for the commercial sector and its Office and Dry Goods Retail components were developed for the period 1965-85. Estimates were made for the region and its three largest counties, King, Pierce, and Multnomah.

The U.S. Bureau of Economic Analysis' (BEA) Regional Economic Information System was used as the primary source of employment data. The BEA data were supplemented with data on covered employment (i.e., covered by unemployment insurance) which were obtained from the employment departments of the states of Washington, Oregon, and Idaho. These secondary data sources were required because the BEA series do not provide sufficient industry detail at the county level to support estimates for the Office and Dry Goods Retail sectors. Employment was allocated from SIC industries to building types using the classification system developed for PNNonRES.

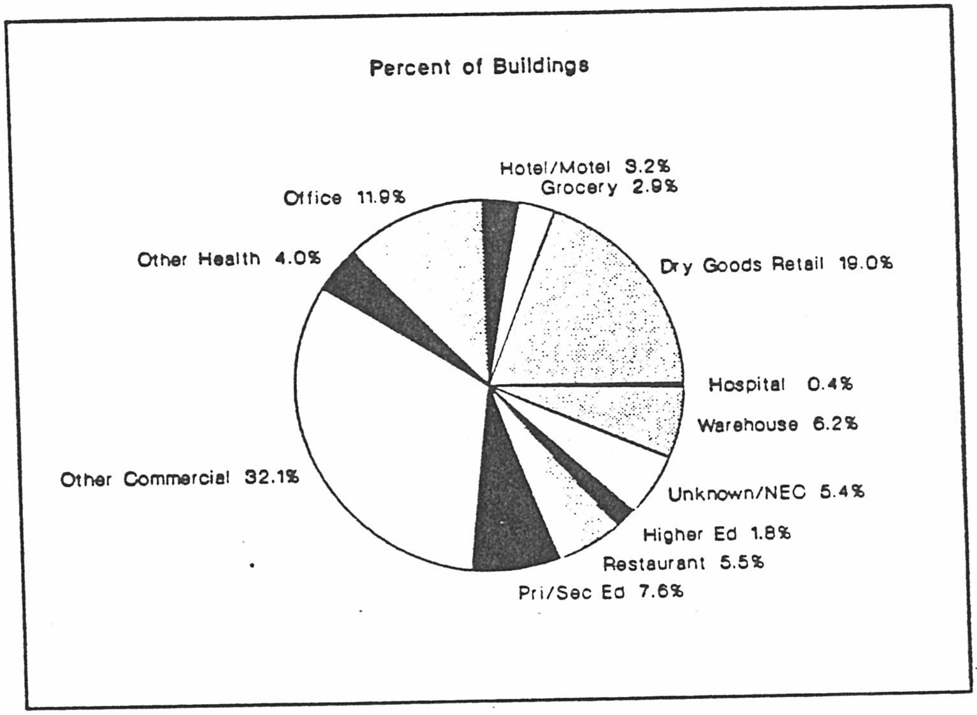
Estimates of regional employment by building type were developed from data for the three states of Washington, Oregon, and Idaho. These states contain approximately 95 percent of the region's total commercial employment. To make the regional building type estimates, the BEA employment figures for the three states were multiplied by a ratio of total region commercial employment to commercial employment in the three states. This ratio was developed from ZIP area level employment data available from the U.S. Census office of County Business Patterns.

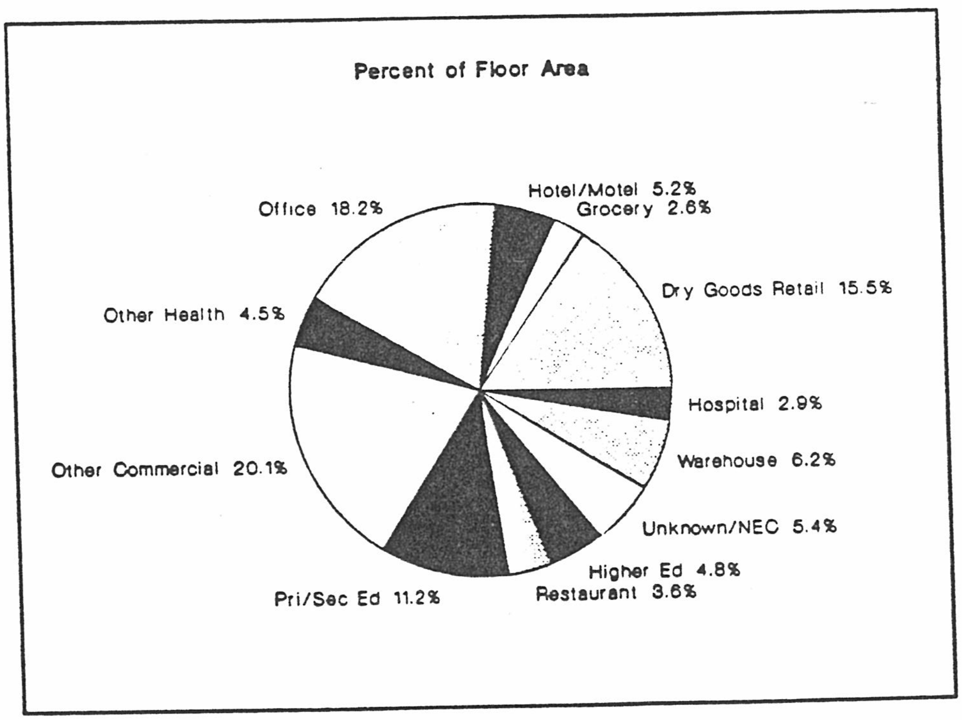
## 2.2 REGIONAL BUILDING STOCK AND FLOOR SPACE ESTIMATES

The first stage of PNNonRES provides a "snapshot" of gross commercial floor area and number of buildings for the region, as of mid-1986. As Figure 2.1 and Table 2.1 show, the region's commercial sector consists of 1,793 million square feet, contained in approximately 224,000 buildings. Office and Dry Goods Retail

FIGURE 2.1

**Building and Floor Area Measures by Building Type**



(DGR) together account for one third of the region's floor space and roughly one third of the total number of buildings. This translates to 605 million square feet contained in 69,200 buildings.

**TABLE 2.1**

**Regional Building and Floor Area Measures by Building Type**

| | | Buildings | | Floor Area | |
|---|---|---|---|---|---|
| | Sample Size | Buildings | Percent of Total | Floor Area (million sqft) | Percent of Total |
| BUILDING TYPE | | | | | |
| Dry Goods Retail | 2046 | 42,500 | 19 | 278 | 16 |
| Office | 1690 | 26,700 | 12 | 327 | 18 |
| Other | 9865 | 155,100 | 69 | 1188 | 66 |
| REGIONAL TOTAL | 13,601 | 224,300 | 100 | 1793 | 100 |

Office buildings represent the second largest of all commercial building types (the general "Other Commercial" category is the largest), accounting for over 26,000 buildings and 327 million square feet in the region. As we will discuss in more detail below, roughly 60 percent of this floor area is contained in the largest 20 percent of the buildings. The Office building type is composed of finance, insurance, real estate, banking, most government services and offices of legal and health professionals.

Buildings classified as Dry Goods Retail constitute the third largest building type in the region. Collectively these buildings account for 278 million square feet contained in 42,500 buildings. Economic activities that fall into this category include department stores, hardware stores, apparel stores, auto dealers, and other miscellaneous retail. This category excludes all businesses associated with the sale of food, i.e. groceries and restaurants.

Note that significant differences can be seen between a building type's share of total buildings and that building type's share of floor area. For example, offices represent only 12 percent of the region's buildings, but 18 percent of the region's commercial floor area, because they are large relative to the average commercial building.

**Size Distribution of Office and Dry Goods Retail Buildings**

The distribution of floor area in commercial buildings is highly skewed -- there are many small buildings, and few large ones. As a result, a large proportion of the region's floor area is concentrated in a small number of the buildings. In the

Pacific Northwest, 20 percent of the commercial buildings account for 60 percent of the commercial floor area. The remaining 80 percent of the buildings account for only 40 percent of the floor area.

This pattern of size distribution is even more pronounced within specific building types. It is particularly pronounced for Office buildings. As Figure 2.2 shows, most of the region's Office buildings are small -- 59 percent of the buildings contain less than 5000 square feet of floor area. Together, all these small buildings contain 10 percent of the region's Office floor space. Large office buildings, though relatively few in number, account for a majority of the region's office floor space. Although only 6 percent of the region's office buildings have more than 30,000 square feet of floor area, these large buildings account for 59% of the region's office floor space.

FIGURE 2.2

Buildings and Floor Area by Building Size in the Pacific Northwest Region

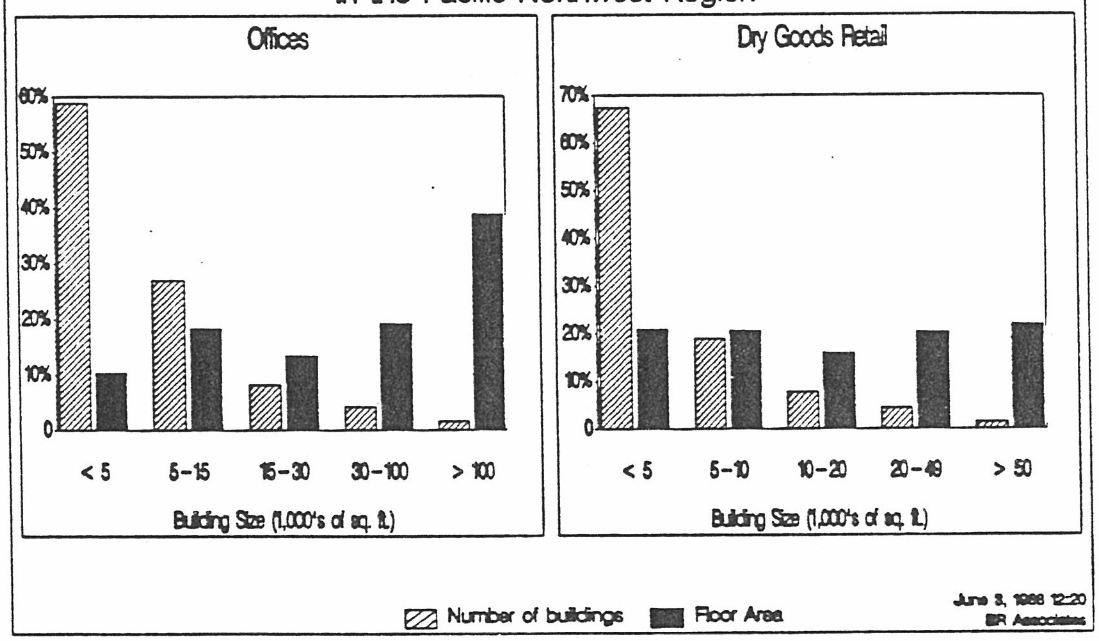



Figure 2.2 also shows the same picture for DGR buildings. Here we see a similar, though less pronounced pattern. Two thirds of the region's DGR buildings contain less than 5000 square feet, yet together these buildings account for 21 percent of the region's DGR floor space. At the other end of the spectrum, 6 percent of the region's DGR buildings are larger than 20,000 square feet, and these large buildings account for 42 percent of the region's DGR floor space.

