PNL--7361

DE91 005448

# END-USE LOAD AND CONSUMER ASSESSMENT PROGRAM

## CHARACTERIZATION OF CHANGES IN COMMERCIAL BUILDING STRUCTURE, EQUIPMENT, AND OCCUPANTS

R. G. Lucas
Z. T. Taylor
N. E. Miller
R. G. Pratt

December 1990

Prepared for
the Bonneville Power Administration
under a Related Services Agreement
with the U.S. Department of Energy
Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Richland, Washington 99352

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

## FOREWORD

Changes in commercial building structure, equipment, and occupants result in changes in building energy use. The frequency and magnitude of those changes have substantial implications for conservation programs and resource planning. For example, changes may shorten the useful lifetime of a conservation measure as well as impact the savings from that measure.

This report summarizes the frequency of changes in a commercial building sample that was end-use metered under the End-Use Load and Consumer Assessment Program (ELCAP). The sample includes offices, dry good retails, groceries, restaurants, warehouses, schools, and hotels. Two years of metered data, site visit records, and audit data were examined for evidence of building changes. The observed changes were then classified into 12 categories, which included business type, equipment, remodel, vacancy, and operating schedule. The analysis characterized changes in terms of frequency of types of change; relationship to building vintage and floor area; and variation by building type. The analysis also examined the energy impacts of various changes.

The analysis determined that the rate of change in commercial buildings is high--50% of the buildings experienced one type of change during the 2 years for which monitoring data were examined. Equipment changes were found to be most frequent in offices and retail stores. Larger, older office buildings tend to experience a wider variety of changes more frequently than the smaller, newer buildings.

The findings described in this document are intended as an information resource to conservation program planners in the region. Conservation resource planners and power forecasters may also find this information useful. Comments regarding the interpretation of the data presented, additional useful data summaries, or modification of existing data summaries should be directed to:

Ms. Frances Petersen
Bonneville Power Administration
P. O. Box 3621 - RPEE
Portland, Oregon 97208
(503) 230-5860

## ACKNOWLEDGMENTS

The analysis documented herein was conducted by the Pacific Northwest Laboratory (PNL) for the Bonneville Power Administration, Office of Energy Resources. This report reflects a team effort involving close collaboration between Bonneville and PNL; the authors wish to express their appreciation for the technical guidance and reviews provided by Bonneville's End-Use Research section staff members Megan Taylor and Rich Gillman.

The authors extend their thanks also to other PNL staff who contributed to this report's preparation: Eric Richman for preparing the graphic plots; Cynthia Selle for word processing; and Andrea Currie for writing various parts and editing the entire report.

## CONTENTS

Section


FOREWORD . . . . . iii

ACKNOWLEDGMENTS . . . . . v

1 INTRODUCTION . . . . . 1-1

2 KEY FINDINGS . . . . . 2-1

Frequency of Change by Building Type . . . . . 2-1

Frequency of Change by Change Type . . . . . 2-1

Equipment Changes . . . . . 2-2

Unclassified Changes . . . . . 2-4

Occupancy Changes . . . . . 2-4

Remodels . . . . . 2-4

Relationship of Change Frequency to Building Size and Vintage . . . . . 2-5

Impact of Changes on Energy Use . . . . . 2-6

3 ANALYSIS OVERVIEW . . . . . 3-1

Motivation . . . . . 3-1

Objectives . . . . . 3-2

4 METHODOLOGY . . . . . 4-1

The Commercial Building Sample . . . . . 4-1

Data Sources . . . . . 4-2

Data Verification Records . . . . . 4-2

Maintenance Records . . . . . 4-3

Site Relations Records . . . . . 4-3

Load Data . . . . . 4-4

**CONTENTS** contd

Section


Day Typing Analysis Results . . . . . 4-4

Change Event Definitions . . . . . 4-4

Approach . . . . . 4-7

Method of Tabulating Change Events . . . . . 4-7

Sample Chronology for a Small Warehouse . . . . . 4-8

5 RESULTS . . . . . 5-1

Observed Types and Frequencies of Change . . . . . 5-1

Change Frequencies by Building Type . . . . . 5-3

Offices . . . . . 5-6

Retails . . . . . 5-7

Groceries . . . . . 5-8

Restaurants . . . . . 5-10

Warehouses . . . . . 5-11

Schools . . . . . 5-13

Universities . . . . . 5-14

Hotels/Motels . . . . . 5-15

Others . . . . . 5-16

Observations Across All Building Types . . . . . 5-17

Variations in Change Frequencies with Building Vintage and Size . . . . . 5-20

Business Type Changes . . . . . 5-21

Partial Vacancies . . . . . 5-21

Tenancy Changes . . . . . 5-23

**CONTENTS** contd

Section


Full Vacancies . . . . . 5-23

Equipment Changes . . . . . 5-27

Remodels . . . . . 5-27

Unclassified Changes . . . . . 5-30

Impact of Changes on Energy Use . . . . . 5-30

Additional Information on Remodels . . . . . 5-32

6 REFERENCES . . . . . 6-1

APPENDIX A - DETAILED DISCUSSION OF CHANGE TABULATION METHODOLOGY . . . . . A-1

APPENDIX B - CONDENSED TABULATION OF CHANGE TYPE AND FREQUENCY FOR ALL SITES IN SAMPLE . . . . . B-1

APPENDIX C - ENERGY IMPACTS OF CHANGES . . . . . C-1

APPENDIX D - DETAILED DISCUSSION OF REMODELS AND RENOVATIONS . . . . D-1

## FIGURES


5-1 Frequency of Changes for Offices . . . . . 5-6

5-2 Frequency of Changes for Dry Good Retails . . . . . 5-8

5-3 Frequency of Changes for Groceries . . . . . 5-9

5-4 Frequency of Changes for Restaurants . . . . . 5-11

5-5 Frequency of Changes for Warehouses . . . . . 5-12

5-6 Frequency of Changes for Schools . . . . . 5-13

5-7 Frequency of Changes for Universities . . . . . 5-14

5-8 Frequency of Changes for Hotels/Motels . . . . . 5-15

5-9 Frequency of Changes for Others . . . . . 5-16

5-10 Frequency of Business Type Changes . . . . . 5-22

5-11 Frequency of Partial Vacancies . . . . . 5-24

5-12 Frequency of Tenancy Changes . . . . . 5-25

5-13 Frequency of Full Vacancies . . . . . 5-26

5-14 Frequency of Equipment Changes . . . . . 5-28

5-15 Frequency of Remodels . . . . . 5-29

5-16 Frequency of Unclassified Changes . . . . . 5-31

C-1 Hypothetical Example of Transition Period for a Single Change . . . . . C-2

C-2 Example of Pre- and Post-Change Data Used for Energy Impacts . . . . . C-5

C-3 Number of Changes Suitable for Energy Calculations in Offices . . . . . C-9

C-4 Number of Changes Suitable for Energy Calculations in Dry Good Retails . . . . . C-9

C-5 Number of Changes Suitable for Energy Impact Calculations in Groceries . . . . . C-10

**FIGURES** contd


C-6 Number of Changes Suitable for Energy Impact Calculations in Restaurants . . . . . C-10

C-7 Impact of Change on Energy Used for Office Building Total . . C-12

C-8 Impact of Change on Energy Used for Office Indoor Lighting . . C-12

C-9 Impact of Change on Energy Used for Office Total HVAC . . . . C-13

C-10 Impact of Change on Energy Used for Office Other . . . . . C-13

C-11 Impact of Change on Energy Used for Office Outdoor Lighting . . . . . C-14

C-12 Impact of Change on Energy Used for Dry Good Retail Building Total . . . . . C-14

C-13 Impact of Change on Energy Used for Dry Good Retail Indoor Lighting . . . . . C-15

C-14 Impact of Change on Energy Used for Dry Good Retail Total HVAC . . . . . C-15

C-15 Impact of Change on Energy Used for Dry Good Retail Other . . C-16

C-16 Impact of Change on Energy Used for Dry Good Retail Outdoor Lighting . . . . . C-16

C-17 Impact of Change on Energy Used for Grocery Building Total . . C-17

C-18 Impact of Change on Energy Used for Grocery Indoor Lighting . . . . . C-17

C-19 Impact of Change on Energy Used for Grocery Total HVAC . . . . C-18

C-20 Impact of Change on Energy Used for Grocery Other . . . . . C-18

C-21 Impact of Change on Energy Used for Grocery Refrigeration . . C-19

C-22 Impact of Change on Energy Used for Grocery Food Preparation . . . . . C-19

C-23 Impact of Change on Energy Used for Grocery Outdoor Lighting . . . . . C-20

C-24 Impact of Change on Energy Used for Restaurant Building Total . . . . . C-20

**FIGURES** contd

C-25 Impact of Change on Energy Used for Restaurant Indoor Lighting . . . . . C-21

C-26 Impact of Change on Energy Used for Restaurant Total HVAC . . C-21

C-27 Impact of Change on Energy Used for Restaurant Other . . . . . C-22

C-28 Impact of Change on Energy Used for Restaurant Refrigeration . . . . . C-22

C-28 Impact of Change on Energy Used for Restaurant Food Preparation . . . . . C-23

C-29 Impact of Change on Energy Used for Restaurant Outdoor Lighting . . . . . C-23

## TABLES


2-1 Changes Observed in Commercial Buildings over a Two-Year Period . . . . . 2-3

4-1 Change Events and Their Definitions . . . . . 4-5

4-2 Change Events for a Small Warehouse . . . . . 4-9

4-3 Consolidated Table of Changes for a Small Warehouse . . . . . 4-10

5-1 Change Types and Frequencies Observed in Commercial Buildings over a Two-Year Period . . . . . 5-2

5-2 Change Types and Frequencies Observed in Offices . . . . . 5-4

5-3 Change Types and Frequencies Observed in Dry Good Retails . . 5-7

5-4 Change Types and Frequencies Observed in Groceries . . . . . 5-9

5-5 Change Types and Frequencies Observed in Restaurants . . . . . 5-10

5-6 Change Types and Frequencies Observed in Warehouses . . . . . 5-12

5-7 Change Types and Frequencies Observed in Schools . . . . . 5-13

5-8 Change Types and Frequencies Observed in Universities . . . . 5-14

5-9 Change Types and Frequencies Observed in Hotels/Motels . . . 5-15

5-10 Change Types and Frequencies Observed in Other Buildings . . . 5-16

5-11 Floor Area Breakpoints for Small/Large Commercial Buildings . . . . . 5-21

A-1 Changes Identified for a Small Warehouse . . . . . A-2

B-1 Definition of Data Source Key Column Codes . . . . . B-1

B-2 Change Mode Code Definitions . . . . . B-2

B-3 Summary of Change Events for All Commercial Sites . . . . . B-3

Section 1

# INTRODUCTION

Public utilities specialists and others in the power industry have long noticed that buildings in the commercial sector undergo frequent changes in structure, equipment, and occupants. Such changes have substantial implications for agencies involved in conservation and resource program planning and power forecasting. These implications include the lifetime of conservation measures, the shelf-life of audit-based savings estimates, conservation opportunities provided by equipment turnover rates, and the effect of vacancies.

Historically, there was little basis for quantifying the changes that were observed to be taking place in the commercial sector. However, in 1983, the Bonneville Power Administration (Bonneville) began the End-Use Load and Consumer Assessment Program (ELCAP). Conducted by the Pacific Northwest Laboratory (PNL), ELCAP involves the collection and analysis of hourly end-use data from, as well as other characteristics information on, commercial and residential buildings in the Pacific Northwest region.

Since the data collection began, program staff have also observed a high rate of occupant-initiated changes in the 126 commercial buildings comprising the sample. Because of the rigorous metering and information collection procedures built into ELCAP, the resulting database offers a uniquely rich source of data for use in quantifying the changes that had previously been only visually observed or suspected.

This report documents the first stage of PNL's analysis, in which we characterized changes in commercial buildings in terms of type and frequency of change. We then examined relationships between the frequency of changes and the characteristics of buildings such as type, age, and size. We also looked at the energy impacts on the commercial sector for the changes events we identified.

Our key findings and observations are presented in Section 2. Section 3 provides the underlying motivation and objectives of the analysis. In Section 4, the methodology we used is documented, including the commercial building sample and the data sources used. We also present our definitions of change events and discuss the overall approach we took. The analysis results are presented in Section 5. Additional details are provided in Appendixes A, B, and C for readers interested in more technical discussions of our methodology and results.

Section 2

# KEY FINDINGS

In this section, we present the key findings gleaned from our analysis of changes in commercial buildings. Based on examination of the events recorded in the ELCAP database, we were able to define 12 types of changes. Overall, we found that 50% of the buildings in our sample experienced at least one type of change during the 2 years for which data were examined. The changes we examined, as well as the actual frequency with which each type of change occurred, are summarized in Table 2-1 to help illustrate some of the more obvious and generally interesting observations cited here.

## FREQUENCY OF CHANGE BY BUILDING TYPE

Of all the building types in our sample, we noted that offices experienced changes of all types most frequently. The mean time between all types of change in offices was about 1.2 years, or, more simply, a change of some type occurred in office buildings once every 1.2 years, on average. Retail buildings also had a high rate of change, about one in every 1.3 years. The rate of change in the other major building types (groceries, restaurants, and warehouses) in the ELCAP sample was about one every 1.7 years.

These change rates are remarkably high, reflecting the continual nature of changes in occupancy, structure, and equipment in commercial buildings. Although many of these changes are undoubtedly minor, these high rates (particularly for office and retail buildings) are cause for concern about retrofit measures that might be removed or disabled by some of the changes.

## FREQUENCY OF CHANGE BY CHANGE TYPE

The most notable observations we made when we examined the change frequency in terms of change type are included here.

## Equipment Changes

We found that equipment changes occurred more frequently than any other type, comprising nearly 40% of all observed changes. As shown in Table 2-1, there were 105 equipment changes across the entire commercial building sample. After averaging the rate of change for each type across buildings in the sample, we found that the average number of years between equipment changes also was much less for offices and retails (3 years) than for the warehouses, groceries, and restaurants (5 years). Thus, overall, equipment changes apparently occur more frequently in offices and retails.

Lighting Equipment. Because the definition of equipment changes is fairly broad, a simple tabulation showed that 25% of the equipment changes involved lighting. When we applied these fractions to the average rates of equipment change cited in the paragraph just above, lighting system changes appear to occur on average about once every 12 years in office and retail buildings and once every 20 years in warehouses, groceries, and restaurants. Because in many instances these changes involve relatively minor changes to the lighting systems, these rates are probably lower bounds on lighting system lifetimes and, hence, conservation measure lifetimes.

Heating/Cooling Equipment. The fraction of equipment changes that involved heating/cooling equipment was 17%. The corresponding rates of change for heating/cooling system components are about 18 and 28 years for offices/retails and warehouses/ groceries/restaurants, respectively. These system lifetimes roughly confirm the generally assumed heating/cooling system lifetimes of 20 to 30 years.

Miscellaneous Equipment. The remaining 60% of the equipment changes were related to changing of miscellaneous equipment in the buildings. With the major exception of refrigeration equipment, the types of equipment involved in these changes are not the target of current or planned conservation programs. Many of these equipment changes involved small pieces of equipment.

TABLE 2-1

Changes Observed in Commercial Buildings
over a Two-Year Period

| Building Type | Numbers of Observed Changes by 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 $\Sigma n = 126$ | 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
2 - tenancy
3 - full vacancy
4 - partial vacancy
5 - fuel type
6 - equipment
7 - remodel
8 - schedule
9 - unclassified load
10 - reconfiguration
11 - electrical change
12 - unclassified spike

## Unclassified Changes

The second most frequently occurring type of change was that defined as unclassified--changes that were observed only from the electrical load data but that had not been noted in any of the other data sources we used in the analysis. A total of 95 unclassified changes occurred across the entire sample, an average of one every 4.9 years.

This finding indicates that the unclassified changes are most likely to be operational changes, such as increased or decreased business hours, levels of business activity, or other such behavioral effects. Some unreported major equipment changes may also be included here.

## Occupancy Changes

Changes in a commercial building's occupancy comprised the third most frequently occurring type of change. In our entire sample, of the types of occupancy changes we found, partial vacancies occurred 19 times, tenant changes 15 times, full vacancies 7 times, and business type changes 4 times. The combined average is about one change every 15 years. These events include any equipment changes and remodeling changes associated with them. They are particularly important because some of these changes involve major restructuring of the building and its systems, potentially removing previously installed conservation measures.

We found that office, retail, and warehouse buildings became partially vacant more frequently than they became fully vacant. This is not surprising because these building types often have multiple tenants.

## Remodels

Eleven remodel changes were found in the ELCAP records. A remodel is defined as a structural change in the building, in the absence of other changes such as equipment, tenancy, or vacancies. A particularly high rate of remodels

is associated with warehouses. Visual inspection of the data indicated that seven major remodels occurred, involving full renovation of the building spaces. Interestingly, none of these was associated with business type or tenancy changes as might be expected due to renovations to suit a new business or tenant.

Because of the importance of remodel frequency to demand-side management programs, we have reviewed this category of changes in greater detail in Appendix D. Most of this document summarizes changes according to a predefined hierarchy of change type definitions. Any change event that involves more than one change type is counted only once and categorized as the change type expected to result in the greatest changes in energy consumption. The information in Appendix D summarizes remodels using a broader categorization of changes, providing additional detail about the nature of remodel activity. Any event that involves more than one type of change is counted as many times as there are change events. We also attempt to determine whether each remodel involved an addition, removal, or replacement of space or equipment.

## RELATIONSHIP OF CHANGE FREQUENCY TO BUILDING SIZE AND VINTAGE

We found some notable correlations between the frequency of the various types of change and the building size and vintage. Here are some of the more evident trends:

- In older office, retail, and warehouse buildings (constructed through 1980), changes in tenancy occurred more frequently than they did in newer buildings of the same types. This may be related to the less stable nature of businesses that move into older (and presumably less expensive) commercial space.

- Large office buildings experienced a higher frequency of tenancy change than did small office buildings. This probably is a result of the multi-tenant nature of larger offices, and so may not have a strong influence on conservation measure lifetime.

- Small retail, grocery, and warehouse buildings underwent changes in tenants more frequently than did large buildings of the same types. This may be the result of more frequent turnover in small businesses than for large corporations that typically occupy large buildings of these types. Thus, larger buildings may be more stable targets for conservation programs.

- The small number of new groceries and restaurants in our sample exhibited a much higher frequency of unclassified changes than older buildings of the same type. This could possibly be related to a "settling in" period that is pronounced for these building types.

- We found no clear relationship between the frequency of equipment changes and building vintage or size across all building types.

## IMPACT OF CHANGES ON ENERGY USE

Buildings that exhibited frequent change often changed almost continually, blurring the distinction between the effects of any individual change. We found the methodology we used in this preliminary effort incapable of reliably dealing with the continual shifting nature of occupancy and loads in commercial buildings. Alternative techniques are suggested in Appendix C for follow-on efforts to quantify change impacts on end-use loads.

Section 3

# ANALYSIS OVERVIEW

In this section, we note the reasons for undertaking this analysis. We also list the analysis objectives in the form of research questions we sought to answer.

## MOTIVATION

Various observers have long noted that commercial buildings undergo rapid, frequent changes in structure, equipment, and occupants. Such changes make it very difficult for agencies such as Bonneville to plan conservation programs for the commercial sector. Planning is difficult for several reasons.

First, forecasting commercial loads by building type and equipment usage is difficult. Second, the length of time a conservation measure (and, hence, the energy savings attributable to that measure) is likely to remain in place is uncertain. Third, the most appropriate way in which to implement a conservation program or measure cannot be known with certainty. Fourth, the most appropriate time at which to implement a conservation program or measure is difficult to predict.

Often, by the time a program has been readied for implementation in a commercial building, the building toward which it is targeted may have undergone yet another change in structure, equipment, and/or occupants. Because the building's energy use might also have changed, the recommended action may have been rendered less cost-effective, inappropriate, or even useless.

Thus, the observed changes in commercial buildings can have far-reaching implications for conservation program planning, resource planning, and power forecasting. To help Bonneville meet the unique challenges imposed on these three areas of emphasis, our analysis to characterize change in the commercial sector was undertaken.

## OBJECTIVES

The primary purpose of this analysis was to classify and quantify the changes observed in the ELCAP metered commercial buildings. To achieve that purpose, we sought to find the answers to the following research questions:

- What types of changes are observed in commercial buildings?
- At what frequency do various types of changes occur?
- How do the change frequencies vary by building type?
- Are there relationships between change rates 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?
- Are there any sites with conservation measures or other technologies of particular interest that can be targeted for future "before/after" studies?
- What are the impacts of changes on energy use, particularly end-use loads?

Section 4

# METHODOLOGY

In this section, we document how we performed the analysis of changes in commercial buildings. First, we describe the sample of commercial buildings from which various types of data are collected as part of ELCAP. Next, we discuss those types of data that we used as sources for identifying changes in the sample commercial buildings. Third, we define the change events that we examined in the analysis, and explain how and why we arranged them in a hierarchy for the analysis. Finally, we discuss the approach we took in using the building sample, data sources, and change definitions to achieve the analysis objectives.

## THE COMMERCIAL BUILDING SAMPLE

The ELCAP commercial sample consists of 126 buildings, or structural entities contained by a continuous building shell. Some of these individual buildings contain multiple sites. The classic example is a retail strip building with a shoe store, fast food restaurant, and a small office. Sites are defined where individual businesses are isolated physically and by the metering equipment. Currently, 143 sites are metered in the commercial building sample.

Data are being collected from this sample for three Bonneville studies. The first is the Commercial Base Study, designed to provide information on end-use loads and conservation potential in the Pacific Northwest. The Commercial Base sample consists of 103 sites considered to represent commercial buildings in the Seattle City Light service area. The second study, the Commercial Audit Program (CAP), provides a sample of 33 sites that are metered to determine the value of utility-sponsored energy audits in predicting energy savings from conservation retrofits. Another 7 sites come from the

third study, the Purchase of Energy Savings (PES) Program, which is designed to evaluate the use of third-party financing to acquire conservation resources. The commercial building sample is described in more detail in Taylor and Pratt (1990).

Nine distinct types of commercial buildings are represented in the samples for the Commercial Base Study, CAP, and PES:

- office
- retail
- grocery
- restaurant
- warehouse
- school
- university
- hotel
- other.

This combined sample provided the source of the information we used in this analysis.

## DATA SOURCES

The various kinds of data collected from and about the 143 sites in the commercial sample reside in the ELCAP database, providing a uniquely rich and comprehensive source of information. For this analysis, we examined five specific types of information available in the database:

- data verification records
- maintenance records
- site relations records
- load data
- day typing analysis results.

Each of these is described in the following paragraphs.

### Data Verification Records

Data verification records are the narrative notes written in the process of verifying the quality of the metered data on electricity use. These records describe any analyst-observed discrepancies between the amount of power entering a metered electrical service panel and the amount of power leaving that panel.

As part of ELCAP, the total electricity entering the panel must equal the sum of the electricity used on the individual circuits leaving the panel (feeder circuits), within reasonable bounds. Whenever an imbalance occurs, the verification analysts flag the building as having potential metering hardware problems or electrical system changes. The analysts also indicate the suspected cause of the imbalance in the data verification records (Pearson, Stokes, and Crowder 1985).

The data verification records provide reliable indicators of occupant-initiated changes in equipment within a building. For example, the addition of new equipment will usually result in observed discrepancies because new, unmonitored feeder circuits are simultaneously added to the electrical service panel to serve the new load.

### Maintenance Records

Whenever a building is visited to correct metering hardware failures or to modify the metering installation to accommodate changes to the building, a report is written to describe the more obvious modifications to the building or its electrical system. These records often confirm the suspicions of the verification analysts noted in the data verification records. The maintenance records provide details of the actual equipment that was added or changed. Occasionally, other changes, unrelated to the metering problems, are identified as well.

### Site Relations Records

Signed building access agreements are maintained with each building owner. These agreements permit ELCAP staff to enter a site to, for example, check on or maintain project metering equipment. A dedicated site relations function tracks and maintains records of changes in building ownership and, when known, changes in building tenancy. These records are useful in detecting occupancy changes.

### Load Data

Many changes can be identified simply by examining the collected load data. Sudden increases in otherwise stable loads are often indicative of added equipment or increased hours of operation, while sudden decreases can indicate full or partial vacancies, reduced hours of operation, or even the implementation of energy conservation strategies.

### Day Typing Analysis Results

Analyses of operating schedules over time have resulted in a database of day type definitions for each building. These analyses characterized the day-of-week operating schedules of all metered buildings and resulted in monthly tables of day type definitions, along with indications of average load levels during each day type. For our analysis, we examined the day typing tables to identify changes in building operation schedules.

## CHANGE EVENT DEFINITIONS

Based on our first review of the data sources just described, we defined 12 change events for this analysis. The events are listed in Table 4-1, along with their definitions.

Most of the definitions are self-explanatory. However, the definitions for two events--unclassified changes and unclassified spikes--require slightly more explanation. These two unclassified events deal with changes identified only from inspection of metered data. The unclassified changes are visually-identified load changes that persist for several months. The unclassified spikes are load changes that last only 1 or 2 months. It is postulated that the spikes are caused primarily by temporary anomalous operations. An example would be extended operating hours as building occupants worked overtime to meet a deadline. Such spikes probably do not represent real changes in a building's structure, equipment, or occupancy; otherwise, the load change would be more permanent.

TABLE 4-1

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. |

We ordered the events in a hierarchy because of potential ambiguities in the definition of some types of change events. For example, a tenancy change almost always includes changed equipment. The order in which events are listed in Table 4-1 reflects our judgment regarding what types of changes are more or less important in explaining why energy use changed. As shown, a change in type of business is the highest event, and an unclassified spike is the lowest event in the hierarchy.

Whenever two or more change events occur or are recorded concurrently, only the type highest in the hierarchical list is counted. For example, the first event in the list is a change in business type. If the type of business operating from a building changes, there will almost assuredly be a change in tenant as well. Likewise, the new tenant is very likely to bring new equipment, change the schedule of operation, and even remodel the structure. None of these changes lower in the list is meaningful without knowledge that the business type changed, so only the change of business type would be recorded.

A similar example is the relative ordering of equipment changes and remodels. Frequently, a remodeling effort will involve many different aspects of the building. For example, the owner may replace the windows, insulate the walls, resurface the roof, <u>and</u> replace incandescent lighting fixtures with more efficient fluorescent units. Because all of these changes occur simultaneously, it would be difficult to separate their energy effects. Therefore, in our analysis, we assumed that changes in equipment are more likely to cause direct changes in energy consumption, and the entire remodel would be classified as an equipment change.

## APPROACH

In this section, we describe the main steps we followed to calculate change frequencies for each building. We then illustrate our approach with a sample building.

## Method of Tabulating Change Events

The tabulation process had two general stages. First, each of the five data sources was examined independently to identify potential changes at each site. Second, this information was consolidated according to the change event hierarchy and judgment of the analyst.

In the first stage, we followed these steps for each building in the sample:

- We looked at the verification records, using keyword searches to identify changes.
- We reviewed the maintenance records and consulted maintenance personnel to clarify any notes that were unclear.
- We visually examined site relations records to find records of changes.
- We visually scanned plots of monthly average load data for the end uses that are not expected to vary with outdoor temperature, to identify sudden changes in otherwise stable loads. We flagged a potential change if it was perceptibly larger than the average month-to-month variation in the load and was reasonably large in overall magnitude.
- Finally, we printed out and visually inspected the monthly day type tables to find schedule and/or other load changes.

For each event, we logged the month in which the change was detected, the source used to detect the change, and the suspected cause of the change. The suspected cause was generally well-known when the change was identified from maintenance or site relations records but, by definition, unknown when the source was the load data or day typing results. Although a schedule change, identified from the day typing analyses, is one of the defined change classifications, the day typing results offer no insight as to whether the change accompanied a tenant change or was indeed a simple operational change.

The second stage occurred after the change events were detected from all data sources and assembled for each building. Whenever multiple data sources obviously detected the same change event, the table entries were consolidated. For example, many of the vacancies reported by the site relations records were confirmed by our visual inspection of the data. Similarly, tenant changes reported through the site relations records were often confirmed by verification/maintenance records because the new tenants had changed the building's wiring.

It should be noted that consolidating events identified by multiple sources is a subjective process. Usually the only date associated with a reported change event is the date on which ELCAP personnel learned of the change. For example, it is possible that a tenant change in July would not be reported or learned of until August or September. Thus, the process of consolidating change events from multiple sources required close scrutiny by an analyst. Visually identified changes were consolidated with recorded changes if the two occurred close to each other in time and in relative isolation from other changes. Differences between the recorded and observed months of change were resolved by assigning the most reasonable date inferred from the load data. Many visually identified load changes could not be linked to recorded changes.

Sample Chronology for a Small Warehouse

The two-stage tabulation process is illustrated here for a small warehouse. Initially, the building was a computer supply warehouse. A remodeling effort converted part of the floor area into a cookie factory, which subsequently went out of business. The computer supply company eventually also went out of business. The next tenant used only a fraction of the building in his business to maintain spray painting equipment. The maintenance business has since relocated, and four new businesses are currently located in the building following a total remodel.

Table 4-2 shows a snapshot of the tabulation results after each of the data sources was independently consulted for this building. Each row in the table corresponds to a change event identified from a distinct data source. The events are listed chronologically and are numbered.

The vacancies in the building were first noted in Event 3 using the verification records as the information source. In Events 4 and 8, new tenants were discovered during site visits by maintenance personnel in months 80 and 86, respectively. Inspection of the energy data and day typing analysis results also revealed the vacancies and subsequent new tenants in Events 5, 6, and 7. The new tenants were later documented by the site relations source in Event 9.

TABLE 4-2

Change Events for a Small Warehouse

| Event | ELCAP Month | % Power Change | Load Data | Day Type | Site Relation | Maintenance | Verification | Analyst Notes |
|---|---|---|---|---|---|---|---|---|
| 1 | 61 | | | | | x | | New tenant: bakery, added $ft^2$ |
| 2 | 72 | | | | | x | | Added oven and mixer |
| 3 | 79 | | | | | | x | Load imbalance on panel, apparently vacant (through 4/88) |
| 4 | 80 | | | | | x | | New tenant: painter replaces bakery |
| 5 | 81 | 85- | x | | | | | Decreased load on inside lighting and plug end uses |
| 6 | 81-85 | | | x | | | | Apparent vacancy |
| 7 | 84+ | 100+ | x | | | | | Increased load on inside lighting end use |
| 8 | 86 | | | | | x | | Four new tenants, total remodel |
| 9 | 88 | | | | x | | | New tenant, more employees/ equipment/lights |

Table 4-3 shows a selected portion of the consolidated table of changes after the analyst combined multiple events. This particular building was in a state of flux during months 79 though 85, with a variety of changes occurring as remodels and equipment changes accommodated the different tenants. After consultation with the maintenance personnel, we decided that Events 3 through 9, found in Table 4-2, should be combined into only two events: 1) a partial vacancy, which started in month 79, and 2) a new tenancy during months 81 through 85.

The warehouse example provides a simplified illustration of the tabulation process for a single building. A more detailed discussion of the tabulation process and the condensed results for each commercial building are available in Appendixes A and B, respectively.

TABLE 4-3

Consolidated Table of Changes for a Small Warehouse

| ELCAP Event | Month | Notes |
|---|---|---|
| 1 | 61 | New tenant: bakery |
| 2 | 72 | Added oven, mixer |
| 3 | 79 | 95% vacant |
| 4 | 81-85 | 4 new tenants; inside lighting and plug loads are at a low point |

Section 5

# RESULTS

Our analysis results are presented in this section. First, we discuss the types and frequencies of changes that we observed and quantified. Next, we show the relationships we found between building type and change frequency, summarizing and illustrating them in terms of both raw and averaged data. We then discuss the relationships we noted between change frequency and building vintage and size. The section ends with a brief discussion of the results we obtained when we examined the energy impact of the changes we had observed, characterized, and quantified.

## OBSERVED TYPES AND FREQUENCIES OF CHANGE

We identified 12 types of changes. These changes and their observed frequencies of occurrence are summarized in Table 5-1. By examining the data in Table 5-1, several overall trends are evident.

Equipment changes are the most frequent type of identified change detected. This might be expected, because this category covers a broad set of changes ranging from major equipment replacements and additions to simple additions of small devices such as personal computers. Regular replacement of equipment is expected, even in buildings that do not experience tenant changes. However, it should also be noted that the nature of the ELCAP system favors detection of equipment changes over most other change types. Whenever a new piece of equipment is added that disturbs the metering setup, ELCAP personnel are immediately made aware through the data quality verification procedure. Such instant feedback is not available for most other changes.

TABLE 5-1

Change Types and Frequencies Observed in Commercial Buildings over a Two-Year Period

| Building Type | Number of Changes by 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 $\Sigma n = 126$ | 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
2 - tenancy
3 - full vacancy
4 - partial vacancy
5 - fuel type
6 - equipment
7 - remodel
8 - schedule
9 - unclassified load
10 - reconfiguration
11 - electrical change
12 - unclassified spike

Although equipment changes occur the most frequently, they are probably the least understood change type within the constraints of this analysis. Without onsite visits to verify these changes first-hand, the details of many are unknown, hindering attempts to break this category into smaller, more easily interpreted classes. For example, it would be helpful to have separate categories for changes in specific equipment pieces such as lighting, HVAC equipment, and refrigeration. Likewise, an indication as to whether the change was an addition, replacement, or elimination would be beneficial.

