Measure Life Study: The Effect of Commercial Building Changes on Energy Using Equipment

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According to a survey conducted by "Buildings Magazine", more money will be spent this year remodeling commercial buildings than building new commercial structures. A study conducted by the Washington State Restaurant Owners' Association found that 80 percent of all new restaurants fail within the first two years of operation. A BPA study found that 40 percent of the buildings retrofit with energy conservation measures either remodeled, renovated, or turned over within two years of the measure installation.

These figures raise questions about the impact of commercial sector remodel and renovation and turnover activities on the *in situ lifetime* of energy using equipment and energy conservation measures, and the *persistence of savings* from program-installed measures. Variations in these types of assumptions could have significant impacts on conservation program design and evaluation for the commercial sector.

This study was conducted in response to this information, and involved site visits to 380 commercial buildings and a phone survey of 100 building professionals. This study examined the extent of building changes and turnover in the commercial sector and the impact on energy-using equipment and equipment lifetimes, as well as highlighting potential variations in the results by type of change, business segment, classes of energy equipment, and geographic area. The study found:

- 25% annual turnover in important commercial segments,
- Renovations and remodels impact the majority of space and virtually always affect lighting systems, and
- Significant variations in results by building segment.

The purpose of the Measure Life Study is to examine these and other findings to determine impacts of changes on equipment/measure lifetimes, identify volatile areas (high frequency of change) and determine direction of future studies.

Introduction

The Bonneville Power Administration and many utilities across the country have designed and introduced a wide variety of commercial-sector energy conservation programs. The estimate of the cost-effectiveness of these programs is generally based on the expected savings from the introduction of a variety of behavioral and measure-based changes. Traditionally, the programs have been designed based on the expected technical lifetime of the measures or estimates of average service lifetimes. With many energy savings estimates based on ECMs which are expected to last ten or more years, it is important that there be some level of confidence in measure lifetime assumptions.

Bonneville and other utilities have developed data on average service life for typical commercial end-use equipment. These service life figures have been used as estimates of the useful life of individual ECMs. Unfortunately, lifetime estimates based on laboratory results or optimum field conditions do not take into account real-life variables such as the installation, operation, and maintenance practices employed at the site in which the ECM is located. Similarly, estimates which consider a less than ideal operating environment, but do not factor in the effects which remodeling, renovation, and business turnover can have on an ECM's life expectancy, may also prove to be inaccurate. Recently, attention has become focused on the impact that the

frequency of remodels and renovations may have on measure lifetimes in the commercial sector.

This study, which SRC conducted under contract to Bonneville Power Administration, was geared toward obtaining a better understanding of commercial renovation, remodeling, and turnover rates, and any resultant effects on energy using equipment. If possible, the probably effect on energy conservation measure (ECM) lifetimes would also be indicated. The study examined the general extent of the impacts of changes in the commercial sector on energy using equipment, as well as potential variations in the results by type of change (renovation, hard remodel, and soft remodel), business segment, and classes of energy equipment.

For this project, over 400 surveys were conducted: (1) over 100 surveys with a variety of construction, remodeling, and building management professionals about general turnover and remodeling frequencies, practices, and other important factors for each business segment and each type of change and (2) over 300 case studies examining the types and extent of actual changes made -- by business segment, change type, and equipment type -- in recent building modifications. The report also includes results of about 100 case studies of previous conservation participants (CIPP and IBP) conducted by Bonneville.

SRC's research was designed to determine (1) the frequency of building modifications in the commercial sector and (2) the effects that commercial renovation, remodeling and turnover rates might have on energy using equipment and, to the extent possible, on ECM lifetimes. The objectives of the study were to develop indicative results (rather than an emphasis on empirical estimates) and to identify areas for further study.

The study yielded disturbing results. While findings were very different for different sectors, it is clear that business turnover and physical modifications occur very frequently among commercial energy users. These changes could have a significant effect on the effective life of energy conservation measures, and, in turn, could have a significant effect on the impact of Demand Side Management programs and estimates of the cost of power made available through these programs.