This skewed distribution of floor area has significant implications for the strategic targeting of conservation or marketing programs, and for design of commercial building research projects. It is possible to focus on a few large buildings and gain insight into a significant proportion of the region's floor area, and hence, an understanding of measures that are related to floor area, such as energy consumption.

**Distribution of Office and DGR Buildings and Floor Area by Location**

PNNonRES data on the location of each sampled building can be used to analyze the regional distribution of commercial activity. The ZIP areas for each building were assigned to climate zones, electric utilities and categories of development density. The density categories were defined by calculating the number of commercial establishments per square mile for each ZIP, then using that density to categorize the ZIP as rural, suburban, or urban. While these categories are somewhat arbitrary, they do serve as useful indicators of commercial density.

With 58 percent of the region's buildings (129,000 buildings) and 63 percent of the floor area (1,132 million square feet), the state of Washington contains more commercial activity than all other states in the region combined. Washington and Oregon together account for 85 percent of the region's buildings (192,000 buildings) and 90 percent of the region's floor area (1,596 million square feet). Not surprisingly, roughly two-thirds of the region's building stock is located west of the Cascades, where most of the region's major population centers are found.

As Table 2.2 shows, this geographical distribution is even more extreme for Office buildings. Almost 24,000 office buildings, 89 percent of the regional total, are located in Washington or Oregon; these two states account for 96 percent of the total regional Office floor area. Most of this activity is concentrated west of the Cascades: Western Washington and Oregon contain 69 percent of the region's Office buildings and 85 percent of the region's Office floor space. Finally, regional Office activity is concentrated in large buildings in the region's urban centers: urban areas (as determined by the density of commercial establishments) contain 21 percent of the region's Office buildings, but over half of the Office floor area. In contrast, rural areas account for 40 percent of the region's Office buildings, but these buildings tend to be relatively small and they comprise only 14 percent of the regional floor area.

The Dry Goods Retail (DGR) sector is geographically distributed similarly to the commercial sector as a whole. Two thirds of the region's DGR floor area and 60 percent of the buildings are located West of the Cascades, and more than half of total regional DGR buildings and floor area are located in Washington. Not surprisingly, the largest proportion of DGR activity is in suburban areas: these areas contain 42 percent of DGR buildings and 52 percent of floor area.

TABLE 2.2

**Office and Dry Goods Retail:**
**Building and Floor Area Measures**
**by Geographic Area**

| | OFFICES | | | | DRY GOODS RETAIL | | | |
|---|---|---|---|---|---|---|---|---|
| | Buildings | | Floor Area | | Buildings | | Floor Area | |
| | Buildings | Percent of Total | Floor Area (million sqft) | Percent of Total | Buildings | Percent of Total | Floor Area (million sqft) | Percent of Total |
| STATE | | | | | | | | |
| Washington | 15,400 | 58 | 232 | 71 | 21,900 | 52 | 152 | 55 |
| Oregon | 8,300 | 31 | 81 | 25 | 14,100 | 33 | 96 | 35 |
| Other NW States | 3,000 | 11 | 14 | 4 | 6,500 | 15 | 30 | 10 |
| CLIMATE ZONE | | | | | | | | |
| East of Cascades | 8,400 | 31 | 50 | 15 | 16,900 | 40 | 91 | 33 |
| West of Cascades | 18,300 | 69 | 277 | 85 | 25,600 | 60 | 186 | 67 |
| DENSITY | | | | | | | | |
| Rural | 10,700 | 40 | 44 | 14 | 16,600 | 39 | 76 | 28 |
| Suburban | 10,400 | 39 | 102 | 31 | 17,900 | 42 | 144 | 52 |
| Urban | 5,600 | 21 | 181 | 55 | 8,000 | 19 | 57 | 20 |
| REGIONAL TOTAL | 26,700 | 100 | 327 | 100 | 42,500 | 100 | 278 | 100 |

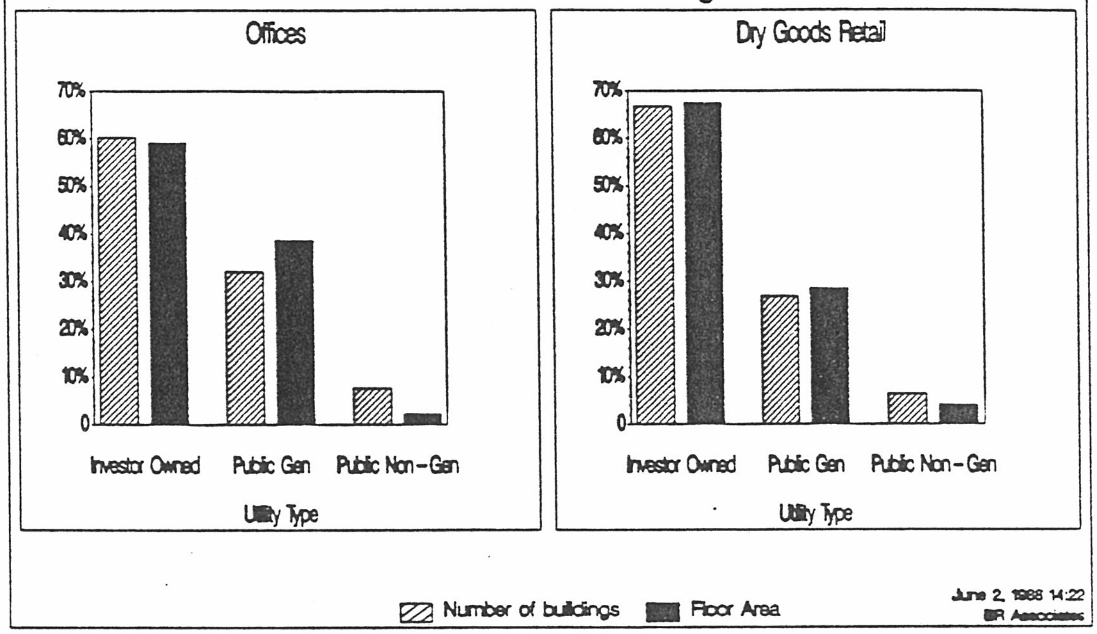
## Distribution of Office and DGR Buildings and Floor Area by Utility Type

The distribution of commercial activity by utility type is of interest to utility planners. These data, combined with information on the size and age distribution of Office and DGR buildings, can be used to more precisely identify important segments of the office and DGR building market for demand-side programs.

In PNNonRES, information about utility type was obtained at the ZIP level. The electric utility serving the majority of each sampled ZIP area was identified and mapped into one of the three utility types shown in the figures below. All enumerated buildings in a ZIP area were then assigned to the utility type designated for that ZIP area.

Approximately 60 percent of the region's office floor space and buildings are served by investor-owned (private) utilities (see Figure 2.3). Most of the remainder is served by public generating utilities. This is not surprising, since these two utility types serve virtually all of the region's medium and large urban areas.

FIGURE 2.3
Buildings and Floor Area by Utility Type
in the Pacific Northwest Region




The DGR sector shows a similar distribution. Two thirds of DGR floor space and buildings are served by private utilities (see Figure 2.3). Most of the remainder is served by public generating utilities.

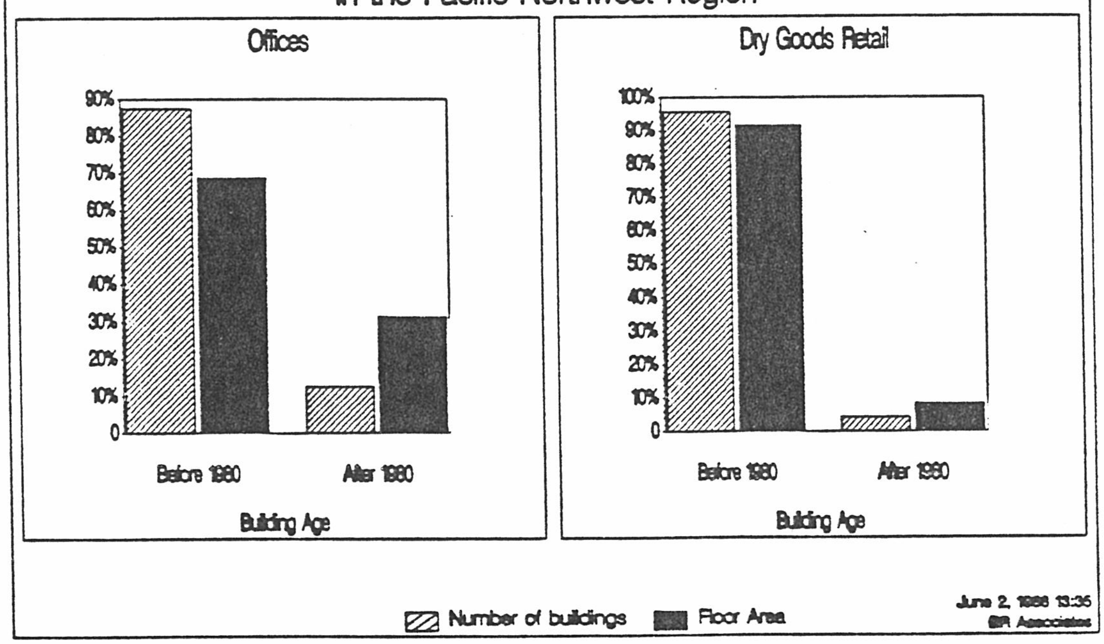
**Distribution of Office and DGR Buildings and Floor Area by Vintage**

As part of the PNNonRES enumeration process, all commercial buildings in the PNNonRES sample were assigned into one of two vintage categories: those built prior to 1980 and those built during or after 1980. In cases where the age was uncertain, the surveyors attempted to verify age via a follow-up phone contact with a building manager or maintenance person. In some cases the building was under construction, or the age was truly unknown.