The unclassified load change (seen in the data but not confirmed by any records) is the second most frequently occurring change type. In most cases, the unclassified spike change is third in terms of occurrence frequency.

No fuel type changes were observed. However, this probably does not mean that no fuel switching occurred, for several reasons. First, many fuel type changes probably accompany a change of tenant, which is higher in the classification hierarchy. Second, many reported equipment changes give no details of the type of equipment change. Some fuel type changes could therefore be coded as simple equipment changes (additions) in this study. Third, if a building occupant removes an electric device and replaces it with a gas device, there would be no disruption of the metered energy balance, so no record of the change would exist unless the occupant deliberately informed ELCAP personnel. As is the case with the equipment changes, the fuel type change result underscores the importance of creating a more refined differentiation among some of the more aggregated change type categories for future analyses.

## CHANGE FREQUENCIES BY BUILDING TYPE

To help interpret the results we present in this section, we offer a brief explanation of how we constructed the tabular and graphic illustrations used here to portray those results.

After we had identified and counted the change events for each site, we organized the information into "raw" data tables, one for each building type. Table 5-2, the summarized change event information for all office buildings, exemplifies these tables.

As shown in Table 5-2, the identification number for each site appears for each row of entries. Note that the number of months since metering equipment was installed varies from site to site. The total number of change events that were detected is shown for each site under the numerically coded column heading. For example, Table 5-2 shows that Site 2 had one tenancy change, three partial vacancies, and two noticeable changes in load data patterns over a period of 47 months. The total number of change events within and across sites is also provided.

TABLE 5-2

Change Types and Frequencies Observed in Offices

| Site | Months Monitored | Change Type 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Site Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 47 | | 1 | | 3 | | | | | 2 | | | | 6 |
| 273 | 47 | | | | | | 2 | | | | | | | 2 |
| 283 | 47 | | 1 | | 2 | | | | | | | | | 3 |
| 286 | 47 | | | 1 | | | 4 | | | 2 | | | | 7 |
| 290 | 33 | | | | | | 2 | | | | | | | 2 |
| 298 | 45 | | | | | | 1 | | | | | | 1 | 2 |
| 299 | 45 | | | | | | 1 | 1 | | 2 | | | 2 | 6 |
| 444 | 45 | | | | | | | | | 2 | | | | 2 |
| 451 | 39 | | | | | | 3 | 1 | | | | | 2 | 6 |
| 453 | 28 | | | | | | | | | | | | | 0 |
| 456 | 42 | | | | | | | | | | | | | 0 |
| 458 | 42 | | | | 1 | | 1 | | | 1 | | | 1 | 4 |
| 538 | 43 | 1 | | | 1 | | | | | 1 | | | | 3 |
| 547 | 42 | | | | | | | | | | | | | 0 |
| 548 | 42 | | | | | | | 1 | | | | 1 | 1 | 3 |
| 565 | 39 | | | | | | | | | | | | | 0 |
| 583 | 43 | | | | | | 1 | | | | | | | 1 |
| 595 | 39 | | | | | | | | | 2 | | | | 2 |
| 600 | 39 | | | | | | | | | 1 | | | | 1 |
| 601 | 39 | | | | | | | | | 2 | | | 1 | 3 |
| 602 | 39 | | 2 | | 1 | | 1 | | | 1 | | | | 5 |
| 607 | 40 | | | | | | 1 | | | | | | | 1 |
| 697 | 37 | | | | 1 | | 5 | | | | | | | 6 |
| 714 | 40 | | | | 1 | | | | | | | | 1 | 2 |
| 717 | 35 | | | | | | 1 | | | 1 | | | | 2 |
| 731 | 36 | | | | 1 | | 1 | 1 | | | | | | 3 |
| 738 | 35 | | | | | | 3 | | | 2 | | | | 5 |
| 747 | 39 | | 1 | | | | 2 | | | 1 | | | | 4 |
| Totals: | | 1 | 5 | 1 | 11 | 0 | 29 | 4 | 0 | 20 | 0 | 1 | 9 | 81 |

We summarized the raw table information further by calculating the averages within each building type. However, because the length of time that each building had been metered as part of ELCAP varied, we used a method of compensating for these differences **before** we calculated the averages within a change event category for each building type. This normalization is best explained using Site 2 (from Table 5-2) as an example again.

The one tenancy change for Site 2 over 47 months is re-expressed as 0.25 tenancy changes per year ( 1/(47÷12) ). Thus, the total count of events for a specific change type for a given site was divided by the fractional number of years during which the site had participated in ELCAP. After each element in the raw data tables was expressed in average changes per year, we computed a simple average across sites within each event type. This condensed unit of analysis is called the ***average number of changes per site-year***. The inverse is the average number of years between changes.

The *average number of changes per site-year* can be interpreted as ***the percentage of buildings of a specific type that could be expected to undergo changes of the type identified each year if the changes are assumed to be randomly distributed across buildings***. In reality, some buildings are much more transient than others, so the "fraction of buildings" interpretation is not completely valid. However, it does provide a basis on which to evaluate the relationship of change type and frequency to building type.

For each building type, we constructed a bar chart showing the averaged number of changes per site-year for each change type. The total number of buildings for which change records are available is also indicated. The vertical axis of each bar chart plot has units of fractional number of changes per site per year. The horizontal axis of each is partitioned into the 12 change types that we noted in Table 5-1. The bar charts are used in conjunction with the raw data tables to illustrate our analysis results for each building type.

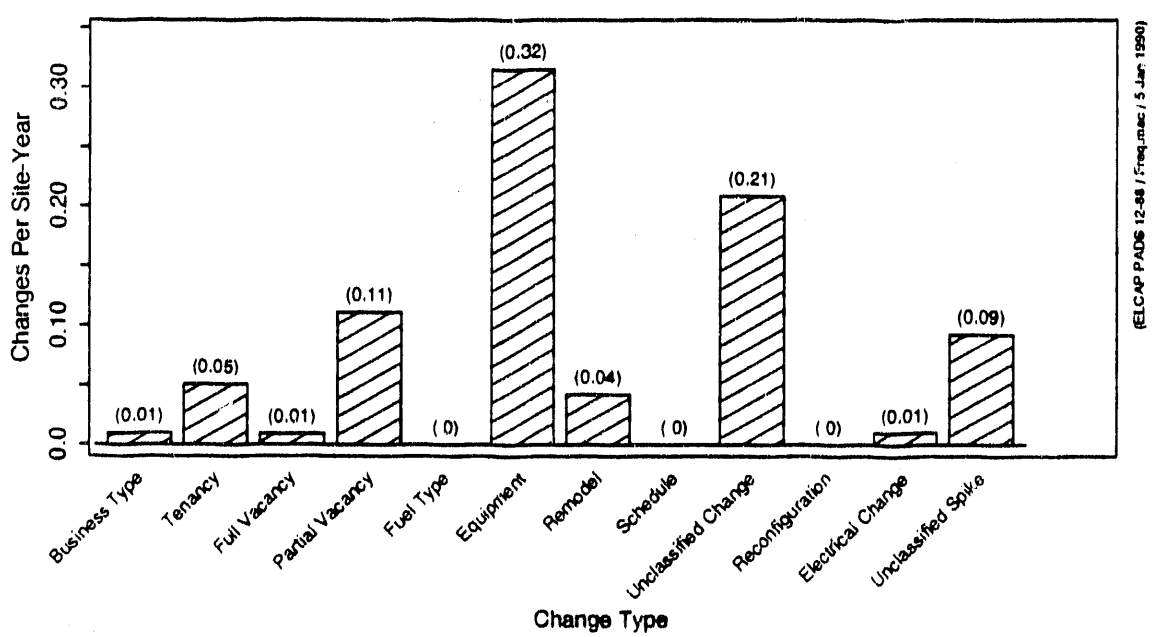
## Offices

Along with retail buildings, offices are the best-represented building type in the ELCAP sample. Twenty-eight buildings contributed to this count of change events. The raw tabular summaries were presented in Table 5-2; the averaged numbers of changes per site-year are shown in Figure 5-1.

The most frequent change type is equipment, averaging 0.32 changes per site per year. The next most common *classified* change type is partial vacancy, averaging 0.11 changes per site-year. It is interesting, although not surprising, that offices are much more likely to become partially vacant than to become fully vacant. This is indicative of the prevalence of multi-tenant office buildings. Tenancy changes are the next most frequent occurrence (0.05 changes per site-year), followed by structural remodels (0.04 changes per site-year).

FIGURE 5-1

Frequency of Changes for Offices (n = 28)



## Retails

Retails are the other best-represented building type in the ELCAP sample, with 28 buildings. Our change type and frequency counts for each retail site are listed in Table 5-3.

The most frequent change type is equipment, averaging 0.32 changes per site per year, interestingly identical to the frequency of office equipment changes. For classified changes, partial vacancies follow at 0.06 changes per site-year and remodels at 0.05 changes per site-year. These results are illustrated in Figure 5-2.

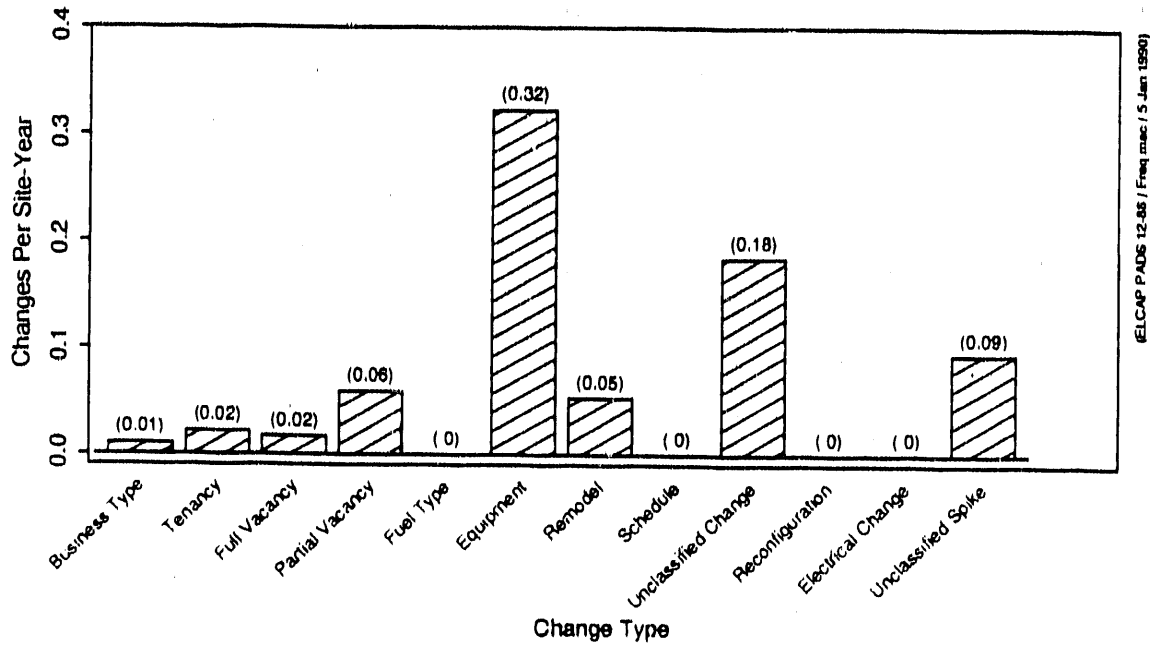
TABLE 5-3

Change Types and Frequencies Observed in Dry Good Retails

| Site | Months Monitored | Change Type 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Site Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12 | 63 | | | | 2 | | | | | | | | | 2 |
| 148 | 40 | | | | | | 1 | | | 1 | | | 2 | 4 |
| 287 | 49 | | | | | | 1 | | | 5 | | | | 6 |
| 289 | 45 | | | | | | 1 | | | | | | | 1 |
| 293 | 45 | | | | | | 1 | | | | | | | 1 |
| 295 | 50 | | | | | | 1 | | | | | | | 1 |
| 442 | 30 | | | | 2 | | | | | 1 | | | | 3 |
| 443 | 16 | | | | | | | 1 | | | | | | 1 |
| 447 | 43 | | | | | | 1 | 1 | | | | | | 2 |
| 449 | 39 | | | | | | 1 | | | | | | 1 | 2 |
| 455 | 26 | | | 1 | | | 1 | | | 1 | | | | 3 |
| 532 | 44 | | | | | | 1 | | | 1 | | | 1 | 3 |
| 544 | 41 | | | | | | 2 | | | 2 | | | | 4 |
| 546 | 42 | | | | | | 3 | | | | | | 1 | 4 |
| 556 | 42 | | | | | | | | | | | | 2 | 2 |
| 566 | 39 | | | | | | 2 | | | 1 | | | | 3 |
| 568 | 39 | | | | | | | | | | | | | 0 |
| 571 | 40 | | | | | | | | | | | | 2 | 2 |
| 582 | 43 | 1 | 1 | | | | | | | 1 | | | | 3 |
| 591 | 36 | | | | | | 3 | | | | | | | 3 |
| 610 | 38 | | | | | | | | | 1 | | | | 1 |
| 681 | 38 | | | | | | 6 | | | | | | | 6 |
| 712 | 39 | | | | | | 1 | | | | | | | 1 |
| 716 | 37 | | | | | | | | | 2 | | | | 2 |
| 723 | 26 | | | | 1 | | 1 | 1 | | | | | | 3 |
| 735 | 36 | | 1 | | | | 1 | | | | | | | 2 |
| 744 | 35 | | | | | | | | | | | | | 0 |
| 751 | 35 | | | | | | 1 | | | 1 | | | | 2 |
| Totals: | | 1 | 2 | 1 | 5 | 0 | 29 | 3 | 0 | 17 | 0 | 0 | 9 | 67 |

FIGURE 5-2

Frequency of Changes for Dry Good Retails (n = 28)




## Groceries

Nineteen grocery stores were available from the ELCAP sample. The raw tabular summaries are found in Table 5-4. The averaged numbers of changes per site-year are shown in Figure 5-3.

Of the classified changes, equipment changes dominate this building type, averaging 0.21 changes per site-year. Full vacancies follow at 0.05 changes per site-year. No partial vacancies were detected, reflecting the fact that few, if any, grocery stores are part of multi-tenant buildings.

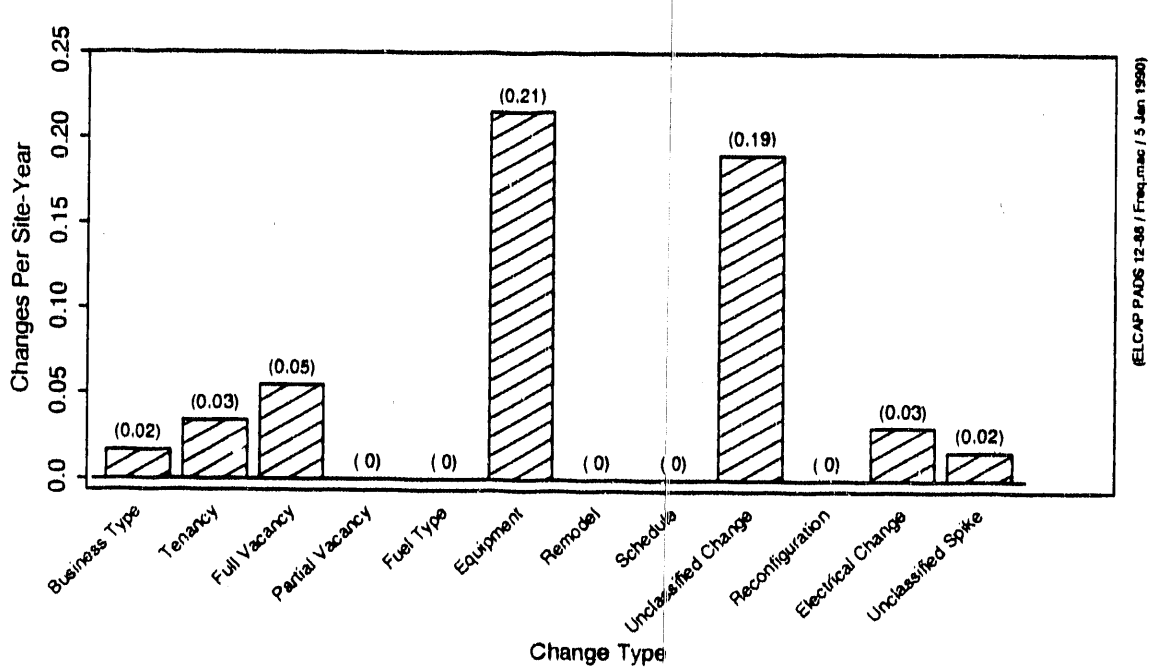
TABLE 5-4

Change Types and Frequencies Observed in Groceries

| Site | Months Monitored | Change Type 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Site Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 47 | | | | | | | | | 1 | | | | 1 |
| 7 | 54 | | | | | | 1 | | | 1 | | | | 2 |
| 37 | 59 | | | | | | 3 | | | 1 | | | | 4 |
| 284 | 34 | | 1 | | | | 1 | | | | | | | 2 |
| 285 | 49 | | | | | | 1 | | | 1 | | | | 2 |
| 297 | 44 | | | | | | | | | 3 | | | | 3 |
| 450 | 39 | | | | | | | | | 3 | | | | 3 |
| 454 | 29 | | | | | | | | | | | | | 0 |
| 533 | 41 | | 1 | 1 | | | | | | | | 2 | | 4 |
| 541 | 41 | | | | | | 1 | | | 1 | | | | 2 |
| 560 | 36 | | | | | | 1 | | | 1 | | | | 2 |
| 587 | 40 | | | | | | 2 | | | | | | | 2 |
| 588 | 38 | 1 | | | | | 3 | | | | | | | 4 |
| 594 | 26 | | | 1 | | | | | | | | | | 1 |
| 597 | 39 | | | | | | | | | | | | | 0 |
| 599 | 25 | | | | | | 1 | | | | | | | 1 |
| 605 | 42 | | | 1 | | | | | | 1 | | | | 2 |
| 690 | 38 | | | | | | | | | | | | 1 | 1 |
| 724 | 36 | | | | | | | | | | | | | 0 |
| Totals: | | 1 | 2 | 3 | 0 | 0 | 14 | 0 | 0 | 13 | 0 | 2 | 1 | 36 |

FIGURE 5-3

Frequency of Changes for Groceries (n = 19)



## Restaurants

Fifteen restaurants were available from the ELCAP sample. The raw data tabulated for each site are summarized in Table 5-5.

As shown in Figure 5-4, equipment changes, averaging 0.20 changes per site-year, clearly dominate this building type. The next most frequent classified change type is electrical changes, which have no net impact on energy consumption.

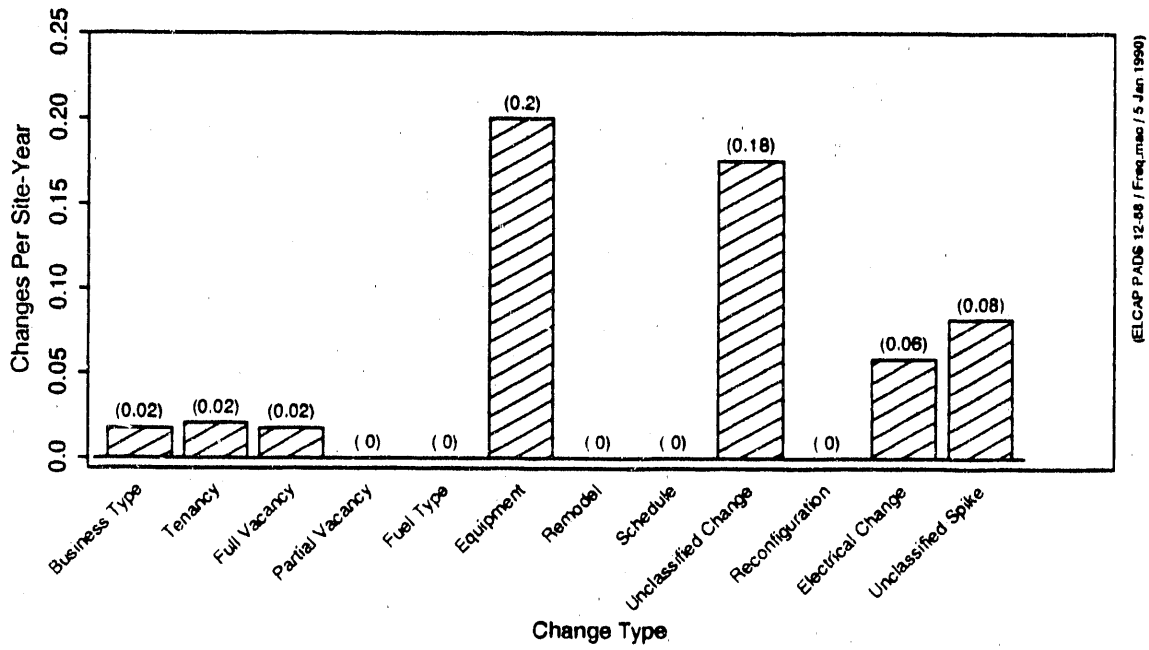
TABLE 5-5

Change Types and Frequencies Observed in Restaurants

| Site | Months Monitored | Change Type 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Site Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9 | 53 | | | | | | | | | | | | | 0 |
| 11 | 62 | | | | | | | | | 2 | | | | 2 |
| 281 | 37 | | | | | | | | | | | | | 0 |
| 292 | 46 | | | | | | | | | | | 1 | | 1 |
| 441 | 43 | | | | | | 4 | | | | | | | 4 |
| 445 | 39 | | | | | | 1 | | | 1 | | 2 | 2 | 6 |
| 457 | 45 | 1 | | 1 | | | | | | 5 | | | | 7 |
| 535 | 41 | | | | | | | | | | | | | 0 |
| 536 | 41 | | | | | | | | | | | | | 0 |
| 554 | 24 | | | | | | | | | | | | | 0 |
| 559 | 41 | | | | | | 1 | | | | | | | 1 |
| 564 | 39 | | | | | | | | | | | | | 0 |
| 593 | 39 | | 1 | | | | 2 | | | | | | 1 | 4 |
| 598 | 36 | | | | | | 2 | | | | | | | 2 |
| 705 | 40 | | | | | | | | | 2 | | | 1 | 3 |
| Totals: | | 1 | 1 | 1 | 0 | 0 | 10 | 0 | 0 | 10 | 0 | 3 | 4 | 30 |

FIGURE 5-4

Frequency of Changes for Restaurants (n = 15)




## Warehouses

We examined the records for 14 warehouses in the ELCAP sample. The raw change frequency tabulations are summarized in Table 5-6. The averaged numbers of changes per site-year are shown in Figure 5-5. As with most other building types, equipment changes dominate, averaging 0.18 changes per site-year. Tenancy changes are second at half this frequency, followed by partial vacancies at 0.07 changes per site-year and structural remodels at 0.06 changes per site-year.

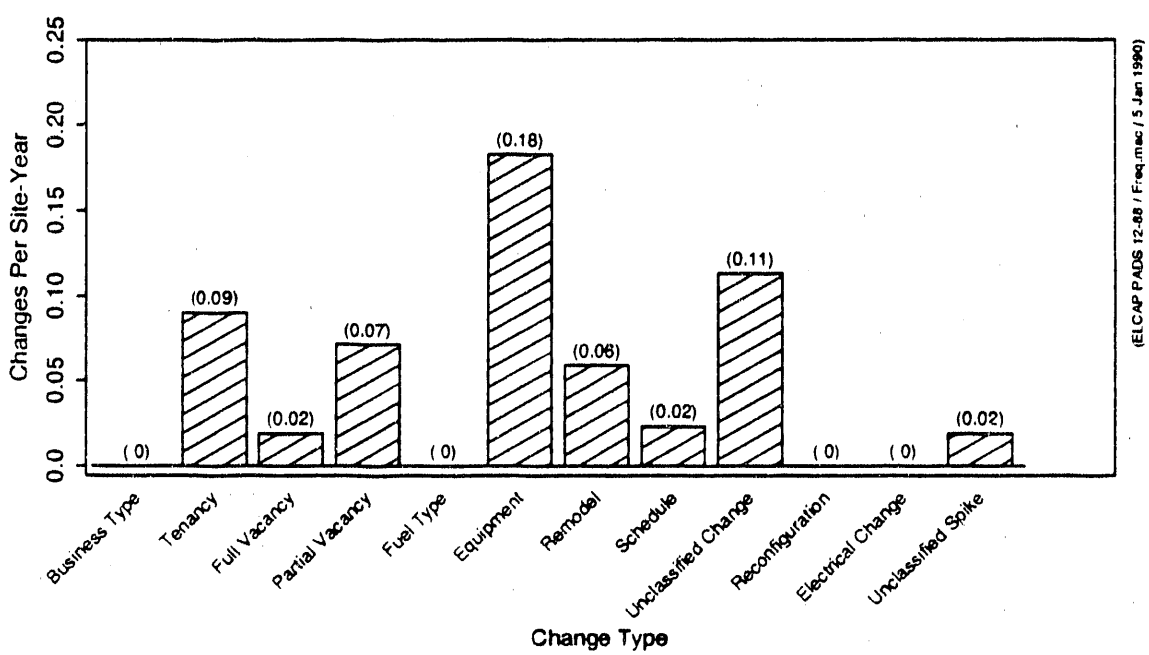
TABLE 5-6

Change Types and Frequencies Observed in Warehouses

| Site | Months Monitored | Change Type 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Site Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 18 | 45 | | 2 | | 1 | | 1 | | | | | | | 4 |
| 40 | 53 | | | | | | | 1 | | 2 | | | | 3 |
| 282 | 45 | | | | | | 1 | | | | | | | 1 |
| 294 | 45 | | | | | | 2 | 1 | | | | | 1 | 4 |
| 300 | 45 | | | 1 | | | 1 | | | | | | | 2 |
| 446 | 45 | | | | | | 1 | | | 3 | | | | 4 |
| 448 | 44 | | | | | | | | | | | | | 0 |
| 460 | 42 | | | | | | | | | | | | | 0 |
| 550 | 30 | | 1 | | 1 | | | | | | | | | 2 |
| 580 | 29 | | | | | | | | | | | | | 0 |
| 586 | 39 | | | | | | 1 | | | | | | | 1 |
| 707 | 37 | | | | | | 2 | | 1 | | | | | 3 |
| 713 | 44 | | | | | | | | | | | | | 0 |
| 736 | 36 | | 1 | | 1 | | | 1 | | 1 | | | | 4 |
| Totals: | | 0 | 4 | 1 | 3 | 0 | 9 | 3 | 1 | 6 | 0 | 0 | 1 | 28 |

FIGURE 5-5

Frequency of Changes for Warehouses (n = 14)



## Schools

Data from the four schools available from the ELCAP sample appear in Table 5-7. The averaged numbers of changes per site-year are shown in Figure 5-6. No verifiable changes were recorded, though several short-term anomalous months were detected by visual inspection of the load data during summer vacations (the unclassified spikes).

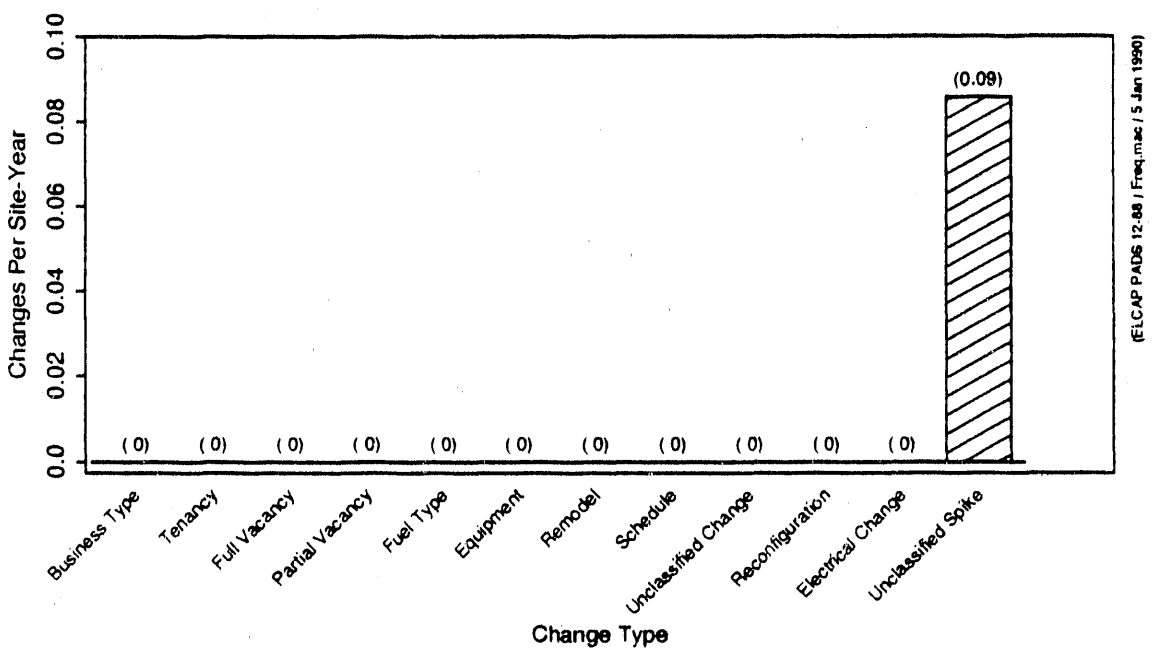
TABLE 5-7

Change Types and Frequencies Observed in Schools

| Site | Months Monitored | Change Type 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Site Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 36 | 36 | | | | | | | | | | | | | 0 |
| 558 | 39 | | | | | | | | | | | | | 0 |
| 753 | 35 | | | | | | | | | | | | 1 | 1 |
| 756 | 35 | | | | | | | | | | | | | 0 |
| Totals: | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |

FIGURE 5-6

Frequency of Changes for Schools (n = 4)



## Universities

With only two buildings in the sample, universities are the least well-represented commercial building type. The type and frequency of changes we observed are summarized in Table 5-8. The averaged number of changes per site-year are shown in Figure 5-7. An average of 0.31 equipment changes per site-year represents the only changes identified.

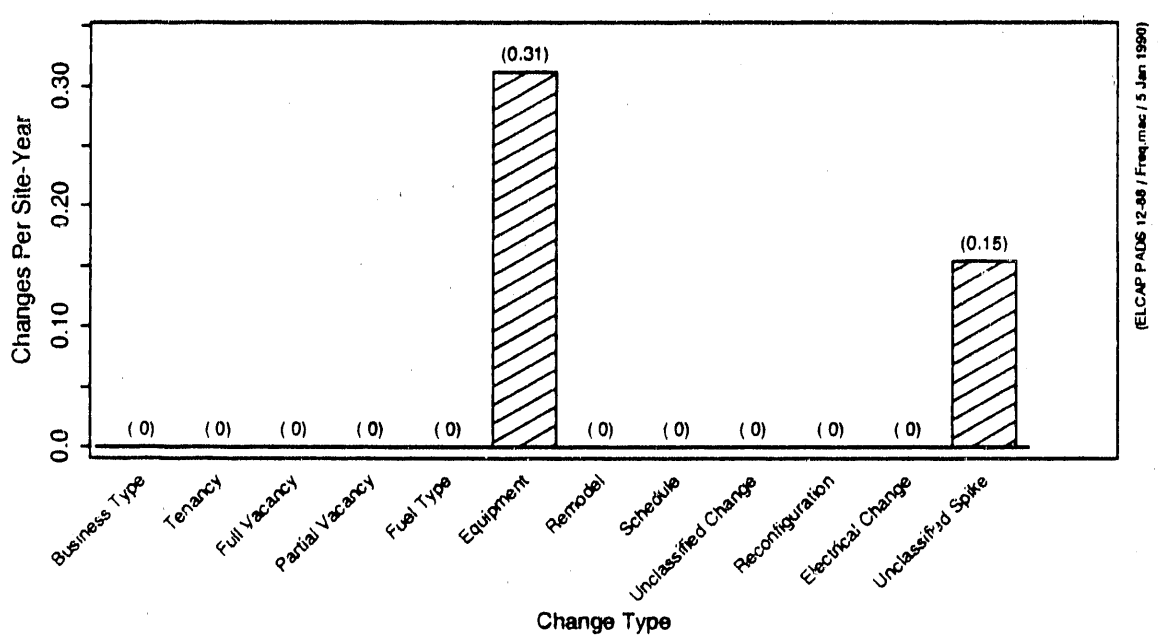
TABLE 5-8

Change Types and Frequencies Observed in Universities

| Site | Months Monitored | Change Type 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Site Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 562 | 39 | | | | | | 1 | | | | | | 1 | 2 |
| 691 | 38 | | | | | | 1 | | | | | | | 1 |
| Totals: | | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 3 |

FIGURE 5-7

Frequency of Changes for Universities (n = 2)



## Hotels/Motels

In the 11 hotels/motels from our sample, only two change types were identified. Equipment averaged 0.3 changes per site-year, followed by 0.03 tenancy changes per site-year. These results are illustrated in Table 5-9 and Figure 5-8.