Neither this paper nor SRC's study for BPA provide specific estimates of real-world measure life, or include specific recommendations for modifying measure life assumptions. Rather, this paper and the study are intended to highlight areas of concern for DSM planners and utilities planning or evaluating DSM programs. Further study will be required to design appropriate analytic remedies or provide specific numeric estimates for measure life assumptions.

The following section summarizes previous research in the area of commercial measure life. The methodology section of this paper provides a detailed description of the surveying and analysis methodology used in this study. The results section presents results of the surveys and analysis, and the conclusions section offers conclusions drawn from this project.

Review of Related Literature

Several previous studies have examined issues related to the lifespan of energy conservation measures (ECMs). The McRae study (McRae 1987) developed estimates of life spans for 51 ECMs. These estimates were developed via a Delphi technique, using surveys of personnel knowledgeable in the field performance of measures. Three estimates are provided for every measure: the test life, the operational life, and the effective life. The last, the effective life, is the life span of an ECM taking into account the behavior of the owner. The interviewees reported that a number of factors played a role in determining the average ECM life spans, including: differing installation, O&M practices, building type, and company practices; regional factors, labor and energy costs, building codes, environment, and real estate markets; renovation and remodeling rates; and manufacturer. The use of a Delphi technique made it difficult to get reliable, quantitative estimates of the measure lifetimes or to perform hypothesis tests. In addition, the study could not consider the specific impacts of factors such as business type, occupancy or building changes.

The Gordon study (Gordon 1988) was a critical review of the McRae work, and identified some of the problems in the data interpretation, and revised some of the estimated measure lives using revised assumptions about rates of commercial building remodeling, renovation, and demolition. The work also pointed out the need for additional research on the effect that renovation, remodel, and demolition rates may have on energy conservation measures in the commercial sector.

Another study (Lucas, et al. 1990) analyzed data collected under the End-Use Load and Consumer Assessment Program (ELCAP) to examine the frequency of changes in the commercial sector. Twelve classifications of building change were identified, and the impacts on building energy usage were also examined. The study examined the relationship of change frequency to building size and age as well as by building type. The frequency of building changes for each building type were provided,

and showed that 40 percent of changes are equipment changes. The study also found that the rate of change in commercial buildings is high -- 50% of the buildings had some type of change over the two-year period, with changes in some building types as frequently as once every 1.2 years to as long as every 5 years. Changes associated with lighting occurred once every 12 years to 20 years, and HVAC changes were reported less frequently. However, the study set up a hierarchy of building changes, so if two distinct changes occurred during the same time period, the one highest on the hierarchy would be the one counted. Therefore, equipment changes were noted only if no change higher on the hierarch (for example, change in business type) took place. Again, the study recommended additional research on the effect building changes have on energy usage.

In a study of lost conservation opportunities (Katz, et al. 1989), the authors noted that the cost effectiveness of an ECM can vary depending on when the ECM is installed in a building's life cycle. They noted that if the basic system is already being changed during a renovation or remodel, the cost of placing a more efficient system in its place is equal to the difference between the initial cost of the standard and efficient systems. However, during a retrofit, the costs of removal and installation must also be added, making some measures less cost effective or even precluding their installation. Conservation opportunities may be lost because optimally energy efficient equipment is not installed during the economically favorable "window" created by building remodel or renovation. Data sources included published data on two conservation programs and interviews with decisionmakers covering building data, incidence of renovation and remodel, and energy conservation information. The study predicted the frequency of renovation and remodel for 13 building types (given in terms of percent of floorspace by the year 2010), and was designed to investigate the impact of lost opportunities between 1989 and 2010. Results were reported separately by building type.

The study "Changes to IBP Buildings" (Petersen and Sandler 1991) examined changes made to 46 case study buildings after energy conservation measures had been installed under the Institutional Buildings Program. Installation occurred between 1983 and 1988, and the follow-up surveys, conducted in 1988 and 1989, collected information on types and frequency of building changes and the connection between changes and conservation measure performance. The study selected those buildings with the greatest level of IBP investment. A high frequency of change at the institutional buildings after the installation of energy measures was reported, with rates that were comparable to changes in the commercial sector at large. Changes were broken into 16 categories including changes in tenancy, schedule, business volume, as well as changes such as remodeling. Changes occurred in 93 percent of the buildings, and energy savings in 70 percent of the buildings were less than estimated.