The desire to divide the stock into pre- and post-1980 vintage groupings is motivated by several related concerns. First, there are significant differences in construction practices and equipment between the two vintages, which determine the applicability of demand-side programs. One such change in building practices is the introduction of more stringent commercial building codes during the post-80 period. Second, buildings of these two vintage categories have somewhat different levels of energy usage.

Figure 2.4 shows estimates of regional Office and DGR buildings and floor area by vintage, as of mid-86. In both cases, the majority of regional buildings (85 percent of Offices, 94 percent of DGR buildings) were constructed before 1980. In the case of DGR, a roughly proportionate amount of floor area (89 percent) was constructed before 1980. However, offices show a much different distribution of floor area across vintage categories. Only 15 percent of Office buildings have been constructed during or after 1980, but these buildings represent 34 percent of total office floor space. Thus office buildings constructed since 1980 are much larger than those constructed prior to 1980. Further examination of the figures reveals that the mean building size in offices constructed before 1980 is 9484 square feet. In contrast, office buildings constructed in 1980 or later averaged 27,834 square feet. This represents almost a tripling in size of the average office building between the two vintage groups.

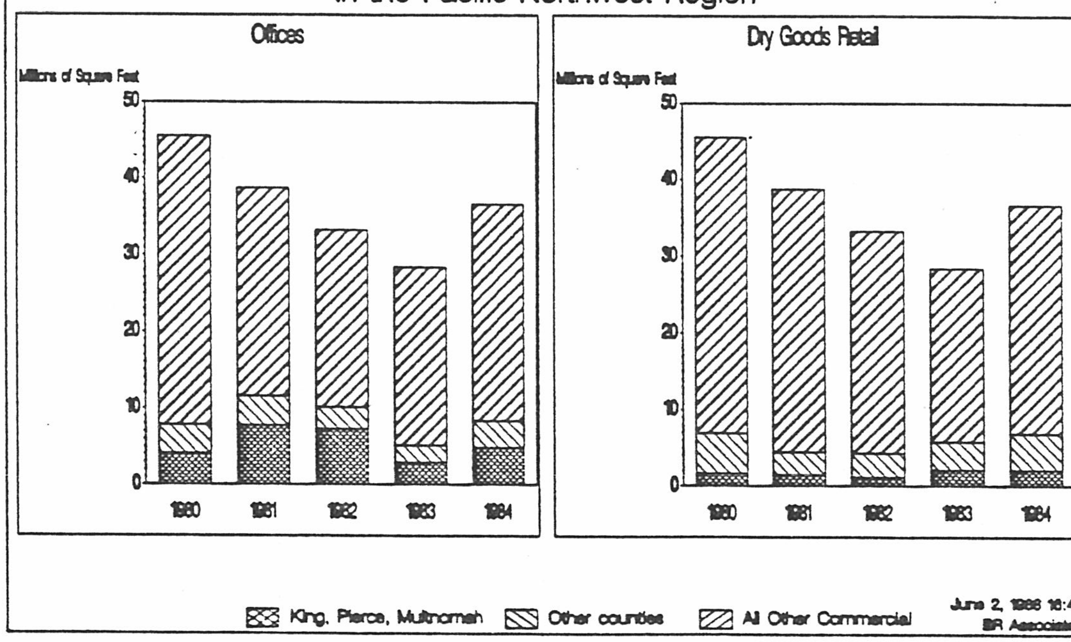
FIGURE 2.4
Buildings and Floor Area by Building Age
in the Pacific Northwest Region



## 2.3 ESTIMATION OF NEW CONSTRUCTION ACTIVITY, 1980 - 1984

Figure 2.5 presents information on commercial construction activity in the region and its three largest counties, King (Seattle), Pierce (Tacoma), and Multnomah (Portland) for the period 1980-84. The figure clearly shows the effect of the 1982 recession upon the region's construction activity, with recovery from the recession observable in 1984. Over the five-year period, office construction accounted for 24 percent of total commercial construction activity, as measured in terms of floor area. Dry Goods Retail accounted for an additional 16 percent. Office construction was concentrated in King, Pierce, and Multnomah Counties, with 63 percent of the 1980-84 office construction activity occurring in those three counties. In 1985, the three counties contained 29 percent of the region's population. In contrast to the office sector, only 30 percent of dry goods retail construction took place in the region's three largest counties during the 1980-84 period.

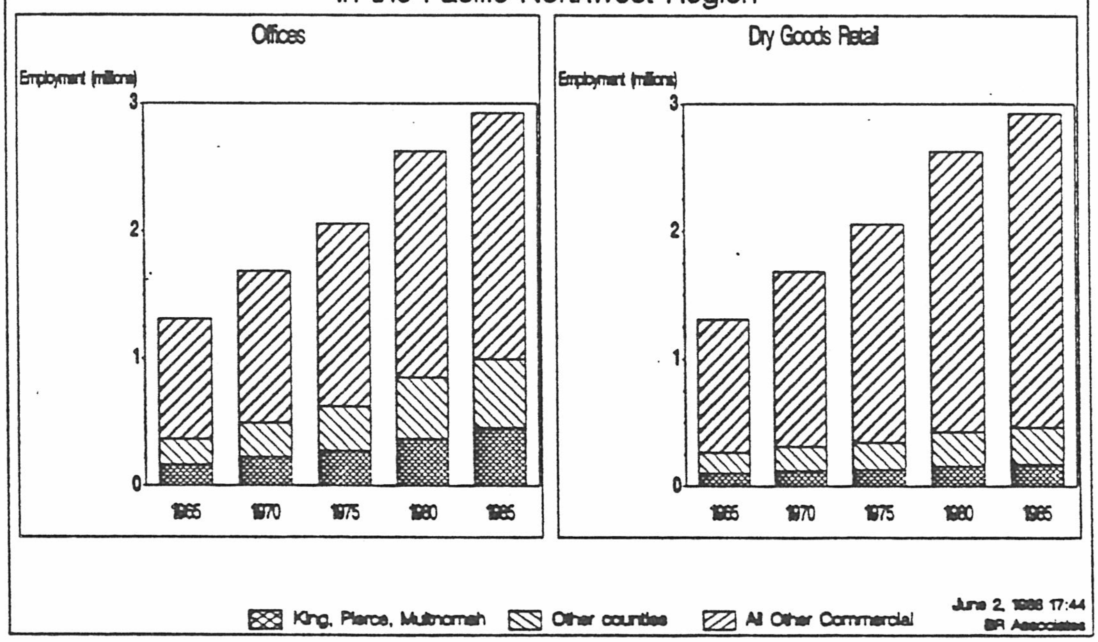
FIGURE 2.5
Commercial Construction Activity 1980 – 1984
in the Pacific Northwest Region



## 2.4 TRENDS IN OFFICE AND DGR EMPLOYMENT

Commercial employment in the region more than doubled during the period 1965-1985, increasing from 1.31 million to 2.93 million (see Figure 2.6). Office employment grew even more rapidly than total commercial employment, increasing by 171 percent, while Dry Goods Retail employment increased by only 76 percent. In 1985, Office employment accounted for 34 percent of total commercial employment, and Dry Goods Retail employment for an additional 16 percent. Commercial employment was concentrated in the region's three largest counties, King, Pierce, and Multnomah. With 29 percent of the region's population in 1985, these three counties accounted for 40 percent of the region's commercial employment, 46 percent of its Office employment, and 38 percent of its Dry Goods Retail employment. Over the 20 year period 1965-85, the three counties' share of the region's Office employment remained constant, while their share of total commercial and Dry Goods Retail employment declined. Thus, not only is Office employment concentrated in large urban areas, but it also is maintaining its concentration in those areas over time.

FIGURE 2.6
Commercial Employment 1965–1985
in the Pacific Northwest Region



# 3

# Electricity End-use Consumption Patterns

Reliable estimates of regional hourly consumption by end use are a valuable analysis tool for answering questions about the nature of consumption in commercial buildings. For example, hourly end-use data can be used to evaluate the impact on regional consumption of changes in commercial buildings (e.g. adoption of new HVAC systems), or utility policy (e.g. promotion of efficient lighting systems). In addition, regional forecasting models require estimates of consumption at an hourly or end-use level.

Until this time, reliable hourly estimates of commercial building electricity consumption by end use have been unavailable. However, three newly available data sets have enable us to develop reliable estimates of regional commercial consumption patterns. These data sets are:

- *ELCAP (BPA's End-use Load and Conservation Assessment Program)* -- provides characteristics data and hourly end use and total loads data for a sample of commercial buildings located mainly in the SCL service area

- *SCLCDB (Seattle City Light Commercial Database)* -- provides characteristics and hourly total loads data for a sample of commercial buildings in the SCL service area

- *PNNonRES (Pacific Northwest Non-Residential Energy Survey)* -- provides regional commercial building characteristics.

These data sets were combined to develop regional end use and total hourly load profiles for Office and Dry Good Retail buildings. The approach used is based on the concept that if a sample is assumed to be representative of a population, then simple ratios can be used to extend data from the sample to that population. The ratio between some known quantity from the population and the corresponding quantity from the sample is embodied in a weight. Data from the sample can then be weighted to produce population level estimates.

In this analysis, we used a two-stage estimation process:

1. *Develop estimates for the SCL service area* -- Starting with the SCLCDB and ELCAP data, we developed total load and end-use profiles for the SCL service area. The weights used to extend the building-level data to the SCL population were based on ratios of total annual electricity consumption.