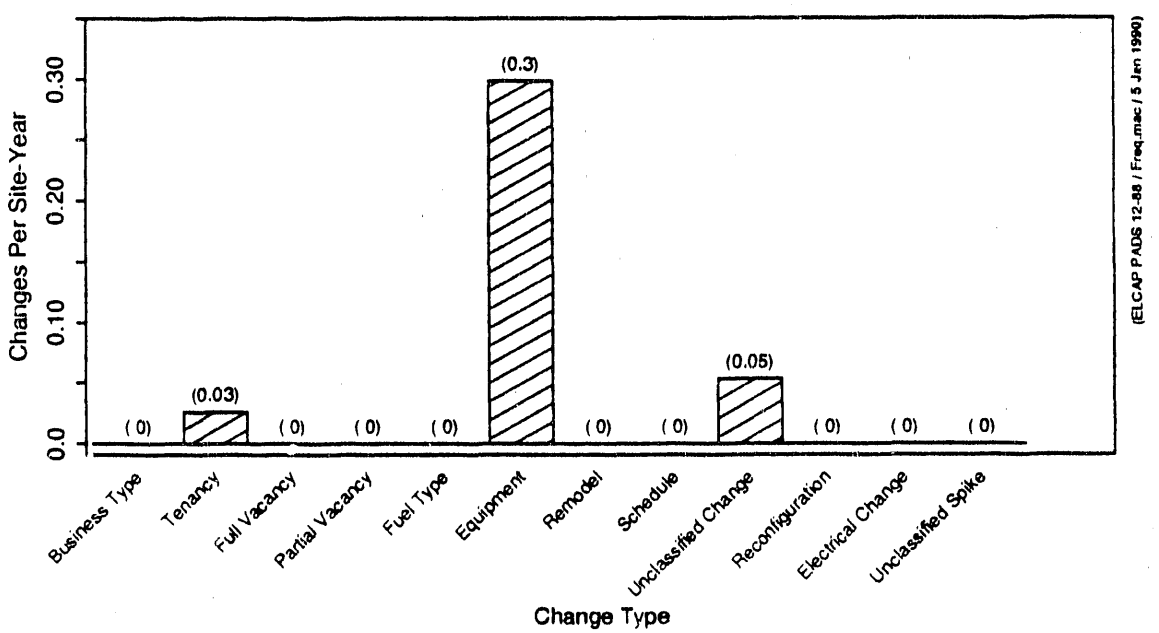
TABLE 5-9

Change Types and Frequencies Observed in Hotels/Motels

| Site | Months Monitored | Change Type 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Site Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 15 | 29 | | | | | | | | | | | | | 0 |
| 41 | 41 | | | | | | 3 | | | 2 | | | | 5 |
| 48 | 41 | | | | | | | | | | | | | 0 |
| 79 | 39 | | | | | | 1 | | | | | | | 1 |
| 81 | 39 | | | | | | 2 | | | | | | | 2 |
| 82 | 53 | | | | | | | | | | | | | 0 |
| 274 | 43 | | | | | | | | | | | | | 0 |
| 534 | 41 | | | | | | 3 | | | | | | | 3 |
| 540 | 43 | | | | | | | | | | | | | 0 |
| 555 | 42 | | 1 | | | | 1 | | | | | | | 2 |
| 726 | 38 | | | | | | 1 | | | | | | | 1 |
| Totals: | | 0 | 1 | 0 | 0 | 0 | 11 | 0 | 0 | 2 | 0 | 0 | 0 | 14 |

FIGURE 5-8

Frequency of Changes for Hotels/Motels (n = 11)



## Others

The "other" building type consists of five buildings: one laundromat, one service station, one church, one library, and one costume rental. The change type and frequency tabulations for these different buildings are listed in Table 5-10. The averaged numbers of changes per site-year are shown in Figure 5-9. As is evident, equal numbers of equipment changes and structural remodels were observed, each averaging 0.1 changes per site-year.

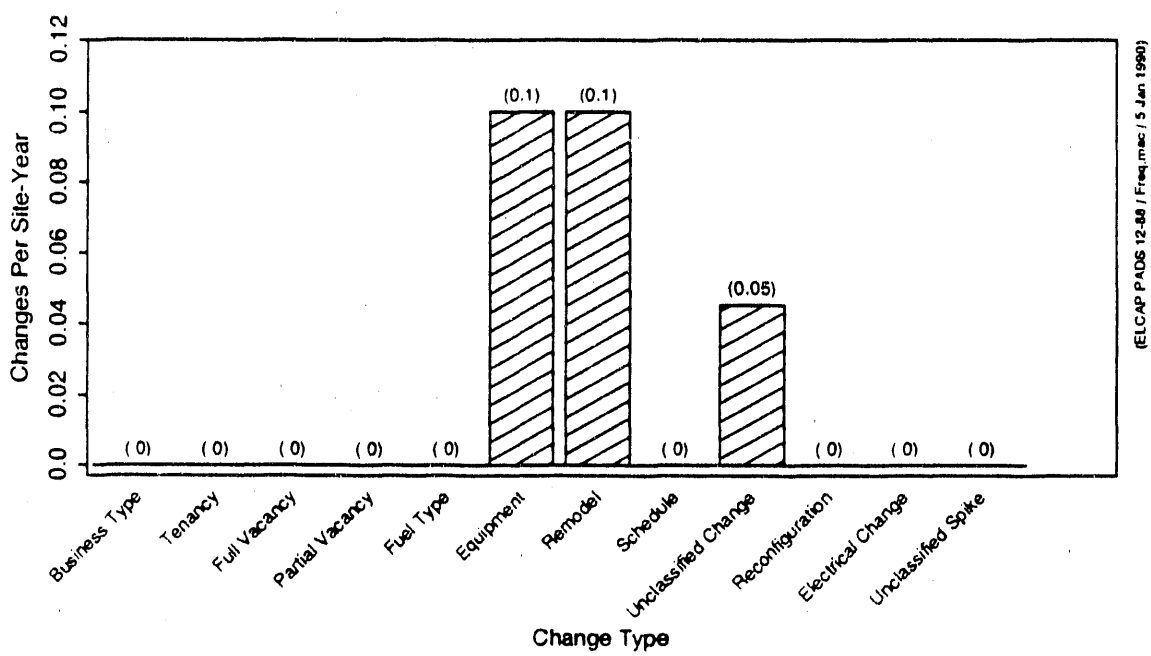
TABLE 5-10

Change Types and Frequencies Observed in Other Buildings

| Site | Months Monitored | Change Type 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Site Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8 | 45 | | | | | | | | | | | | | 0 |
| 13 | 53 | | | | | | | | | 1 | | | | 1 |
| 14 | 34 | | | | | | | | | | | | | 0 |
| 722 | 37 | | | | | | | | | | | | | 0 |
| 752 | 24 | | | | | | 1 | 1 | | | | | | 2 |
| Totals: | | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 3 |

FIGURE 5-9

Frequency of Changes for Others (n = 5)



Observations Across All Building Types

Of all the building types in our sample, we noted that offices experienced changes of all types most frequently. The mean change frequency in offices was about 0.85 per site-year (once every 1.2 years). Retail buildings also had a high rate of change, about 0.75 per site-year (one every 1.3 years). The rates of change in the other major building types in the ELCAP sample (groceries, restaurants, and warehouses) were all similar, ranging from 0.55 to 0.58 per site-year (about one every 1.7 years). These rates of change are remarkably high, reflecting the continual nature of changes in occupancy, structure, and equipment in commercial buildings. While many of these changes are undoubtedly minor, these high rates (particularly for office and retail buildings) are cause for concern about retrofit measures that might be removed or disabled by some of the changes.

Equipment changes occurred more frequently than any other type, comprising nearly 40% of all observed changes. The average rate of equipment changes was much greater for offices and retails (0.32 per site-year) than for the groceries, restaurants, and warehouses, which all had similar rates (0.18 to 0.21 per site-year). These rates are equivalent to changes about once every 3 and 5 years, respectively. The difference between the rates for the building types may be related to the presence of more numerous but smaller pieces of equipment in offices, as well as to frequent small changes in display lighting in retail buildings.

Because the definition of equipment changes is fairly broad, a simple tabulation showed that the fraction of the equipment changes (listed in Appendix B) that involved lighting was 25%. When this fraction is applied to the average rates of equipment change by building type, lighting system changes appear to occur at an average rate of 0.08 per site-year (about once every 12 years) in office and retail buildings and 0.05 per site-year (about once every 20 years) in warehouses, groceries, and restaurants. Because in many instances these changes involve relatively minor changes to the lighting

systems, these rates are probably lower bounds on lighting system lifetimes and, hence, conservation measure lifetimes. More directly, the rates are also indicative of lost opportunities for conservation, as some or all the lighting equipment in the buildings is being replaced at these rates. Programs could be designed to affect the type of lighting equipment selected for use at these times.

The fraction of equipment changes that involved heating/cooling equipment was 17%. The corresponding rates of change for heating/cooling system components are 0.054 per site-year (about once every 18 years) for offices/retails and 0.034 per site-year for warehouses/groceries/restaurants (about once every 28 years). These system lifetimes roughly confirm the generally assumed heating/cooling system lifetimes of 20 to 30 years. These rates of change are also indicative of equipment lifetimes and lost opportunities for rebate or incentive programs.

The remaining 60% of the equipment changes were related to changing of miscellaneous equipment in the buildings. With the major exception of refrigeration equipment, the types of equipment involved in these changes are not the target of current or planned conservation programs. Many of these equipment changes involved small pieces of equipment. Only 2% had a noticeable impact on the metered loads, and reporting of minor equipment changes is casual on the part of building owners and ELCAP maintenance personnel. So, the rate of change for miscellaneous equipment is likely to be greatly underestimated. A planned resurvey of the equipment inventory in the buildings is now being conducted to provide more accurate estimates of these changes.

The second most frequently occurring type of change was that defined as unclassified--changes that were observed from the electrical load data but that had not been noted in any of the other data sources we used in the analysis. An average rate of 0.20 unclassified changes per site-year occurred across the entire sample, an average of about once every 4.9 years. Of all

the load changes initially detected by examining the end-use data, only a very small fraction was confirmed by other project records as being associated with any of the classified types of change event. This indicates that the unclassified changes are most likely to be operational changes such as increased or decreased business hours, levels of business activity, or other such behavioral effects. Some unreported major equipment changes may be included here also.

The unclassified changes have a significant impact on conservation programs for existing buildings, in that the building-specific assumptions about building usage in the energy audit process apparently become inaccurate over time. This shortens the applicable shelf-life of energy audits, over which the resulting load estimates are likely to be increasingly in error. Similarly, it suggests that energy audits might use standard operating conditions (as new building standards do) to prepare a second set of savings estimates that may be more representative of its usage over the lifetime of the building.

Changes in a commercial building's occupancy comprised the third most frequently occurring type of change. In our entire sample, partial vacancies occurred 19 times, tenant changes 15 times, full vacancies 7 times, and business type changes 4 times. The combined average is about one change every 15 years. These events include any equipment changes and remodeling changes associated with them. They are particularly important in that some fraction of these changes involves major restructuring of the building and its systems, potentially removing previously installed conservation measures, and providing an opportunity for programs to install measures at minimal cost.

Office, retail, and warehouse buildings became partially vacant more frequently than they became fully vacant. This is not surprising, in that these building types often have multiple tenants. Partial vacancies may be frequent enough that load forecasts should consider including their effects.

Eleven remodel changes were found. Remodels are defined as a structural change in the building, in the absence of other changes such as equipment, tenancy, or vacancies. A particularly high rate of remodels is associated with warehouses. Casual inspection of the data indicated that seven major remodels occurred, in which the building spaces were fully renovated. Interestingly, none of these was associated with business type or tenancy changes as might be expected due to renovations to suit a new business or tenant.

## VARIATIONS IN CHANGE FREQUENCIES WITH BUILDING VINTAGE AND SIZE

Because changes in commercial buildings can have such dramatic impacts on the useful life or effectiveness of installed conservation measures, it is important to know the types or classes of buildings that are most susceptible to frequent changes. In this way, conservation programs can be targeted at the buildings most likely to result in real energy savings over extended periods. Similarly, power forecasters can benefit from a knowledge of change frequency as a function of building age, because forecasts are generally based on the product of future regional floor space estimates and fixed annual end-use consumption estimates. If, for example, aging buildings are found to be vacant more frequently than new buildings, a forecast might benefit from taking this into account.

Here we present the frequencies of the various types of change segregated into subclasses of the major building types according to vintage and size. A building is considered new if its construction permit was obtained during or after 1981. The distinction between "large" and "small" differs among building types. Buildings with floor areas larger than the square-footage breakpoints found in Table 5-11 are defined as large.

The illustrations in this section show the frequency of changes broken down by new/old and large/small classifications. The vertical axis of each figure has units of changes per site-year. The horizontal axis is partitioned

TABLE 5-11

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 |

by building type and further by the new/old or large/small categories. The height of each bar gives the average number of changes per site-year within the category. Along the top of each figure are printed the numbers of buildings available from each building type within the two size or vintage categories. Along the bottom are two numbers for each building type, giving the actual number of events identified within the two size or vintage categories. These numbers, divided by the total number of site-years for which data are available, give the heights of the bars.

Business Type Changes

As shown in Figure 5-10, only one business type change was identified in each of the office, retail, grocery, and restaurant building types. Therefore, no size- or vintage-related impacts are revealed. No business type changes were found in any other building types.

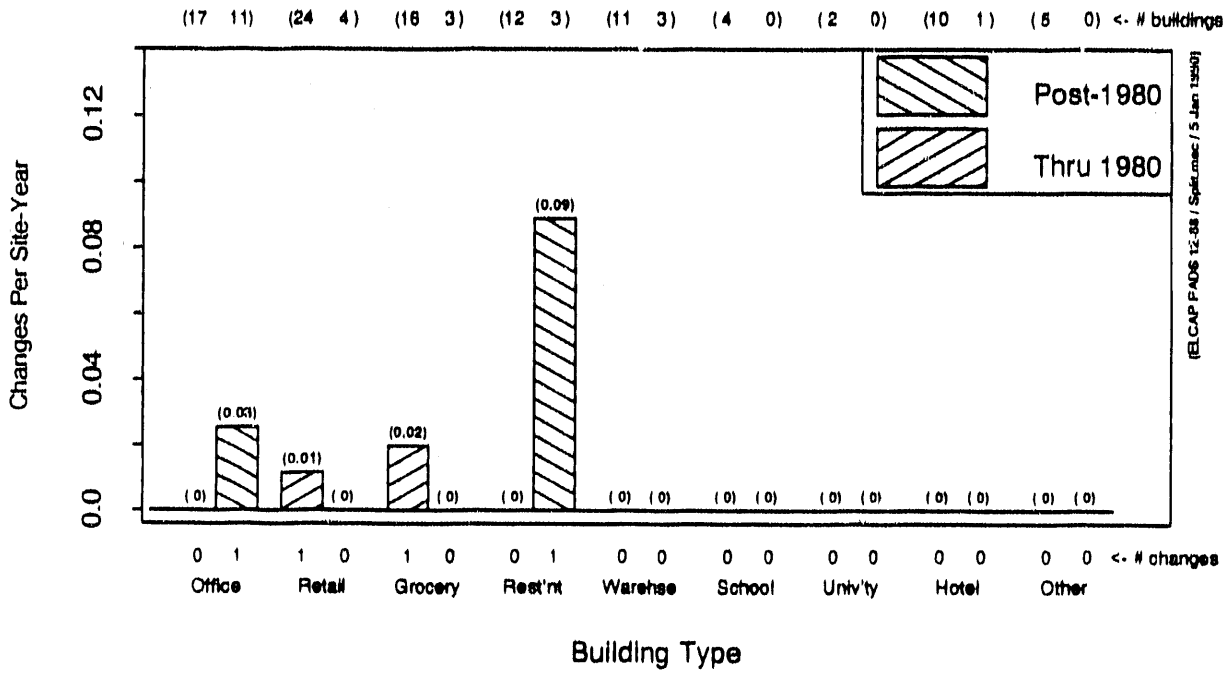
Partial Vacancies

Partial vacancies identified in offices are detected among new and old buildings, with 0.10 and 0.13 changes per site-year, respectively. This result

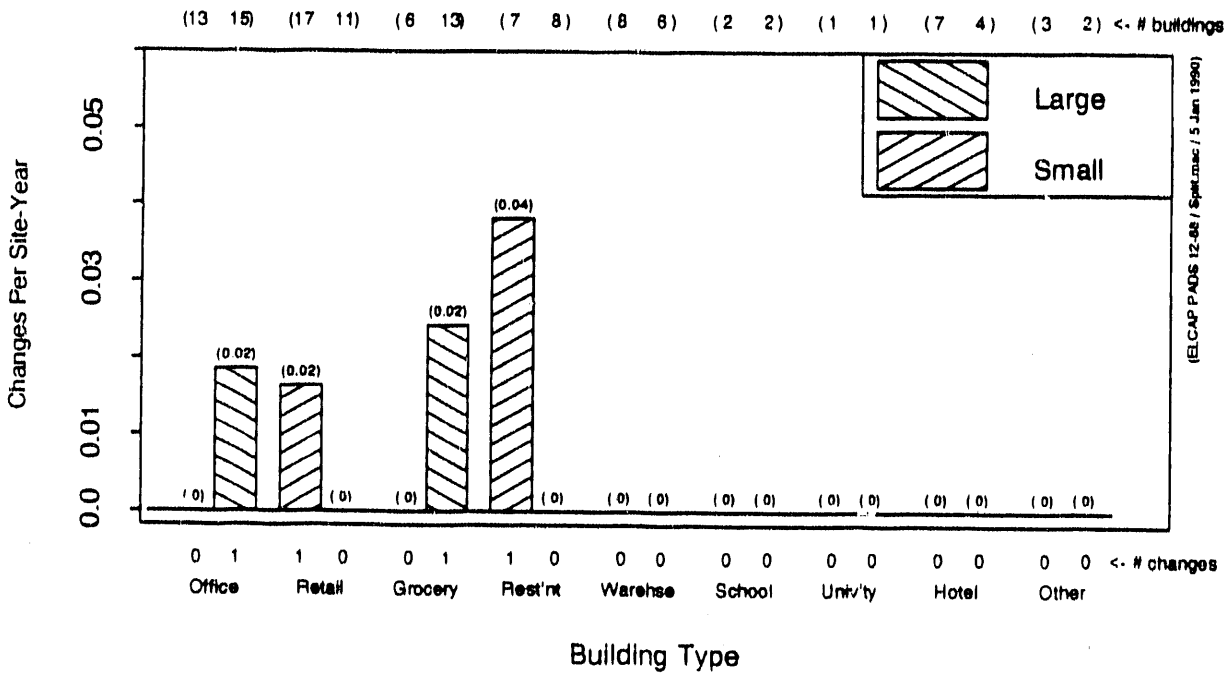
FIGURE 5-10

Frequency of Business Type Changes

a) by Vintage




b) by Floor Area



is apparent from Figure 5-11. As expected, large offices, which are more likely to have multiple tenants, have notably higher partial vacancy rates (0.15) than small offices (0.06).

Tenancy Changes

For offices, retails, and warehouses, represented in Figure 5-12, old buildings appear to undergo tenancy changes more frequently than new buildings. Old warehouses, in particular, show a rate of 0.12 changes per site-year, compared with no changes for new warehouses. Note, however, that there are only three new warehouses in the sample. This may be related to the less stable nature of businesses that move into older (and presumably less expensive) commercial space. The higher rate of change in older buildings further shortens the shelf-life of energy audits and adds uncertainty to the savings estimates obtained.

With respect to floor area, larger offices are more likely to experience tenancy changes, probably due to the multi-tenant nature of many larger buildings. Conversely, smaller buildings experience more tenant changes in the retail, grocery, and warehouse building types. This is perhaps consistent with the tendency for larger buildings, in these categories, to be occupied by large, well-established commercial chains. Thus, larger buildings may be more stable targets for conservation programs.

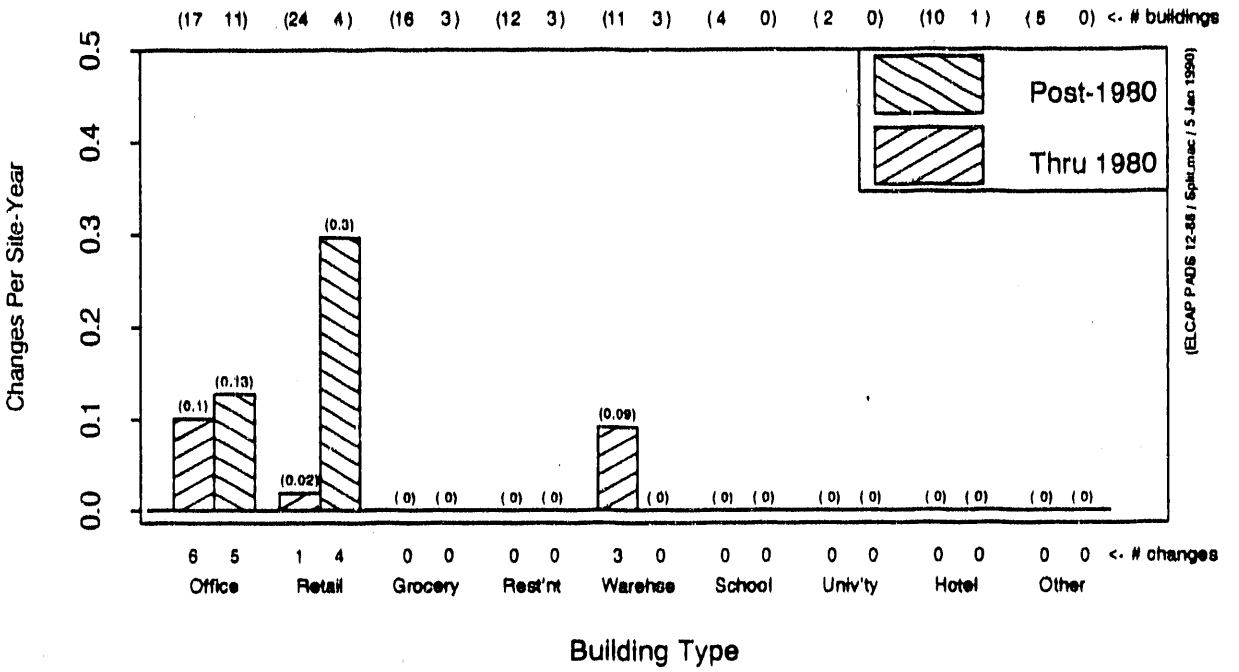
Full Vacancies

As indicated in Figure 5-13, only groceries experienced more than a single full vacancy. All of these involved older buildings. All full vacancies occurred in smaller buildings, except for groceries. A rate of 0.05 is reported for small groceries compared to a rate of 0.06 for larger groceries.

FIGURE 5-11

Frequency of Partial Vacancies

a) by Vintage




b) by Floor Area

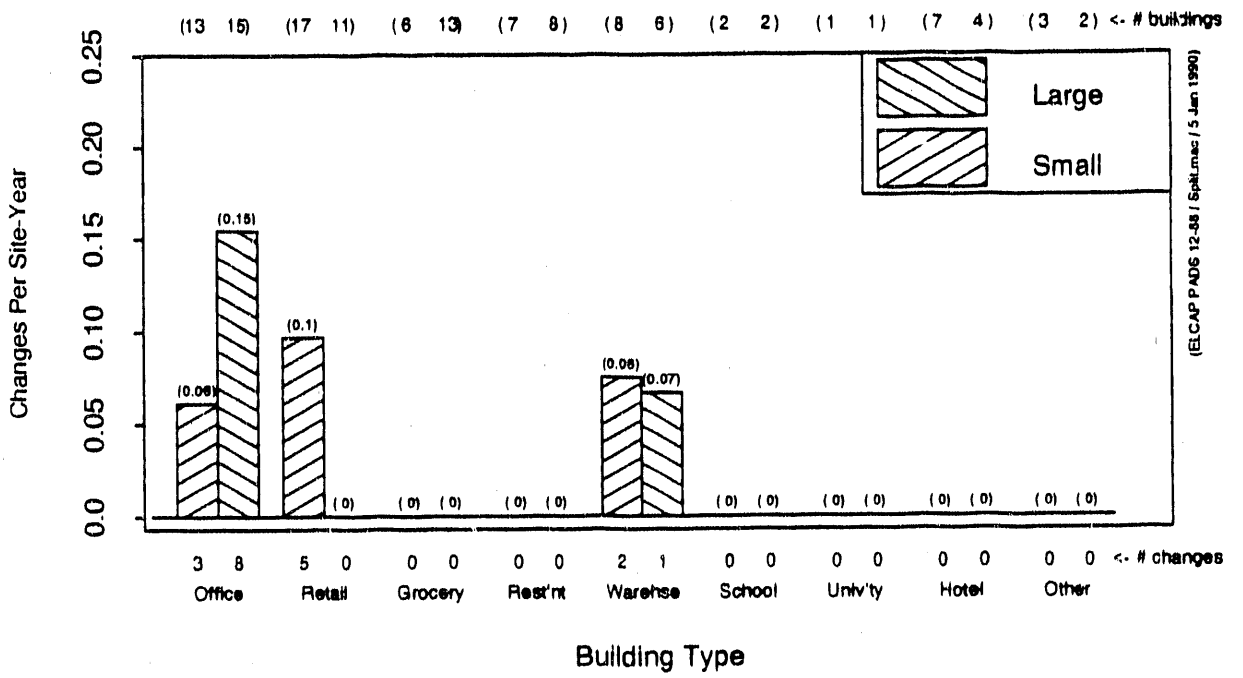
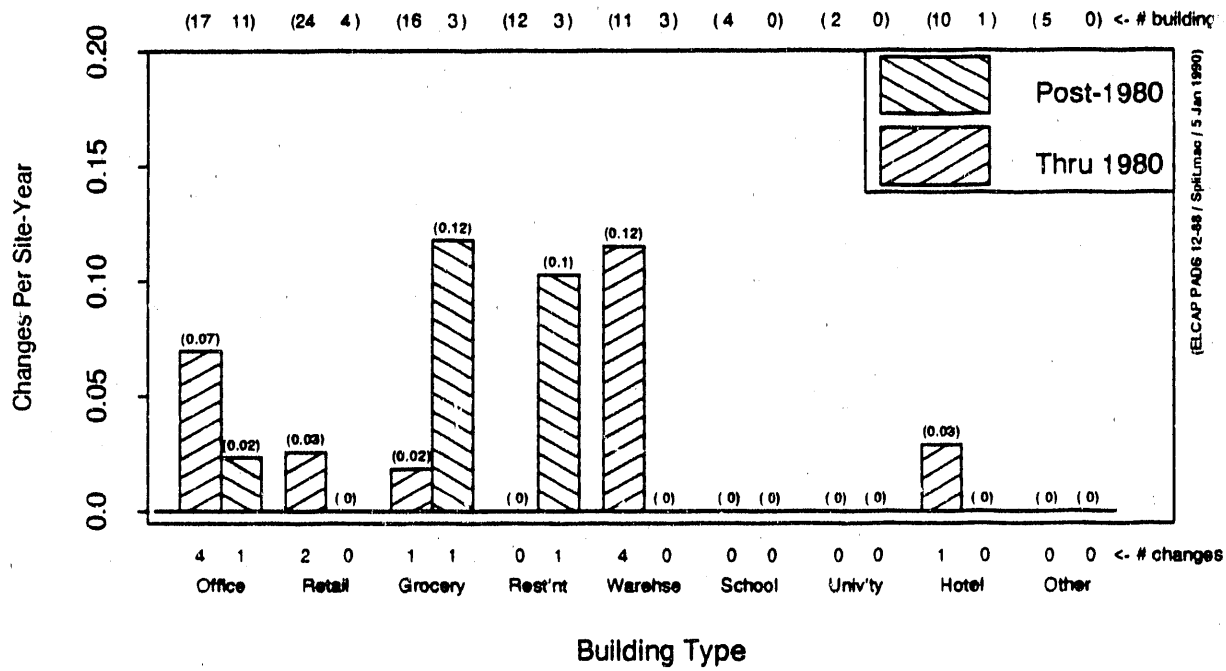


FIGURE 5-12

Frequency of Tenancy Changes

a) by Vintage




b) by Floor Area

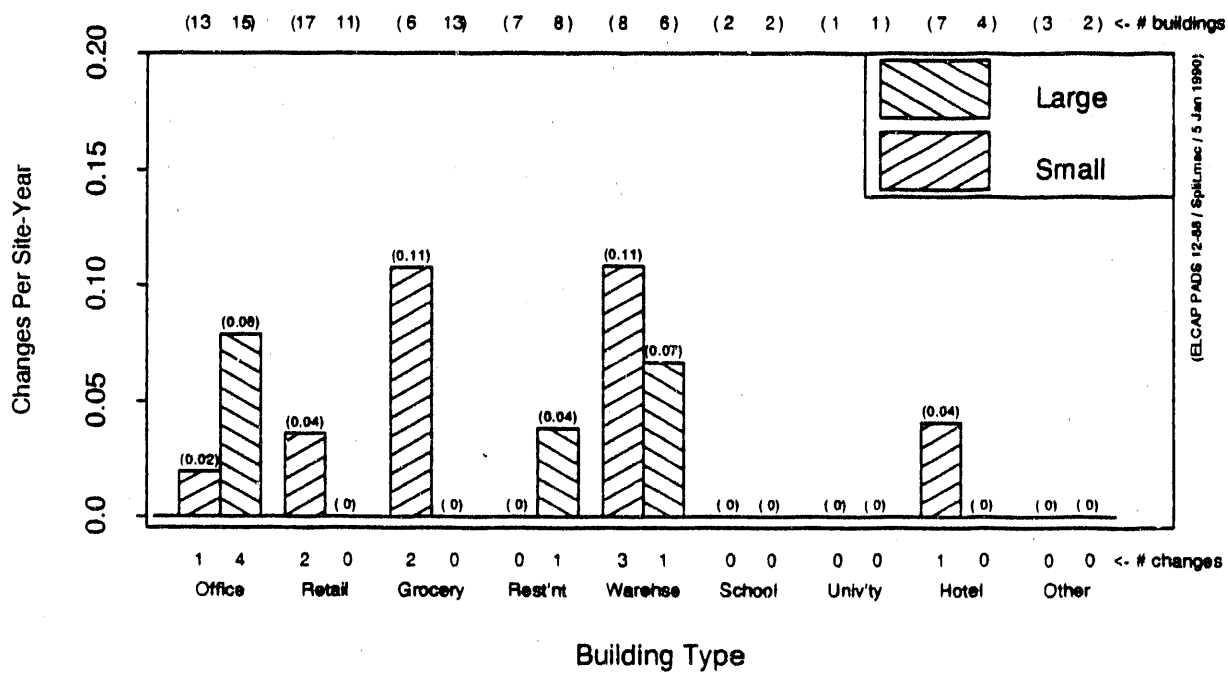
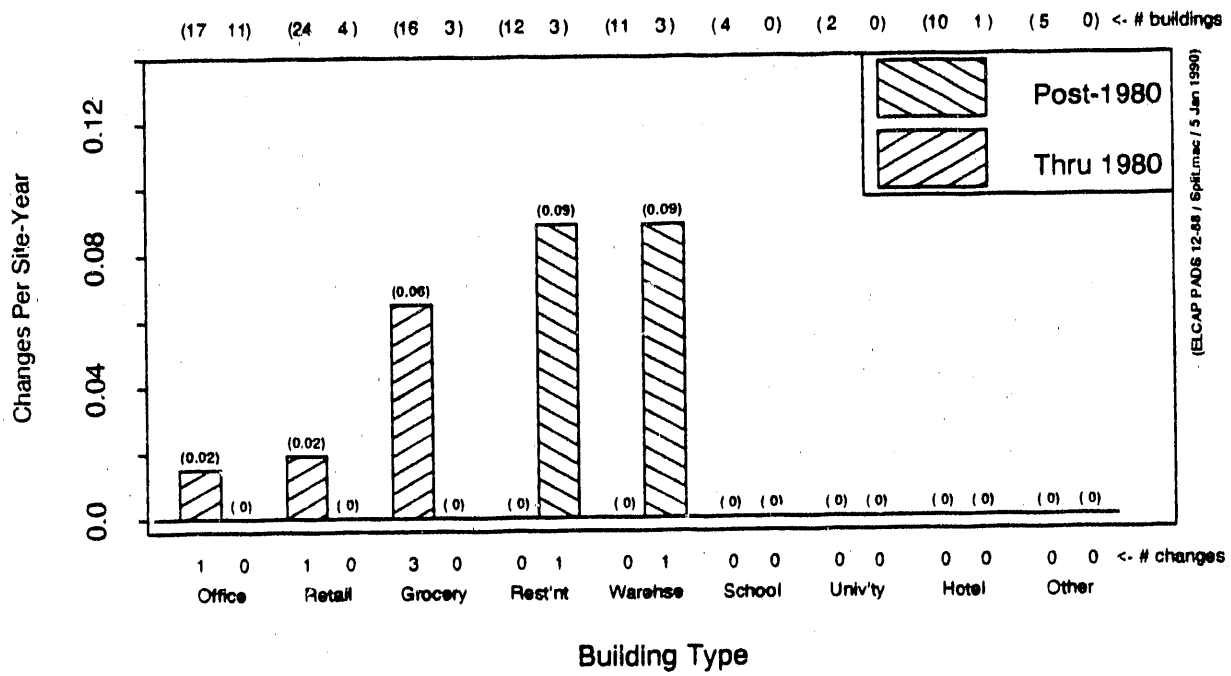


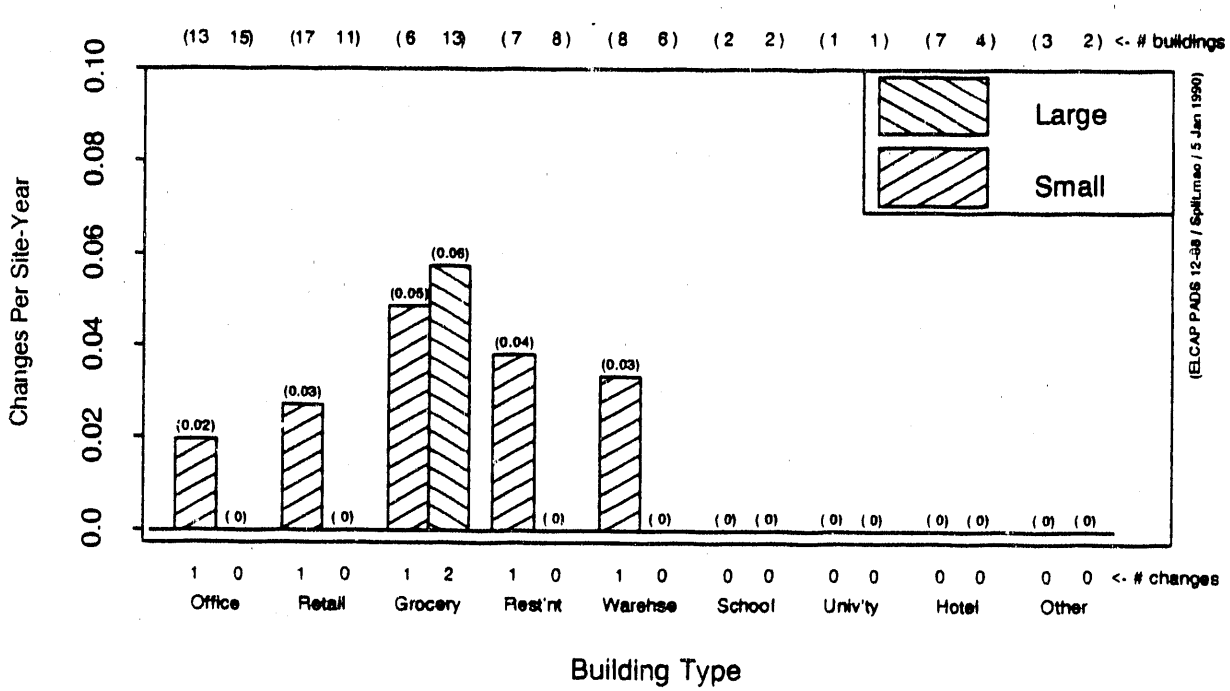
FIGURE 5-13

Frequency of Full Vacancies

a) by Vintage




b) by Floor Area



Retails, however, show a much higher rate for small buildings (0.10) than for large (0), and a rate for new buildings (0.30) fifteen times that for old buildings (0.02). A partial vacancy rate of 0.09 is noted for old warehouses compared to none for new, while size correlates much less than vintage, with 0.08 change per site-year for small and 0.07 change for large warehouses.