A further examination of these IBP case studies (Kunkle and Johnson 1991) focussed on the physical changes to institutional buildings. A follow-up phone survey was conducted to expand the available data, and the study examined the types and frequency of physical changes occurring as well as the impact on building efficiency. The study also examined the problems causing partial or complete failure of program-installed measures and whether the problems had been resolved. The findings were based on interviewee recollection, and included only those buildings with the largest level of IBP investment. The figures found that changes occur approximately once every three years. The majority of changes were renovations, and they most often affected HVAC systems and controls. Remodels were more evenly divided between whole buildings and just the lighting system. Changes were reported most frequently in hospitals, local governments, and a port.

These studies provided good background for the SRC study, and provided order of magnitude checks for the results that the SRC study developed.

The review pointed out those areas in particular need of additional data.

Methodology

This study focused on collecting and analyzing significant amounts of primary data. Data from three sources were analyzed:

- 106 telephone surveys conducted with a variety of construction, remodeling, and building management professionals about general turnover and remodeling frequencies, practices and other important factors for each business segment and each type of building modification.

- 306 case study/on-site interviews at buildings that had recently undergone renovation or remodeling activities, to understand the types and extent of changes made in the commercial sector.

- 46 randomly selected site visits made by BPA to Commercial Incentive Pilot Program (CIPP) participants, to collect, among other data, information on measure persistence and reasons for removal.

The surveys were designed with different purposes and audiences in mind, to be used together to create a more complete picture of the effect of renovation/remodel on energy using equipment. The telephone survey gathered information from experts on renovation and remodel, and provides background data on the *overall and relative frequencies* of general types of change among building segments. The case study survey provided information on what specific things happened and what equipment was affected *when a renovation or remodel did occur.* The case study survey sample was not designed to should not be inferred to be representative of the level of change activity in the commercial sector. It is *not* a statistically derived sample, and was specifically designed to over-sample some types of change and some building segments, so that even smaller segments are examined to a meaningful degree.

Data from BPA's Commercial Incentive Pilot Program Survey provided information about the longevity of Energy Conserving Measures which were installed under the CIPP program.

Telephone Surveys

A telephone survey was conducted for this study during March and April of 1991. The principal objective of this survey was to gather background information and expert opinions on building and business changes that occur in the commercial sector. Experts in the field, including architects, contractors, and building owners, were selected from trade association lists and the telephone yellow pages. One hundred and six telephone surveys were completed in all, with respondents representing the geographic areas of King County (Seattle Area), Multnomah County (Portland Area), and the city of Yakima in eastern Washington. Additionally, a number of surveys were conducted with persons at national or regional headquarters of chain or franchise businesses.

The survey was divided into four sections. The first had general questions about the respondents' experience and responsibilities, and about their views of changes in the commercial construction and remodelling business. The second section dealt with "renovations," defined as major changes to a building associated with a complete rehabilitation of the building. The third section included questions about "hard remodels," or alterations associated with changes in tenant needs. Hard remodels may include structural or functional changes, and typically involve more than cosmetic changes. The fourth section of the survey focused on "soft remodels," appearance upgrades which may include lighting changes.

Case Study/On-Site Interview Methodology

In contrast to the telephone interviews, which relied on the personal impressions and experiences of building industry professionals, the case study interview process sought detailed information about buildings which had actually undergone recent renovation or remodelling. On-site surveys were conducted in three different geographic areas: King County, Washington (includes Seattle), Multnomah County, Oregon (includes Portland), and the city of Yakima, Washington. Survey questions probed for specific information about the systems affected by the change, and the extent of the change by system, the result of the change, and the reasons behind the change. Some pre-change equipment inventory information was also collected.