2. *Develop estimates for the Pacific Northwest region (BPA's service area)* -- Starting with the profiles for the SCL service territory, we developed total load and end use profiles for the region. The total load profile was based on SCLCDB, while the end use shares were derived from ELCAP. The weights used to extend SCL level data to the region were based on ratios of floor area.

This chapter documents the development of the regional energy consumption estimates. (A more complete documentation can be found in *Development of Preliminary Regional End-use Loads Estimates*, BR Associates, Feb. 1988.) First the data sets used in the analysis are briefly described. Then each of the two estimation steps are explained. Finally, the regional estimates are presented.

## 3.1 DESCRIPTION OF DATA SETS

A combination of four separate data sources provided the data necessary to develop regional hourly energy consumption estimates. This section provides a brief overview of each of these data sets.

### ELCAP

The End-use Load Conservation Assessment Project (ELCAP) involves the hourly monitoring of end-use loads in 115 commercial sites, 85 of which are located in the Seattle City Light service territory. Each of these sites was also thoroughly audited. As a result, the ELCAP study provides us with the most detailed combination of end-use loads and characteristics data available in the region. 56 of the ELCAP sites are Office or Dry Goods Retail buildings.

The majority of the ELCAP sites were selected in a two-stage stratified random sample. This sample was then supplemented with additional buildings constructed since 1980 and with BPA Commercial Audit Program (CAP) buildings located in six cities throughout the region.

An ELCAP site consists of one building, or part of one building. For each site, hourly data are being collected for approximately 20 end uses, including heating, cooling, ventilation, auxiliary HVAC, mixed HVAC, interior lighting, exterior lighting, service hot water, refrigeration, and a variety of other specialized end uses. In this analysis, these end uses were aggregated to HVAC, Lights and Other. The loads data used in the analysis are from the year spanning July 1986 to June 1987.

Characteristics data were collected for each site during a thorough audit of the site. Data were collected at the building, tenant and zone level. For this analysis, data for the Office and Dry Good Retail sites were aggregated to the site (building) level. Summary variables that were derived included floor area, primary HVAC type, and primary space heat fuel type.

**Seattle City Light Commercial Data Base (SCLCDB)**

Seattle City Light maintains ongoing monitoring of a sample of its commercial customers. Presently, the hourly total load is being monitored at about 500 sites in the SCL service territory. This sample is useful because it is a larger sample than ELCAP, but was selected from the same population as ELCAP. The consumption data from the SCLCDB provides an opportunity for comparison and validation of the more detailed ELCAP data.

Most of the meters in the SCLCDB were selected for monitoring in order to fulfill PURPA reporting requirements. This sample was supplemented with small and medium consumption meters, which were underrepresented in the original sample, and with meters for very large customers, which are used for billing purposes.

An SCLCDB site was identified as all buildings served by an hourly meter, and all other meters serving those buildings. Thus an SCLCDB site may consist of one or more buildings, and may include several conventional meters (for which monthly or bimonthly data are available) in addition to the hourly meter that defines the site. Data from all meters at a site were combined to produce an hourly profile that maintained the original hourly data's shape, but with increased consumption at each hour. Thus, the hourly consumption data for each SCLCDB site represent all consumption at the site. In this analysis, we used consumption data from mid-1985 to mid-1986 (unfortunately, data for the time period corresponding to the ELCAP data were not available).

The site level characteristics available for the SCLCDB sites include floor area, space heat fuel type, number of tenants, and primary electric HVAC system (for buildings with electric space heat). In addition, each site was classified by business type according to the BPA definitions developed for PNNonRES.

**Pacific Northwest Non-Residential Energy Survey (PNNonRES)**

The Pacific Northwest Non-Residential Energy Survey (PNNonRES) is a two-stage survey undertaken by BPA to provide a statistically robust assessment of commercial building characteristics in the Northwest. This survey is discussed in detail in Chapter 2. PNNonRES provides the best available source of regional commercial building characteristics. It is used in the estimation process to generalize the estimates obtained for the SCL service area to the entire region.

**Seattle City Light Commercial Sector Sales**

Seattle City Light maintains a billing records database for its commercial customers. This database includes monthly or bi-monthly consumption and an SIC code for each commercial meter. Commercial consumption estimates for the year 1986 were derived from this database by aggregating individual meters in the population by building type and consumption strata. These aggregations represent commercial population consumption for the SCL service territory, and provide the basis for extending detailed building-specific data to the SCL service territory.

## 3.2 ESTIMATING TOTAL CONSUMPTION FOR THE SCL SERVICE AREA

The first stage in estimating regional hourly energy consumption entailed developing estimates for the SCL service area from the ELCAP and SCLCDB data sets. The estimation process involved both ELCAP and SCLCDB data sets because they complement each other. SCLCDB is a larger sample than ELCAP and is a consumption-based sample. It therefore provides more statistically reliable estimates for the SCL population. However, ELCAP is the only source of hourly end use data.

This section discusses the methodology used to derive the SCL population level class load shapes from ELCAP and SCLCDB building data. Four steps were involved, each of which are briefly described below.

**Step 1: Prepare Site Level Data**

ELCAP and SCLCDB loads and building characteristics data for Office and DGR sites were extracted and processed to develop site level characteristics and hourly consumption data. Sites were then screened to remove those that were unsuitable for analysis.

Hourly loads data for all Office and Dry Goods Retail sites were extracted from the full ELCAP and SCLCDB data bases. Missing values were estimated for the data when necessary. For each site, a file consisting of one record for each month-daytype-hour combination was created. The daytype categorization used was weekday/weekend for both building types. These files became the basis for all subsequent analysis.

Building characteristics data were extracted for each of the Office and DGR buildings. The data were then cleaned and aggregated to the site level (to correspond to the loads data). The primary site level characteristics thus obtained included: building type, floor area, space heat fuel, vintage and number of tenants.

All sites were then screened to remove those that were unsuitable for analysis. Sites were removed for the following reasons:

- Missing all loads or characteristics data
- Inadequate loads data -- In the case of ELCAP, sites were dropped if more than 35 percent of the hours were originally missing and required filling. In the case of SCLCDB, sites were dropped if less than 33 percent of the total consumption at the site was recorded on the hourly meter, or if the building type assigned by SCL to the hourly meter differed from the building type assigned to the site as a whole.
- Specific screens -- Specific sites were screened out for various reasons. ELCAP sites located East of the Cascades, and ELCAP buildings with more than one monitored site were removed, as were sites with anamolous data for one or more of the major end uses. In SCLCDB, several sites that were obvious outliers (extremely low or high annual EUIs, evident on plots) were removed.

The screening removed about 40 percent of the SCLCDB sites, and 50 percent of the ELCAP sites. The ELCAP data set used in the analysis contained 15 Office buildings and 12 Dry Goods Retail buildings (a total of 27 buildings), while the SCLCDB data set contained 69 Office buildings and 19 Dry Goods Retail (a total of 88 buildings).

**Step 2: Calculate SCL Population Weights**

Treating ELCAP and SCLCDB separately, consumption-based weights were developed to generalize from individual sites to the SCL population. Weights were developed for each combination of building type and consumption strata. Each building in a stratum received the same weight.

First, ELCAP and SCLCDB sites were classified by building type (Office or Dry Goods Retail) and consumption. The consumption dimension was included in order to be able to develop different weights for small and large buildings within a building type. Consumption was used as a measure of size because the available SCL population data consists of annual consumption. Using the total annual consumption, each site was allocated to one of three consumption strata. The exact consumption ranges covered by each stratum varied for ELCAP and SCLCDB, and for building types within ELCAP. The goal in setting the stratum ranges was to have a roughly equal number of sites in each stratum, and to have no empty strata.

Second, our measure of the SCL population, the SCL database of all commercial meters in the service territory, was separated into identical building type and consumption strata. The SCL commercial meters corresponding to Office and Dry Goods Retail were classified by building type and divided into consumption strata that exactly corresponded to those used to classify the ELCAP and SCLCDB buildings.

Third, the total consumption was calculated for each stratum. This was done by separately summing the annual consumption for all the ELCAP buildings in a stratum and all the SCLCDB buildings in a stratum. Similarly, total consumption was calculated for each stratum in the SCL population of commercial meters.

Finally, sample-to-SCL population weights were calculated separately for each building type and stratum within each data set. For each stratum, the sample-to-SCL population weight is calculated as the ratio between total SCL population consumption in a stratum and total sample consumption in that stratum. All buildings in a stratum received the weight calculated for that stratum.

**Step 3: Develop SCL Class Total Load Shapes**

Once weights were calculated, they were used to develop SCL class level load shapes from the individual building data. Separate load shapes were developed from each set of building data (one set from ELCAP, one set from SCLCDB). Each set of building data was used to develop an Office and a Dry Goods Retail SCL class load shape.

The class load shapes were developed by multiplying each building's hourly load profile by its weight to obtain building-level load profiles weighted to the SCL population, and then summing these weighted load shapes for all the buildings in a given building type. This process aggregates buildings across consumption strata to generate class load shapes by building type from each data set.

The use of weights that are related to consumption strata ensures that the buildings with high consumption do not obscure the buildings with low consumption. Small buildings have higher weights than larger buildings, which helps to balance out the differences in consumption. The resultant aggregate load shape provides a representative picture of large and small consumers combined.

