REMODEL AND TENANCY CHANGES: THREATS TO THE RELIABILITY OF COMMERCIAL CONSERVATION SAVINGS

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Changes in commercial building energy use result from schedule changes, remodels, and vacancies followed by new tenants. The frequency and magnitude of those changes have substantial implications for conservation programs and resource planning. Changes may shorten conservation measure lives or affect savings. This report discusses the findings of an analysis of the frequency of changes in a sample of 106 buildings that were end-use metered under the End-use Load and Consumer Assessment Program (ELCAP). The sample includes offices, drygoods retail, groceries, restaurants, warehouses, schools, and hotels. Two years of metered data, site visit records, and audit data were examined for evidence of building changes. Changes were then classified into 11 categories including business type, equipment, remodel, schedule, etc. Key questions analyzed included: frequency of types of change; relationship to vintage and floor area; variation by building type; and, energy impacts of changes. The basic finding of this analysis is that change rates in commercial buildings are high--fifty percent of the buildings had at least one type of change during the two years for which monitoring results were analyzed. Examples from Bonneville's Energy Edge and Commercial Incentives Pilot Program corroborate the frequency of changes found in the ELCAP commercial sample. This report will conclude with suggestions for additional analysis.

INTRODUCTION

Bonneville Power Administration (Bonneville) considers the commercial sector to be an important energy resource. As the region shifts towards an electricity deficit, Bonneville's energy efficiency acquisitions in this sector will ramp up from 3 average Megawatts (aMW) in fiscal year 1991 to 10 aMW in fiscal year 1995. Bonneville has a keen interest in understanding the dynamics of the commercial sector to plan programs that are effective in acquiring resources at cost effective prices. Bonneville has observed a substantial rate of change in buildings retrofitted in commercial programs and in a commercial building sample metered under the End-use Load and Consumer Assessment Program (ELCAP). Changes in commercial sector buildings are a two edged sword--they provide both cost advantaged opportunities to acquire conservation and a threat to the measure life of already installed measures.

The effect of renovation and remodel on opportunities for cost advantaged conservation and measure life has been explored in several instances (Ecotope 1989; Gordon 1988). This paper attempts to add to that body of knowledge by summarizing the results of research by Pacific Northwest Laboratory (Lucas 1990) under contract to Bonneville by analyzing the potential application, relating findings to the changes in Bonneville's commercial program sample, and suggesting research to clarify outstanding issues.

RESEARCH QUESTIONS

This section of the paper summarizes and distills the results of an analysis performed by Pacific Northwest Laboratory (PNL), under my management. The analysis was designed to address the following research questions:

- What types of changes are observed in commercial buildings?
- With what frequency do various types of changes occur?
- How does the frequency of changes vary by building type?
- Are there relationships between rates of change and building vintage or floor area?
- Are any end-use loads or conservation measures particularly affected by changes? Are there any that are largely unaffected by, or "immune", to the change problem?
- What are the impacts of changes on energy use, particularly end-use loads?

SOURCE OF DATA IN ELCAP

The 143 sites in the ELCAP commercial sample provide an excellent opportunity for a study requiring time series data. Primarily located in the Seattle area, the offices, retail, grocery, restaurants, warehouses, schools, universities, and hotels have been end-use metered for 2 years. In addition to the metered load data, the analysis relied on records of site visits, site equipment maintenance records, and data quality verification records. Day typing analysis also contributed to the study. These five sources of information were reviewed individually, and then combined to provide as comprehensive as possible a basis for determining the timing of the change events and categorizing them. Three of the sources actually exist to help support the maintenance and quality of the load data base. One source is site "relations" records, which track building ownership and tenancy. An ELCAP staff person maintains current building access agreements so that project metering equipment can be maintained. A second source is site maintenance records which include reports on metering hardware failures or modifications, and their causes. Frequently, this has occurred when equipment was added or changed in the building. Data quality verification records, the third data source, are notes on discrepancies found through the automated sum checking process. This process checks the amount of power entering the metered electrical service panel versus the total amount of power measured by end-use. Fourth, the load data themselves are a major source of information, particularly with dramatic shifts in loads resulting from vacancies. Analysis of day-of-week schedules of metered buildings led to the development of day type definitions, with indications of average load levels during each day type. This fifth data source can be summarized in day type tables to identify changes in building operation schedules.