The case study building sample was derived from two sources: commercial building permit data and referrals from the telephone survey. The primary source of interview subjects was building permit data. Using this source had several advantages:

- assured getting to commercial buildings that had recently undergone some type of change;
- allowed geographic dispersion;
- in some cases allowed some pre-identification of level of change and type of building;
- allowed at least a crude method of "scaling up" the data.

The 306 on-site interviews were conducted using a non-representative, non-statistical sampling approach. The objective was to gather information about *all* building types and *all* types of changes, so that volatile areas could be identified. To be representative, the size of the required sample would have been prohibitively large, given the number of building and change (building modification/turnover) types and the fact that some change or business types occur relatively infrequently. Therefore, a *quota* approach was used, assuring a minimum number of on-site observations per cell, with cells defines on a building type/change type/regional basis. This approach insured that information would be derived for *all* change/building type combinations, and that indicative results could be derived about areas that merited further study. The on-site interviews were designed so that data could be used in conjunction with data from the telephone survey--we would know what types of changes are made for all business and equipment types from the on-sites,

and we would have the ability to put the data in perspective and infer frequency and importance from the telephone survey.

The survey was divided into five sections. This allowed the interviewer to skip sections if specific building components were not affected during the building change. The sections of the survey included:

- Respondent information: respondent name and title, source of referral, and job function.
- Site characteristics: building address, number of buildings, number remodelled, number of tenants, shared systems, number of tenants affected, square footage information (total, conditioned, percent remodeled).
- Renovation/remodel activity: date and duration of the remodel, reasons for the remodel, and the general types of changes made.
- Baseline equipment information: the types of equipment in the space before the remodel including indoor and outdoor lighting, heating equipment (and fuel), cooling and ventilation, HVAC controls, refrigeration, water heat, cooking, and other equipment.
- Building Changes: including detailed sets of questions about the changes made *by energy-related components*. The questions included:
  - why the component was changed.
  - the extent of the changes.
  - the original equipment that was removed, and the type of equipment that was added (additions and replacements).
  - the relative efficiency of the new equipment.
  - whether the modified equipment was installed as a conservation measure or as part of a utility program.
  - the disposition of equipment that was removed.

BPA Commercial Incentive Pilot Program Survey

BPA performed site visits of 46 randomly selected participants in its Commercial Incentive Pilot Program. This survey allowed for direct analysis of the longevity of Energy Conserving Measures actually installed under a utility incentive program.

Results

Based on the results of this study, we found:

- **Business Turnover:** Results of the telephone survey indicated business turnover[1] is most frequent in the small office, small retail, and restaurant sectors, with over 25 percent turnover per year for these segments. Over 75 percent of these buildings turn over to the same business segment, but a significant share of groceries and convenience stores are reported to change business segments at turnover. Hard remodels or renovations frequently accompany a turnover (more than half the time) in large office, large retail, mall, restaurant, grocery, and health sectors.
- **Frequency of Renovation, Hard Remodel, and Soft Remodel:**
  - Communities require building permits for almost all non-trivial building changes. Of those permits issued for the changes and business segments studied, by far the largest percentage of permits were issued for office and retail-sector remodels/renovations. Very few permits were issued for changes in malls, fast food, convenience stores, groceries, hotels, and schools.
  - Soft remodels are the most frequent type of building change. Hard remodels are less frequent and renovations are the least frequent. Estimates based on the judgment of building professionals showed that soft remodels occur in between 14 percent and 60 percent of buildings each year, with significant variation based on business segment (fast food, small office, and convenience stores are reported with highest percentages). Hard remodels are reported to occur in 9 percent to 23 percent of buildings per year (with the highest percentages in the fast food, grocery, and convenience stores segments), with renovations between 4 percent and 14 percent per year (most frequent in hotel and restaurant/fast food categories). The restaurant and fast food segments are among the most frequent segments noted for each change category.

- Among previous conservation program participants, 21 of 46 sites surveyed had undergone renovation or remodel since participating in the program.

- **Extent and Types of Changes in Renovations and Remodels:** Based on the research, renovations and remodels typically:

  - impact a large percentage of the building space.

  - impact the entire lighting, heating, and cooling system if at all.

  - result in more comfort.