Equipment Changes

Equipment changes are the most frequent type of change identified for all building types. Figure 5-14 shows that the rate of equipment changes in old buildings tends to be greater than or just about equal to the rate for new buildings. Warehouses are the notable exception, with a rate of 0.36 for new buildings compared to 0.14 for old buildings.

Overall rates of equipment changes with no building class distinctions are roughly equal for new and old buildings with rates of 0.24 and 0.26, respectively, indicating that, at least for our sample, equipment changes are fairly frequent occurrences in all buildings, regardless of vintage.

Building size has a mixed effect on equipment change rates. Offices, retails, and groceries clearly show higher rates in larger buildings. This is not surprising, because larger buildings can hold more equipment and the change rates are expressed per building. However, restaurants, warehouses, and hotels show converse behavior, with visibly higher change rates for small buildings.

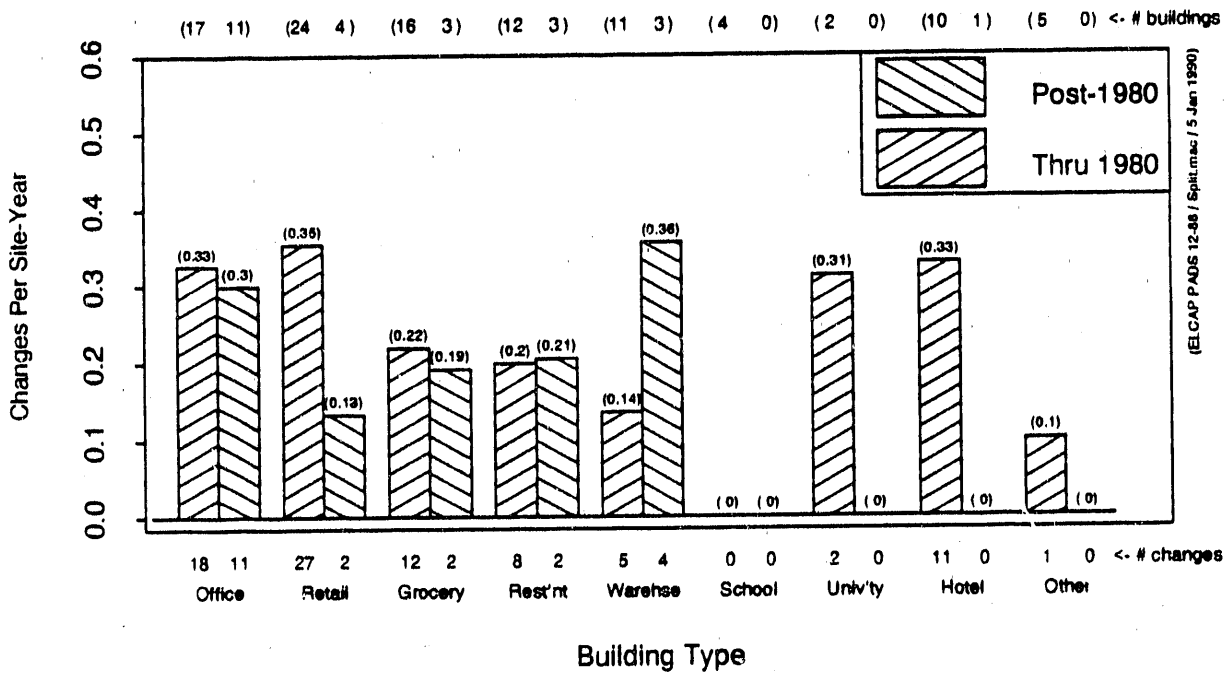
Remodels

Age of the building does not provide a clear overall trend for the rate of remodeling events in our sample, as is evident from Figure 5-15. Rates are greater in newer offices and warehouses. This trend is reversed for buildings in the retail and other categories. Overall rates of remodels with no building

FIGURE 5-14

Frequency of Equipment Changes

a) by Vintage




b) by Floor Area

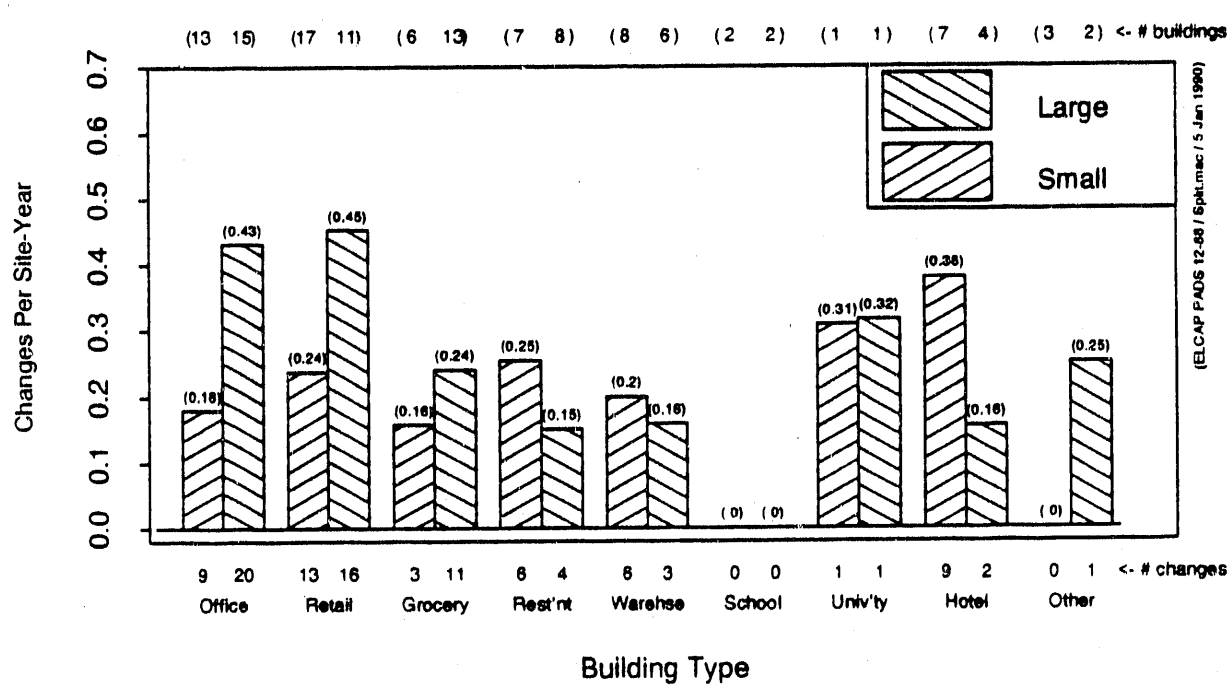
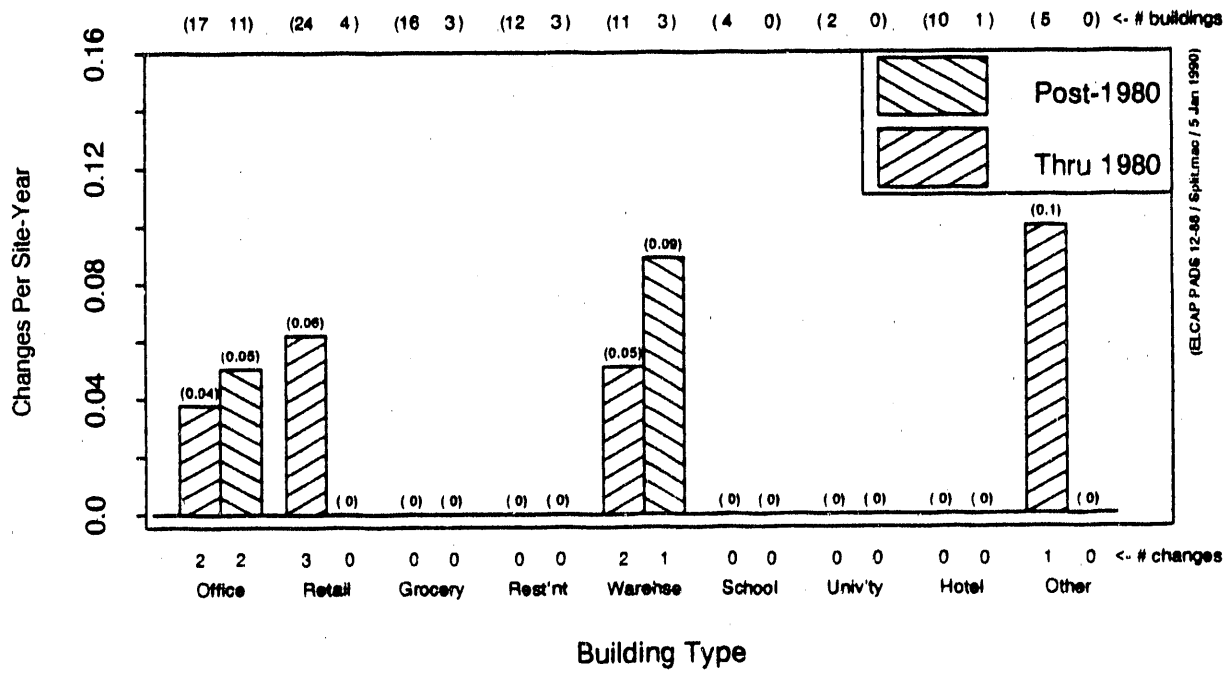


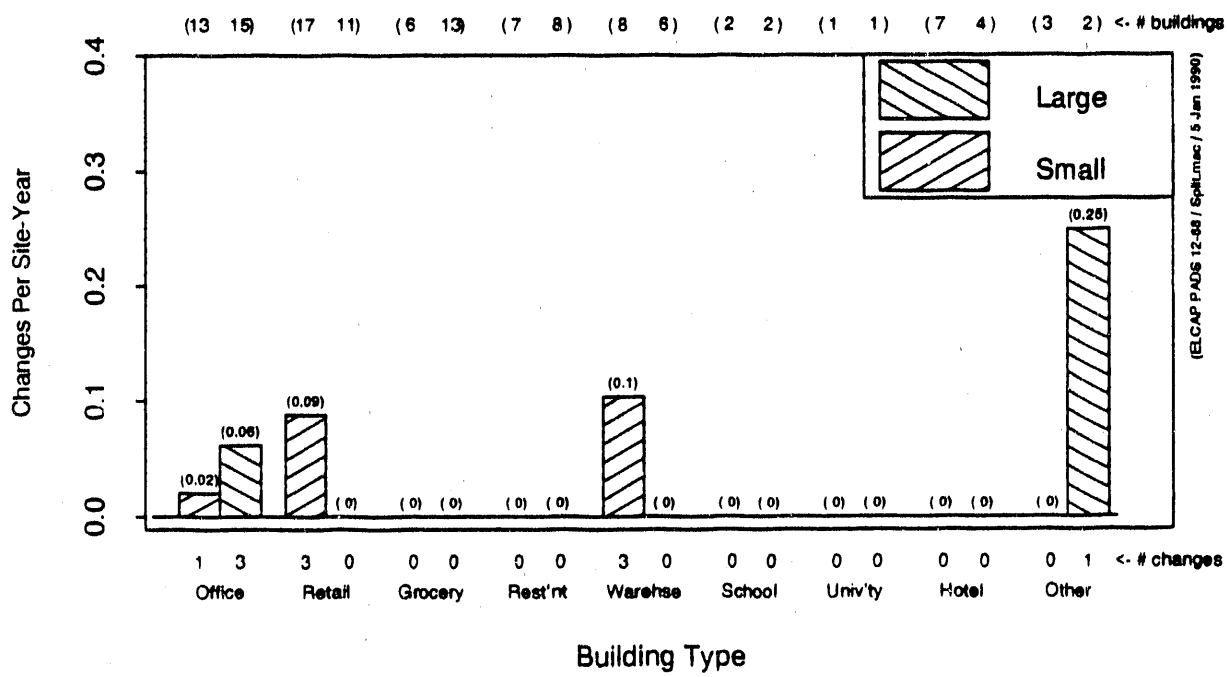
FIGURE 5-15

Frequency of Remodels

a) by Vintage




b) by Floor Area



type distinction are identical for old and new classes, each at 0.06. The only remodels detected for retails and warehouses are found in small buildings. Offices have remodels detected in both large and small buildings, with the rate for larger office remodels three times the rate for that found in smaller offices.

### Unclassified Changes

Because the causes of the unclassified load changes are unknown, it is difficult to draw detailed conclusions from these change rates. However, they are indicative of the general load stability within the various building types. As seen in Figure 5-16, all building types show higher rates for older buildings except for restaurants and groceries. For restaurants and groceries, the rates for new buildings are two and four times higher, respectively. This could possibly be related to a "settling in" period that is pronounced for these building types.

Rates of changes are higher for small buildings across all building classes. This may simply be due to masking of small changes by the higher loads in the large buildings, and so may not be important to policy or programs. Building size appears to make the least difference for restaurants among those building types with unclassified changes detected; rates for small and large are 0.19 and 0.16, respectively.

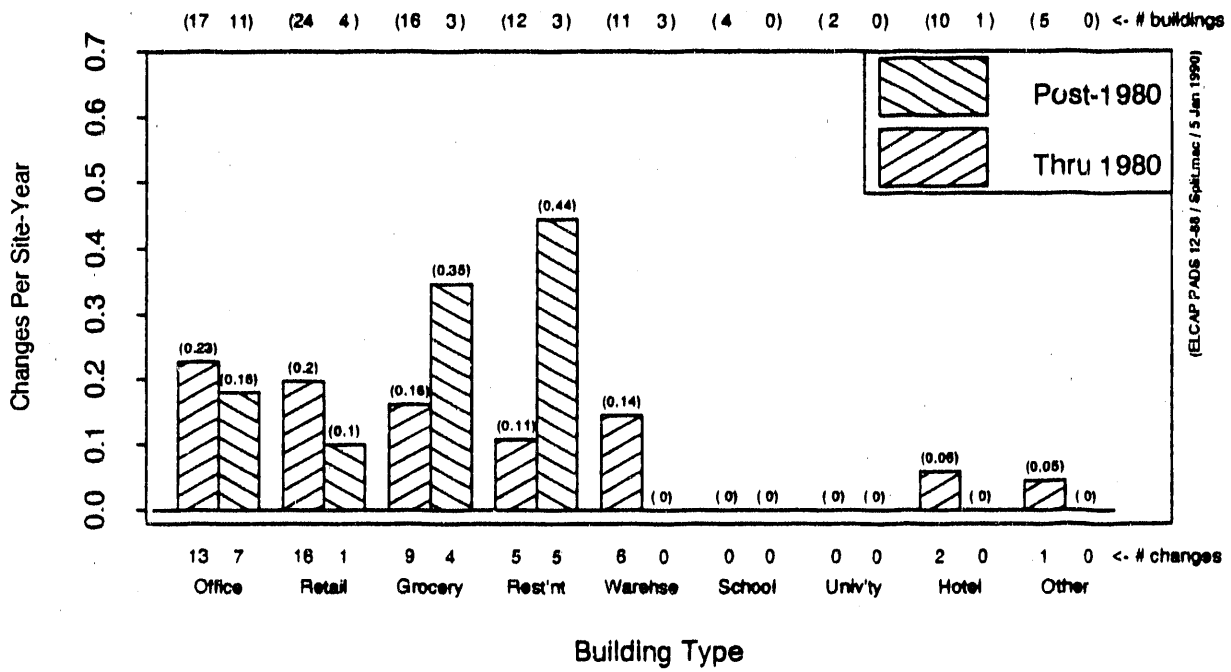
## IMPACT OF CHANGES ON ENERGY USE

In this initial effort, we also tried to develop a simple estimate of load impacts by end use resulting from each of the change events for buildings in our sample. However, this attempt was largely unsuccessful, due to the continual nature of change in the buildings and the masking of the change impacts by the normal fluctuation of the end-use loads. Buildings that

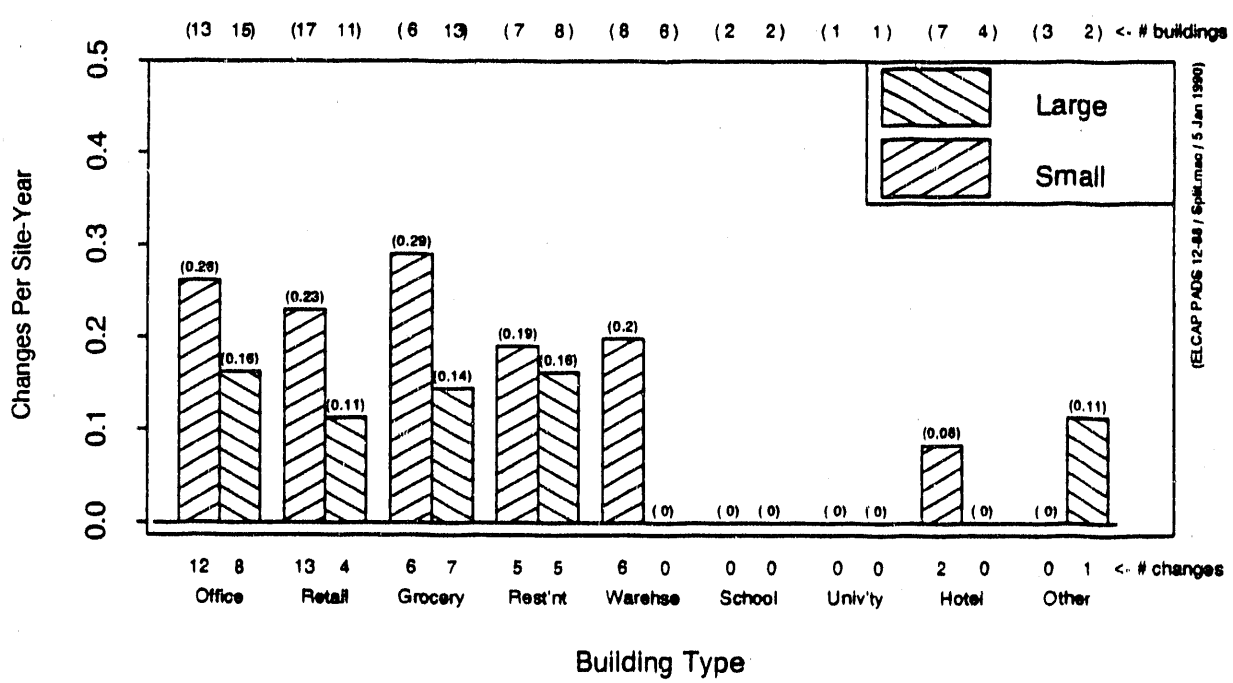
FIGURE 5-16

Frequency of Unclassified Changes

a) by Vintage




b) by Floor Area



exhibited frequent change often changed almost continually, blurring the distinction between the effects of any individual change. Further, many changes disrupted the metering equipment for a time, decreasing the available data between changes with which to quantify their effect.

The few energy impact estimates we were able to calculate are too limited for use as reliable, valid indicators of either ELCAP sample or commercial building population behavior. In Appendix C, we present those results both textually and graphically, to illustrate our discussion of the analysis difficulties we encountered.

The lack of success of this preliminary effort simply serves to underscore the continual shifting nature of occupancy and loads in commercial buildings. Alternative techniques are suggested in Appendix C for follow-on efforts to quantify change impacts on end-use loads.

## ADDITIONAL INFORMATION ON REMODELS

The hierarchy of change type definitions we use throughout this report is intended to best capture the true cause of observed changes in energy consumption. Because we attempt to associate each change event with a change in energy consumption, a single event that involved several change types is classified as a single change type according to the defined hierarchy. However, in many situations this approach tends to mask information regarding some change types. Remodels, for example, are expected to occur frequently when tenants change or the type of business operating from a building changes. Because the remodel is a result of the business type change, the hierarchy assumes that the business type change is more important in explaining energy consumption changes. The event is classified as a business type change and the remodel goes uncounted.

Because of the importance of remodel frequency to demand-side management programs, we have reviewed this category of changes in greater detail in Appendix D. In that appendix, we abandon the hierarchical classification scheme in favor of additional detail regarding each remodel event. We further

redefine "remodel" to include any change that affects either structure or equipment or any combination thereof. Finally we attempt to classify each remodel as having either added, removed, or replaced building space or equipment.

Section 6

# REFERENCES

Pearson, E. W., G. M. Stokes, and R. S. Crowder. 1985. "Data Verification in End-Use Metering." *Electric Power Research Institute Metering Workshop Papers*. DOE/BPA-13795-3, Bonneville Power Administration, Portland, Oregon.

Taylor, Z. T., and R. G. Pratt. 1990. *Description of Electric Energy Use in Commercial Buildings in the Pacific Northwest*. DOE/BP-13795-22, Bonneville Power Administration, Portland, Oregon.

# APPENDIX A

## DETAILED DISCUSSION OF CHANGE TABULATION METHODOLOGY

# APPENDIX A

## DETAILED DISCUSSION OF CHANGE TABULATION METHODOLOGY

The data sources described in Section 4 were searched to identify changes occurring in each building in the sample. We first examined each record source independently of the others. We then consolidated events that were cited in more than one source into single events.

Table A-1 is an actual example of the results of this process. The changes we identified from all data sources are listed for a small warehouse.

The headings found in Table A-1 are defined as follows:

- SITE - The identification number used by the ELCAP system to track the site.
- BLDG TYPE - The generic business type dominant in the building. If more than one business type is present in the building, the one occupying the greatest floor area is used to define the type for the building. The codes are as follows: 1 = office, 2 = retail, 3 = grocery, 4 = restaurant, 5 = warehouse, 6 = school, 7 = university, 8 = hotel, 9 = other.
- EVENT - A sequential number assigned to each change event identified for a building.
- ELCAP MONTH - The month in which the observed change occurred or was reported. Month #1 is defined to be January 1981, with subsequent months numbered sequentially. For example, in the first entry in Table A-1, month 61 is January 1986.
- LOAD DATA, DAY TYPE, SITE RELATION, MAINTENANCE, VERIFICATION - The various data sources from which the change was identified. An x in the column beneath one of these headings shows it was the data source that identified the change.
- NOTES - Comments regarding the type of change. These vary widely in detail, depending on the amount of information contained in the data source.

TABLE A-1

Changes Identified for a Small Warehouse

| Site | Bldg Type | Event | ELCAP Month | % Power Change | Load Data | Day Type | Site Relation | Maintenance | Verification | Analyst Notes |
|---|---|---|---|---|---|---|---|---|---|---|
| 18 | 5 | 1 | 61 | | | | | X | | New tenant: bakery, added ft² |
| 18 | 5 | 2 | 72 | | | | | X | | Added oven and mixer |
| 18 | 5 | 3 | 79 | | | | | | X | PCDs, apparently vacant (through 4/88) |
| 18 | 5 | 4 | 80 | | | | | X | | New tenant: painter ~~replace bakery~~ |
| 18*& | 5 | 5 | 81 | 85- | X | | | | | Inside lights, plug |
| 18 | 5 | 6 | 81-5 | | | X | | | | Apparent vacancy |
| 18* | 5 | 7 | 84+ | 100+ | X | | | | | Inside lights |
| 18 | 5 | 8 | 86 | | | | | X | | Four new tenants, total remodel |
| 18 | 5 | 9 | 88 | | | | X | | | New tenant, more employees/ equipment/lights |

* - The analyst was skeptical that the load change was large enough to be classified as an *event*.

& - A serious missing data problem makes the date of the change uncertain. Direct calculation of energy impacts may not be possible.

^ - The building has multiple tenants.

Many change events listed in Table A-1 were counted multiple times because of the disparate data sources used. For example, a vacancy was suspected in Site 18 from an examination of the day type data. This is indicated by the X in the DAY TYPE column. The ELCAP MONTH column shows that the apparent period of vacancy was months 81 through 85. The MAINTENANCE column indicates that 80% of the building became vacant in month 81. This indication concurs with the analyst's suspicions from looking at the load data. Furthermore, maintenance records indicated that new tenants occupied the building in month 86. This, too, agrees with the analyst's conjecture. Therefore, we concluded that the two events listed in Table A-1 actually represent the same change.

We followed the same procedure to examine and characterize the events listed for each site.

# APPENDIX B

## CONDENSED TABULATION OF CHANGE TYPE AND FREQUENCY FOR ALL SITES IN SAMPLE

## APPENDIX B

## CONDENSED TABULATION OF CHANGE TYPE AND FREQUENCY FOR ALL SITES IN SAMPLE

In this appendix, the type and frequency of change events we found are summarized for all sites in our sample. Our summary closely resembles that presented for the small warehouse example in Table A-1, Appendix A, but with two important exceptions.

First, the data source identifiers in our whole-site summary appear as numerals in a column labeled Key, rather than as Xs under narrative headings. The meanings of the key codes are shown in Table B-1.

Second, each change event is denoted more specifically, in terms of its type and extent of impact upon the data source from which it was identified, as FIRST MODE and SECOND MODE. The FIRST MODE is the highest mode

TABLE B-1

Definition of Data Source Key Column Codes

| Code | Meaning |
|---|---|
| 1 | Change was identified visually from EITHER the monthly load data OR the day typing results. |
| 2 | Change was identified visually from BOTH the monthly load data AND the day typing results. |
| 3 | Change was identified in a SINGLE record source. |
| 4 | Change was identified in MULTIPLE record sources. |
| 5 | Change was identified by both record AND data sources. |

classification, from the hierarchy described in Section 4 and listed in Table 4-1, that applies to the change event. The SECOND MODE is the secondary change mode that was subsumed by the FIRST MODE if multiple change types occurred concurrently. The modes are shown as integers ranging from 1 to 12. The codes are defined in Table B-2.

TABLE B-2

Change Mode Code Definitions

| Code | Meaning |
|---|---|
| 1 | Business type change |
| 2 | Tenant(s) change |
| 3 | Partial vacancy |
| 4 | Full vacancy |
| 5 | Fuel type change |
| 6 | Equipment change |
| 7 | Remodel |
| 8 | Schedule change |
| 9 | Unclassified load change |
| 10 | Reconfiguration of electric panel (loads are "moved" from one metered channel to another, but there is no net change in building energy consumption) |
| 11 | Electrical change (circuits are rearranged such that no changes in end-use loads actually occur, but the metering setup is disturbed) |
| 12 | Unclassified load spike |

The change events we tabulated for all sites in our sample are summarized in Table B-3. Multiple events have been combined according to the analyst's judgment.

To clarify the meaning of the FIRST MODE and SECOND MODE columns, consider the following example. Site number 7 in Table B-3 shows a change (starting in month 92) that is classified as an equipment change (type 6). The NOTES column shows that a new delicatessen was added, which probably involved new equipment, and there was a change to the lighting. Both of these fall under the equipment category. However, the notes also indicate a remodel of the building structure at the same time. Because remodels are lower in the hierarchy than equipment changes, the change event is defined to be an equipment change (type 6) in the FIRST MODE column, but the remodel code (7) is retained in the SECOND MODE column for reference.

