Effective ECM and Equipment Lifetimes in Commercial Buildings: Calculation and Analysis

Lisa A. Skumatz, Skumatz Economic Research Associates
Curtis Hickman, Bonneville Power Administration

The estimated useful lifetime of energy conservation measures (ECMs) is a critical input to program cost-effectiveness calculations. Although average service life data have been used as ECM lifetime estimates, changes are constantly occurring in commercial buildings—tenants change, spaces are remodeled/renovated, or the functional use of the space changes-and these changes may have significant impacts on on-site lifetimes of individual ECMs.

This study used data from an on-site survey of almost 600 buildings (300 each in two studies) to examine more precisely the effective measure life of ECMs, given the real-world dynamics of the usage and maintenance of commercial buildings. Although data on all commercial building types were collected, the study and sampling plan emphasized three particularly important business types: office, retail, and grocery, building types with historically significant conservation investment and/or high turnover/remodel potential. The survey examined ECMs in indoor and outdoor lighting, HVAC, refrigeration, water heating, and envelope. The study collected and statistically analyzed detailed field data to:

- estimate frequency of equipment removal from participant and non-participant buildings due to renovation, remodel, and other reasons.
- determine relative efficiency of replacement equipment and disposition/ reuse of removed equipment.
- examine differences in removal and renovation rates between urban/non-urban, participant/non-participants, and building types.
- estimate updated ECM measure lifetimes based on the field survey data.

These analyses provided specific numeric estimates of measure lives that are representative of regional conditions, appropriate for program design and calculation purposes, (including targeting of measures and building types, if appropriate), and useful for modifying regional supply curves.

Introduction

The Bonneville Power Administration (BPA) and many utilities across the nation have designed and introduced a wide variety of commercial-sector energy conservation programs. Acquisition from commercial sector energy conservation measures (ECMs) are a primary focus in Bonneville's conservation activities because of the large load represented by the sector.

The major inputs to the calculation of program cost-effectiveness are measure cost, kWh savings, and *lifetime.* Certainly, the ultimate savings of the program are a function of a broader range of factors, including not only measure *retention,* but also the performance of the measure, market progression, and other issues. This paper focuses on the issue of the effective on-site measure lifetime, and the factors that influence early change-outs.

Utilities have developed data on average service life for typical commercial end-use equipment, and these service life data have been used as estimates of the useful life of individual ECMs. But, recognizing that changes are constantly occurring in commercial and industrial buildings—tenants change, spaces are remodeled or renovated and/or the functional use of the space changes-considerable attention has begun to be placed on examining the impact of real-world operating and business conditions on the *in situ* lifetimes of commercial sector energy equipment.

Objectives of the Study

The scope and objectives of this study are to enhance the work started in Bonneville's Measure Life Study I (MLS I), but to further investigate measure life implications for three important business types (retail, grocery, and office) and to concentrate on providing statistical, quantitative estimates of measure lives for the measures encountered in the study.

The objectives are:

- *Remodeling and Renovation:* Improve estimates of the impact that remodeling and renovation may have on typical equipment lifetimes. Examine differences in remodel and renovation rates between urban/non-urban areas.
- *Non-Measure Life Issues:* Examine the frequency with which ECMs and equipment are removed before the end of operational lifetimes. Examine operational and maintenance issues, decisions regarding equipment removal, and examine the fate of removed equipment. Determine if equipment that is replaced is replaced with equipment of higher or lower efficiency.
- *Measure Lifetime Estimates:* Derive estimates of effective measure lifetimes given data focused on three building types. Determine whether the current measure lives used in the Energy Smart Design Program are reasonable.