  - increase or do not affect system efficiency.

- **Types of Energy Using Equipment Affected:** Renovations and remodels typically impact the lighting, HVAC systems and controls, and building interior shell. Results indicate that there are differences in the types of components typically affected in changes in the different business segments.

- **Effect of Changes on ECMs:** It is difficult to make any conclusions about the effect of renovation or remodel activity on energy conservation measure lifetimes. Respondents to the case study survey indicate that previously-installed ECMs were not usually removed in a change.

  Although results from a survey of previous CIPP participant sites indicate that the removal or deactivation of previously-installed ECMs may be significant, the stated reasons for the removal or deactivation were, in most cases, related to measure design or performance rather than to renovations or remodels of the site.

- **Decision-making Factors:** The most common reason for modifications was to meet tenant needs. Other important factors cited were improvements in efficiency and appearance. The end of useful lifetime is cited as a change-out reason for about 70 percent of equipment or measure changes. Energy efficiency was one factor considered in new equipment decisions. Most professionals are selecting more energy efficient equipment, and consider efficient equipment widely available.

- **Building Professionals Involved:** A wide variety of building professionals are involved in the decisions and implementation regarding remodels and renovations. These include architects, property managers and real estate professionals, general contractors and construction managers, mechanical engineers, and sales and design professionals. Tenants most often propose renovations/remodels, and architects, owners, and tenants determine what would be renovated. Decisions on changes are most often made at the local level, and tend to be approved by the owner or CEO or Board.

  Among previous conservation program participants, the parties most frequently responsible for decisions to renovate or remodel are owners and boards of directors.

Effect on Measure Lifetimes

The ultimate results of this study were indicative results that could provide a better understanding of the effect of renovation and remodeling on the lifetimes of energy using equipment and, if possible, some indication of the effect on ECM lifetimes.

As part of the technical report, a number of summary tables were prepared (Tables 1-4, following pages). These tables combine the results of the phone and case study surveys to determine the expected rate at which certain types of energy using equipment are removed or altered for various commercial business segments and by change type.

The expected rate at which the particular types of equipment are removed or altered in renovations, hard remodels, and soft remodels, by business segment, can be estimated from data in the surveys, as the multiplicative product of four elements:

- Annual rate of change (renovation, hard remodel, or soft remodel), by business segment (from the phone survey).

- Percent of renovated/remodeled sites affecting each building component, by business segment (from case study survey).

- Average percent of renovated/remodeled floorspace affected for each building component changed (from case study survey).

- Percent of total number of changes affecting the building component that involve removal/alteration of the component (from case study survey).

Table 1. Frequency of Change to Indoor Lighting Due to Renovation, Hard Remodel, and Soft Remodel

INDOOR LIGHTING FIXTURES	Large Office	Small Office	Large Retail	Small Retail	Restau-rant	Fast Food	Grocery	Conven. Store	Hotel/ Motel	Educa-tion	Ware-house	Hospital
Freq. of Renovation (% per year)	6%	11%	8%	9%	12%	12%	9%	13%	14%	4%	8%	5%
% Renovations Affecting Indoor Lighting System	100%	94%	100%	95%	100%	100%	100%	100%	100%	94%	89%	88%
% of Indoor Lighting System Affected	94%	92%	91%	76%	80%	100%	100%	99%	83%	93%	92%	100%
# Renovations Affecting Indoor Lighting System	16	31	5	18	14	3	6	4	4	17	8	7
# w/Fixture Removal/Alteration	16	30	4	13	8	2	6	4	4	14	7	5
% Fixtures Removed/Altered Annually due to Renovation	6%	9%	6%	5%	5%	8%	9%	13%	12%	3%	6%	3%
Freq. of Hard Remodel (% per year)	12%	16%	12%	17%	15%	23%	23%	23%	10%	14%	15%	13%
% Hard Remodels Affecting Indoor Lighting System	100%	100%	100%	92%	100%	100%	83%	67%	100%	100%	100%	100%
% of Indoor Lighting System Affected	85%	86%	81%	82%	79%	100%	52%	100%	40%	78%	90%	84%
# Hard Remodels Affecting Indoor Lighting System	20	24	6	11	7	5	5	2	1	3	3	10
# w/Fixture Removal/Alteration	18	21	4	10	7	4	4	1	1	3	2	8
% Fixtures Removed/Altered Annually due to Hard Remodel	9%	12%	6%	12%	12%	18%	8%	8%	4%	11%	9%	9%
Freq. of Soft Remodel (% per year)	22%	37%	20%	24%	27%	60%	17%	32%	23%	24%	21%	14%
% Soft Remodels Affecting Indoor Lighting System	75%	83%	100%	100%	100%		50%		100%	100%	100%	100%
% of Indoor Lighting System Affected	86%	100%	100%	90%	100%		100%		95%	80%	75%	42%
# Soft Remodels Affecting Indoor Lighting System	6	5	1	2	1		1		3	6	1	3
# w/Fixture Removal/Alteration	6	2	1	2	1		1		3	6	1	3
% Fixtures Removed/Altered Annually due to Soft Remodel	14%	12%	20%	22%	27%		9%		22%	19%	16%	6%