DATA REVIEW

Scanning these multiple records, the analysts were able to detect and confirm changes in the buildings. The site maintenance, load data, and other records were reviewed independently to identify changes in the buildings. In many cases, combining the load data and other data explained the change in the building. In some cases load changes were unexplained by the other data sources. In others, multiple changes occurred and a dominant "theme" had to be chosen. To structure the 263 changes found, 12 types of change were defined. Eight of these categories are change in: business type, tenancy, full vacancy, partial vacancy, fuel type, equipment, remodel, and schedule. The four remaining change types are changes in load only, or redistribution of end-uses within the buildings' electrical system. These are unclassifiable loads, where a load change cannot be categorized by other data sources; load reconfiguration; change in load distribution without a net change in total consumption; electrical distribution change without any load change; and short lived unclassifiable spikes. Each change event was placed into one of the 12 categories shown in Table 1. The categories were ordered in terms of decreasing effect on building energy use.

Table 1. Change Events and Their Definitions

Change	Definition
Business Type	The business conducted at the site changes to another type business (conversion of the majority of the floor space in a site with mixed tenant business types).
Tenancy	A tenant changes, but the business type (predominant type for mixed use sites) does not. A change in tenant or business type may follow a full or partial vacancy, and the impact is, in this case, defined in terms of the previous tenant, not the vacancy period.
Full vacancy	The site becomes entirely vacant.
Partial vacancy	One or more tenant zones of the site become vacant.
Fuel type	Conversion between electricity and another fuel for an end use.
Equipment	HVAC, lighting, or plug load equipment (including refrigeration and food preparation) is added, changed, or removed.
Remodel	The building undergoes a structural change; e.g., a floor plan change, a change of ceiling, wall, window, or roof components, or an addition to, or conversion of, existing space.
Schedule	The hours of operation per day or the operating days of the week change.
Unclassified load	A change is identified in the load data but not confirmed by any of the record sources.
Reconfiguration	A load change in which loads are moved from one end use to another in the metering plan for a building, resulting from project data reconstruction/data processing activities or a change to the electrical distribution system by the owner/manager. There is no net change to the building total consumption.
Electrical change	The owner or building management changes the electrical distribution system in a way that affects the metered data quality checks, but no load changes are evident.
Unclassified spike	A short-lived change, usually of one or two months duration, identified in the load data but not confirmed by any of the record sources.

(Lucas, et al. 1990)

DATA PROCESSING

For each site the raw data included the frequency of each change event, the source used to detect the change, and suspected cause of the change. All data were then consolidated. Table 2 shows a summary of the raw data. The raw data were next organized by building type. For each type of building function a table was developed showing the number of changes in each category plus the total. It also included the number of months of end-use data available for each site. For example, in the 28 offices, the available data ranged from a low of 28 months to a high of 47 months. Because the length of time each building was metered varied, the data were normalized by the fractional number of years of data available for that building. This put all sites on a level playing field. Then a simple average was computed across sites by change type. The resulting number is the average number of changes per site per year, assuming changes were to occur on a random basis.

Table 2. Changes Observed in Commercial Buildings over a Two-Year Period

	Numbers of Observed Changes by Type												
Building Type	1[(a)]	2	3	4	5	6	7	8	9	10	11	12	Total
Offices (n = 28)	1	5	1	11	0	29	4	0	20	0	1	9	81
Dry Good Retails (n = 28)	1	2	1	5	0	29	3	0	17	0	0	9	67
Groceries (n = 19)	1	2	3	0	0	14	0	0	13	0	2	1	36
Restaurants (n = 15)	1	1	1	0	0	10	0	0	10	0	3	4	30
Warehouses (n = 14)	0	4	1	3	0	9	3	1	6	0	0	1	28
Schools (n = 4)	0	0	0	0	0	0	0	0	0	0	0	1	1
Universities (n = 2)	0	0	0	0	0	2	0	0	0	0	0	1	3
Hotels/Motels (n = 11)	0	1	0	0	0	11	0	0	2	0	0	0	14
Other (n = 5)	0	0	0	0	0	1	1	0	1	0	0	0	3
Totals (n = 126)	4	15	7	19	0	105	11	1	69	0	6	26	263