To support more quantitative and targeted analysis, the data for this study were derived from three sources:

- Participants in Bonneville's Commercial Incentives Pilot Program (CIPP). These buildings represent participants in a Bonneville conservation program. Approximately 70 CIPP buildings representing the three sectors of interest (retail, grocery, and office).
- Buildings selected from Bonneville's Commercial Audit Program (CAP). About 50 buildings from the CAP program were available; these buildings are primarily non-urban type buildings.
- Buildings from the Pacific Northwest Non Residential Survey (PNNonRES). Bonneville provided approximately 211 grocery, office, and retail buildings from the PNNonRES survey. This survey provides a database that is representative of buildings in the BPA region.

The use of these three databases as the source for the on-site sample provided the possibility to improve previous work in several ways: (1) ability to generalize to representative buildings; (2) compare with information from site visits conducted 3-5 years ago; (3) include a greater number of participant buildings; (4) focus on three key business types, allocating greater sample sizes to the sectors; and (5) incorporate significant numbers of rural buildings in addition to urban setting to examine the effect of possible lower remodel rates.

Specifically, these three business types (retail, grocery, and office) were responsible for 55% of the kWh acquired by Bonneville's Energy Smart Design (ESD) program in fiscal year 1993 (and the building types were numbers 1, 3, and 5 in terms of acquired kWh).

The completed audits from this Measure Life II (MLS II) survey included: 178 from PNNonRES, 58 from CIPP, and 32 from CAP. Recategorized by business type, 88 retail, 45 grocery, and 135 office on-sites were completed. Finally, 41 of the on-sites were completed in rural locations, with the remaining 227 completed on urban buildings.

Analytical Approach

Approach for Non-Measure Lifetime Analyses

One key emphasis of this study was to gather information that could help provide an understanding of the factors that affect early changeout. A variety of factors related to measure retention, decision-making, and disposition have implications for both program design and evaluation. In particular, the on-site survey included questions designed to examine:

- *Maintenance procedures:* How well equipment is being maintained may be assumed to have a direct impact on the lifetimes of measures. The survey asked questions related to maintenance frequency, observed condition of the equipment, and maintenance staffing/contract arrangements.
- *Reasons for change:* The underlying reasons for removing equipment may provide information to indicate how far from operational lifetimes measures should be assumed to last on-site, and provides information on program design issues. If "looks" are a

key change factor for certain equipment in certain business types, that might influence the program design and measure availabilities. If renovation/remodel is a key reasons for changeouts, revisions to the cost-effectiveness calculations may be appropriate for volatile sectors or measures.

- *Disposal of equipment:* The ultimate destination of disposed equipment may shed light on the length of time for which equipment may be able to provide savings. If equipment is put into another location within the building, or if it is sold to a secondary market, the equipment may still have a chance of providing the region with savings, even if it has been removed from the original installation. If removed equipment goes to the landfill, savings are not on-going.

The results of these analyses are provided in the summary and conclusions sections.

Deriving Measure Life Estimates

Using field data for calculating measure lifetimes presents some special problems. In the ideal case, data could be collected that would support estimation of lifetimes using a "survival analysis" technique. Survival analysis requires data be known on the type of equipment installed, date of installation, date of removal/failure, and preferably, reason for removal/failure. However, unless the original program was designed with this purpose in mind, it is rare that the data would be sufficient to support the estimation using this technique. Specifically, the problems with implementing this approach include:

- Determining whether the noted equipment (or the program-installed equipment) is still in place is problematic. For lighting and other equipment it can be difficult to determine *which* equipment was installed as part of the program. In addition, defining a "match" may include not only type of equipment, but for instance, number of fixtures installed.

- There can be conflicts between database records and customer-supplied information. Customers may not agree with records on whether an item was installed as part of a program.

- Other problems may arise, such as removal dates may be unavailable; defining "failure" of a measure is not always obvious; and sample sizes for particular measures may be small because of eligibility issues.

- Some measures of interest may have been in the market too short a time to gather a history of enough failures to derive an estimate of lifetime.