**Step 4: Compare SCLCDB and ELCAP Based Class Load Shapes**

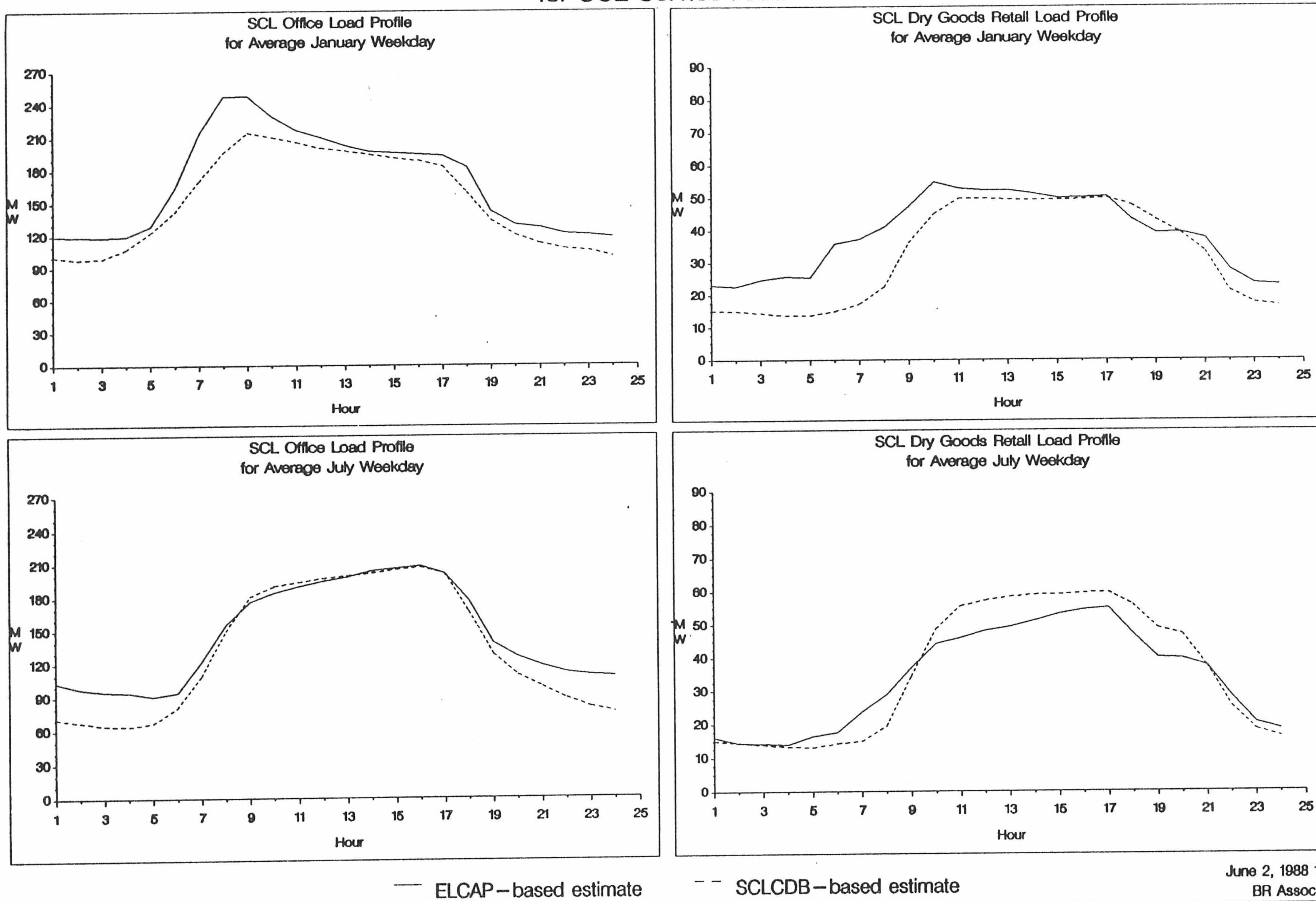
Since the SCLCDB sample of buildings is much larger than the ELCAP sample, we have assumed that the hourly total loads data from the SCLCDB provides the best available representation of SCL class load shapes. The class load shapes derived from ELCAP can be compared with those derived from SCLCDB to determine whether ELCAP provides a good representation of the SCL population.

Figure 3.1 shows typical class load profiles for Office and for Dry Goods Retail for the Seattle City Light population. Two plots are shown for each building type: typical January weekdays and typical July weekdays. Each plot contains two load shapes. One is the population total load based on ELCAP, and the other is the population total load based on SCLCDB.

Unfortunately, the time periods represented by the two data sets are not identical. The SCLCDB data represent the period of September 1985 to August 1986. The ELCAP data represent the period of July 1986 to June 1987. The class load profiles shown below depict only January and July. Of these months, January of the ELCAP year (1987) was considerably colder than January of the SCLCDB year (1986). July 1986 is used in both data sets.

FIGURE 3.1

# ELCAP vs. SCLCDB Load Profiles for SCL Service Area

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A comparison of the ELCAP-based and SCLCDB-based profiles on each plot reveals several general patterns. On each plot, the shapes of the two profiles tend to be quite similar, and the timing of the daily peak is also similar. However, notable differences in magnitude occur in some of the plots.

In the two Office plots, the ELCAP-based and SCLCDB-based load profiles show very similar shapes, especially during operating hours. In the January plot, the ELCAP-based profile shows a significantly higher morning peak. Most likely, this is due to the fact that the January represented by the ELCAP data was colder than that represented by the SCLCDB data, thus necessitating additional HVAC use to warm the buildings in the morning. In July, the two profiles match virtually exactly during operating hours. During the non-operating hours of both months, the ELCAP profiles show a consistently higher level of demand. This consistent difference is seen in weekend profiles also. It may be partially caused by the difference in typical building size in the two samples. The office buildings in the ELCAP sample generally are much smaller than those in the SCLCDB sample. It is likely that smaller buildings are operated less efficiently than larger buildings (i.e. controls systems are not as prevalent, and less attention is paid to scheduling the operation of HVAC and lighting), resulting in a smaller difference in loads between operating and non-operating hours.

The SCLCDB-based and ELCAP-based Dry Goods Retail profiles also show very similar shapes. In January, ELCAP demand is higher than SCLCDB demand in the morning hours, probably due to additional heat required because of the colder weather during the ELCAP January. Shape and magnitude are very similar for the remaining January hours. The July plot shows the two profiles to have roughly similar shapes, but different magnitudes during operating hours. This difference is most likely due to data limitations such as the small sample size, and filled loads data for one ELCAP site for the month.

In general, though the ELCAP sample is considerably smaller than the SCLCDB sample (particularly for Office buildings), the ELCAP data provides a good representation of Office and Dry Goods Retail consumption for the Seattle City Light service area. In addition, though the distribution of building size is significantly different in the two samples, the class load shapes are remarkably consistent.

## 3.3 ESTIMATING REGIONAL TOTAL AND END-USE CONSUMPTION

The second stage in estimating regional hourly energy consumption entailed extending the estimates for the SCL service area to the region. Ideally, in generalizing results from one population to a larger population, we would like to be able to consider a variety of factors that affect consumption and that may be distributed differently in the two populations. Currently, however, the only available source of regional characteristics data is the first stage of PNNonRES, which contains data on floor area by building type. Therefore the only adjustment that can be made at this time to reflect differences between SCL and the region is to adjust for differences in the distribution of floor area. All other factors, such as fuel saturations, hours of operation, lighting capacity and HVAC system type, have to be held constant until data from the second stage of PNNonRES are available. Thus the weighting method used in this stage is based on floor area.

Since PNNonRES enables us to distinguish between Large and Small buildings within each building type (based on BPA's definition, Large DGR includes all buildings over 20,000 sqft, and Large Office includes all buildings over 30,000 sqft), we have developed regional load shapes using this distinction. Regional class load shapes were developed from the SCLCDB data for Large and Small Office, and for Large and Small DGR. End-use shares were calculated from the ELCAP data for each of these four BPA building types, and these shares were applied to the SCLCDB based load shapes to obtain end-use class load shapes.

This section discusses the methodology used to derive the regional class load shapes from the SCL population level estimates. Three steps were involved, each of which are briefly described below:

**Step 1: Calculate Regional Weights**

Treating ELCAP and SCLCDB separately, floor area-based weights were developed to generalize from the SCL population to the region. Weights were developed for each combination of building type and floor area strata. Each building in a stratum received the same weight.

First, ELCAP and SCLCDB sites were classified by BPA building type (Large Office -- more than 30,000 sqft, Small Office -- less than 30,000 sqft, Large Dry Goods Retail -- more than 20,000 sqft, Small Dry Goods Retail -- less than 20,000 sqft). These building types were further divided into size strata based on floor area. These divisions were included in order to be able to develop different weights for small and large buildings within a BPA building type. Floor area was used as a measure of size because the best available representation of regional characteristics are the floor area estimates from PNNonRES. Using total floor area, each site was allocated to one of three consumption strata. The exact floor area ranges covered by each stratum varied for ELCAP and SCLCDB, and for each BPA building type. The goal in setting the stratum ranges was to have a roughly equal number of sites in each stratum, and to have no empty strata.

Second, our measures of the regional population were the regional floor area estimates provided by the first stage of PNNonRES. We selected all PNNonRES Office and DGR buildings, divided them into Large and Small groupings based on their floor area, and then assigned them to the floor area size strata used for ELCAP and SCLCDB.

Third, the total floor area was calculated for each stratum. Once ELCAP and SCLCDB buildings were classified by BPA building type and floor area size strata, the total floor area, *weighted to the SCL population*, was calculated for each stratum. The sample-to-SCL population weights described in Section 3.2 were applied to each building, and the weighted floor area for each building in a stratum wassummed to provide an estimate of the total SCL floor area in each stratum. Total regional floor area for each stratum was obtained from the PNNonRES data. Weights developed for the first stage of PNNonRES were applied to each PNNonRES building, and the weighted floor area was summed for all buildings in a stratum.

Finally, SCL-to-region weights were calculated separately for each building type and stratum within each dataset. For each stratum, the SCL-to-region weight is calculated as the ratio between total regional floor area in a stratum and total SCL floor area in that stratum. All buildings in a stratum received the weight calculated for that stratum.

**Step 2: Develop Regional Class Total Load Shapes**

Estimates of regional total hourly loads were derived by applying both the sample-to-SCL weights described in Section 3.2 and the SCL-to-region weights described above to the SCLCDB hourly data. The SCLCDB data set was chosen for this purpose because its SCL population estimates are thought to be more reliable than those derived from ELCAP. Regional load shapes were developed for Large and Small Office and for Large and Small Dry Good Retail.

The regional class load shapes were developed by multiplying each SCLCDB building's hourly load profile by its combined weight (sample-to-SCL weight multiplied by SCL-to-region weight) to obtain building level load profiles weighted to the region, and then summing these weighted load shapes for all the buildings in a given BPA building type. This process aggregates buildings across consumption strata and floor area strata to generate regional class load shapes by BPA building type.