(a) The types of changes examined in this analysis are as follows:

1 - business type	7 - remodel
2 - tenancy	8 - schedule
3 - full vacancy	9 - unclassified load
4 - partial vacancy	10 - reconfiguration
5 - fuel type	11 - electrical change
6 - equipment	12 - unclassified spike

For a small group of sites--about 25 percent of the total--the changes were discrete enough to identify the load effects. That is, a month of load data pre-and post-change event were available. Impacts for a particular change type and building were normalized by building floor area in order to obtain an average watts/square foot impact.

KEY FINDINGS

First, change events were scanned to determine the types of changes occurring in the ELCAP commercial sites. This preliminary review resulted in development of the change hierarchy described earlier. Analysis also determined that the overall rate of change was high, 50 percent of the sites had at least one type of change during the 2 years of end-use metering.

Next, changes were summed by change type to determine the frequency with which types of changes occur. Equipment changes were most common: Forty percent of the total number of changes, or 105 events. Twenty-five percent of equipment changes involved lighting and 17 percent involved heating and cooling systems. The remaining 60 percent involved refrigeration and miscellaneous small equipment.

Unclassified changes, approximately 30 percent of the total, were the second most frequently occurring type of change. These were observed in the load data, not identified by any other record. Therefore, it is difficult to explain their cause.

Occupancy changes (full or partial) were the third most frequent type of change. Partial vacancies occurred 79 times, tenant changes 15 times, full vacancies 7 times, and business type change 4 times. The reader should be aware that this includes associated remodeling, renovation, and equipment. Remodels without occupancy changes were the fourth most frequent changes. These involved structural changes. Only 11 remodel changes occurred, including full building structure renovations.

Relationship of Change Frequency to Building Type

Across all building types and all changes, offices changed the most. Changes occurred in offices once every 1.2 years. Retail stores followed closely behind offices in their frequency of changes at one change every 1.3 years. Groceries, restaurants, and warehouses had rates of change of once every 1.7 years. The frequencies of change types were cross tabulated by building type. This was done by creating a table of change types and their frequencies for each site within a building type. The total number each type of change for each site was divided by the number of months of data to yield an average number of changes per site year. The inverse would be the average number of year expected between changes. The overall relative frequencies of type of changes across all buildings is reflected within each building type. For example, overall, the most frequent change was equipment. This was also true in office buildings.

Equipment changes were greater in offices and retail stores than in groceries, restaurants, and warehouses. Offices and retails changed some equipment at the equivalent of once every 3 years, while in groceries, restaurants, and warehouses equipment was changed every 5 years. The high frequency of change reflects the intense use of miscellaneous equipment, such as computers. The lighting (25 percent) and heating/cooling equipment (17 percent) fractions can be used to extract the average rates of change by building type for these changes.

Offices and retail buildings changed their lighting systems at an average rate of .08 per site-year or about once every 12 years. Warehouses, groceries, and restaurants changed lighting at a less frequent rate of .05 per site-year, or about once in 20 years.

Heating and cooling equipment also changed more frequently in offices and retail. The rate of .054 per site-year represents a change about once every 18 years contrasted with the less frequent rate of change in warehouses, groceries, and restaurants (once every .034 years). This approximates a system lifetime of 28 years.

The second highest level of changes were not classifiable. These 95 events were observed in the end-use metered data, but the other data sources did not provide the basis for assigning a cause for the change. Given the sensitivity of the ELCAP data quality checks to any changes that effect the metering set up, it is likely that these are behavioral changes, such as hours of occupancy and of business volume rather than equipment changes.