TABLE B-3

Summary of Change Events for All Commercial Sites
(Condensed Classification - 8/30/89)

| Site | Bldg Type | Event | ELCAP Month | Key | First Mode | Second Mode | Notes |
|---|---|---|---|---|---|---|---|
| 2 | 1 | 1 | 63 | 1 | 9 | | inside lights drop |
| 2 | 1 | 2 | 68 | 3 | 4 | | tenant vacated |
| 2 | 1 | 3 | 75 | 3 | 2 | | tenant moved in |
| 2 | 1 | 4 | 78 | 3 | 4 | | tenant vacated |
| 2 | 1 | 5 | 81 | 1 | 9 | | inside lights single drop |
| 2 | 1 | 6 | 83 | 3 | 4 | | new tenants, interior wall change |
| 5* | 3 | 1 | 59 | 1 | 9 | | inside lights drop |
| 7& | 3 | 1 | 84 | 1 | 9 | | plug increase |
| 7 | 3 | 2 | 92-5 | 4 | 6 | 7 | added deli, light change, remodel |
| 11* | 4 | 1 | 82 | 1 | 9 | | outside lights drop |
| 11 | 4 | 2 | 86 | 1 | 9 | | inside lights increase |

TABLE B-3 contd

| Site | Bldg Type | Event | ELCAP Month | Key | First Mode | Second Mode | Notes |
|---|---|---|---|---|---|---|---|
| 12^ | 2 | 1 | 66 | 3 | 4 | | plugs added, 2+ tenant changes |
| 12^ | 2 | 2 | 83 | 3 | 4 | | tenant vacated |
| 13 | 9 | 1 | 76+ | 1 | 9 | | inside lights, outside lights drop |
| 18 | 5 | 1 | 61 | 3 | 2 | 6 | new tenant: bakery |
| 18 | 5 | 2 | 72 | 3 | 6 | | added oven, mixer |
| 18 | 5 | 3 | 79 | 3 | 4 | 6 | 95% vacant |
| 18 | 5 | 4 | 81-5 | 5 | 2 | 6 | four new tenants; inside lights, plug low point |
| 37 | 3 | 1 | 69 | 3 | 6 | | frozen food equipment added |
| 37 | 3 | 2 | 79 | 3 | 6 | | wine/beer coolers added |
| 37 | 3 | 3 | 86 | 1 | 9 | | plug winter jump |
| 37 | 3 | 4 | 97 | 3 | 6 | | pop+yogurt machine, battery chargers added |
| 40 | 5 | 1 | 69-71 | 2 | 9 | | plug*,inside lights jump |
| 40 | 5 | 2 | 75-7 | 1 | 9 | | outside lights drop |
| 40 | 5 | 3 | 93 | 4 | 7 | | new addition of 6200 sqft (monitored?) |
| 41 | 8 | 1 | 76 | 3 | 6 | | added lighting |
| 41& | 8 | 2 | 78-80 | 5 | 9 | | inside lights, plug jump, Positive checksum differences |
| 41 | 8 | 3 | 82 | 4 | 6 | | added AC |
| 41 | 8 | 4 | 89 | 1 | 9 | | inside lights jump |
| 41 | 8 | 5 | 94 | 3 | 6 | | added AC |
| 79 | 8 | 1 | 82 | 3 | 6 | | pop, ice machine, plugs, washer/dryer |
| 81 | 8 | 1 | 64 | 4 | 6 | | new water heater |
| 81 | 8 | 2 | 72-3 | 3 | 6 | | new water heaters |
| 148^* | 2 | 1 | 78 | 5 | 12 | | remod expected, plug spike |
| 148^ | 2 | 2 | 79 | 1 | 9 | | inside lights drop |
| 148^ | 2 | 3 | 81-2 | 4 | 6 | | new loads; washers |
| 148^* | 2 | 4 | 85 | 1 | 12 | | plug single spike |
| 273 | 1 | 1 | 62 | 3 | 6 | | fans added |
| 273 | 1 | 2 | 88 | 3 | 6 | | computer added |

TABLE B-3 contd

| Site | Bldg Type | Event | ELCAP Month | Key | First Mode | Second Mode | Notes |
|---|---|---|---|---|---|---|---|
| 282 | 5 | 1 | 83-9 | 5 | 6 | 7 | added commissary |
| 283^ | 1 | 1 | 75 | 3 | 4 | | vacant |
| 283^ | 1 | 2 | 88 | 3 | 4 | | vacant |
| 283^ | 1 | 3 | 93 | 3 | 2 | | new tenant, no elec changes |
| 284 | 3 | 1 | 70 | 4 | 2 | | new owner, no elec changes |
| 284 | 3 | 2 | 74 | 3 | 6 | | added chicken cooker |
| 285& | 3 | 1 | 82 | 1 | 9 | | inside lights, plug drop |
| 285 | 3 | 2 | 101 | 4 | 6 | | cardboard bailer added |
| 286 | 1 | 1 | 60 | 1 | 9 | | big inside lights drop, vacancy? |
| 286 | 1 | 2 | 77 | 2 | 9 | | inside lights triples |
| 286 | 1 | 3 | 82 | 3 | 6 | | new tenant, added AC, lights, plugs |
| 286 | 1 | 4 | 85-7 | 3 | 6 | | owner mods start Jan 1 |
| 286 | 1 | 5 | 98 | 4 | 6 | | new plugs, computers, BB heat, dishwasher, ACs. |
| 286 | 1 | 6 | 101 | 4 | 6 | | new AC |
| 286 | 1 | 7 | 102 | 3 | 3 | | vacant |
| 287*& | 2 | 1 | 63 | 1 | 9 | | plug jump |
| 287 | 2 | 2 | 70+ | 2 | 9 | | inside lights increases, outside lights drop |
| 287* | 2 | 3 | 73 | 1 | 9 | | plug drop |
| 287* | 2 | 4 | 83 | 1 | 9 | | outside lights jump |
| 287* | 2 | 5 | 84 | 1 | 9 | | plug jump |
| 287 | 2 | 6 | 99 | 4 | 6 | | owner mods, HVAC rework |
| 289 | 2 | 1 | 97 | 3 | 6 | | replaced air compressor |
| 290 | 1 | 1 | 76 | 3 | 6 | | owner mods, 10kW Positive checksum difference begin?? |
| 290 | 1 | 2 | 82-4 | 5 | 6 | | plug jump, light, plugs added |
| 292 | 4 | 1 | 63 | 3 | 11 | | breaker switched. (fixed??) |
| 293 | 2 | 1 | 78 | 3 | 6 | | added exhaust fans |

TABLE B-3 contd

| Site | Bldg Type | Event | ELCAP Month | Key | First Mode | Second Mode | Notes |
|---|---|---|---|---|---|---|---|
| 294 | 5 | 1 | 76-8 | 4 | 6 | | expanded, new computer equipment |
| 294 | 5 | 2 | 82 | 3 | 6 | | added AC |
| 294* | 5 | 3 | 86 | 1 | 12 | | inside lights peak, seasonal? |
| 294 | 5 | 4 | 103 | 3 | 7 | | building being enlarged |
| 295 | 2 | 2 | NA | 3 | 6 | 7 | added 18kW light, boarded windows |
| 297 | 3 | 1 | 72 | 1 | 9 | | plug drop |
| 297 | 3 | 2 | 86 | 1 | 9 | | plug jump |
| 297 | 3 | 3 | 93 | 1 | 9 | | plug jump |
| 298 | 1 | 1 | 73 | 3 | 6 | | added wall to shield from unconditioned space |
| 298* | 1 | 2 | 79-80 | 1 | 12 | | outside lights low point, seasonal? |
| 299* | 1 | 1 | 68 | 1 | 12 | | inside lights, low point |
| 299 | 1 | 2 | 72-4 | 4 | 6 | | new HP, air handler, alarm, office(?) |
| 299* | 1 | 3 | 80 | 1 | 9 | | inside lights low, outside lights drop |
| 299 | 1 | 4 | 81 | 3 | 7 | | parking enclosed |
| 299* | 1 | 5 | 87 | 1 | 9 | | inside lights drop |
| 299* | 1 | 6 | 89 | 1 | 12 | | outside lights peak |
| 300 | 5 | 1 | 74 | 3 | 6 | | added lights |
| 300 | 5 | 2 | 88-9 | 5 | 3 | | vacant, big drops |
| 441 | 4 | 1 | 64 | 3 | 6 | | new A/C unit |
| 441 | 4 | 2 | 89 | 3 | 6 | | added ice machine, food warmer |
| 441 | 4 | 3 | 92 | 3 | 6 | | Incand. to Florsct, 3600W to 780W |
| 441 | 4 | 4 | 93 | 3 | 6 | | exhaust fan added |
| 442^ | 2 | 1 | 66 | 3 | 4 | | 3 vacancies |
| 442^ | 2 | 2 | 74 | 3 | 4 | | 80% vacant |
| 442^ | 2 | 3 | 82 | 2 | 9 | | inside lights drop, vacant? |
| 443 | 2 | 1 | 83 | 3 | 7 | | major remodel |

TABLE B-3 contd

| Site | Bldg Type | Event | ELCAP Month | Key | First Mode | Second Mode | Notes |
|---|---|---|---|---|---|---|---|
| 444* | 1 | 1 | 76 | 1 | 9 | | outside lights jump |
| 444* | 1 | 2 | 79 | 1 | 9 | | plug jump |
| 445 | 4 | 1 | 72 | 1 | 12 | | plug peak, seasonal? |
| 445 | 4 | 2 | 77 | 3 | 6 | | new oven |
| 445& | 4 | 3 | 83 | 1 | 12 | | plug peak, seasonal? |
| 445 | 4 | 4 | 89 | 1 | 9 | | outside lights drop |
| 445 | 4 | 5 | 91 | 3 | 11 | | owner re-arranged breaker |
| 445 | 4 | 6 | 97 | 3 | 11 | | CTs melted |
| 446& | 5 | 1 | 80? | 1 | 9 | | plug drop |
| 446* | 5 | 2 | 83 | 1 | 9 | | outside lights goes to zero |
| 446* | 5 | 3 | 92 | 1 | 9 | | plug drop |
| 446 | 5 | 4 | 98 | 3 | 6 | 7 | added heat, office |
| 447^ | 2 | 1 | 67 | 3 | 7 | | remodeled |
| 447^ | 2 | 2 | 83 | 3 | 6 | | lights, terminals |
| 449 | 2 | 1 | 66 | 3 | 6 | | new heat and lights |
| 449 | 2 | 2 | 88-91 | 1 | 12 | | plug, low point, seasonal? |
| 450 | 3 | 1 | 75-8 | 1 | 9 | | plug jump |
| 450 | 3 | 2 | 75 | 1 | 9 | | inside lights jump |
| 450 | 3 | 3 | 79-81 | 2 | 9 | | plug, inside lights, outside lights, drop |
| 451 | 1 | 1 | 63 | 3 | 6 | | plugs added |
| 451 | 1 | 2 | 72 | 1 | 12 | | inside lights, plug low point |
| 451 | 1 | 3 | 81 | 4 | 6 | | added computer |
| 451 | 1 | 4 | 84 | 1 | 12 | | plug peak |
| 451 | 1 | 5 | 84 | 3 | 7 | | moved lunch room |
| 451 | 1 | 6 | 89 | 3 | 6 | | added plugs, copy machine |
| 455 | 2 | 1 | 81 | 3 | 6 | | lights, AC added |
| 455& | 2 | 2 | 84 | 1 | 9 | | inside lights higher, missing data |
| 455 | 2 | 3 | 87 | 3 | 3 | | vacancy |
| 457& | 4 | 1 | 66 | 1 | 9 | | inside lights, plug drop |
| 457& | 4 | 2 | 66 | 1 | 9 | | outside lights jump |

TABLE B-3 contd

| Site | Bldg Type | Event | ELCAP Month | Key | First Mode | Second Mode | Notes |
|---|---|---|---|---|---|---|---|
| 457 | 4 | 3 | 70 | 3 | 1 | | new bus type/tenant, ref removed |
| 457 | 4 | 4 | 71 | 1 | 9 | | inside lights drop |
| 457* | 4 | 5 | 77 | 1 | 9 | | plug jump |
| 457 | 4 | 6 | 82-3 | 1 | 9 | | plug drop |
| 457& | 4 | 7 | 87-8 | 5 | 3 | | inside lights, outside lights drop, vacant |
| 458^ | 1 | 1 | 73-5 | 1 | 12 | | outside lights, peak, seasonal? |
| 458^ | 1 | 2 | 84 | 3 | 4 | | downstairs tenant moved out |
| 458^ | 1 | 3 | 85 | 1 | 9 | | plug jump |
| 458^ | 1 | 4 | 88 | 3 | 6 | 7 | new plugs, some remodeling |
| 532 | 2 | 1 | 74 | 1 | 9 | | outside lights drop |
| 532 | 2 | 2 | 83-4 | 1 | 12 | | outside lights low point |
| 532 | 2 | 3 | 98 | 3 | 6 | | wine cooler display, cash registers |
| 533 | 3 | 1 | 74 | 3 | 11 | | hardware failure |
| 533 | 3 | 2 | 76 | 4 | 2 | | new owner |
| 533 | 3 | 3 | 91 | 3 | 11 | | hardware failure |
| 533 | 3 | 4 | 100 | 3 | 3 | | vacant, bankrupt |
| 534 | 8 | 1 | 74 | 3 | 6 | | kitchen outlets added |
| 534 | 8 | 2 | 76 | 4 | 6 | | remodeled front, added computer, lights |
| 534 | 8 | 3 | 100 | 4 | 6 | | remodeled, new restaurant |
| 538^ | 1 | 1 | 79 | 1 | 9 | | plug, low power |
| 538^ | 1 | 2 | 85 | 3 | 4 | 7 | partial vac., remodel upstairs |
| 538^ | 1 | 3 | 94 | 3 | 1 | 6 | new tenants, ice cream shop, remodel |
| 541 | 3 | 1 | 74 | 1 | 9 | | plug drop |
| 541 | 3 | 2 | 83 | 3 | 6 | | new walk-in cooler: bakery, lights, plugs, fans |
| 544 | 2 | 1 | 72 | 3 | 6 | | added lights |
| 544& | 2 | 2 | 80? | 1 | 9 | | outside lights jump |
| 544 | 2 | 3 | 87 | 3 | 6 | | new computer |

TABLE B-3 contd

| Site | Bldg Type | Event | ELCAP Month | Key | First Mode | Second Mode | Notes |
|---|---|---|---|---|---|---|---|
| 544& | 2 | 4 | 90? | 1 | 9 | | outside lights drop |
| 546 | 2 | 1 | 66 | 3 | 6 | | new lights and plugs |
| 546 | 2 | 2 | 85-6 | 1 | 12 | | plug peak |
| 546 | 2 | 3 | 97 | 4 | 6 | | plugs, lights |
| 546 | 2 | 4 | 100 | 4 | 6 | | new water heater |
| 548 | 1 | 1 | 73 | 3 | 7 | | added wall separating cond/uncond |
| 548 | 1 | 2 | 85 | 1 | 12 | | plug peak |
| 548 | 1 | 3 | 97 | 3 | 11 | | rearranged breakers |
| 550 | 5 | 1 | 82+ | 5 | 4? | | four tenant vacancies, proc eqpt replaced, drops |
| 550 | 5 | 2 | 88-8 | 4 | 2 | | all new tenants, new assembly line |
| 555 | 8 | 1 | 95 | 3 | 2 | | new owner |
| 555 | 8 | 2 | 97 | 3 | 6 | | added exterior lighting |
| 556 | 2 | 1 | 72-5 | 2 | 12 | | inside lights peak |
| 556 | 2 | 2 | 81 | 2 | 12 | | inside lights peak |
| 559 | 4 | 1 | 93 | 3 | 6 | | added micowave, pop machine, steam table |
| 560& | 3 | 2 | 75? | 1 | 9 | | plug drop |
| 560 | 3 | 4 | 82 | 3 | 6 | | added track lights, bev. coolers, ice case, juicer, plugs |
| 562 | 7 | 1 | 84 | 1 | 12 | | plug peak |
| 562 | 7 | 2 | 102 | 3 | 6 | | upholstery to photo shop |
| 566 | 2 | 1 | 73 | 2 | 9 | | inside lights increase |
| 566 | 2 | 2 | 82 | 4 | 6 | | added cash machine, lights, plugs, cash regstr |
| 566 | 2 | 3 | 97 | 3 | 6 | | added plugs, computer, outside lights, register |
| 571^ | 2 | 1 | 80-1 | 1 | 12 | | outside lights peak |
| 571^ | 2 | 2 | 84-5 | 1 | 12 | | outside lights peak |

TABLE B-3 contd

| Site | Bldg Type | Event | ELCAP Month | Key | First Mode | Second Mode | Notes |
|---|---|---|---|---|---|---|---|
| 582 | 2 | 1 | 71 | 2 | 9 | | inside lights, outside lights drop |
| 582 | 2 | 2 | 74-5 | 3 | 2 | | full vacant |
| 582 | 2 | 3 | 93 | 4 | 1 | 6 | new business type |
| 583 | 1 | 1 | 76 | 3 | 6 | | owner mods unknown, SV planned |
| 586 | 5 | 1 | 70 | 3 | 6 | | new computers? |
| 587 | 3 | 1 | 70 | 3 | 6 | | total remodel |
| 587 | 3 | 2 | 82 | 3 | 6 | | added toaster, bun warmer |
| 588 | 3 | 1 | 76 | 4 | 6 | | added egg case |
| 588 | 3 | 2 | 82 | 3 | 6 | | added yogurt machine |
| 588 | 3 | 3 | 96 | 3 | 1 | 6 | added bank: pop+ice machines |
| 588 | 3 | 4 | 102 | 3 | 6 | | chicken service deli |
| 591 | 2 | 1 | 74 | 3 | 6 | | removed gas heater |
| 591 | 2 | 2 | 86 | 4 | 6 | | changed lights |
| 591 | 2 | 3 | 100 | 4 | 6 | 7 | remodel |
| 593 | 4 | 1 | 69-71 | 4 | 2 | | new tenant, remodel, more area |
| 593 | 4 | 2 | 76 | 3 | 6 | | added food prop breaker |
| 593 | 4 | 3 | 79 | 3 | 6 | | added salar bar, kettles lights |
| 593 | 4 | 4 | 89-90 | 1 | 12 | | outside lights low point |
| 594 | 3 | 1 | 85 | 2 | 3 | | plug, inside lights drop, out of business |
| 595 | 1 | 1 | 83 | 1 | 9 | | plug, outside lights jump |
| 595 | 1 | 2 | 88 | 1 | 9 | | inside lights jump |
| 598 | 4 | 1 | 79 | 3 | 6 | | added ice cream machine |
| 598 | 4 | 2 | 86 | 4 | 6 | 7 | total remodel, complete new equipment/systems |
| 599 | 3 | 1 | 76 | 3 | 6 | 7 | lights changed, equip added |
| 600* | 1 | 1 | 80-3 | 1 | 9 | | plug drop |

TABLE B-3 contd

| Site | Bldg Type | Event | ELCAP Month | Key | First Mode | Second Mode | Notes |
|---|---|---|---|---|---|---|---|
| 601 | 1 | 1 | 72 | 1 | 9 | | inside lights jump |
| 601 | 1 | 2 | 75 | 1 | 12 | | plug peak |
| 601 | 1 | 3 | 84 | 1 | 9 | | outside lights, jump seasonal |
| 602 | 1 | 1 | 70 | 3 | 2 | 4 | new tenant, added computers |
| 602 | 1 | 2 | 74 | 4 | 6 | | added plugs, moved breakers |
| 602 | 1 | 3 | 77 | 5 | 2 | | outside lights drop, tenant change |
| 602 | 1 | 4 | 88 | 3 | 4 | | vacancy |
| 602 | 1 | 5 | 89 | 1 | 9 | | outside lights jump |
| 605 | 3 | 1 | 81 | 1 | 9 | | inside lights, slight drop |
| 605 | 3 | 2 | 101 | 1 | 3 | | out of business |
| 607 | 1 | 1 | 81 | 3 | 6 | | oulets added |
| 610* | 2 | 1 | 88-90 | 2 | 9 | | inside lights drop |
| 681 | 2 | 1 | 70 | 3 | 6 | | added track lights, changed to flourescent |
| 681 | 2 | 2 | 71 | 3 | 6 | | added track lights |
| 681 | 2 | 3 | 73 | 3 | 6 | | added box compactor |
| 681 | 2 | 4 | 82 | 3 | 6 | | owner mods, lighting (686) |
| 681 | 2 | 5 | 86 | 3 | 6 | | added lights, cash register |
| 681 | 2 | 6 | 89 | 3 | 6 | | added lights, cash register |
| 690 | 3 | 1 | 73 | 1 | 12 | | outside lights peak |
| 691^ | 7 | 1 | 97 | 3 | 6 | | added computers |
| 697 | 1 | 1 | 70 | 3 | 4 | | tenant change, vacancy |
| 697 | 1 | 2 | 71 | 3 | 6 | | new outlets, food prep |
| 697 | 1 | 3 | 78-82 | 3 | 6 | | owner mods, remodeling? |
| 697 | 1 | 4 | 88 | 3 | 6 | | added plugs, telephone |
| 697 | 1 | 5 | 94 | 3 | 6 | | added plugs, range, cranked up fan |
| 697 | 1 | 6 | 101 | 3 | 6 | | added copier |
| 705 | 4 | 1 | 66 | 1 | 9 | | outside lights drop |

TABLE B-3 contd

| Site | Bldg Type | Event | ELCAP Month | Key | First Mode | Second Mode | Notes |
|---|---|---|---|---|---|---|---|
| 705 | 4 | 2 | 74 | 5 | 9 | | outside lights, inside lights jump |
| 705 | 4 | 3 | 77 | 1 | 12 | | plug peak |
| 707 | 5 | 1 | 85 | 3 | 6 | | new energy mgmt control system |
| 707& | 5 | 2 | 89 | 5 | 8 | | all out operation for convention |
| 707 | 5 | 3 | 94 | 3 | 6 | | added exhaust fans |
| 712 | 2 | 1 | 75 | 3 | 6 | | added energy management system |
| 714 | 1 | 1 | 80-1 | 1 | 12 | | outside lights, low point |
| 714 | 1 | 2 | 101 | 4 | 4 | | new tenant (dentist) |
| 716 | 2 | 1 | 72-3 | 2 | 9 | | inside lights drop |
| 716 | 2 | 3 | 84+ | 1 | 9 | | inside lights jump |
| 717 | 1 | 1 | 82 | 3 | 6 | | added computer, copier, telephone system |
| 717 | 1 | 2 | 93 | 1 | 9 | | outside lights drop |
| 723 | 2 | 1 | 83+ | 3 | 4 | | tenants, equip, struct. mods |
| 723 | 2 | 2 | 86 | 3 | 6 | | added film equipment, plugs, sept. 87? (81) |
| 723 | 2 | 3 | 88 | 3 | 7 | | upstairs made usable space for rent |
| 726 | 8 | 1 | 89 | 4 | 6 | | added coffee maker, ovens |
| 731 | 1 | 1 | 80 | 3 | 7 | | window film added north |
| 731 | 1 | 2 | 88 | 3 | 6 | | added plugs, dishwasher, disposal, telephone |
| 731 | 1 | 3 | 88 | 3 | 4 | | tenant changes |
| 735 | 2 | 1 | 77 | 3 | 6 | | lights |
| 735 | 2 | 2 | 78 | 3 | 2 | 6 | new business/owners, added air conditioning, plugs |
| 736 | 5 | 1 | 70 | 3 | 2 | | day care closed |
| 736 | 5 | 2 | 77 | 1 | 9 | | inside lights jump |

TABLE B-3 contd

| Site | Bldg Type | Event | ELCAP Month | Key | First Mode | Second Mode | Notes |
|---|---|---|---|---|---|---|---|
| 736 | 5 | 3 | 94 | 3 | 4 | | vacant? (ver. notes says NOT vacant) |
| 736 | 5 | 4 | 101 | 4 | 7? | | remodelled (deli) |
| 738^ | 1 | 1 | 74 | 3 | 6 | | added plugs |
| 738^ | 1 | 2 | 82 | 1 | 9 | | plug jump |
| 738^ | 1 | 3 | 87+ | 1 | 9 | | plug jump |
| 738 | 1 | 4 | 90+ | 3 | 6 | | added HVAC mixing boxes to separate zones |
| 738^ | 1 | 5 | 94 | 4 | 6 | | remodel, added lights |
| 747 | 1 | 1 | 61 | 3 | 6 | | owner mods |
| 747 | 1 | 2 | 69 | 3 | 6 | | unmon load??? |
| 747 | 1 | 3 | 72 | 4 | 2 | 6 | new tenant, remodel, track lights added |
| 747 | 1 | 4 | 87 | 1 | 9 | | outside lights jump |
| 751 | 2 | 1 | 72 | 3 | 6 | | added computer, ordering machine |
| 751 | 2 | 2 | 79 | 1 | 9 | | outside lights drop |
| 752 | 9 | 1 | 64 | 3 | 7 | | windows to double pane |
| 752 | 9 | 2 | 93 | 3 | 6 | | PLANNED heat (to gas), light, insul. renov. |
| 753& | 6 | 1 | 78 | 2 | 12 | | inside lights, outside lights, plug low point |
| 6010 | 2 | 1 | 80-1 | 1 | 12 | | outside lights peak |
| 6010 | 2 | 2 | 87 | 1 | 9 | | outside lights drop |
| 6011 | 2 | 1 | 79 | 2 | 9 | | inside lights drop |
| 6011* | 2 | 2 | 84-5 | 1 | 12 | | outside lights, seasonal peak |
| 6020 | 1 | 1 | 82 | 2 | 9 | | inside lights, plug drop |
| 6023& | 5 | 1 | 92 | 1 | 9 | | plug jump |

TABLE B-3 contd

| Site | Bldg Type | Event | ELCAP Month | Key | First Mode | Second Mode | Notes |
|---|---|---|---|---|---|---|---|
| 6028 | 2 | 1 | 91 | 1 | 9 | | inside lights drop, vacancy? |
| 6[illegible]1& | 1 | 1 | 73 | 1 | 9 | | plug drop |
| 6035* | 4 | 1 | 79 | 1 | 9 | | inside lights jump |
| 6035 | 4 | 2 | 81 | 1 | 9 | | plug jump |
| 6042 | 3 | 1 | 88 | 2 | 9 | | inside lights jump |

# APPENDIX C

# ENERGY IMPACTS OF CHANGES

# APPENDIX C

## ENERGY IMPACTS OF CHANGES

One objective of our analysis was to quantify the average energy impact of each change type through an explicit examination of end-use loads before and after each change. Our non-case study approach was unsuccessful, in part due to the high frequency with which changes were encountered.

This appendix includes a description of the complexities involved in assessing the energy impacts of changes. Understanding these complexities provides insight into the nature of change processes in the commercial sector. Here we briefly discuss the methodology that we applied to the change data to calculate the energy impacts. Included are graphical summaries to illustrate the rate at which change events were "lost" to the impact analysis. The limited set of change events with energy impact estimates is discussed and graphically summarized. This appendix concludes with suggestions for further research to assess the energy impacts of change events.

### COMPLEXITIES IN ASSESSING CHANGE IMPACTS

Although the process of comparing pre- and post-change load levels for an end use may seem straightforward, it is complicated by a number of practical considerations. Those factors are discussed here in the context of developing an automated technique for measuring change impacts on the relatively large scale of the ELCAP sample.

It is clear that a case study approach would likely yield the most useful results. However, this approach was not selected for the current work because of the large number of ELCAP buildings and the volume of the available data and record sources. Below are the major impediments to simple calculation of change impacts in the ELCAP study.

## Uncertainty of the Exact Time of Change

The nature of most of the information sources in the ELCAP database is that change events are not reported or do not become obvious until after they have already occurred. Frequently, for example, a change in building tenancy will not be immediately reported to ELCAP personnel. Likewise, a lighting retrofit may not be reported at all but might be discovered by maintenance personnel many months later. In such cases, an attempt is made to ascertain the exact time of change. However, this is not always possible, especially if a new tenant has occupied the building subsequent to the change in question.

## Transition Periods Surrounding Changes

It may be expected that many changes will involve a transition period before the loads of the affected end uses stabilize. In its simplest form, this phenomenon relates only to the month in which the change occurs, as illustrated in Figure C-1. The plot shows a hypothetical end use load that is affected by a partial vacancy occurring in June of the second metered year. If the vacancy occurred in the middle of the month, the June monthly load for the end use would drop only halfway to its eventual lower bound.

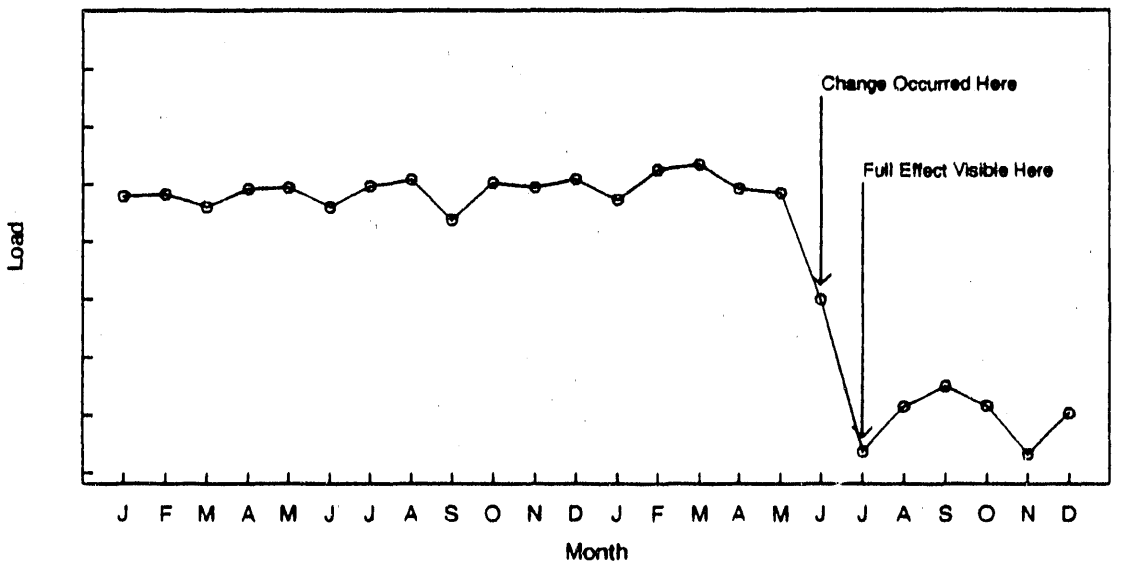
In more complicated forms, this phenomenon can affect many months' loads. For example, a tenant may move out of a building in phases, taking several months to completely vacate. Or, a new tenant might take several months to establish a routine so that end-use loads would be indicative of long-term, stable loads.

## Seasonal and Weather-Dependent Loads

Many loads, particularly those for HVAC and refrigeration, are highly dependent on outdoor temperatures. If a change is expected to impact one of these loads, it is highly unlikely that a simple before/after load comparison would give meaningful results, because the weather is likely to have changed over that interval.

FIGURE C-1

Hypothetical Example of Transition Period for a Single Change




Unavailability of Load Data Before and After a Change

In any metering project, especially one as extensive as ELCAP, missing data are inevitable. Random hardware failures and/or owner interventions in the electrical panel distribution result in periods of missing data. In the ELCAP data, this problem is especially evident after equipment changes, which frequently disturb the metering hardware and result in missing load data for one or more months.

Uncertainty About Which End Uses Are Affected

The extent of detailed information known about changes varies dramatically. Some changes are understood fully, while others are known only from terse written comments alluding to the change. Thus, it is seldom understood *a priori* exactly which end uses will be impacted by a change.

The following example illustrates the problem. Suppose two changes occur in successive months. The first change impacts lighting loads, but the second change does not. The records of these changes contain insufficient detail to convey that only the first change affected lighting, so it must be assumed that both loads might have affected the lighting end use. Because the second change occurred before sufficient data were collected to get reasonable post-change load estimates for the first change, no estimate of lighting impacts is possible.

## METHODOLOGY USED TO DIRECTLY ASSESS CHANGE IMPACTS

The methodology we used simply involved computing, for each discrete change event, the difference between pre-change and post-change loads for each end use at the affected site. We divided the changes in loads by the floor area in the building so that we could average the impacts across buildings. We had to examine several end uses because many change events are not described well enough in our data sources to determine exactly which end uses will be impacted.

For each of the four building types--offices, retails, groceries, and restaurants--we calculated energy impact estimates for the following end uses: building load total, inside lights, total HVAC, and other. Groceries and restaurants also have estimates for refrigeration and food preparation.[a] For groceries and restaurants, the end use designated as other excludes loads from the refrigeration and food preparation end uses.

Conceptually, each end use was processed as follows. The monthly time series of end-use load data was obtained. These monthly values were calculated using two data types, which are part of the PADS-COM-Dec88 standard

---

(a) These end uses are described by Halverson, Mazzucchi, Hadley, and Caplinger in their May 1989 draft document, *End Uses*.

monthly aggregations.[a] The averaged monthly power value, data type "f," was accepted for our analysis if 360 hours (15 days) were present for the month, based on an examination of data type "n."

The monthly time series was "marked" at each month during which a change was detected. Figure C-2 illustrates this procedure with a 15-month time series from a hypothetical building. The time line represents months for which load data are available. The example building underwent four changes, which are marked by arrows in Figure C-2.

Before pre- and post-change data for each event were identified, several months' data were eliminated (made "missing") to account for transition periods and the uncertainties in event dates. As shown by the shaded pairs of arrows in Figure C-2, each month in which a change was reported **and** the previous month were eliminated, based on assumptions that the actual month of change is likely to be a transition month and that the ELCAP records will often be at least one month late in reporting the event.

Next, for each event, all data prior to the event but subsequent to any previous event were averaged, and all data subsequent to the event but prior to the next event were averaged. This ensured that only one event contributed to the calculated load differences. The difference between the mean post-change data and the mean pre-change data was defined as the energy impact of the change event.

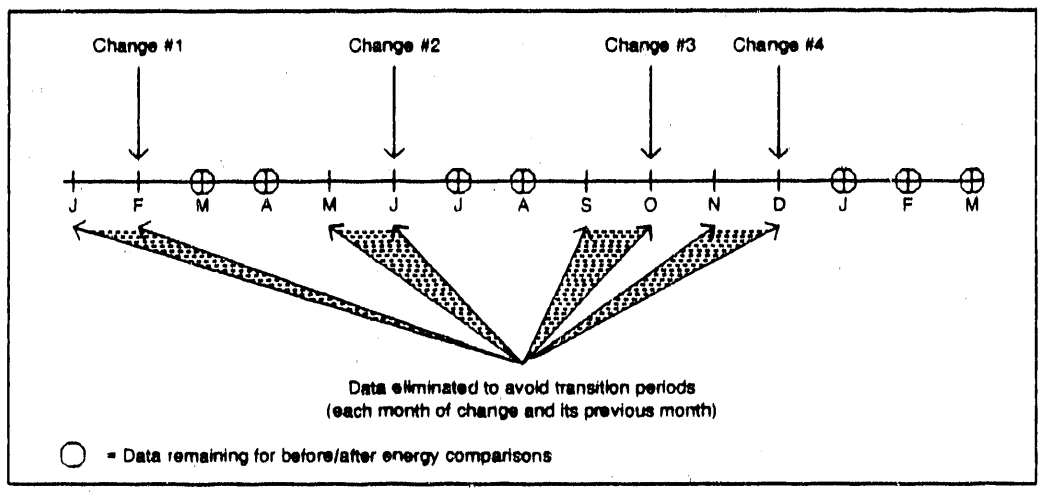
Two methods of operating on the monthly power values in the candidate pre- and post-change energy data windows were used to calculate impact estimates. In the first method, all months of data in each of the candidate pre- and post-change windows were averaged separately before those mean loads were subtracted. In the second method, only the single closest month within

---

(a) These data types are described by Caplinger and Schwab in their September 1989 draft document, *ELCAP Pre-Aggregated Data Set Design and Specification Document*.

FIGURE C-2

Example of Pre- and Post-Change
Data Used for Energy Impacts




each candidate pre-change and post-change window was selected and subtracted. In either case, the pre-change value was subtracted from the post-change value to calculate the impact. Thus, a positive impact implies a greater load after the change event.

In this manner, end-use load impacts (watts/square foot) were calculated for every identified event. Then, the load impacts of all events were averaged within change type and building type categories. This calculation yields, for example, the average impact on lighting loads of full vacancies in offices.

As shown in Figure C-2, however, only one of the change events (Change #2) had enough pre- and post-change data for us to calculate an energy impact. This situation was encountered in a large number of the ELCAP buildings. The fraction of events for which direct pre- and post-change loads were available was very small. The example in Figure C-2 does not reflect the frequent periods of missing data that are especially common during periods of high change event activity, which further complicated direct calculations.