**Step 3: Develop Regional End-use Shares from ELCAP**

Since ELCAP is the only available source of hourly end-use data, it was used to develop end-use shares for HVAC (includes heating, cooling, and ventilation), Lights (interior) and Other, which could then be applied to the regional total load shapes generated in Step 2.

Estimates of regional end-use hourly loads were derived by applying the combined weights to the ELCAP hourly data. Regional load shapes were produced by end use for each of the four BPA building types. These regional end-use loads were then recalculated as a percentage of total load by dividing each end-use observation by the corresponding total load for that hour. The percentage end-use shares were then applied to the total load shapes derived from the SCLCDB to obtain end-use profiles for each building type.

## 3.4 RESULTS: REGIONAL TOTAL AND END-USE LOADS

This section presents regional end-use energy consumption estimates for Small Offices, Large Offices, Small Dry Goods Retail, Large Dry Goods Retail, and for all Offices combined and all Dry Goods Retail combined. Estimates are provided at the annual, monthly and hourly level. Finally, Office and Dry Goods Retail peak day loads are depicted.

When examining these results, it is important to keep several points in mind. First, the sample sizes used to develop these estimates are small. The SCLCDB sample, from which the total load estimates were developed, is particularly small for Small Office and Small DGR. The ELCAP sample, from which the end-use splits were developed, is particularly weak in Large Office and Large Dry Good Retail, and all the ELCAP Office buildings used in this analysis have electric space heat. Second, these results are preliminary. The end-use splits are based on one year of ELCAP data (all that was available when we began this analysis), and the extrapolations to the region are based strictly on floor area (no other regional characteristics are currently available). Third, since all of the buildings used in this analysis are located in the Seattle area, these results are based on Seattle weather. Finally, given the small sample sizes and the absence of regional data on fuel saturations and other characteristics, we have chosen not to disaggregate the results by space heat fuel type.

**Annual Loads**

Table 3.1 depicts regional end-use EUIs (energy use intensities, in kBtu/sqft) and end-use shares for each of the four building types we analyzed.

**Table 3.1**

**Regional End-Use EUIs by Building Type (kBtu/sqft)**

| | END USE | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | HVAC | | LIGHTS | | OTHER | | TOTAL | |
| | EUI | Pct | EUI | Pct | EUI | Pct | EUI | Pct |
| OFFICE | | | | | | | | |
| Small: < 30,000 sqft | 24.0 | 52 | 18.9 | 41 | 3.2 | 7 | 46.1 | 100 |
| Large: > 30,000 sqft | 39.9 | 51 | 31.9 | 40 | 7.1 | 9 | 78.9 | 100 |
| All | 33.2 | 51 | 26.4 | 41 | 5.4 | 8 | 65.0 | 100 |
| DRY GOODS RETAIL | | | | | | | | |
| Small: < 20,000 sqft | 13.6 | 31 | 26.0 | 59 | 4.3 | 10 | 43.9 | 100 |
| Large: > 20,000 sqft | 15.4 | 19 | 52.8 | 75 | 3.8 | 5 | 82.0 | 100 |
| All | 14.3 | 24 | 41.6 | 69 | 4.1 | 7 | 60.0 | 100 |

In Offices, HVAC and interior lighting are roughly equivalent in energy consumption, with HVAC accounting for 50 percent and lighting accounting for 40 percent of the total EUI. The Other end use category typically accounts for 8 percent of total consumption. These figures implicitly assume a 100 percent saturation of electric space heat; all of the ELCAP Office buildings used to develop the end-use splits have electric space heat.

In Dry Goods Retail buildings, interior lighting is the dominant end use, accounting for 60 to 70 percent of total electricity consumption. HVAC requires

20 to 30 percent of total consumption, while Other uses 7 percent. The end-use estimates shown for Small Dry Goods Retail imply a 45 percent saturation of electric space heat; 4 of the 9 ELCAP buildings have electric space heat. The Large Dry Goods Retail end-use estimates imply a 33 percent saturation of electric space heat; 1 of the 3 ELCAP buildings is electrically heated.

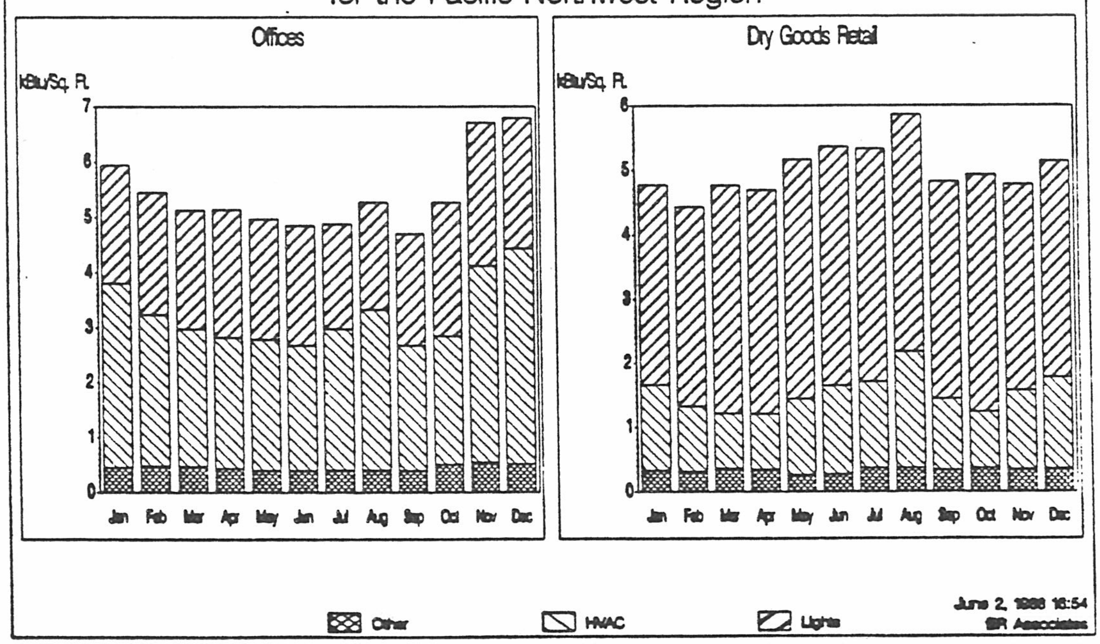
It should be noted that the estimates obtained for Large Dry Good Retail are based on very limited data (14 SCLCDB and 3 ELCAP buildings). In particular, the use of end-use splits from predominately non-electric buildings to partition total consumption has resulted in overestimation of the lighting EUI.

**Monthly Loads**

Figure 3.2 depicts monthly consumption by end use for Office and Dry Goods Retail buildings. Consumption has not been weather normalized, it represents the time period spanning July 1985 to June 1986. The estimates represent regional monthly electricity use for a building type, normalized by regional floor area for that building type. Consumption estimates are in kBtu/square foot.

Both graphs show some variation in monthly consumption, primarily due to HVAC, but the majority of consumption remains constant from month to month.

FIGURE 3.2
End-Use Consumption by Month
for the Pacific Northwest Region



Offices show a base monthly consumption of about 4.7 kBtu/sqft, which is 70 percent of the peak month's consumption (6.8 kBtu/sqft in December). This base level of consumption consists primarily of lighting (47 percent) and HVAC (43 percent). The base HVAC component (HVAC consumption that remains constant from month to month) includes non-temperature sensitive HVAC equipment such as ventilation fans and pumps, as well as some mix of heating and cooling. The variation seen across months in Offices is virtually entirely due to variation in HVAC consumption. HVAC loads are at a minimum in September, when temperatures are moderate and little heating or cooling is required. They reach a maximum in December, due to high space heat requirements. Note that this graph reflects a 100 percent saturation of electric space heat.

The Dry Goods Retail graph also shows a significant amount of base consumption that remains constant from month to month, and some monthly variation due to HVAC. In Dry Goods Retail buildings, the base portion of monthly consumption is about 4.5 kBtu/sqft. It consists primarily of lighting (80 percent). The main source of variation in monthly consumption is the HVAC load. HVAC consumption is highest in summer months, when cooling demand is large. Peak monthly consumption (5.8 kBtu/sqft) occurs in August.

In comparison to the Offices plot, the Dry Goods Retail plot shows relatively little HVAC consumption, especially during winter months, and much higher lighting consumption. There are several likely reasons for this. First, DGR buildings tend to have large lighting loads. These lighting loads provide high internal gains, which help to offset heating loads. DGR buildings may also be more likely than Offices to use ventilation rather than cooling in summer months, reducing summer HVAC loads. In addition, less than 50 percent of the Dry Goods Retail buildings used to obtain the end-use splits shown here have electric space heat, while 100 percent of the Office buildings used have electric space heat. Thus, the impact of heating on monthly HVAC consumption is smaller for the DGR buildings.

### Hourly Load Profiles

Figures 3.3 through 3.6 show regional hourly end-use consumption profiles (in MW) for each of the four BPA building types. Each figure includes four plots: January weekday and weekend, and July weekday and weekend.

Certain general patterns can be seen in all of the plots. First, total hourly electricity demand is significantly higher during building operating hours (e.g. roughly 8 to 6 on weekdays) than during non-operating hours. This pattern is so pronounced, one can make conclusions about typical operating schedules based on the hourly profiles shown here. For example, Offices typically are not occupied on weekends, while Dry Goods Retail buildings do show operation on weekends.