Table 2. Frequency of Change to Heating Equipment Due to Renovation, Hard Remodel, and Soft Remodel

HEATING EQUIPMENT	Large Office	Small Office	Large Retail	Small Retail	Restau-rant	Fast Food	Grocery	Conven. Store	Hotel/ Motel	Educa-tion	Ware-house	Hospital
Freq. of Renovation (% per year)	6%	11%	8%	9%	12%	12%	9%	13%	14%	4%	8%	5%
% Renovations Affecting Heating System	100%	91%	100%	84%	93%	33%	83%	75%	100%	94%	67%	100%
% of Heating System Affected	93%	93%	100%	90%	100%	100%	100%	100%	83%	84%	84%	100%
# Renovations Affecting Heating	16	30	5	16	13	1	5	3	4	17	6	8
# w/Heating Equipment Removal	10	23	4	5	8	0	5	3	2	8	4	5
% Heating Equipment Removed Annually due to Renovation	3%	7%	6%	2%	7%	0%	7%	10%	6%	1%	3%	3%
Freq. of Hard Remodel (% per year)	12%	16%	12%	17%	15%	23%	23%	23%	10%	14%	15%	13%
% Hard Remodels Affecting Heating System	85%	54%	33%	50%	57%	60%	33%	67%		67%	67%	70%
% of Heating System Affected	81%	74%		90%	77%	100%	50%	100%		100%	53%	73%
# Hard Remodels Affecting Heating	17	13	2	6	4	3	2	2	0	2	2	7
# w/Heating Equipment Removal	4	3	0	3	0	1	1	2	0	0	2	0
% Heating Equipment Removed Annually due to Hard Remodel	2%	1%	0%	4%	0%	5%	2%	15%		0%	5%	0%
Freq. of Soft Remodel (% per year)	22%	37%	20%	24%	27%	60%	17%	32%	23%	24%	21%	14%
% Soft Remodels Affecting Heating System	50%	100%			100%				67%	50%		100%
% of Heating System Affected	100%	100%			10%				100%	52%		2%
# Soft Remodels Affecting Heating	4	6	0	0	1		0		2	3	0	3
# w/Heating Equipment Removal	0	1	0	0	1		0		1	1	0	0
% Heating Equipment Removed Annually due to Soft Remodel	0%	6%			3%				8%	2%		0%

Table 3. Frequency of Change to Cooling Equipment Due to Renovation, Hard Remodel, and Soft Remodel

