SCHEDULES AS A PRIMARY DETERMINANT OF ENERGY USAGE AND COST OF SERVICE IN COMMERCIAL BUILDINGS

ABSTRACT

This research examines the importance of scheduling in the determination of total energy use, the temporal distribution of use and the cost of service. Four archetypes of diurnal and seasonal end-use load shapes are proposed; two of which are primarily determined by the building and equipment schedules (Figure 1A) and two of which are primarily determined by ambient temperatures and the thermodynamic characteristics of the building (Figure 1B). These archetypes are used to describe the interaction between schedules and the lighting, equipment, heat and cooling loads in the determination of end-use consumption and variation in use. The diurnal and seasonal load shapes for the total building load are shown to be the product of the shapes of the dominant end use(s) as shown in the examples of actual building loads in Figure 1A and Figure 1B.

The concepts of schedule and temperature-determined variation in loads are then empirically examined using available ELCAP data on commercial buildings. Hourly end-use loads for five buildings of differing types are examined and compared with the archetypes. The contribution of each of the archetypes to total building energy use are evaluated for the five buildings. A method for quantitatively representing schedules and modeling their impact on variability in building energy use is described. This method is used to estimate the share of variability in energy use attributable to schedules alone. This method is also shown to be a good predictor of end use and total building hourly energy use.

The primary findings of the research are that building and equipment operating schedules are a dominant force in determining building energy usage, load shapes, and the cost of service for those buildings analyzed. This outcome is attributable to five factors, each of which can be represented by one of the four archetypal load shapes in Figure 1.

- Non-heat end uses (principally lighting), which are operated on schedules corresponding to the building service hours (Figure 1A), accounted for greater than 75% of total energy consumption in the buildings analyzed. As a consequence, any expansion or reduction to the number of hours of operation would result in significant changes to both total energy consumption and load shape.

- Ventilation systems, where present, appeared to be controlled independently of the operation of the heating or cooling equipment. These ventilation systems were operated on schedules which corresponded to the building's service hours, in a manner similar to lighting.

- Refrigeration, where present, represented almost a constant load which reacted minimally to changes in outside temperature (Figure 1A).
• Heating and cooling systems are also found to be operated in conjunction with the building service hours, either through system shut-down during off hours, or through extreme setbacks/setups of thermostat settings during off hours. Significant internal gains attributable to waste heat from lighting and other equipment served to further restrict the heating requirements to the early morning hours, prior to the start-up of this equipment. The result was a characteristic heating spike for the buildings analyzed (Figure 1B).

• Cooling systems were found to function primarily as a means of removing the waste heat generated by lighting or other equipment, and secondarily in response to changes in outside air temperature. As a result, the diurnal load shape of the cooling load tended to correspond closely to that of lighting and/or other major equipment (Figure 1B).

As a consequence of these factors, the buildings analyzed exhibited hourly load surfaces which correspond generally to three-dimensional box-car forms. In cases where cooling loads were small, the load surface fit the first archetype quite closely (Figure 2). More complex buildings displayed significant interactions between lighting and cooling, resulting in substantial mid-morning and afternoon cooling, such as the example in Figure 3. In both cases, heating loads were seen in the form of an early morning spike of limited duration.

Reference to the hourly commercial load surface for a major Pacific Northwest utility, Seattle City Light, suggests that the dominant role of scheduling in determining seasonal, day of week, and diurnal load shapes seen in this analysis is present for the commercial sector as a whole (Figure 4). This pattern is in distinct contrast to the residential non-heat sector, which contains a comparable saturation of electric resistance space heating to the commercial sector in this utility, but whose load surface is greatly affected by ambient temperature, water supply temperatures, and the number of hours of daylight (Figure 4).

The second major finding of the research is that building and/or major equipment schedules accounted for 50-80% of the variation in hourly building loads from mean consumption for the study period. Simple scheduling functions used to examine the contribution of schedules to variance also produced predictors of diurnal load shapes which corresponded closely to average hourly load shapes.

The general conclusion of the research to date is that more attention should be devoted to assessing how schedules impact energy use, load shapes, and cost of service in the commercial sector. These questions are particularly important to the conduct of forecasting and conservation analysis. For example, estimates of the economic value of conservation savings in the commercial sector are extremely sensitive to the hourly distribution of the savings, which in turn is dependent on building and equipment schedules.

Opportunities exist to better represent schedules in commercial sector analysis through the acquisition of simple scheduling information in conjunction with other building characteristics. This information is essential to the process of generalizing the hourly conclusions of the ELCAP study to the remainder of the Pacific Northwest region.
A. Non-Temperature Sensitive -- Determined by Service Hours

**Archetype** | **Examples**
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Lites Equip | Warehouse
Fans Refrig | Grocery

B. Temperature Sensitive -- Determined by Service Hours, Internal Loads and Outside Temperature

**Archetypes**

- Heat
  - Church

- Cooling
  - Dry Good Retail

Figure 1
Archetypal Load Shapes
Figure 2
Seattle Warehouse: Building and End-Use Load Surfaces
Figure 3
Seattle Dry Good Retail: Building and End-Use Load Surfaces
Seattle City Light Residential and Commercial Hourly Loads

SCL Commercial Average Hourly Load Profile by Month
July 1, 1980 to June 30, 1981

SCL Residential Nonheat Average Hourly Load Profile
January 1, 1980 to December 31, 1980

Figure 4
Seattle City Light Residential and Commercial Hourly Loads