FIGURE 3.3

# Regional Large Office Load Profiles
## By End Use

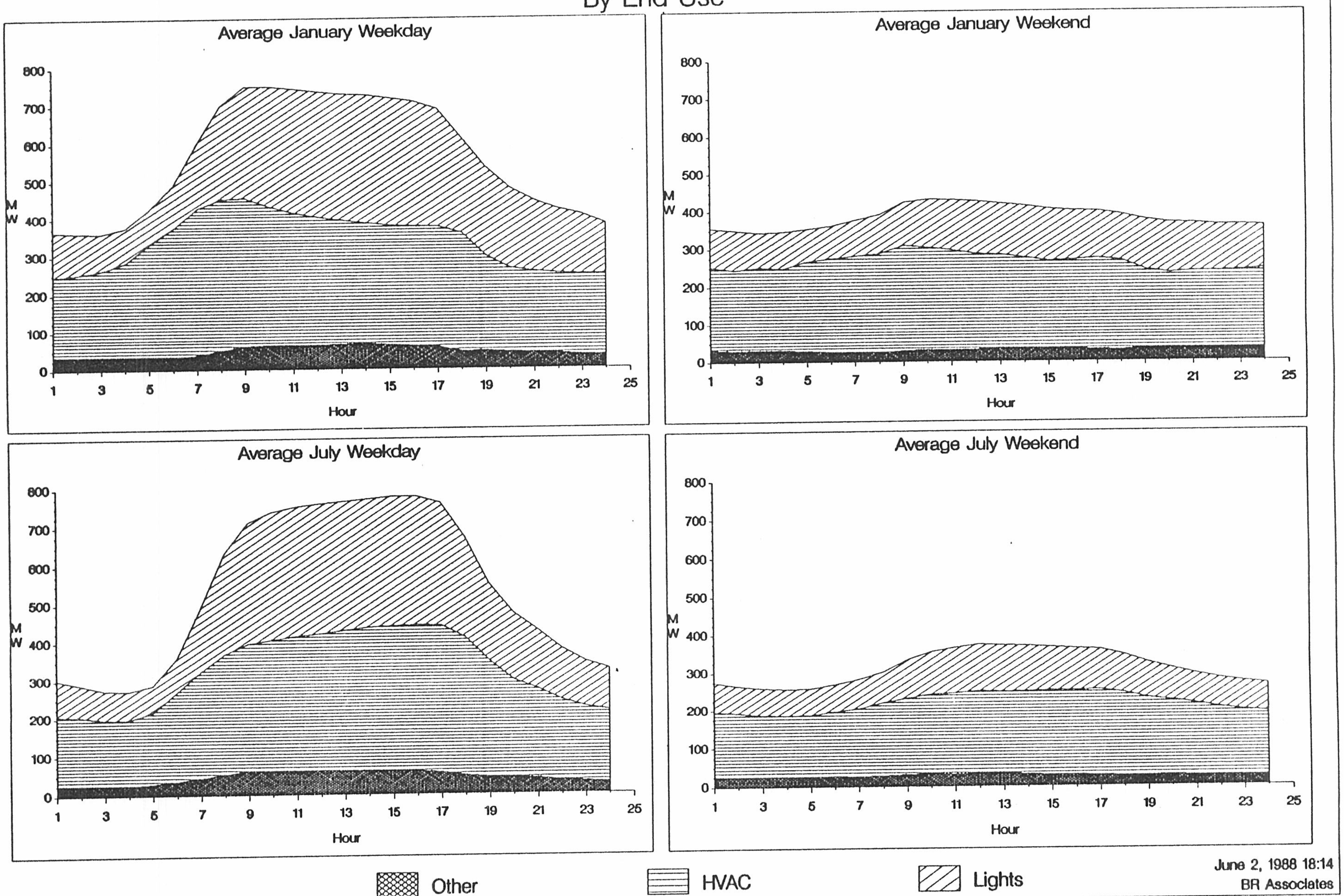


FIGURE 3.4

# Regional Small Office Load Profiles
## By End Use

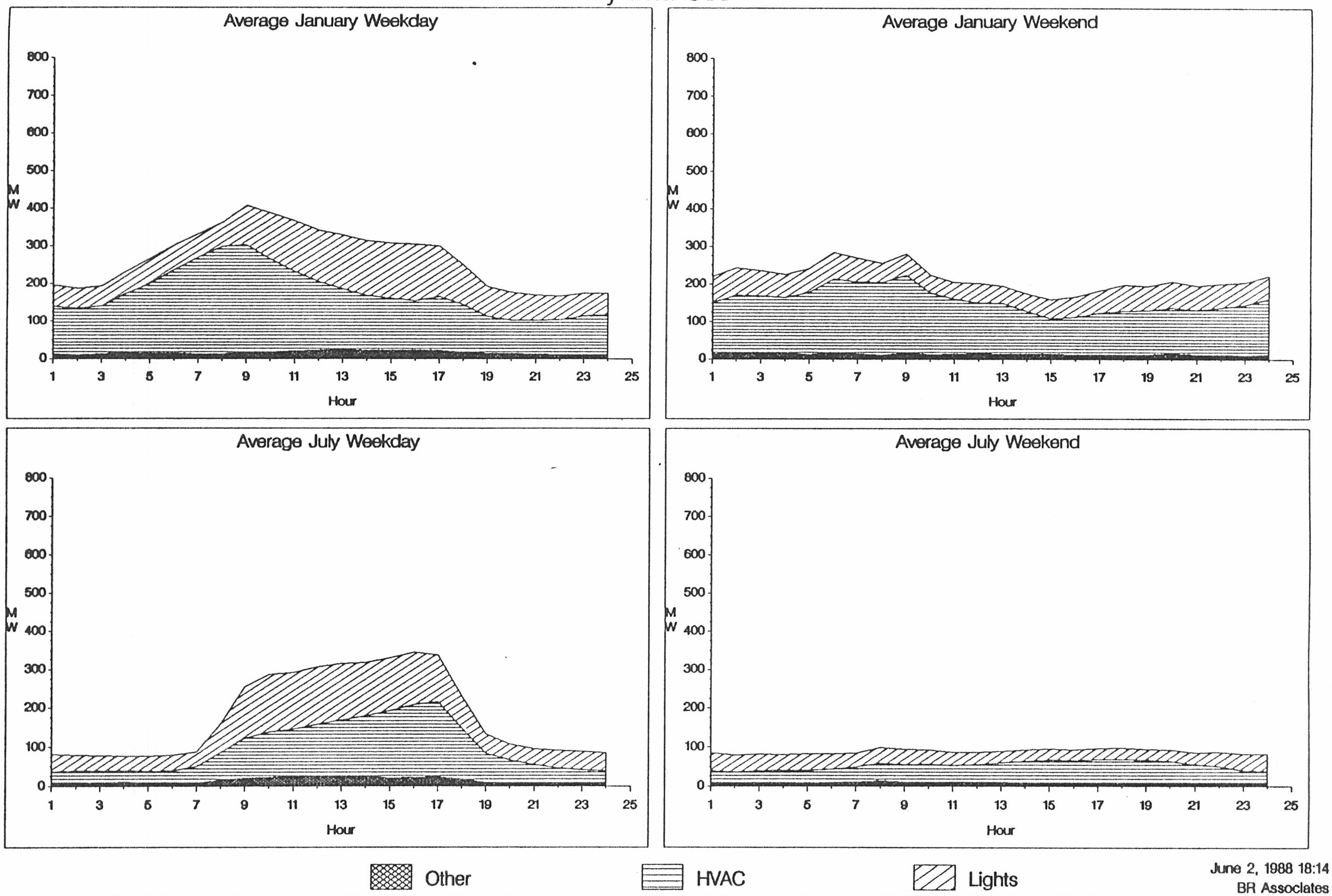


FIGURE 3.5

# Regional Large Dry Goods Retail Load Profiles
## By End Use

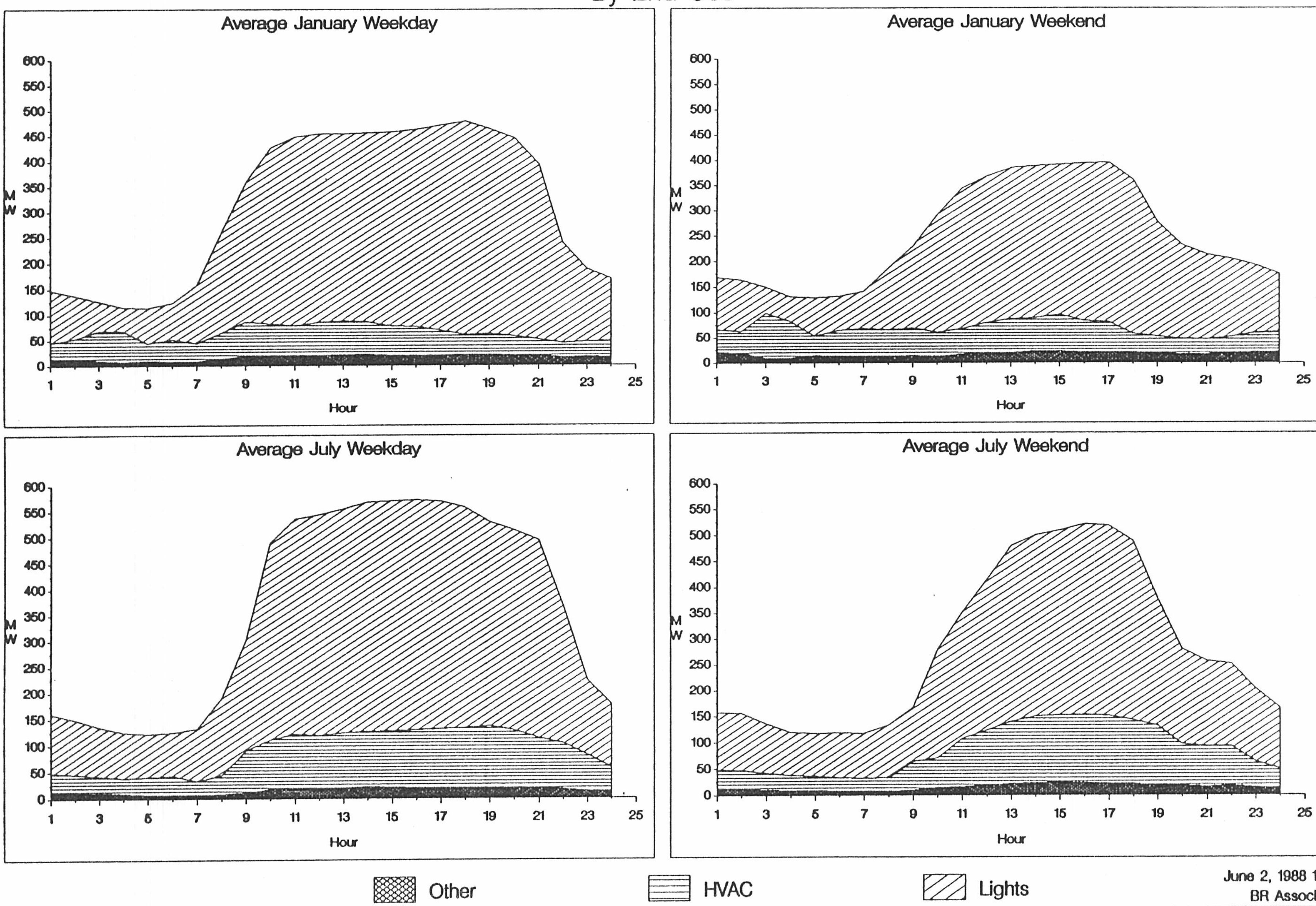



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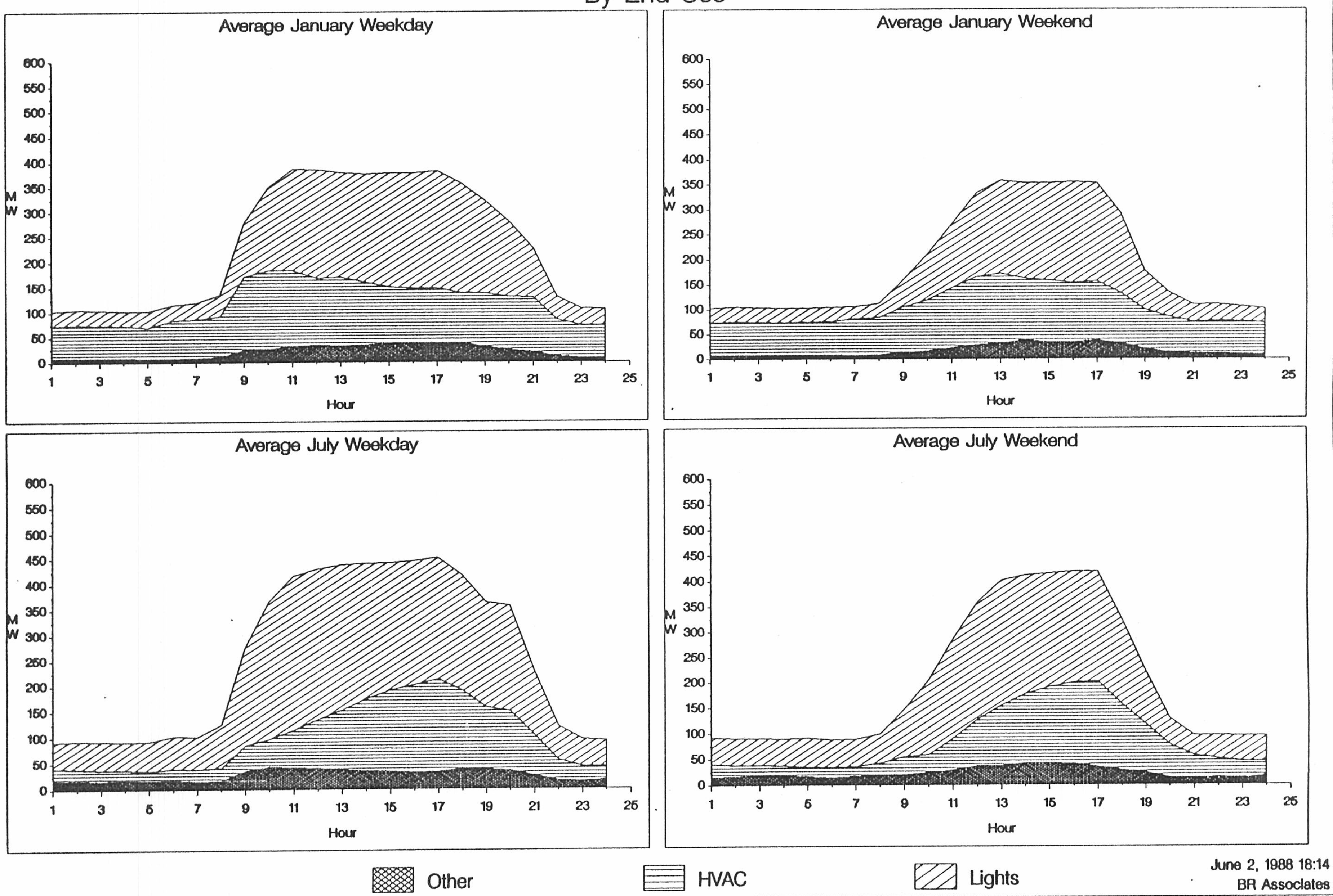
FIGURE 3.6

# Regional Small Dry Goods Retail Load Profiles

## By End Use



Second, each end use load shows a typical pattern. HVAC, which includes heating, cooling and ventilation, shows higher loads during operating hours than during non-operating hours. In winter (January), HVAC loads peak in the morning, when heat is needed to warm up the building. In summer (July), HVAC peaks in the afternoon, when cooling loads reach a maximum. Interior lighting demand is strongly related to operating schedule. During non-operating hours lighting remains constant at a relatively low level; during operating hours lighting loads remain constant at a much higher level. In comparison to the other end uses, demand for Other is quite small. It too shows a relatively constant level during operating hours and a lower constant level during non-operating hours.

Figure 3.3 shows typical load profiles for the region's Large Offices (office buildings with more than 30,000 square feet). On weekdays, hourly demand during operating hours remains relatively constant at about 700 MW, while demand during non-operating hours levels off at 375 MW in the winter and 300 MW in the summer. The January peak of 750 MW occurs at 9 AM, and is caused by morning warm-up heating requirements. January HVAC shows a clear peak in the morning, tapering off later in the day. The July peak of 775 MW occurs at 4:30 PM, and is caused by large cooling requirements. Lighting loads increase significantly as buildings open in the morning (about 8 AM) remain constant all day, then decrease as buildings close in the evening (about 6 PM). Weekend loads in Large Offices look very similar to loads seen during the non-operating hours of weekdays. This indicates that Offices are generally not occupied during the weekend.

Figure 3.4 shows typical load profiles for the region's Small Office buildings (office buildings with less than 30,00 square feet). In general, these building show sharper HVAC peaks than the Large Offices, which in turn cause sharper total peaks. This is because HVAC loads in smaller buildings tend to be more sensitive to temperature effects. On January weekdays, Small Office loads peak at 400 MW at 9 AM, due to morning heat requirements. HVAC loads then fall off significantly throughout the day, as internal gains offset heating loads. Lighting remains constant from 9 AM to 5 PM. During non-operating hours, demand remains at a constant 200 MW. On July weekdays, Small Office loads peak at 350 MW at about 5 PM. The HVAC load is probably dominated by cooling throughout the day, peaking in late afternoon. Loads remain steady at 100 MW during non-operating hours. As was the case for Large Offices, low weekend loads indicate that the buildings are generally unoccupied during the weekend. The increased consumption seen in the morning hours on January weekends is probably due to a limited morning warm-up effect caused by HVAC systems operating even when the buildings are unoccupied.