Changes in building occupancy were the third most frequently occurring change. Occupancy changes vary in their level of effect by building type. Office, retail, and warehouse buildings became partially vacant more frequently than fully vacant. Typically, full vacancies included remodeling, involving restructuring of the building and potentially removing previously installed conservation measures, where as the partial vacancies found multi tenant did not usually involve major building restructuring. Partial vacancies occurred more frequently than full vacancies, reflecting the multi-tenant nature of most office buildings. Remodels follow as the fourth most frequent change. Dry Good Retails follow the overall pattern. In groceries, however, vacancies were always full, reflecting the single tenant nature of the business type.

Relationship of Change Frequency to Building Vintage and Size

To determine whether changes varied by building age and size, the analysis broke out frequencies by these factors. New buildings were defined as those constructed later than 1981 or after implementation of the Seattle Energy Code in 1980.

The breakout for large versus small buildings is shown in Table 3.

Equipment changes, the most frequent type identified, tend to occur equally across buildings regardless of vintage. Warehouses were the exception, with new warehouses experiencing equipment changes at twice the rate of old warehouses. Old and new warehouses were at opposite ends of the range of rates of change for equipment. No clear conclusions emerged when changes were arrayed by building size. Offices, retails, and groceries showed higher rates in larger buildings; however, restaurants and warehouses showed the reverse.

Table 3. Floor Area Breakpoints for Small/Large Commercial Buildings

Building Type	Breakpoint, ft^2
Office	10,000
Retail	20,000
Grocery	7,000
Restaurant	6,000
Warehouse	15,000
School	50,000
University	50,000
Hotel	20,000
Other	5,000

(Baker 1984)

Clear trends were shown in tenancy changes, where older office, retail, and warehouse buildings changed tenants more frequently than the newer buildings of the same type. Large office buildings experienced a higher frequency of tenancy change than did small office buildings. This trend was reversed in small retail, grocery, and warehouses.

Finally, small, new groceries and restaurants showed higher numbers of unclassified changes than older groceries and restaurants.

IMPACTS ON END-USES, ENERGY USE AND MEASURE LIVES

Assessing the energy impacts of changes proved to be a difficult task. Buildings changed so frequently that it was difficult to identify change events that had a month of pre-and post modification end-use metered data available. Seasonal and weather sensitive loads, primarily HVAC and refrigeration are extremely difficult to analyze. Even in a sample as closely tracked as is ELCAP, changes are not observed or reported in a timely manner.

Some building types and certain end-uses were affected more by the changes than others. The overall rate of change in office and retail buildings is remarkably high. While some changes are minor, the continual parade of changes in equipment, occupancy, etc., are cause for concern about the stability of efficiency measures.

In offices, for example, the changes in lighting equipment would be expected to occur on an average of once every 12 years. This contrasts with current assumptions of 15 year measure lives.

For each event with the requisite data the analyst calculated the difference between pre-change and post-change loads by end use. The categories were building total inside lights HVAC and other. To normalize for building size, the load impact was divided by floor area. This was done for groceries, offices, retail and restaurants. Given the standards for data available and quality very few events were available for analysis. The results are anecdotal. A few examples are: Buildings with equipment changes tended to show an increase in total load of point .1 to .3 watts per foot square. The unclassified changes showed a decrease in total building loads across all building types. Equipment changes tended to show an increase in total load of .1 to .3 W/ft^2. Most of this seems attributable to HVAC load increases. Predictably, full and partial vacancies showed decreases in consumption across all end-uses.