COOLING EQUIPMENT	Large Office	Small Office	Large Retail	Small Retail	Restau-rant	Fast Food	Grocery	Conven. Store	Hotel/ Motel	Educa-tion	Ware-house	Hospital
Freq. of Renovation (% per year)	6%	11%	8%	9%	12%	12%	9%	13%	14%	4%	8%	5%
% Renovations Affecting Cooling System	94%	91%	100%	58%	86%	33%	67%	75%	100%	67%	44%	100%
% of Cooling System Affected	89%	90%	100%	100%	100%	100%	100%	100%	88%	56%	68%	100%
# Renovations Affecting Cooling	15	30	5	11	12	1	4	3	4	12	4	8
# w/Cooling Equipment Removal	4	13	5	2	4	0	3	1	1	2	0	2
% Cooling Equipment Removed Annually due to Renovation	1%	4%	8%	1%	3%	0%	5%	3%	3%	0%	0%	1%
Freq. of Hard Remodel (% per year)	12%	16%	12%	17%	15%	23%	23%	23%	10%	14%	15%	13%
% Hard Remodels Affecting Cooling System	80%	50%	67%	50%	57%	40%	33%	100%		33%		60%
% of Cooling System Affected	68%	75%	75%	83%	65%	100%	28%	100%				67%
# Hard Remodels Affecting Cooling	16	12	4	6	4	2	2	3	0	1	0	16
# w/Cooling Equipment Removal	3	2	1	1	0	0	0	0	0	0	0	3
% Cooling Equipment Removed Annually due to Hard Remodel	1%	1%	2%	1%	0%	0%	0%	0%		0%		1%
Freq. of Soft Remodel (% per year)	22%	37%	20%	24%	27%	60%	17%	32%	23%	24%	21%	14%
% Soft Remodels Affecting Cooling System	50%	83%		50%					67%	33%		100%
% of Cooling System Affected	100%	100%							100%	85%		2%
# Soft Remodels Affecting Cooling	4	5	0	1	0		0		2	2	0	3
# w/Cooling Equipment Removal	1	1	0	0	0		0		1	1	0	0
% Cooling Equipment Removed Annually due to Soft Remodel	3%	6%		0%					8%	3%		0%

Table 4. Frequency of Change to HVAC Controls Due to Renovation, Hard Remodel, and Soft Remodel

HVAC CONTROLS	Large Office	Small Office	Large Retail	Small Retail	Restau-rant	Fast Food	Grocery	Conven. Store	Hotel/ Motel	Educa-tion	Ware-house	Hospital
Freq. of Renovation (% per year)	6%	11%	8%	9%	12%	12%	9%	13%	14%	4%	8%	5%
% Renovations Affecting HVAC Controls	94%	91%	100%	74%	93%	67%	83%	100%	100%	94%	78%	75%
% of HVAC Controls Affected	100%	96%	100%	96%	100%	100%	100%	100%	88%	90%	84%	100%
# Renovations Affecting HVAC Controls	15	30	5	14	13	2	5	4	4	17	7	6
# w/HVAC Control Removal	13	24	4	6	7	1	5	3	3	11	5	4
% HVAC Controls Removed Annually due to Renovation	5%	8%	6%	3%	6%	4%	7%	10%	9%	2%	4%	3%
Freq. of Hard Remodel (% per year)	12%	16%	12%	17%	15%	23%	23%	23%	10%	14%	15%	13%
% Hard Remodels Affecting HVAC Controls	90%	67%	67%	58%	43%	60%	33%	67%		67%	33%	70%
% of HVAC Controls Affected	91%	100%	100%	100%	100%	100%	50%	100%		100%	100%	82%
# Hard Remodels Affecting HVAC Controls	18	16	4	7	3	3	2	2	0	2	1	7
# w/HVAC Control Removal	9	9	3	4	2	1	1	2	0	2	1	4
% HVAC Controls Removed Annually due to Hard Remodel	5%	6%	6%	6%	4%	5%	2%	15%		9%	5%	4%
Freq. of Soft Remodel (% per year)	22%	37%	20%	24%	27%	60%	17%	32%	23%	24%	21%	14%
% Soft Remodels Affecting HVAC Controls	75%	83%		50%	100%		50%		100%	67%		33%
% of HVAC Controls Affected	100%	100%			100%		100%		100%	73%		100%
# Soft Remodels Affecting HVAC Controls	6	5	0	1	1		1		3	4	0	1
# w/HVAC Control Removal	3	3	0	0	1		0		3	1	0	0
% HVAC Controls Removed Annually due to Soft Remodel	8%	18%		0%	27%		0%		23%	3%		0%

The tables provide results for a number of energy equipment types.