Figure 3.5 shows typical load profiles for the region's Large Dry Goods Retail buildings (DGR buildings with more than 20,000 square feet). These profiles are obviously different from those seen for Offices; they are dominated by lighting, and operating hours (as reflected by higher loads) are 9 AM to 9 PM. January weekday demand during operating hours is about 475 MW. Although HVAC demand peaks in the morning, the total peak occurs at 5 PM, apparently due to increased lighting loads in the late afternoon and evening (remember that only one third of the buildings used to develop these end-use splits have electric space heat, so the morning heat effect is less pronounced than in Offices). July weekday demand during operating hours is about 550 MW, occurring at about 4 PM. HVAC loads remain relatively constant throughout the day, and probably consist mostly of cooling. Lighting loads are very high (about 400 MW) during operating hours in both January and July. The weekend profiles indicate that Large Dry Goods Retail stores are open on weekends, but for shorter hours than on weekdays. Loads are similar for all operating hours and for all non-operating hours, regardless of whether we look at weekday or weekend profiles. Thus the weekend /weekday distinction is much less meaningful for Dry Goods Retail than for Offices.

Figure 3.6 shows typical load profiles for the region's Small Dry Goods Retail buildings (DGR buildings with less than 20,00 square feet). In winter, loads peak at 475 MW at about 11 AM, and then remain at that level throughout the day. HVAC peaks at 10 AM. In summer, total loads peak at 450 MW at 5 PM; this peak is caused by cooling requirements. During non-operating hours, loads remain constant at about 100 MW. Again we see sharper HVAC peaks in Small DGR than in Large DGR, due to the increased sensitivity to temperature effects in small buildings. The weekend profiles show that the DGR buildings are occupied on weekends, but operating hours are shorter.

**Peak Day Load Profiles**

BPA must provide enough resources to meet the system demand on the peak day. Information about subsector demand for the system peak day helps identify loads that could be managed in order to reduce peak system demand. Figure 3.7 shows hourly loads for the total regional system and the Office and Dry Goods Retail sectors for the day of peak consumption in 1986 (December 10, 1986).

Both the system and Offices had late morning peaks. The system peak occurred at 8 AM, while Offices experienced peak demand for a three hour period beginning at 9 AM. The Office peak is driven by morning warm-up heat requirements. At the system's peak hour, demand in Office buildings accounted for 5 percent of total system loads. The system also shows a late afternoon peak, a profile typical of residential demand. Office demand does not peak at that time.

Dry Goods Retail consumption showed an almost steady load from 11 AM to 9 PM. At the system's peak hour, demand in DGR buildings accounted for only 2 percent of total system loads. DGR reached its peak well after the system loads peak occurred. However, demand in DGR buildings represents 3 percent of the system's afternoon peak.

In general the system peak is apparently driven more by residential than by commercial consumption, since the peak profile is more similar to a residential profile than to a commercial profile. Therefore load management efforts in Office and Dry Goods Retail buildings will not significantly reduce the system peak, though they could reduce overall system demand to some extent.

FIGURE 3.7
Peak Day Load Shapes