IMPLICATIONS AND IMPORTANCE OF FINDINGS

As mentioned in the introduction, Bonneville is interested in the frequency of changes in commercial sector buildings from two perspectives. One perspective is the loss of savings from a measure installed. From the perspective of a retrofit program, the rate of changes in commercial buildings is of concern, because the expected effective life of a measure may be shortened. It may be shortened by removal, or its impact affected by other changes in the building's equipment, schedules, etc. A fairly practical concern is the affect on audits. Audit recommendations may be inappropriate or inaccurate as changes affect the buildings energy use. Recent field work included site visits to 37 participating buildings. Commercial Incentive Pilot Program (CIPP) buildings were evaluated for 15 types of changes (Cambridge 1990). (Unfortunately, for purposes of this paper, the categories were different than those used in analysis.) The CIPP categories included: changes in hours of occupancy, measure disconnections, measure not replaced, equipment use, increase in business level, light equipment use, fuel type, envelope modification, SIC, heated area, HVAC setpoint, measure malfunction, incorrect audit, management, and building vacancy. The researchers developed these categories to help achieve their goal--to determine the reasons for discrepancies between audit predictions and actual savings. Sixty-one changes were determined to have occurred in the 37 buildings over the 2 year period. Sixty-three percent of the total changes occurred in 4 categories; hours of occupancy (10 changes); increased business volume (10 changes); increase and or change in equipment use (9 changes) and envelope modifications (8 changes). This compares plausibly with the ELCAP data where changes in equipment and renovation (structural or envelope modification) were first and fourth in frequency. ELCAP equipment is relatively less sensitive to changes in hours of occupancy and increased business volume, whereas CIPP would be more sensitive since it was based on field work. The CIPP visits found removal or replacement of measures on four instances, including one directly related to a vacancy. The study concluded that changes, particularly increases in lighting and equipment, effect energy use--frequently resulting in a net increase in consumption.

The second perspective is the timing of measure installation, and the effect of that timing on the cost and cost effectiveness of the measure. For example, under the CIPP, existing building owners had an opportunity for a free audit and partial payment for installed energy conservation measures. The energy savings for a retrofit project must justify the removal of old equipment, full societal cost of the measure, and its installation. Where buildings are being remodeled, the building owner has already budgeted for the basic costs of labor and materials to remove old equipment and purchase and install new equipment. Under these circumstances the energy savings must only justify the incremental costs between the original equipment and the more efficient equipment. The advantage is that individual measures can be installed at a lower effective cost. Also, at less-than-retrofit cost, a broader group of measures may become cost-effective. Because of the advantages of this window of opportunity, it is important for Bonneville's planning purposes to know how often it is open.

In the smaller Energy Edge program, 2 new buildings out of 27 had major changes in their first 2 years. For example, a grocery changed owners and doubled its lighting. A combination retail/office building had a portion of a floor totally renovated to accommodate a new tenant. Two other buildings have each had a vacant period. In addition, to end-use metering on some sites, Energy Edge buildings have field inspections every 6 months. This database should provide additional information on the frequency of changes in new buildings.

The trends found in the ELCAP, CIPP, and Energy Edge give us glimpses into the dynamics of the commercial sector, that, when combined with other analyses, will be able to improve DSM program planning, targeting, and management.

DIRECTIONS FOR FURTHER RESEARCH

The keys are to be able to determine specifically what the change event was and when it occurred. This can only be accomplished through site visits or tracking by building owners and managers. Because of the near term need for this information case studies of groups of buildings or strip malls under the same management may provide opportunities to assess whole building impacts of known changes. A revisit to the ELCAP commercial sample may also prove fruitfull. Battelle staff are currently re-surveying the sites analogous to an audit.

The field work plus the accumulation of additional load data should provide a better basis for future case studies of energy impacts of changes in commercial buildings.

REFERENCES

Baker, M. and P. Reiter 1984. *Commercial Sector Sample Design.* Baker Reiter & Associates. Seattle, WA.

Cambridge Systematics Inc., 1990 Evaluation of the Commercial Incentives Pilot Program, Draft Impact Evaluation Report, Chapter 3, Bonneville Task Order DE-AT79-88BP3987 Cambridge Systematics Inc., 2855 Telegraph Avenue, Suite 305, Berkeley, CA 94705.

Ecotope and Momentum Engineering 1989 Lost Conservation Opportunities created by Remodeling and Renovation in the Commercial Sector, Bonneville Power Administration, P.O. Box 3621, Portland, OR 97208.

Gordon F., Use of Commercial Energy Efficiency Measure Service Life Estimates in Program and Resource Planners. Proceedings of the *ACEEE 1988 Summer Study on Energy Efficiency in Buildings* Volume 3 August 1988, Santa Cruz, CA.

Lucas, R.G., Taylor, Z.T., Miller, N.E. and Pratt, R.G., 1990 "Characterization of changes in Commercial Building Structure, Equipment and Occupants" Pacific Northwest Laboratories (DOE/BP-13795), Richland, WA.