## NUMBER OF CHANGE EVENTS WITH ENERGY IMPACT ESTIMATES

Although a fairly large number of change events were identified for the buildings included in this study, we were unable to calculate energy impacts for most of them. The goal of estimating the energy impacts was to provide the average watts/square foot associated with each of the various change event classes by building type.

The summary graphics presented in this section for four building types --offices, retails, groceries, and restaurants--illustrate the rate at which change events were "lost" to the energy impact analysis.

The change events for which impact estimates were calculated may be roughly characterized as having a non-empty window of pre-change and a non-empty window of post-change energy data, subject to several conditions. These conditions include

- at least a half-month of energy data in both the pre- and post-change windows
- a pre-change window that ends at least 2 months before the month in which the change event had been recorded and that starts completely after the month in which any previous change event was recorded
- a post-change window that was selected after the month of the recorded change but 2 months before any month of a subsequently recorded change.

The nature of the commercial building change process itself violates the relative isolation of the change events from each other. In addition, the most common change event--adding new equipment--often leads to critical periods of missing data. This is because the ELCAP metering equipment is disturbed as the owner modifies the electric circuitry of the building. Finally, the project records contain information going well beyond the cutoff date for the energy data. The energy data available for this analysis, the ELCAP Pre-Aggregated Data set [PADS-COM-Dec88], contains no data after November 1988.

The largest number of changes were identified for offices, dry good retails, restaurants, and groceries. These four groups comprise the best-represented building types in the commercial combined studies. For each of these four building types, Figures C-3 through C-6 illustrate dramatically how many events were available to the energy impact calculations compared to the total number of events identified. The events reported on are

- business type changes
- tenant changes
- vacancy changes
- equipment changes
- unclassified changes (noted from an examination of the load data).

The height of each bar in Figures C-3 through C-6 represents the number of change events in the specified category. For each change type, the first bar shows the total number of events identified. The second bar shows the number of events that occurred within the time window of on-line data collection. The third bar shows the number of events for which load impact calculations were possible. In general, these illustrations indicate that only about one-third of the total change events identified in the frequency results have energy impact estimates.

## LIMITED RESULTS

Because the number of events with energy impact estimates is so small, we feel that **these results must not be interpreted as representative for the sample.** Our energy impact estimates are included here for illustrative purposes only.

Figures C-7 through C-30, ordered by building type, display the results we obtained by using both methods to calculate the energy impacts. In each figure, the estimate that resulted from using a single month on either side of the change event is indicated in the legend as "Use 1 Month"; the estimate resulting from using the widest pre- and post-change window, subject to the constraints noted above, is indicated in the legend as "Use All."

FIGURE C-3

Number of Changes Suitable for Energy Impact Calculations in Offices (n = 28)

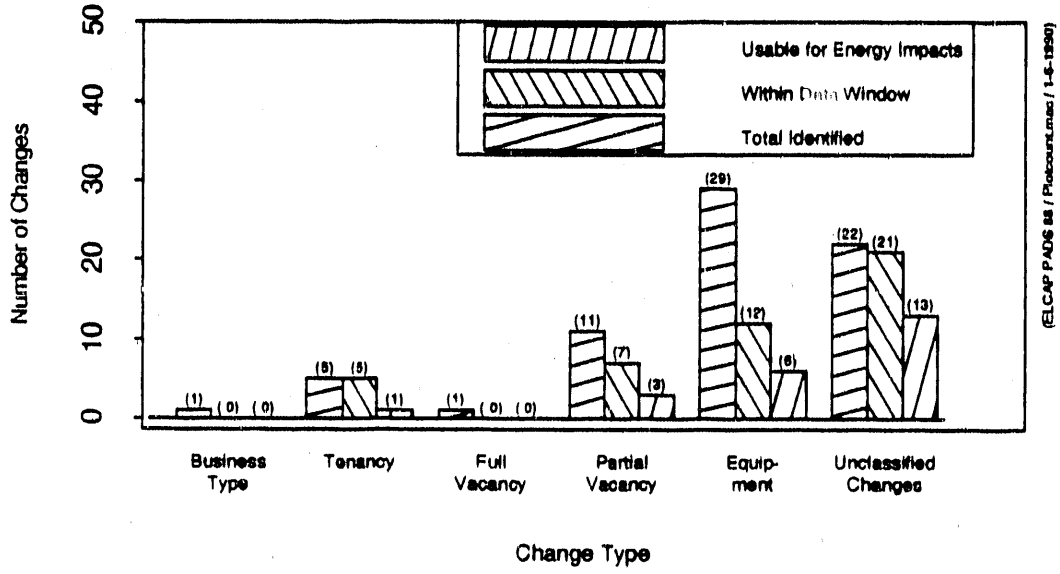



FIGURE C-4

Number of Changes Suitable for Energy Impact Calculations in Dry Good Retails (n = 28)

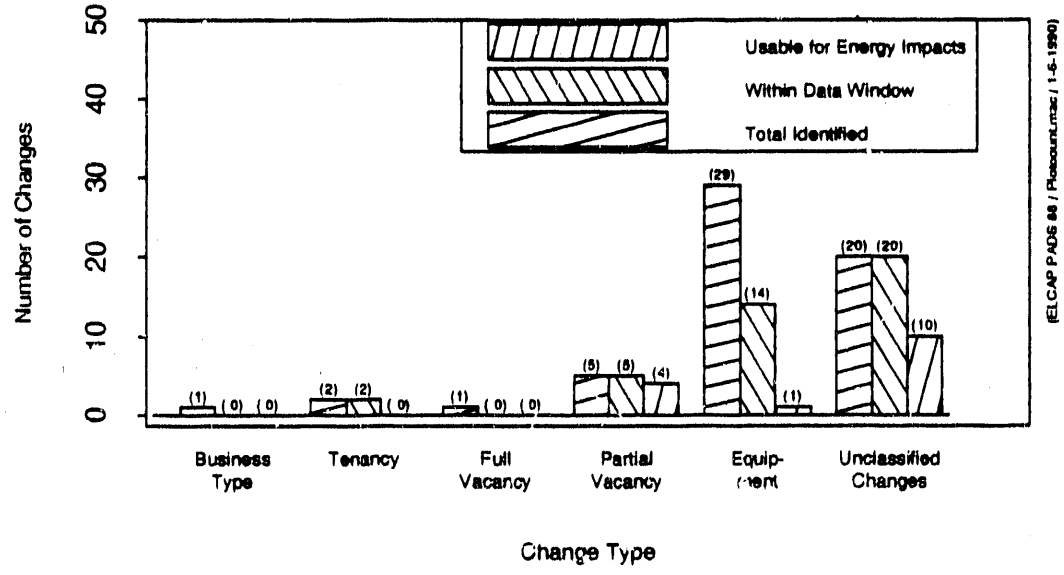


FIGURE C-5

Number of Changes Suitable for Energy
Impact Calculations in Groceries (n = 19)

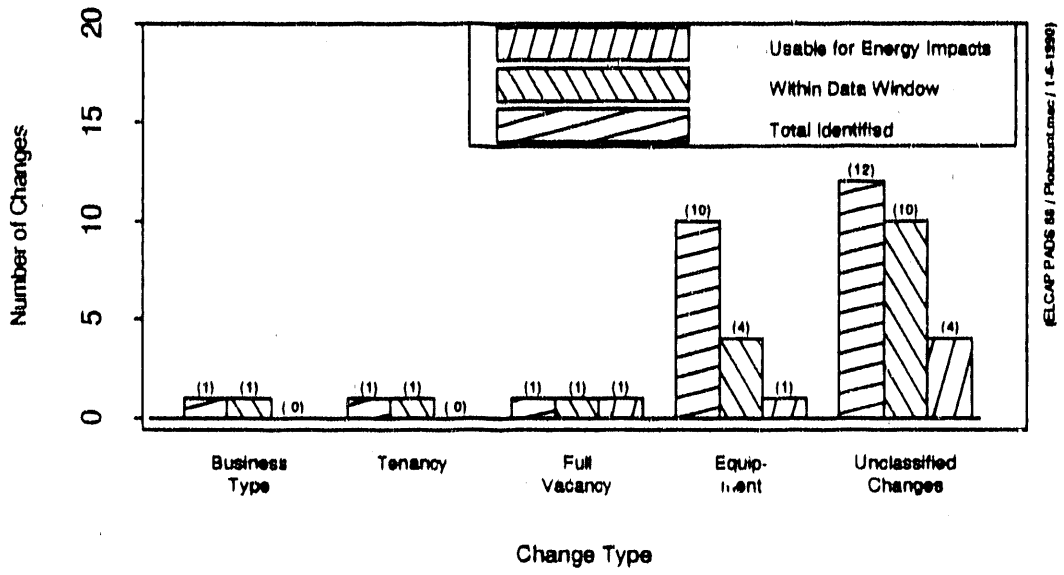
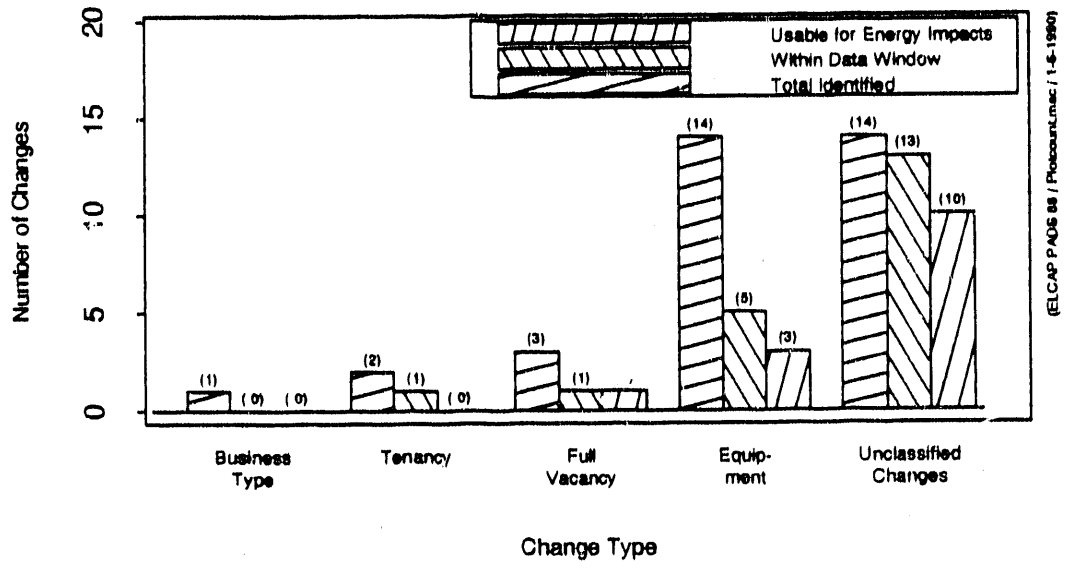



FIGURE C-6

Number of Changes Suitable for Energy
Impact Calculations in Restaurants (n = 15)



The height of the bar in each illustration gives the average power in watts/square foot for each of the two methods used to calculate the energy impacts. Each bar represents an average of all the change events of the specified class within the building type. The total number of events that the mean represents is indicated along the horizontal axis. The numbers along the vertical axis may be transformed into annual watt-hours/square foot by multiplying by 8760, the number of hours in a year. It is possible for some end uses not to exist for some time periods. Thus, there is some variation in the total number of events within a given building class across the end uses.

The change events for which impact estimates are given are business type, tenancy, full vacancy, partial vacancy, equipment, and unclassified changes. Each of these is discussed in turn in the following paragraphs.

Business Type

There were no analyzable business type changes.

Tenancy

A single analyzable tenancy change was available from the sample of office buildings (Figures C-7 through C-11). As shown in Figure C-7, the calculated impact of the tenancy change is strongly dependent on the calculation technique used. When only the closest months were used to calculate the impact, total energy consumption is shown to drop by about 0.7 W/ft$^2$. When all available pre- and post-change data were used, however, the total load increases by about 0.3 W/ft$^2$. Similar trends are evident for total HVAC loads and outdoor lighting loads. Indoor lighting and miscellaneous equipment loads are shown to decrease by both methods, but by differing amounts.