Table 1 displays these calculations for indoor lighting fixtures. The first section of the table addresses renovations. The first row of this section shows that 6 percent of large office buildings are renovated each year. The second row of the section shows that 100 percent of renovations of large office buildings affect the indoor lighting system. The third row of the section shows that 94 percent of the lighting system is, on average, affected by renovations that affect indoor lighting. The ratio of number of renovations affecting lighting (the fourth row) to number removing or altering lighting (the fifth row) shows that 100 percent of renovations of large office buildings affecting the indoor lighting system involve either removal (either with or without replacement) or alteration of lighting fixtures. For indoor lighting systems, we interpret "alteration" of fixtures to mean removal of one or more components, such as ballasts. Multiplying these figures, which are all derived from the telephone or case study data, results in the percent of fixtures removed or altered annually due to renovation -- in this case, 6 percent of the indoor lighting fixtures (6% x 100% x 94% x 16/16) in large office buildings are removed or altered annually due to renovations.

Moving across the columns of the first section of Table 1, we find that the percentage of indoor lighting fixtures that are removed or altered annually due to renovations varies from 3 percent in education and hospital/health care to 13 percent in convenience stores. The second section of the table shows that the percentage of indoor lighting fixtures removed or altered annually due to hard remodels varies from 4 percent in hotel/motel to 15 percent in convenience stores. The third section of the table shows that the removal or alteration percentage due to soft remodels varies from zero in several building types to 27 percent in restaurants.[2]

Tables 2 through 4 display similar calculations for heating, cooling, and HVAC control systems.

Effect on Lifetimes of Previously-Installed ECMs. Specific questions were asked in the case study survey which might also be used to compute percent of previously installed ECMs that were removed or replaced due to a renovation/remodel. Unfortunately, the number of case study respondents that had previously installed ECMs is so small that the resulting estimates were meaningless.

The CIPP evaluation completed by Bonneville indicates, however, that the incidence of removal of ECMs by previous program participants is relatively high. About 40 percent of respondents to the CIPP evaluation survey had removed or altered previously-installed ECMs. The most frequent reasons given for the removal or alteration, however, were:

- Poor design,
- equipment malfunction,
- vandalism, and
- O&M problems.

Only one respondent indicated that a previously-installed ECM had been removed or altered due to a renovation at the site. This indicates that, because the rate of ECM alteration and removal may be very high, it is important to understand the reasons in order to more effectively design conservation programs which will continue to deliver energy savings as expected. However, the high rate of renovation and remodeling activity in the commercial sector *does not translate directly* into a high rate of ECM removal. The other reasons given by program participants for removal or alteration of ECMs should be fully explored as well.

Conclusions

This study indicates that the high level of business turnover, renovations and remodels may be an area of concern for analysts designing DSM programs or examining their effectiveness. The major objective of this research was to derive indicative information about the potential impact that renovation, remodel, and turnover in the commercial sector might have on the in situ lifetimes of energy using equipment. This study collected a large amount of data related to these issues, including information about:

- General trends and types of activities prevalent in the sector based on interviews of over 100 building professionals.
- Specific changes implemented in over 300 case studies of buildings that had undergone remodel or renovation.

A wealth of information was collected on changes and practices for several business segments and numerous building components, as well as by type of change (renovation, hard remodel, and soft remodel). Critical findings of the report include:

- 25% annual turnover in important commercial segments,
- Renovations and remodels impact the majority of space and virtually always affect lighting systems, and
- Significant variations in results by building segment.

Additional targeted research on volatile segments or equipment will be useful in determining more precisely the level to which these changes affect actual measure lifetimes.

Endnotes

1. Business turnover is defined as a business moving in or out of a building, or a business closing.

2. Note that because the data for percent renovated, hard remodeled, or soft remodeled were asked separately in the telephone survey, there may be some element of overlap between the categories. Because the extent of "double-counting" cannot be estimated, the annual rates of change within each business segment and type of energy using equipment for each of the three change types should be looked at separately and not added up.

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