FIGURE C-7

Impact of Change on Energy Used for Office Building Total

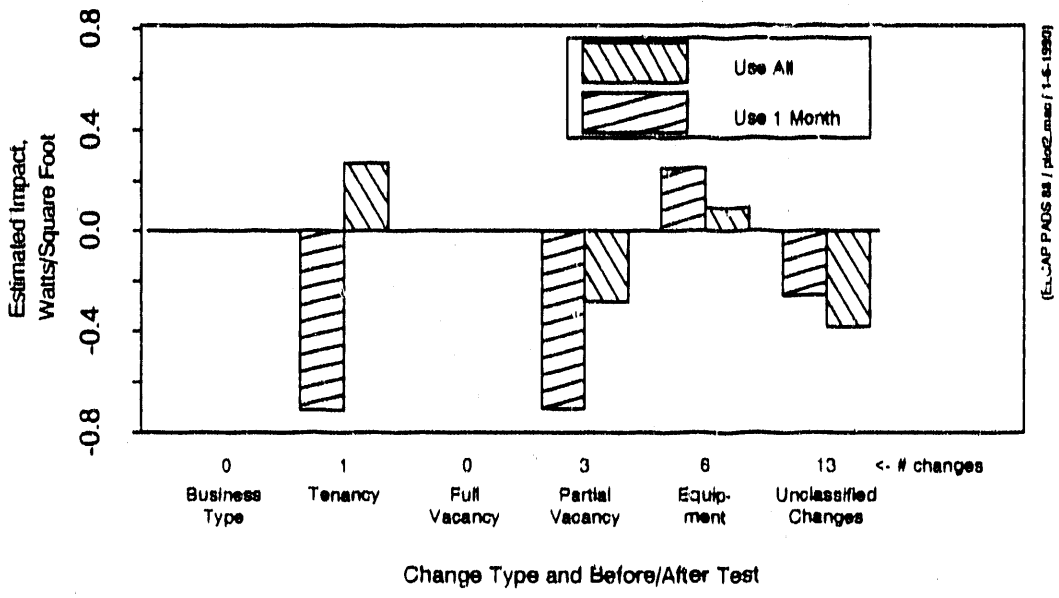



FIGURE C-8

Impact of Change on Energy Used for Office Indoor Lighting

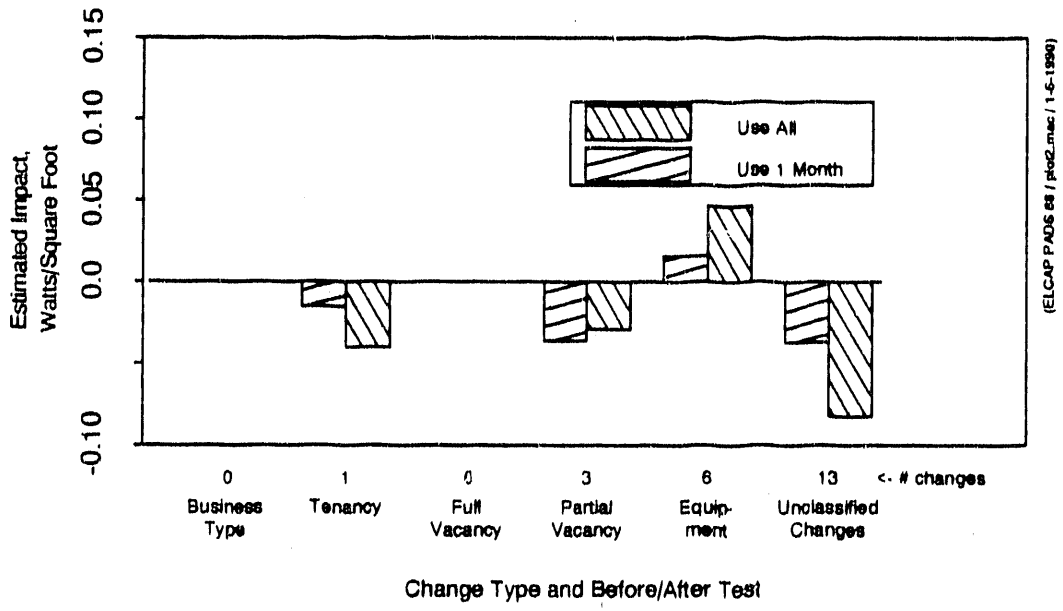


FIGURE C-9

Impact of Change on Energy Used for Office Total HVAC

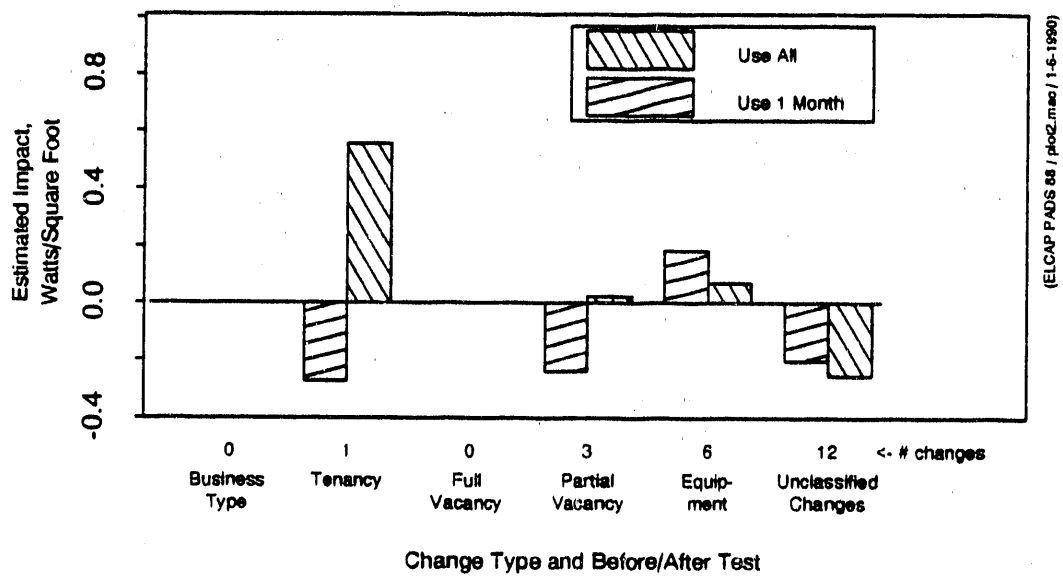



FIGURE C-10

Impact of Change on Energy Used for Office Other

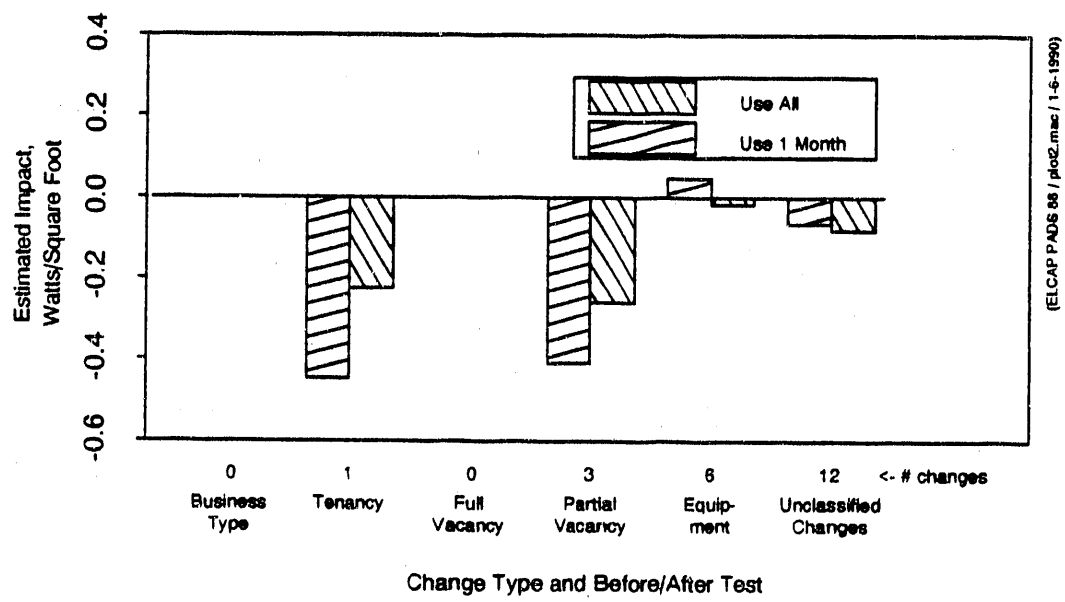


FIGURE C-11

Impact of Change on Energy Used for Office Outdoor Lighting

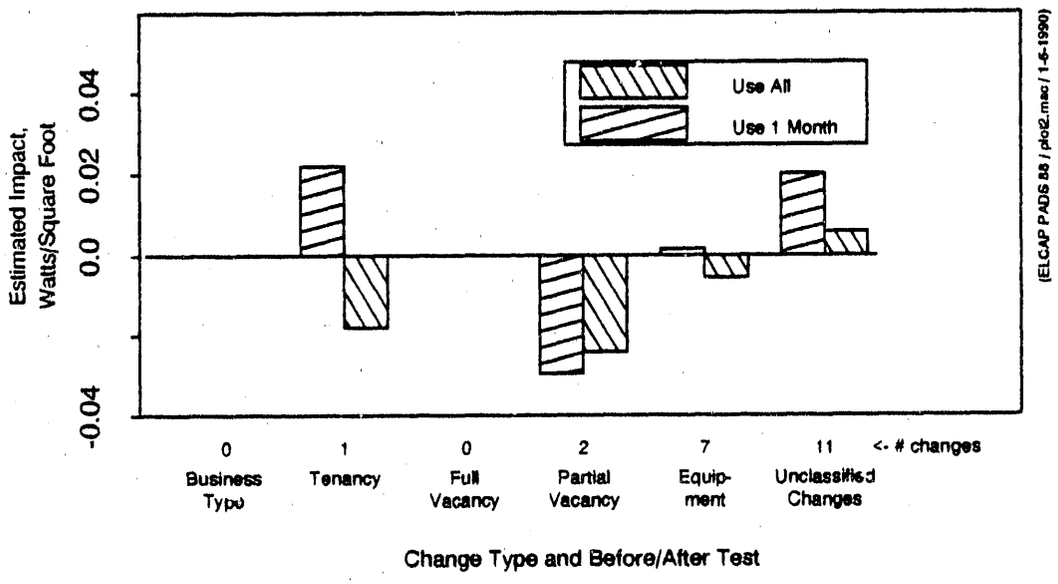



FIGURE C-12

Impact of Change on Energy Used for Dry Good Retail Building Total

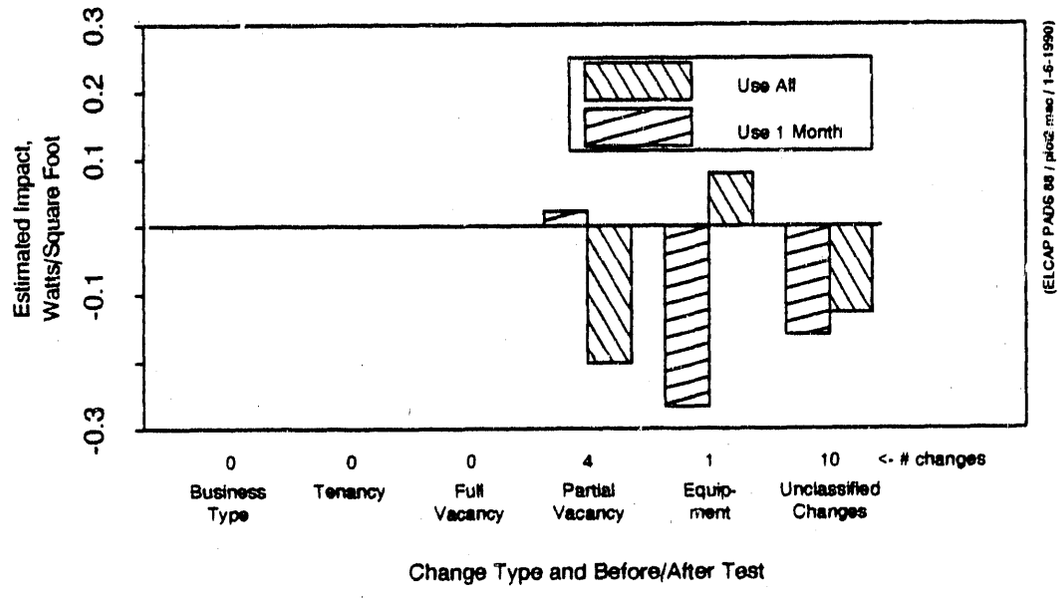


FIGURE C-13

Impact of Change on Energy Used for Dry Good Retail Indoor Lighting

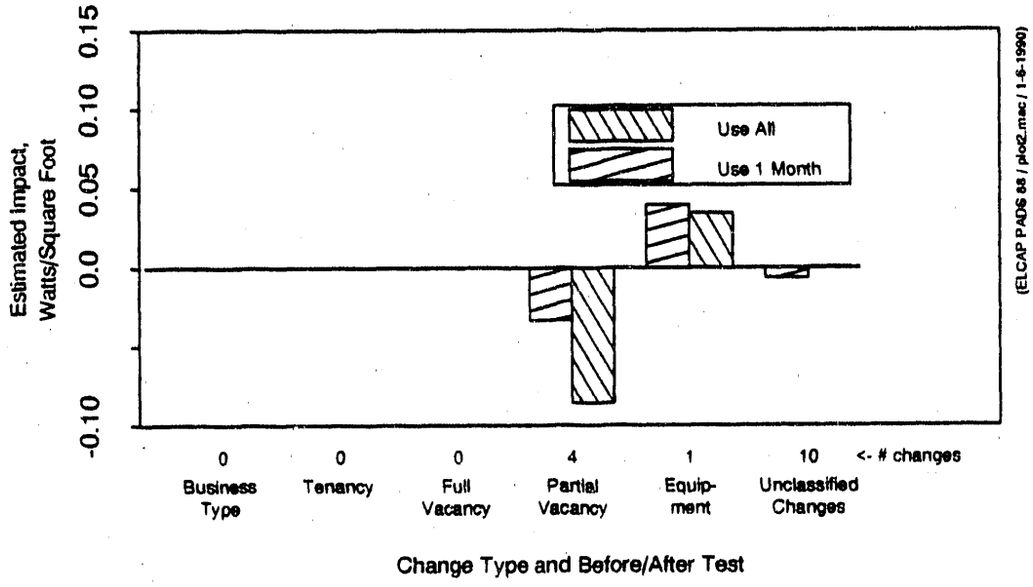



FIGURE C-14

Impact of Change on Energy Used for Dry Good Retail Total HVAC

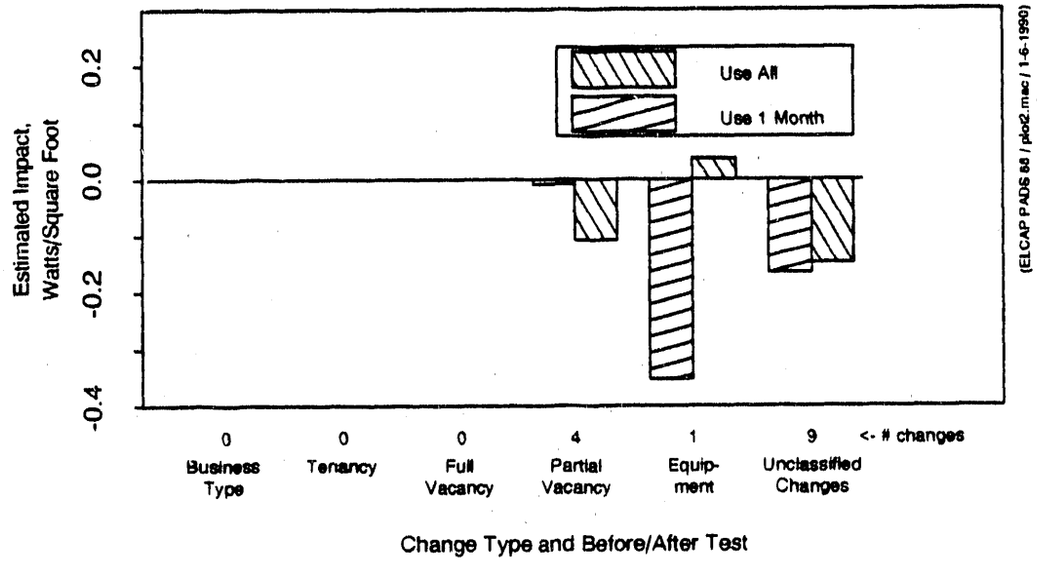


FIGURE C-15

Impact of Change on Energy Used for Dry Good Retail Other

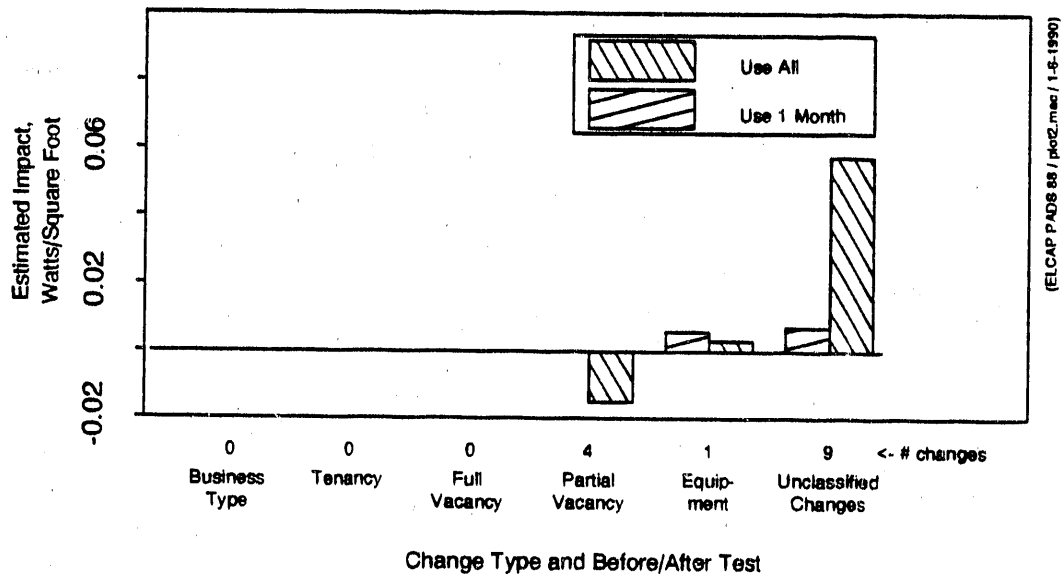



FIGURE C-16

Impact of Change on Energy Used for Dry Good Retail Outdoor Lighting

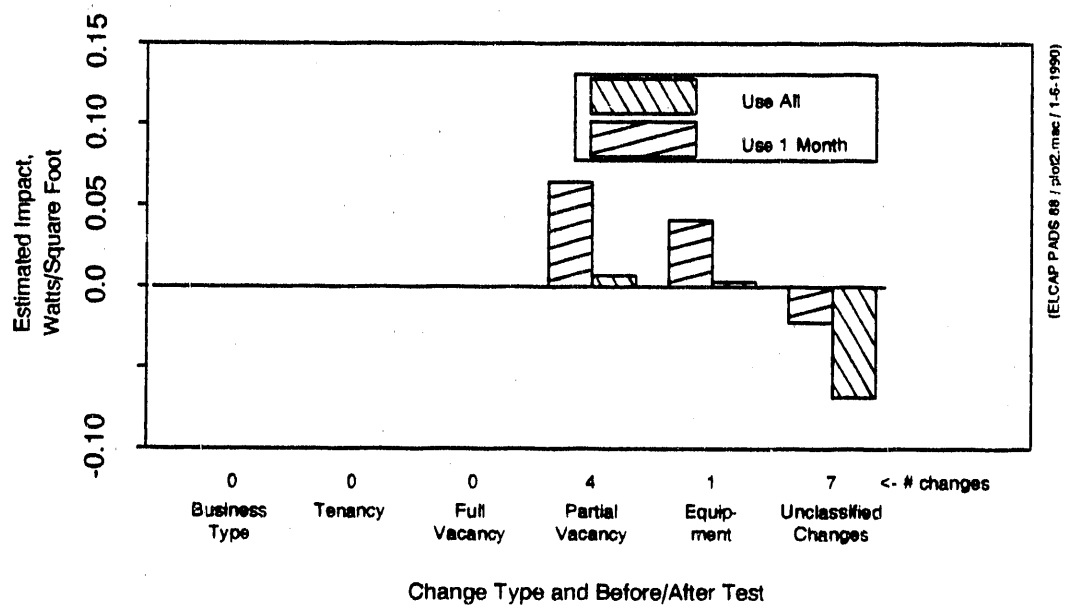


FIGURE C-17

Impact of Change on Energy Used for Grocery Building Total

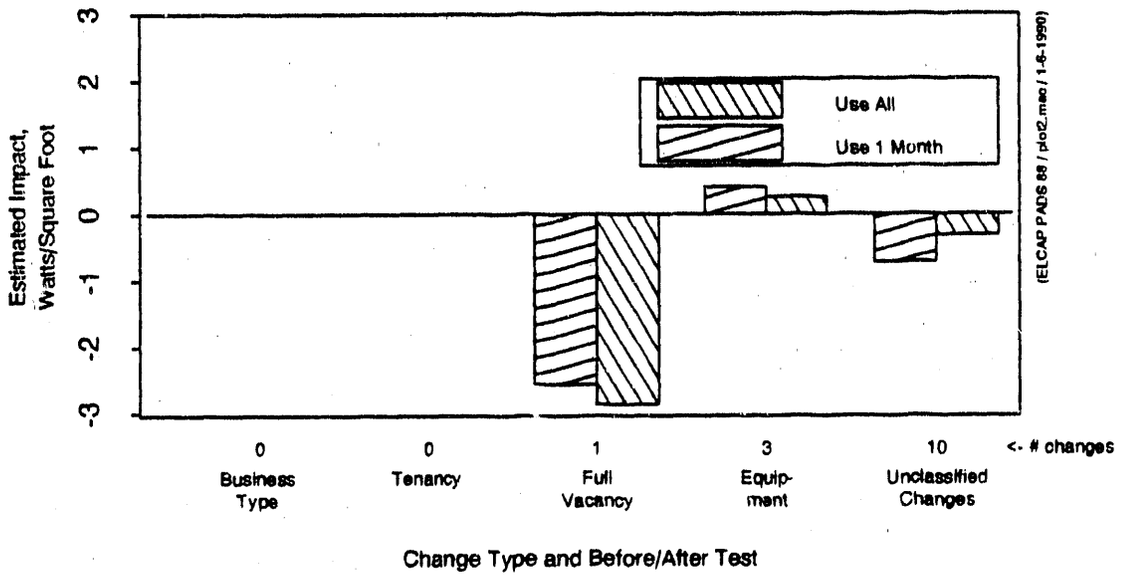



FIGURE C-18

Impact of Change on Energy Used for Grocery Indoor Lighting

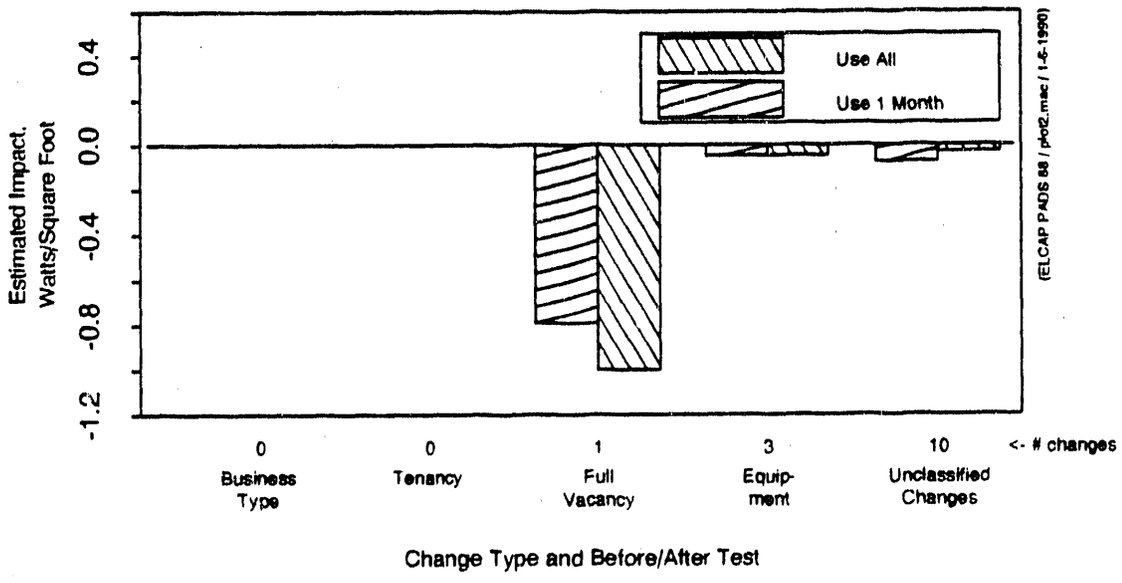


FIGURE C-19

Impact of Change on Energy Used for Grocery Total HVAC

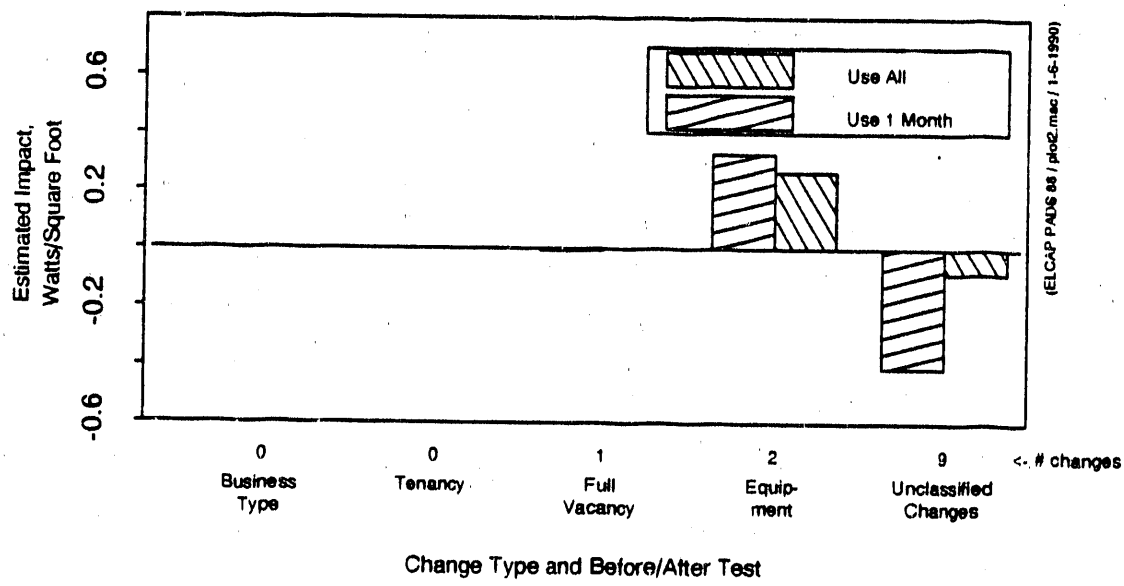



FIGURE C-20

Impact of Change on Energy Used for Grocery Other

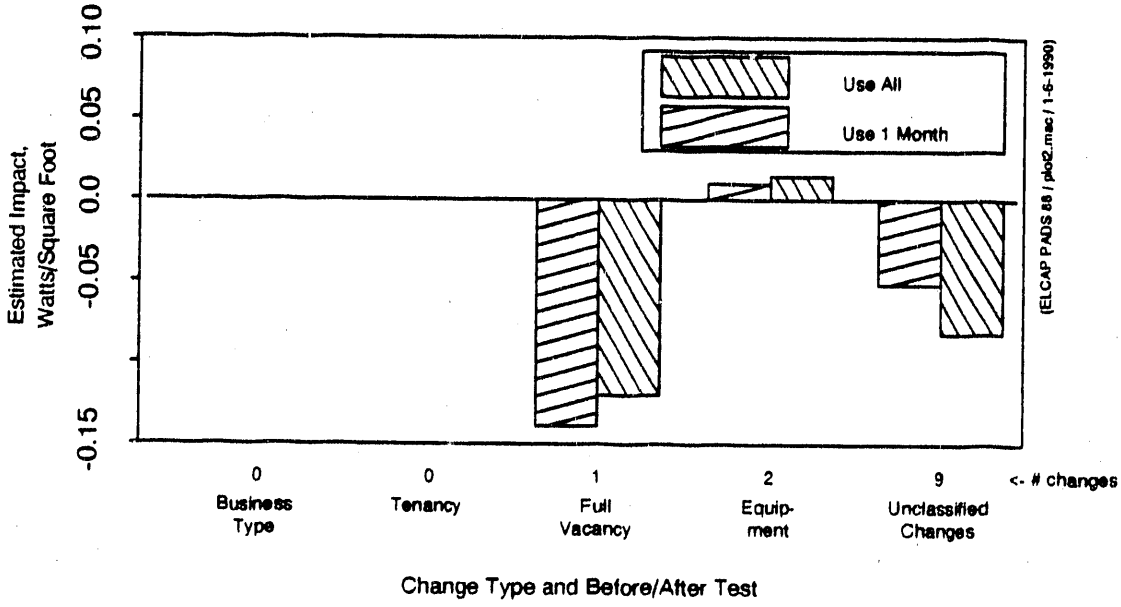


FIGURE C-21

Impact of Change on Energy Used for Grocery Refrigeration

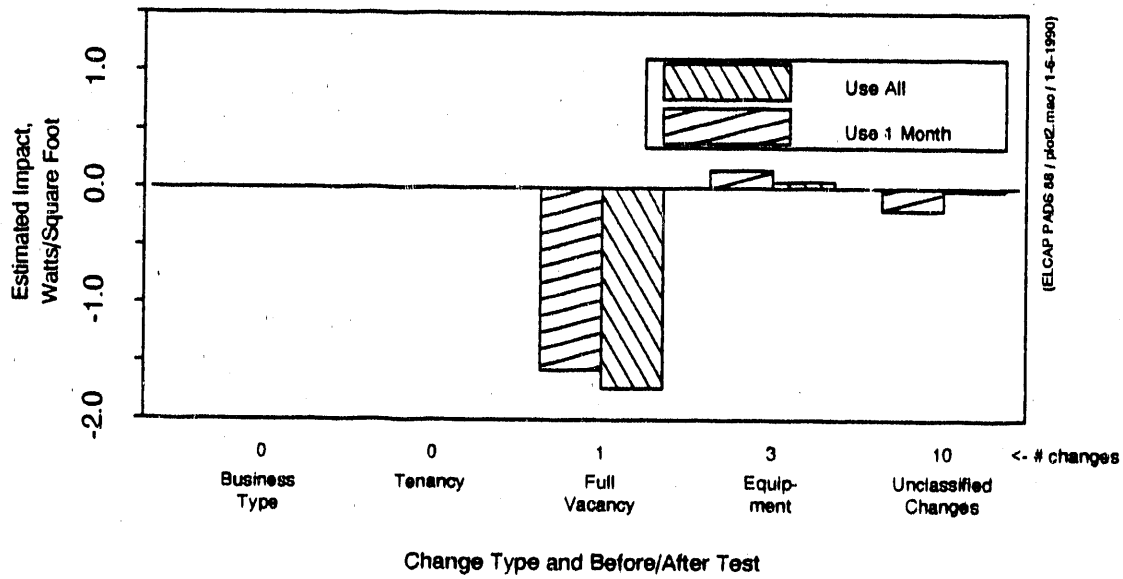



FIGURE C-22

Impact of Change on Energy Used for Grocery Food Preparation

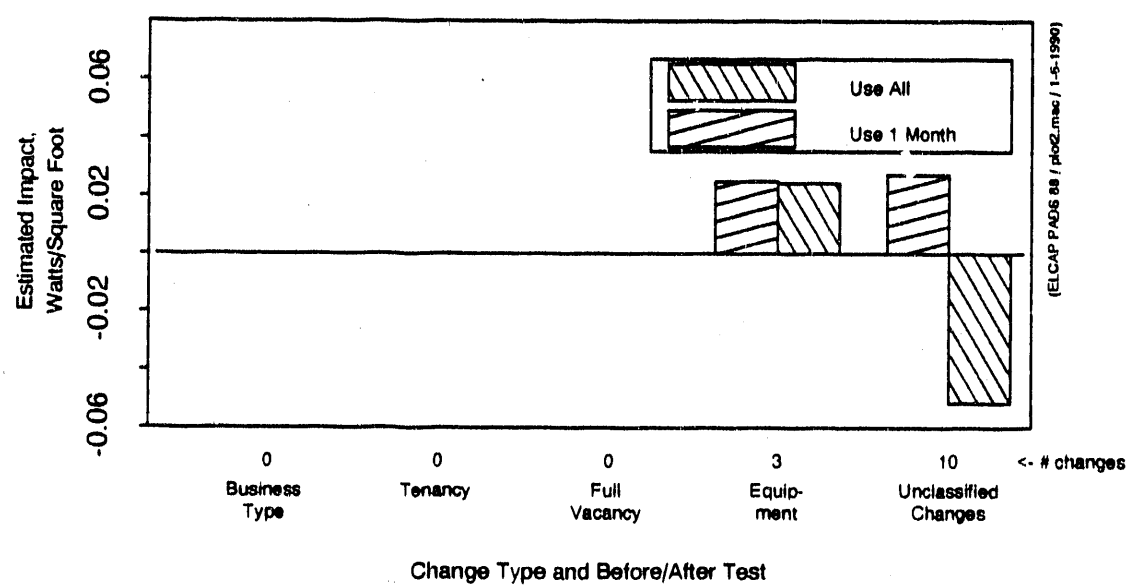


FIGURE C-23

Impact of Change on Energy Used for Grocery Outdoor Lighting

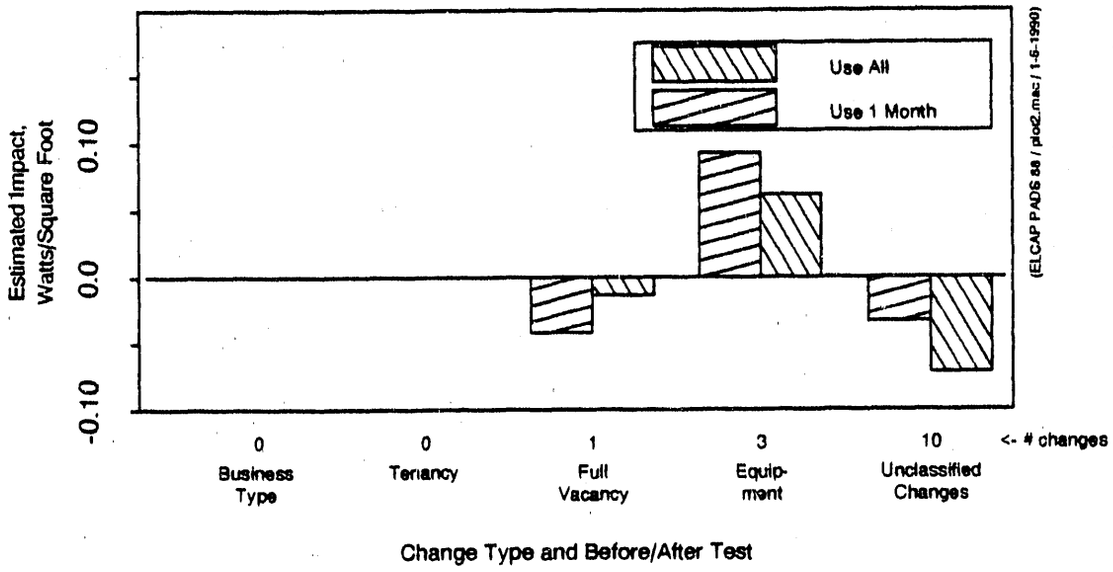



FIGURE C-24

Impact of Change on Energy Used for Restaurant Building Total

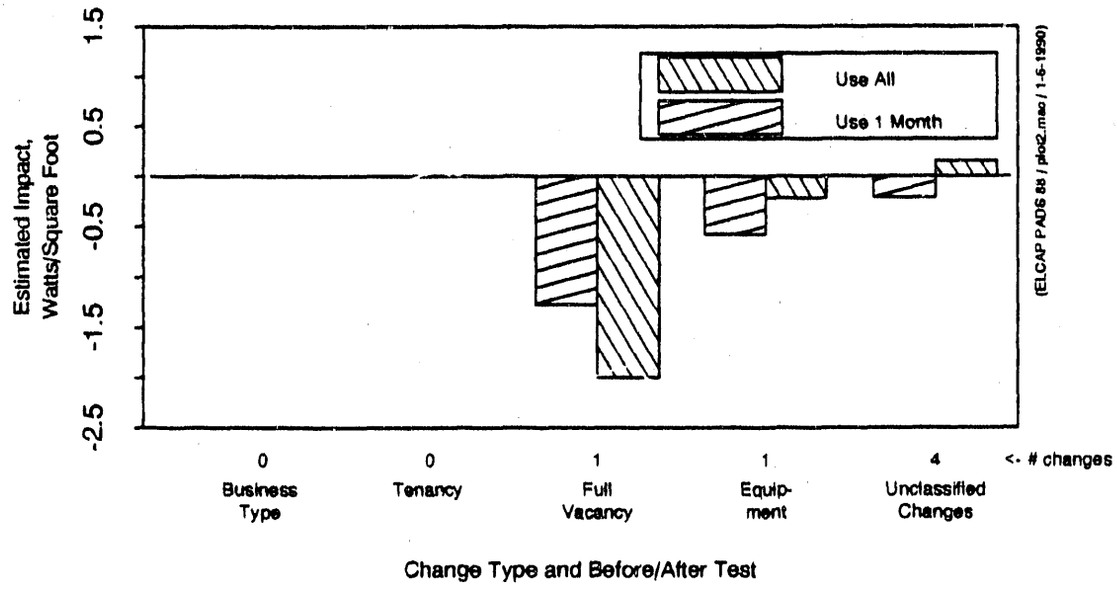


FIGURE C-25

Impact of Change on Energy Used for Restaurant Indoor Lighting

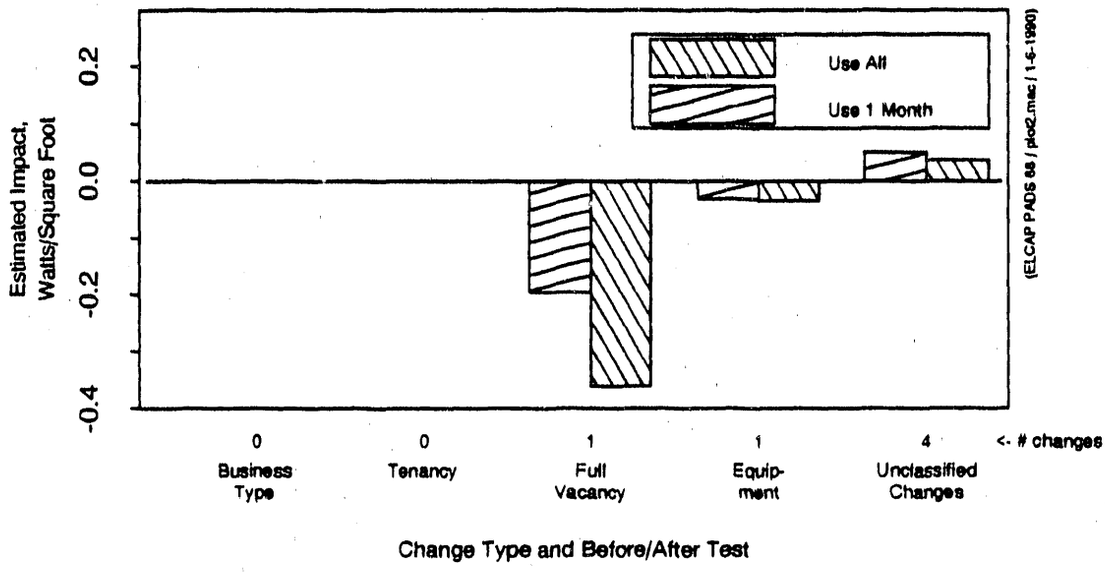



FIGURE C-26

Impact of Change on Energy Used for Restaurant Total HVAC

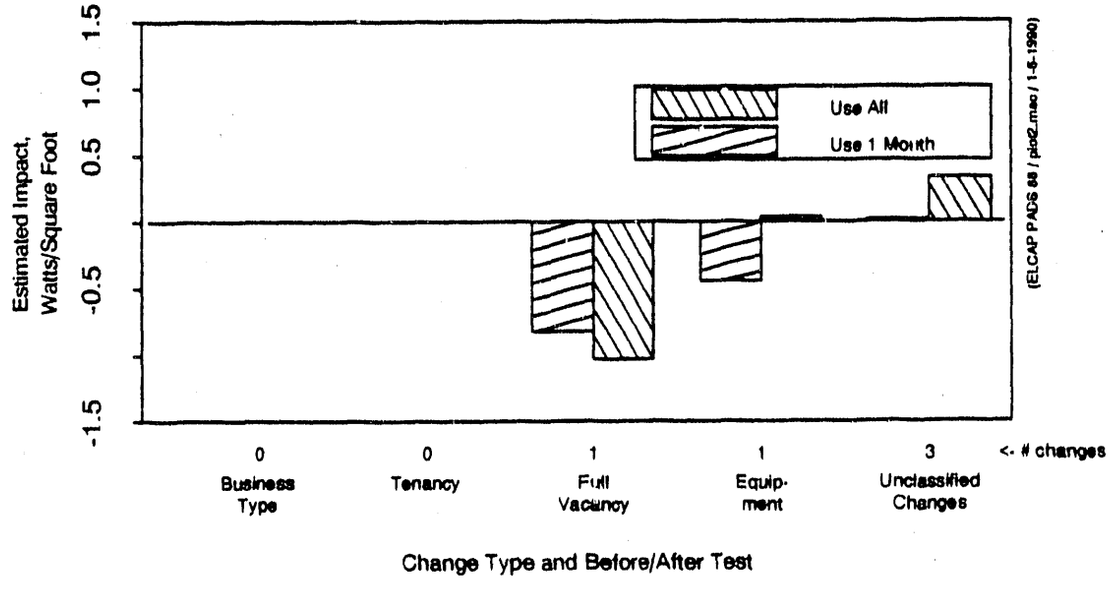


FIGURE C-27

Impact of Change on Energy Used for Restaurant Other

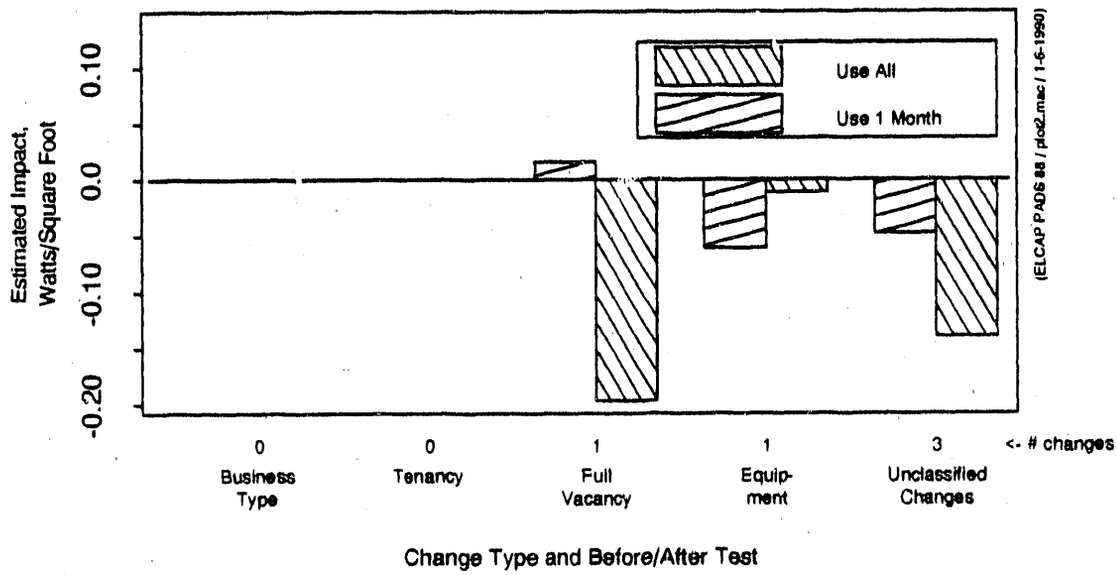



FIGURE C-28

Impact of Change on Energy Used for Restaurant Refrigeration

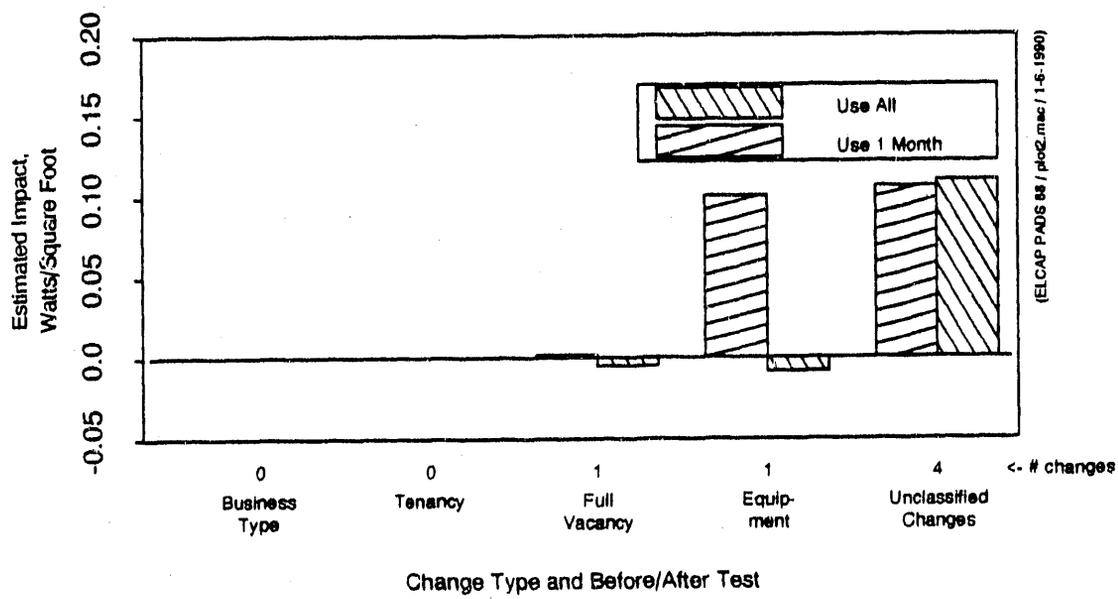


FIGURE C-29

Impact of Change on Energy Used for Restaurant Food Preparation

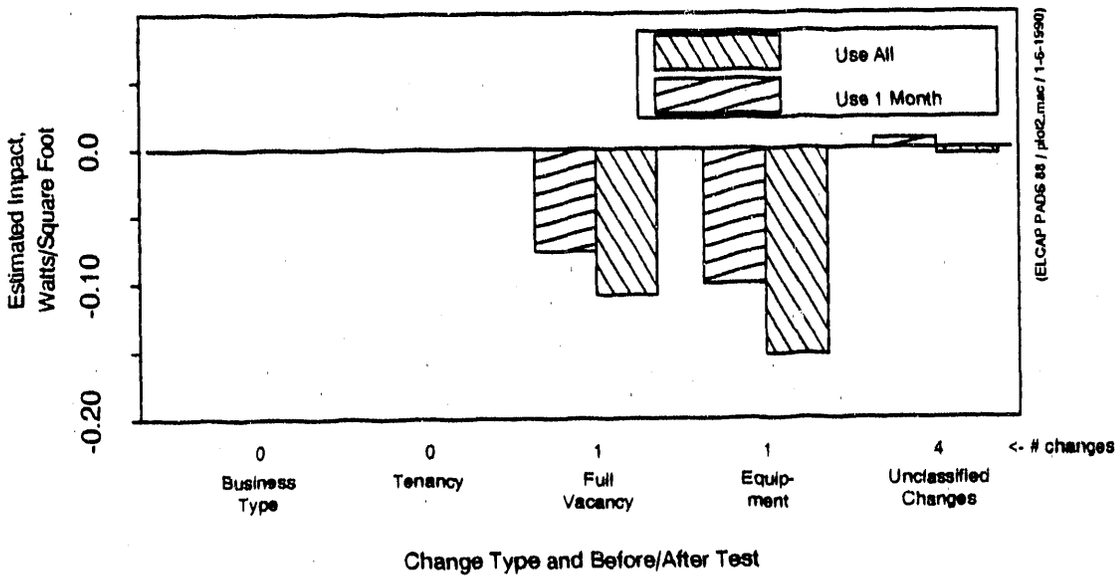
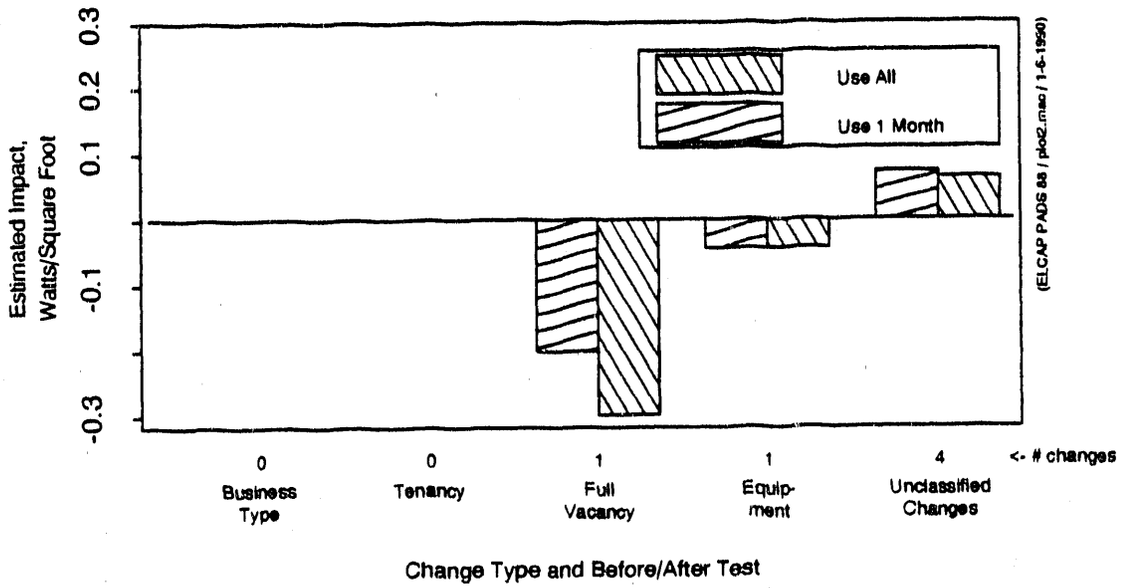



FIGURE C-30

Impact of Change on Energy Used for Restaurant Outdoor Lighting



## Full Vacancy

There were two analyzable full vacancies, one each from the grocery (Figures C-17 through C-23) and restaurant (Figures C-24 through C-30) samples. The grocery vacancy reduced building total consumption between 2.5 and 3.0 W/ft², with reasonable consistency between the two calculation techniques. Most of the change is accounted for by reductions in indoor lighting and refrigeration. HVAC loads were unchanged, while outdoor lighting and other loads dropped slightly. The restaurant vacancy impact, as calculated by either technique, reduced the building total load by at least 1.3 W/ft², though moreso by using all available pre- and post-change data. All end uses except refrigeration underwent noticeable decreases, although the miscellaneous equipment load increased slightly when calculated using a single pre- and post-change month.

## Partial Vacancy

Three partial vacancies were observed in the office sample; four were found in the retail sample. As expected, the end-use loads generally decrease. Again, however, the results often differ widely between the two calculation techniques. For example, compare the office HVAC loads in Figure C-9 with the retail building total loads in Figure C-12.

## Equipment

Except for unclassified changes, equipment changes are the most prevalent change type. In offices, the equipment changes appear to have increased total loads on average. As shown in Figure C-7, total loads increased an average of 0.1 to 0.3 W/ft². However, most of this change appears to be attributable to HVAC load increases. While this might indicate an increased cooling load due to higher internal gains, it could also be a result of changes in weather. The latter is probable because neither lighting nor equipment loads show an obvious increase.

Only one analyzable equipment change was available in the retail sample. Its effect appears to be small. The apparent large change in HVAC loads may be due to weather differences.

Equipment changes in groceries caused relatively small load changes, especially in light of the high overall loads of this building type. Most of the energy impact appears in the HVAC and outdoor lighting end uses.

The single equipment change in restaurants has a relatively small overall impact on total loads. The HVAC end use appears to have the largest change--but again, this may be the result of weather changes.

Unclassified Changes

Altogether, 37 unclassified changes were available for energy impact analysis: 13 for offices, 10 for restaurants, 10 for groceries, and 4 for restaurants. The averaged energy impacts for these events generally show a decrease in total load, except for restaurants; there, the two methods of impact provided strongly divergent results. The largest energy changes occur in groceries, decreasing on average by 0.8 to 0.3 W/ft$^2$.

## SUGGESTIONS FOR FURTHER RESEARCH

Several factors prevented the direct calculation of change impacts in most of the sample buildings: the high frequency of changes; the close temporal proximity of changes, often with following periods of missing metered data that result from the change; the uncertainties associated with change event dates; and the uncertainty concerning which end uses were affected.

In light of these problems, two alternative approaches might better ascertain the energy impacts of changes: a case study approach, or use of a regression model that facilitates indirect impact calculations.

The case study method would be very costly but would give the most reliable results for the greatest number of change events. The second method, use of a regression model, would likely increase the number of events for which we can currently calculate energy impacts. It also would require considerably less effort than a case study approach.

In the case study approach, additional building records could be examined or building owners could be contacted to resolve uncertainties in change event dates. This information would allow a more detailed classification of changes with respect to change type and end uses affected. These records might include survey data and detailed measurement plans for the buildings. By pinpointing the actual dates on which changes occur, the global elimination of data to avoid transition periods could be reduced. By positively identifying the end uses that will be affected by a change using survey data and measurement plans, the time windows of valid pre- and post-change data might be extended in many cases. Finally, increasing the detail of change classifications would make the results more interpretable.

The regression model approach avoids the necessity of building case studies, with the possible exception of attempting to classify equipment changes in more detail. This approach would circumvent the need for pre-and post-change data for every event. It would also minimize the need to know *a priori* which end uses will be affected by a change, as well as minimizing problems associated with missing data.

The first step in the suggested technique would be to divide each building's data into 1-year windows. The difference between the average loads at the beginning and end of the year would be examined in light of the change events that occurred during that year. Thus, the temporal proximity of changes within the year would be of no concern.

# APPENDIX D

## DETAILED DISCUSSION OF REMODELS AND RENOVATIONS

## APPENDIX D

## DETAILED DISCUSSION OF REMODELS AND RENOVATIONS

Throughout most of this report, changeover frequencies are reported and categorized by a strict hierarchy of change type definitions (see Table 4-1). The hierarchy is intended to place change events in the category that best explains changes in energy consumption. For example, a change in ownership might result in a change in the type of business operating from a building. The new owner is likely to remodel the structure and replace most major equipment, significantly impacting the building's energy consumption. However, the structural and equipment changes are results of the business type change, so the event would be categorized as a business type change.

In this appendix, we abandon the hierarchy of change type definitions in favor of more details regarding each remodel event. If a remodel involves both structural and equipment changes, it is counted as an instance of both. We also attempt to classify each change as an addition, removal, or replacement of existing space or equipment.

Table D-1 is a listing of all remodel events identified from the ELCAP records. It is an expanded subset of Table B-3, which contains the exhaustive list of identified changes. Table D-1 contains all entries from Table B-3 that involve change to building structure or equipment. Events that impact both structure and equipment are expanded into two separate events. Finally, the events are categorized as either additions, removals, or replacements.

The columns of Table D-1 are defined as follows:

- Site - the unique number identifying the individual site
- Bldg Type - the business type category of the building when metering equipment was installed
- Yrs Obsv - the number of years covered by building records--the time period over which changes were observed

- Event Date - the best estimate of the date of the change event

- Category of Remodel - Tells what was impacted by the change. Each event is classified as having affected structure, HVAC, lighting, refrigeration, food preparation, or miscellaneous equipment. In addition, remodel events that occurred concurrently with a change in business type or tenant are so noted.

- Type of Remodel - Describes whether the remodel involved addition, removal, or replacement of space or equipment.

- Comments - the comments pertaining to the change event found in the ELCAP records - because some change events affect multiple categories, the same comments are often repeated in sequential rows of the table.

TABLE D-1

All Remodel Events Identified from ELCAP Records

| Site | Bldg Type | Yrs Obsv | Event Date | Category of Remodel | Type of Remodel | Comments |
|---|---|---|---|---|---|---|
| 7 | gro | 4.5 | Nov 89 | structural | added | added deli, light change, remodel |
| 7 | gro | 4.5 | Nov 88 | lighting | unknown | added deli, light change, remodel |
| 18 | war | 3.8 | Jan 86 | structural | unknown | new tenant: bakery |
| 18 | war | 3.8 | Jan 86 | tenancy | | new tenant: bakery |
| 18 | war | 3.8 | Dec 86 | food prep | added | added oven, mixer |
| 37 | gro | 4.9 | Sep 86 | refrigeration | added | frozen food equipment added |
| 37 | gro | 4.9 | Jul 87 | refrigeration | added | wine/beer coolers added |
| 37 | gro | 4.9 | Jan 89 | refrigeration | added | pop+yogurt machine,battery chrgrs added. |
| 37 | gro | 4.9 | Jan 89 | misc equip | added | pop+yogurt machine,battery chrgrs added. |
| 40 | war | 4.4 | Sep 88 | structural | added | new addition of 6200 sqft (monitored?) |
| 41 | htm | 3.4 | Apr 87 | lighting | added | added lighting |
| 41 | htm | 3.4 | Oct 87 | hvac | added | added AC |
| 41 | htm | 3.4 | Oct 88 | hvac | added | added AC |
| 79 | htm | 3.3 | Oct 87 | refrigeration | unknown | pop, ice machine, plugs, washer/dryer |
| 79 | htm | 3.3 | Oct 87 | misc equip | unknown | pop, ice machine, plugs, washer/dryer |
| 81 | htm | 3.3 | Apr 86 | misc equip | unknown | new water heater |
| 81 | htm | 3.3 | Jan 87 | misc equip | unknown | new water heaters |
| 148 | dgr | 3.3 | Oct 87 | misc equip | added | new loads;washers |
| 273 | off | 3.9 | Feb 86 | hvac | added | fans added |
| 273 | off | 3.9 | Apr 88 | misc equip | added | computer added |
| 282 | war | 3.8 | May 88 | structural | added | added comissary |
| 284 | gro | 2.8 | Feb 87 | food prep | added | added chicken cooker |

TABLE D-1 (contd)

| Site | Bldg Type | Yrs Obsv | Event Date | Category of Remodel | Type of Remodel | Comments |
|---|---|---|---|---|---|---|
| 285 | gro | 4.1 | May 89 | misc equip | added | cardboard bailer added |
| 286 | off | 3.9 | Oct 87 | hvac | added | new tenant, added AC, lights, plugs |
| 286 | off | 3.9 | Oct 87 | lighting | added | new tenant, added AC, lights, plugs |
| 286 | off | 3.9 | Oct 87 | misc equip | added | new tenant, added AC, lights, plugs |
| 286 | off | 3.9 | Oct 87 | tenancy | | new tenant, added AC, lights, plugs |
| 286 | off | 3.9 | Feb 89 | hvac | unknown | new plugs, computers, BB heat, dwasher, ACs. |
| 286 | off | 3.9 | Feb 89 | misc equip | unknown | new plugs, computers, BB heat, dwasher, ACs. |
| 286 | off | 3.9 | May 89 | hvac | unknown | new AC |
| 287 | dgr | 4.1 | Mar 89 | hvac | replaced | owner mods, HVAC rework |
| 289 | dgr | 3.8 | Jan 89 | misc equip | replaced | replaced air compressor |
| 290 | off | 2.8 | Dec 87 | lighting | added | plg jump, light,plugs added |
| 290 | off | 2.8 | Dec 87 | misc equip | added | plg jump, light,plugs added |
| 293 | dgr | 3.8 | Jun 87 | hvac | added | added exhaust fans |
| 294 | war | 3.8 | Jun 87 | structural | added | expanded, new computer equip. |
| 294 | war | 3.8 | Jun 87 | misc equip | unknown | expanded, new computer equip. |
| 294 | war | 3.8 | Oct 87 | hvac | added | added AC |
| 294 | war | 3.8 | Jul 89 | structural | added | building being enlarged |
| 295 | dgr | 4.2 | Mar 81 | lighting | added | added 18kW light, boarded windows |
| 295 | dgr | 4.2 | Mar 81 | structural | replaced | added 18kW light, boarded windows |
| 298 | off | 3.8 | Jan 87 | structural | replaced | added wall to shield from uncon. space |
| 299 | off | 3.8 | Feb 87 | hvac | unknown | new HP, air handler, alarm, office(?) |
| 299 | off | 3.8 | Feb 87 | misc equip | unknown | new HP, air handler, alarm, office(?) |
| 299 | off | 3.8 | Sep 87 | structural | added | parking enclosed |
| 300 | war | 3.8 | Feb 87 | lighting | added | added lights |
| 441 | res | 3.6 | Apr 86 | hvac | unknown | new A/C unit |
| 441 | res | 3.6 | May 88 | refrigeration | added | added ice machine, food warmer |
| 441 | res | 3.6 | May 88 | food prep | added | added ice machine, food warmer |
| 441 | res | 3.6 | Aug 88 | lighting | replaced | Incand. to Florsct, 3600W to 780W |
| 441 | res | 3.6 | Sep 88 | hvac | added | exhaust fan added |
| 443 | dgr | 1.3 | Nov 87 | structural | unknown | major remodel |
| 445 | res | 3.3 | May 87 | food prep | unknown | new oven |
| 446 | war | 3.8 | Feb 89 | hvac | added | added heat, office |
| 447 | dgr | 3.6 | Jul 86 | structural | unknown | remodeled |
| 447 | dgr | 3.6 | Nov 87 | lighting | unknown | lights, terminals |
| 447 | dgr | 3.6 | Nov 87 | misc equip | unknown | lights, terminals |
| 449 | dgr | 3.3 | Jun 86 | hvac | unknown | new heat and lights |
| 449 | dgr | 3.3 | Jun 86 | lighting | unknown | new heat and lights |
| 451 | off | 3.3 | Mar 86 | misc equip | added | plugs added |
| 451 | off | 3.3 | Sep 87 | misc equip | added | added computer |
| 451 | off | 3.3 | Dec 87 | structural | unknown | moved lunch rm |
| 451 | off | 3.3 | May 88 | misc equip | added | added plugs,copy machine |
| 455 | dgr | 2.2 | Sep 87 | lighting | added | lts, ac added |
| 455 | dgr | 2.2 | Sep 87 | hvac | added | lts, ac added |

TABLE D-1 (contd)

| Site | Bldg Type | Yrs Obsv | Event Date | Category of Remodel | Type of Remodel | Comments |
|---|---|---|---|---|---|---|
| 457 | res | 3.8 | Oct 86 | refrigeration | eliminated | new bus type/tenant, ref removed |
| 457 | res | 3.8 | Oct 86 | business type | | new bus type/tenant, ref removed |
| 458 | off | 3.5 | Apr 88 | misc equip | added | new plugs, some remdelling |
| 458 | off | 3.5 | Apr 88 | structural | unknown | new plugs, some remdelling |
| 532 | dgr | 3.7 | Feb 89 | refrigeration | unknown | wine cooler display, cash registers |
| 532 | dgr | 3.7 | Feb 89 | misc equip | unknown | wine cooler display, cash registers |
| 534 | htm | 3.4 | Feb 87 | misc equip | added | kitchen outlets added |
| 534 | htm | 3.4 | Apr 87 | structural | replaced | remodeled front, added computer, lights |
| 534 | htm | 3.4 | Apr 87 | misc equip | added | remodeled front, added computer, lights |
| 534 | htm | 3.4 | Apr 87 | lighting | added | remodeled front, added computer, lights |
| 534 | htm | 3.4 | Apr 89 | structural | unknown | remodeled, new restaurant |
| 538 | off | 3.6 | Jan 88 | structural | replaced | partial vac., remodel upstairs |
| 538 | off | 3.6 | Jan 88 | partial vacancy | | partial vac., remodel upstairs |
| 538 | off | 3.6 | Oct 88 | structural | replaced | new tenants, ice cream shop, remod |
| 538 | off | 3.6 | Oct 88 | structural | unknown | new tenants, ice cream shop, remod |
| 538 | off | 3.6 | Oct 88 | business type | | new tenants, ice cream shop, remod |
| 541 | gro | 3.4 | Nov 87 | refrigeration | added | new walk-in cooler: bakery, lts, plgs, fans |
| 541 | gro | 3.4 | Nov 87 | lighting | unknown | new walk-in cooler: bakery, lts, plgs, fans |
| 541 | gro | 3.4 | Nov 87 | misc equip | unknown | new walk-in cooler: bakery, lts, plgs, fans |
| 541 | gro | 3.4 | Nov 87 | hvac | unknown | new walk-in cooler: bakery, lts, plgs, fans |
| 544 | dgr | 3.4 | Dec 86 | lighting | added | added lights |
| 544 | dgr | 3.4 | Mar 88 | misc equip | unknown | new computer |
| 546 | dgr | 3.5 | Jun 86 | lighting | unknown | new lights and plugs |
| 546 | dgr | 3.5 | Jun 86 | misc equip | unknown | new lights and plugs |
| 546 | dgr | 3.5 | Jan 89 | lighting | unknown | plugs, lights |
| 546 | dgr | 3.5 | Jan 89 | misc equip | unknown | plugs, lights |
| 546 | dgr | 3.5 | Apr 89 | misc equip | unknown | new water htr |
| 548 | off | 3.5 | Jan 87 | structural | replaced | added wall separating cond/uncond |
| 550 | war | 2.5 | Oct 87 | misc equip | replaced | 4 tenant vacancies,proc eqpt replaced, drops |
| 550 | war | 2.5 | Oct 87 | partial vacancy | | 4 tenant vacancies,proc eqpt replaced, drops |
| 550 | war | 2.5 | Apr 88 | misc equip | added | all new tenents, new assembly line |
| 550 | war | 2.5 | Apr 88 | tenancy | | all new tenents, new assembly line |
| 555 | htm | 3.5 | Jan 89 | misc equip | added | added exterior lighting |
| 559 | res | 3.4 | Sep 88 | food prep | added | added micowave, pop machine, steam table |
| 559 | res | 3.4 | Sep 88 | refrigeration | added | added micowave, pop machine, steam table |
| 560 | gro | 3.0 | Oct 87 | lighting | added | added track lts, bev. coolers, ice case, juicer, plgs |
| 560 | gro | 3.0 | Oct 87 | refrigeration | added | added track lts, bev. coolers, ice case, juicer, plgs |
| 560 | gro | 3.0 | Oct 87 | misc equip | added | added track lts, bev. coolers, ice case, juicer, plgs |
| 562 | uni | 3.3 | Jun 89 | unknown | unknown | upholstery to photo shop |
| 566 | dgr | 3.3 | Oct 87 | misc equip | added | added cash machine, lts,plgs, cash regstr |
| 566 | dgr | 3.3 | Oct 87 | lighting | added | added cash machine, lts,plgs, cash regstr |
| 566 | dgr | 3.3 | Jan 89 | misc equip | added | added plgs, computer, olt, register |
| 582 | dgr | 3.6 | Sep 88 | misc equip | added | new business type, new dishwasher |
| 586 | war | 3.3 | Oct 86 | misc equip | unknown | new computers? |

TABLE D-1 (contd)

| Site | Bldg Type | Yrs Obsv | Event Date | Category of Remodel | Type of Remodel | Comments |
|---|---|---|---|---|---|---|
| 587 | gro | 3.3 | Oct 86 | structural | unknown | total remodel |
| 587 | gro | 3.3 | Oct 87 | food prep | added | added toaster, bun warmer |
| 588 | gro | 3.2 | Apr 87 | refrigeration | added | added egg case |
| 588 | gro | 3.2 | Oct 87 | refrigeration | added | added yogust machine |
| 588 | gro | 3.2 | Dec 88 | refrigeration | added | added bank: pop+ice machines |
| 588 | gro | 3.2 | Dec 88 | business type | | added bank: pop+ice machines |
| 588 | gro | 3.2 | Jun 89 | misc equip | unknown | chicken service deli |
| 591 | dgr | 3.0 | Feb 87 | hvac | eliminated | removed gas heater |
| 591 | dgr | 3.0 | Feb 87 | fuel type | | removed gas heater |
| 591 | dgr | 3.0 | Feb 88 | lighting | replaced | changed lights |
| 591 | dgr | 3.0 | Apr 89 | structural | unknown | remodel |
| 593 | res | 3.3 | Nov 86 | structural | added | new tenant (Szzler),remodel, more area |
| 593 | res | 3.3 | Nov 86 | tenancy | | new tenant (Szzler),remodel, more area |
| 593 | res | 3.3 | Jul 87 | refrigeration | added | added salar bar, kettles lights |
| 593 | res | 3.3 | Jul 87 | food prep | added | added salar bar, kettles lights |
| 593 | res | 3.3 | Jul 87 | lighting | added | added salar bar, kettles lights |
| 598 | res | 3.0 | Jul 87 | refrigeration | added | added ice cream machine |
| 598 | res | 3.0 | Feb 88 | structural | unknown | total remodel,complete new equip/systems |
| 598 | res | 3.0 | Feb 88 | misc equip | added | total remodel,complete new equip/systems |
| 599 | gro | 2.1 | Apr 87 | lighting | replaced | lights changed, equip added |
| 599 | gro | 2.1 | Apr 87 | misc equip | added | lights changed, equip added |
| 602 | off | 3.3 | Oct 86 | misc equip | added | new tenant, added computers |
| 602 | off | 3.3 | Oct 86 | tenancy | | new tenant, added computers |
| 602 | off | 3.3 | Feb 87 | misc equip | added | added plgs, moved breakers |
| 607 | off | 3.3 | Sep 87 | misc equip | added | oulets added |
| 681 | dgr | 3.2 | Oct 86 | misc equip | added | added track lights, changed to florsnt. |
| 681 | dgr | 3.2 | Nov 86 | lighting | added | added track lights |
| 681 | dgr | 3.2 | Nov 86 | lighting | replaced | added track lights |
| 681 | dgr | 3.2 | Jan 87 | lighting | added | added box compactor |
| 681 | dgr | 3.2 | Oct 87 | lighting | unknown | owner mods, lighting (686) |
| 681 | dgr | 3.2 | Feb 88 | lighting | added | added lights, cash regstr |
| 681 | dgr | 3.2 | Feb 88 | misc equip | addod | added lights, cash regstr |
| 681 | dgr | 3.2 | May 88 | lighting | added | added lights, cash regstr |
| 681 | dgr | 3.2 | May 88 | misc equip | added | added lights, cash regstr |
| 691 | uni | 3.2 | Jan 89 | misc equip | added | added computers |
| 697 | off | 3.1 | Nov 86 | food prep | added | new outlets, food prep |
| 697 | off | 3.1 | Oct 87 | structural | unknown | owner mods, remodeling? |
| 697 | off | 3.1 | Apr 88 | misc equip | added | added plgs, telephone |
| 697 | off | 3.1 | Oct 88 | misc equip | added | added plgs, range, cranked up fan |
| 697 | off | 3.1 | Oct 88 | food prep | added | added plgs, range, cranked up fan |
| 697 | off | 3.1 | May 89 | misc equip | added | added copier |
| 707 | war | 3.1 | Jan 88 | misc equip | added | new energy mgmt control system |
| 707 | war | 3.1 | Oct 88 | hvac | added | added exhaust fans |
| 712 | dgr | 3.3 | Mar 87 | misc equip | added | added energy management system |
| 717 | off | 2.9 | Oct 87 | misc equip | added | added computer, copier, telephone sys |

TABLE D-1 (contd)

| Site | Bldg Type | Yrs Obsv | Event Date | Category of Remodel | Type of Remodel | Comments |
|---|---|---|---|---|---|---|
| 723 | dgr | 2.2 | Nov 87 | structural | unknown | tenants,equip,struct. mods |
| 723 | dgr | 2.2 | Nov 87 | misc equip | unknown | tenants,equip,struct. mods |
| 723 | dgr | 2.2 | Nov 87 | tenancy | | tenants,equip,struct. mods |
| 723 | dgr | 2.2 | Feb 88 | misc equip | added | added film eq., plgs, sept. 87? (81) |
| 723 | dgr | 2.2 | Apr 88 | structural | replaced | upstairs made usable space for rent |
| 726 | htm | 3.2 | May 88 | food prep | added | added coffee maker, ovens |
| 731 | off | 3.0 | Aug 87 | structural | replaced | window film added north |
| 731 | off | 3.0 | Apr 88 | misc equip | added | added plgs, dishwshr, disposal, telephone, tenant |
| 731 | off | 3.0 | Apr 88 | tenancy | | added plgs, dishwshr, disposal, telephone, tenant |
| 735 | dgr | 3.0 | May 87 | lighting | unknown | lights |
| 735 | dgr | 3.0 | Jun 87 | hvac | added | new business/owners, added ac, plugs |
| 735 | dgr | 3.0 | Jun 87 | misc equip | added | new business/owners, added ac, plugs |
| 735 | dgr | 3.0 | Jun 87 | business type | | new business/owners, added ac, plugs |
| 736 | war | 3.0 | May 89 | structural | unknown | remodelled (deli) |
| 738 | off | 2.9 | Feb 87 | misc equip | added | added plgs |
| 738 | off | 2.9 | Jun 88 | hvac | replaced | added HVAC mixing boxes to separate zones |
| 738 | off | 2.9 | Oct 88 | lighting | added | remodel, added lights |
| 738 | off | 2.9 | Oct 88 | structural | unknown | remodel, added lights |
| 747 | off | 3.3 | Dec 86 | lighting | added | new tenant, remodel, track lights added |
| 747 | off | 3.3 | Dec 86 | structural | unknown | new tenant, remodel, track lights added |
| 747 | off | 3.3 | Dec 86 | tenancy | | new tenant, remodel, track lights added |
| 751 | dgr | 2.9 | Dec 86 | misc equip | added | added computer, ordering machine |
| 752 | oth | 2.0 | Apr 86 | structural | replaced | windows to dbl pane |

Table D-2 summarizes the recategorized remodel events. For each category and type of remodel, the total number of observed events is shown. For example, in the 28 office buildings in the ELCAP sample, there was one structural addition, five structural replacements, and six events that affected structure in an unknown manner. Note that these are total counts of changes, regardless of how long each building was observed. Therefore, Table D-2 is a simple summary of Table D-1 and does not directly imply change rates.

TABLE D-2

Total Numbers of Remodels Observed in ELCAP Buildings

Office (n = 28)

| | Added | Eliminated | Replaced | Unknown | Total |
|---|---|---|---|---|---|
| Structural | 1 | 0 | 5 | 6 | 12 |
| Lighting | 4 | 0 | 0 | 0 | 4 |
| HVAC | 2 | 0 | 1 | 3 | 6 |
| Refrigeration | 0 | 0 | 0 | 0 | 0 |
| Food prep | 2 | 0 | 0 | 0 | 2 |
| Misc equip | 16 | 0 | 0 | 2 | 18 |
| Unknown | 0 | 0 | 0 | 0 | 0 |
| Total | 25 | 0 | 6 | 11 | 42 |

Retail (n = 28)

| | Added | Eliminated | Replaced | Unknown | Total |
|---|---|---|---|---|---|
| Structural | 0 | 0 | 2 | 4 | 6 |
| Lighting | 8 | 0 | 2 | 6 | 16 |
| HVAC | 3 | 1 | 1 | 1 | 6 |
| Refrigeration | 0 | 0 | 0 | 1 | 1 |
| Food prep | 0 | 0 | 0 | 0 | 0 |
| Misc equip | 11 | 0 | 1 | 7 | 19 |
| Unknown | 0 | 0 | 0 | 0 | 0 |
| Total | 22 | 1 | 6 | 19 | 48 |

Grocery (n = 19)

| | Added | Eliminated | Replaced | Unknown | Total |
|---|---|---|---|---|---|
| Structural | 1 | 0 | 0 | 1 | 2 |
| Lighting | 1 | 0 | 1 | 2 | 4 |
| HVAC | 0 | 0 | 0 | 1 | 1 |
| Refrigeration | 8 | 0 | 0 | 0 | 8 |
| Food prep | 2 | 0 | 0 | 0 | 2 |
| Misc equip | 4 | 0 | 0 | 2 | 6 |
| Unknown | 0 | 0 | 0 | 0 | 0 |
| Total | 16 | 0 | 1 | 6 | 23 |

TABLE D-2 (contd)

Restaurant (n = 15)

| | Added | Eliminated | Replaced | Unknown | Total |
|---|---|---|---|---|---|
| Structural | 1 | 0 | 0 | 1 | 2 |
| Lighting | 1 | 0 | 1 | 0 | 2 |
| HVAC | 1 | 0 | 0 | 1 | 2 |
| Refrigeration | 4 | 1 | 0 | 0 | 5 |
| Food prep | 3 | 0 | 0 | 1 | 4 |
| Misc equip | 1 | 0 | 0 | 0 | 1 |
| Unknown | 0 | 0 | 0 | 0 | 0 |
| Total | 11 | 1 | 1 | 3 | 16 |

Warehouse (n = 14)

| | Added | Eliminated | Replaced | Unknown | Total |
|---|---|---|---|---|---|
| Structural | 4 | 0 | 0 | 2 | 6 |
| Lighting | 1 | 0 | 0 | 0 | 1 |
| HVAC | 3 | 0 | 0 | 0 | 3 |
| Refrigeration | 0 | 0 | 0 | 0 | 0 |
| Food prep | 1 | 0 | 0 | 0 | 1 |
| Misc equip | 2 | 0 | 1 | 2 | 5 |
| Unknown | 0 | 0 | 0 | 0 | 0 |
| Total | 11 | 0 | 1 | 4 | 16 |

School (n = 4)

| | Added | Eliminated | Replaced | Unknown | Total |
|---|---|---|---|---|---|
| Structural | 0 | 0 | 0 | 0 | 0 |
| Lighting | 0 | 0 | 0 | 0 | 0 |
| HVAC | 0 | 0 | 0 | 0 | 0 |
| Refrigeration | 0 | 0 | 0 | 0 | 0 |
| Food prep | 0 | 0 | 0 | 0 | 0 |
| Misc equip | 0 | 0 | 0 | 0 | 0 |
| Unknown | 0 | 0 | 0 | 0 | 0 |
| Total | 0 | 0 | 0 | 0 | 0 |

TABLE D-2 (contd)

University (n = 2)

| | Added | Eliminated | Replaced | Unknown | Total |
|---|---|---|---|---|---|
| Structural | 0 | 0 | 0 | 0 | 0 |
| Lighting | 0 | 0 | 0 | 0 | 0 |
| HVAC | 0 | 0 | 0 | 0 | 0 |
| Refrigeration | 0 | 0 | 0 | 0 | 0 |
| Food prep | 0 | 0 | 0 | 0 | 0 |
| Misc equip | 1 | 0 | 0 | 0 | 1 |
| Unknown | 0 | 0 | 0 | 1 | 1 |
| Total | 1 | 0 | 0 | 1 | 2 |

Hotel (n = 11)

| | Added | Eliminated | Replaced | Unknown | Total |
|---|---|---|---|---|---|
| Structural | 0 | 0 | 1 | 1 | 2 |
| Lighting | 2 | 0 | 0 | 0 | 2 |
| HVAC | 2 | 0 | 0 | 0 | 2 |
| Refrigeration | 0 | 0 | 0 | 1 | 1 |
| Food prep | 1 | 0 | 0 | 0 | 1 |
| Misc equip | 3 | 0 | 0 | 3 | 6 |
| Unknown | 0 | 0 | 0 | 0 | 0 |
| Total | 8 | 0 | 1 | 5 | 14 |

Other (n = 5)

| | Added | Eliminated | Replaced | Unknown | Total |
|---|---|---|---|---|---|
| Structural | 0 | 0 | 1 | 0 | 1 |
| Lighting | 0 | 0 | 0 | 0 | 0 |
| HVAC | 0 | 0 | 0 | 0 | 0 |
| Refrigeration | 0 | 0 | 0 | 0 | 0 |
| Food prep | 0 | 0 | 0 | 0 | 0 |
| Misc equip | 0 | 0 | 0 | 0 | 0 |
| Unknown | 0 | 0 | 0 | 0 | 0 |
| Total | 0 | 0 | 1 | 0 | 1 |

As an indicator of how often remodels were the result of some other type of change, such as business type or tenant, Table D-3 shows the total number of observed remodels that occurred concurrently with other types of changes. Only the building types with at least one instance of this are shown. Changes in building tenancy, which occurred eight times in this sample of buildings, are the most common change type associated with remodels. Changes in business type are second with four changes. Two remodels were associated with partial vacancies, indicating that tenants vacated and removed some equipment. A single fuel type change, associated with an equipment replacement, was the only other event that occurred concurrently with a remodel.

TABLE D-3

Total Number of Non-Remodel Changes Occurring Concurrently with Remodels

| | Office | Retail | Grocery | Restaurant | Warehouse |
|---|---|---|---|---|---|
| Business type | 1 | 1 | 1 | 1 | 0 |
| Tenancy | 4 | 1 | 0 | 1 | 2 |
| Partial vacancy | 1 | 0 | 0 | 0 | 1 |
| Fuel type | 0 | 1 | 0 | 0 | 0 |

Table D-4 shows remodel frequencies in average changes per site per year, the same units used in all graphics in this document. The categories showing the greatest remodel frequencies are, with a few exceptions, miscellaneous equipment and lighting. Structural and HVAC changes are also common. In virtually every building type, additions outnumber removals and replacements. While this tends to support the common presumption that these loads are growing in the commercial sector, it must be understood that the nature of the ELCAP data sources favors identification of additions over other types of changes. Many changes are identified when the metering hardware is upset by building occupants, a frequent occurrence when new equipment is added to a building. Removal of equipment generally does not disturb the metering setup.

TABLE D-4

Mean Changeover Rates (Changes/Site-Year) by Change Category and Type

Office (n = 28)

| | Added | Eliminated | Replaced | Uknown |
|---|---|---|---|---|
| Structural | 0.01 | 0 | 0.05 | 0.07 |
| Lighting | 0.05 | 0 | 0.0 | 0.0 |
| HVAC | 0.02 | 0 | 0.01 | 0.03 |
| Refrigeration | 0.0 | 0 | 0.0 | 0.0 |
| Food prep | 0.02 | 0 | 0.0 | 0.0 |
| Misc equip | 0.18 | 0 | 0.0 | 0.02 |
| Uknown | 0.0 | 0 | 0.0 | 0.0 |

Retail (n = 28)

| | Added | Eliminated | Replaced | Uknown |
|---|---|---|---|---|
| Structural | 0.0 | 0.0 | 0.03 | 0.07 |
| Lighting | 0.09 | 0.0 | 0.02 | 0.06 |
| HVAC | 0.04 | 0.01 | 0.01 | 0.01 |
| Refrigeration | 0.0 | 0.0 | 0.0 | 0.01 |
| Food prep | 0.0 | 0.0 | 0.0 | 0.0 |
| Misc equip | 0.13 | 0.0 | 0.01 | 0.08 |
| Uknown | 0.0 | 0.0 | 0.0 | 0.0 |

Grocery (n = 19)

| | Added | Eliminated | Replaced | Uknown |
|---|---|---|---|---|
| Structural | 0.01 | 0 | 0.0 | 0.02 |
| Lighting | 0.02 | 0 | 0.03 | 0.03 |
| HVAC | 0.0 | 0 | 0.0 | 0.02 |
| Refrigeration | 0.11 | 0 | 0.0 | 0.0 |
| Food prep | 0.03 | 0 | 0.0 | 0.0 |
| Misc equip | 0.07 | 0 | 0.0 | 0.03 |
| Uknown | 0.0 | 0 | 0.0 | 0.0 |

Restaurant (n = 15)

| | Added | Eliminated | Replaced | Uknown |
|---|---|---|---|---|
| Structural | 0.02 | 0.0 | 0.0 | 0.02 |
| Lighting | 0.02 | 0.0 | 0.02 | 0.0 |
| HVAC | 0.02 | 0.0 | 0.0 | 0.02 |
| Refrigeration | 0.08 | 0.02 | 0.0 | 0.0 |
| Food prep | 0.06 | 0.0 | 0.0 | 0.02 |
| Misc equip | 0.02 | 0.0 | 0.0 | 0.0 |
| Uknown | 0.0 | 0.0 | 0.0 | 0.0 |

TABLE D-4 (contd)

Warehouse (n = 14)

| | Added | Eliminated | Replaced | Uknown |
|---|---|---|---|---|
| Structural | 0.07 | 0 | 0.0 | 0.04 |
| Lighting | 0.02 | 0 | 0.0 | 0.0 |
| HVAC | 0.06 | 0 | 0.0 | 0.0 |
| Refrigeration | 0.0 | 0 | 0.0 | 0.0 |
| Food prep | 0.02 | 0 | 0.0 | 0.0 |
| Misc equip | 0.05 | 0 | 0.03 | 0.04 |
| Uknown | 0.0 | 0 | 0.0 | 0.0 |

School (n = 4)

| | Added | Eliminated | Replaced | Uknown |
|---|---|---|---|---|
| Structural | 0 | 0 | 0 | 0 |
| Lighting | 0 | 0 | 0 | 0 |
| HVAC | 0 | 0 | 0 | 0 |
| Refrigeration | 0 | 0 | 0 | 0 |
| Food prep | 0 | 0 | 0 | 0 |
| Misc equip | 0 | 0 | 0 | 0 |
| Uknown | 0 | 0 | 0 | 0 |

University (n = 2)

| | Added | Eliminated | Replaced | Uknown |
|---|---|---|---|---|
| Structural | 0.0 | 0 | 0 | 0.0 |
| Lighting | 0.0 | 0 | 0 | 0.0 |
| HVAC | 0.0 | 0 | 0 | 0.0 |
| Refrigeration | 0.0 | 0 | 0 | 0.0 |
| Food prep | 0.0 | 0 | 0 | 0.0 |
| Misc equip | 0.16 | 0 | 0 | 0.0 |
| Uknown | 0.0 | 0 | 0 | 0.15 |

Hotel (n = 11)

| | Added | Eliminated | Replaced | Uknown |
|---|---|---|---|---|
| Structural | 0.0 | 0 | 0.03 | 0.03 |
| Lighting | 0.05 | 0 | 0.0 | 0.0 |
| HVAC | 0.05 | 0 | 0.0 | 0.0 |
| Refrigeration | 0.0 | 0 | 0.0 | 0.03 |
| Food prep | 0.03 | 0 | 0.0 | 0.0 |
| Misc equip | 0.08 | 0 | 0.0 | 0.08 |
| Uknown | 0.0 | 0 | 0.0 | 0.0 |

TABLE D-4 (contd)

Other (n = 5)

| | Added | Eliminated | Replaced | Uknown |
|---|---|---|---|---|
| Structural | 0 | 0 | 0.1 | 0 |
| Lighting | 0 | 0 | 0.0 | 0 |
| HVAC | 0 | 0 | 0.0 | 0 |
| Refrigeration | 0 | 0 | 0.0 | 0 |
| Food prep | 0 | 0 | 0.0 | 0 |
| Misc equip | 0 | 0 | 0.0 | 0 |
| Uknown | 0 | 0 | 0.0 | 0 |

# END

# DATE FILMED

02 / 25 / 91