Although some program databases are very detailed, the databases used for this study were not designed to support measure retention analysis. Although the on-site auditors for this project were instructed to give high priority to finding the equipment noted on the survey forms, we found that there seemed to be an unacceptably high percentage of equipment could not be found on-site, and because of the wide range of reasons for non-matches, the simple assumption that all non-matched equipment must have been removed was not appropriate. In addition, dates for removal were only recalled for about 50% of the equipment changes. Finally, the records for dates for installation of equipment only provided information for the fiscal year of installation, leading to some fuzziness on the age of the equipment.

Several analytical methods were tested for use in this project. Each had strengths and weaknesses. The approaches, and their pros and cons are described below.

- *Survival analysis:* In this method, equipment that was noted to be on-site during the original on-site would either still be there or would be removed, and the percentages and dates of removal would provide the basis for survival analysis. Some of the sample would fail or be replaced by the time of the MLS II equipment surveys; from these failure proportions and dates, expected measure lives could be inferred for different equipment classes. This is a credible analysis method, but the data did not provide high enough quality to support the method.

- *Distribution of equipment ages:* In the absence of a survival sample, the observed distribution of equipment age at the survey date can be used to estimate measure lifetimes. For a survival data set, we would establish a sample of equipment with known ages, and follow it for a period of time, noting the age of equipment when it fails. In the method described here, we take a "snapshot" of the age of all existing equipment at a single point in time. Intuitively, the current equipment age distribution bears some relation to the average lifetime of the equipment. If the average service life to fluorescent bulbs is three times that of incandescent bulbs, it would be surprising if the average age of the current fluorescent bulb population is not higher than the average age of the incandescent bulb population. However, there are pitfalls with this approach. To make inferences about a population's measure life distribution from its age distribution, we must assume that if a member of the population "dies" (i.e., if equipment is taken out of service) it is replaced with a new member of the same population. Given this assumption of a self-replicating population, the population age distribution will converge in distribution to a scaled survival curve. However, there are two problems associated with using this technique for the MLS II analysis. The first is that in some cases, equipment may not be replaced with like equipment. The second is that this method does not control for the fact that some equipment has not been in the marketplace long and the equipment cannot yet have reached a stable state of replacement. In these cases, the equipment lifetimes will merely reflect the length of time the equipment has been in the market, rather than the ultimate lifetime.

Two other methods were also attempted, but the necessary assumptions or the data available were problematic. These included using reported equipment ages, or using building age and information on equipment changes.

In general, the age distribution of equipment was used for calculating measure lifetimes for this study (unless otherwise noted in the tables or text). The approach allowed the most observations to be used, and did not rely on matching equipment. However, *the results for some measures must be used with judgement,* Some equipment, especially newer equipment and more efficient equipment will not fit the assumption of "steady state replacement", and the estimated measure lifetime will only indicate the length of time the equipment or technology has been in the marketplace in this region.

Two types of analyses were conducted:

- Aggregate equipment types: analysis of broad classes of equipment, which increased the sample sizes and allowed analysis of differences between building subgroups, and

- Specific measure estimates: analysis of more disaggregate and specific measures and equipment. The sample sizes for these measures were smaller, and analysis between groups of buildings and other disaggregation was not possible.

The results of each of these analyses are presented separately in the results section.

Results and Conclusions

The findings of this study are summarized below.

Renovation Rate and Measure Life Results

- Average buildings renovation rates for these three business sectors was estimated at 10% annually. The highest rates were found for offices (12 %), followed by retail (8.4%) and groceries (7.4%), although the differentials were not significantly different. These rates were smaller than the combination of the *renovation, hard remodel, and soft remodel* included in MLS I, but are more similar to the reported rates for renovation and hard remodel. This result may be expected, because MLS II concentrated on renovation/remodel. Renovation rates were also lower for rural buildings, although not significantly so.

- The estimated measure lifetimes in the business sectors generally followed the pattern that would be reflected by the higher and lower estimated renovation rates. Groceries tended to have longer lifetimes for key equipment (with some exceptions, for example outdoor lighting). The retail sector showed shorter lifetimes for key heating and cooling equipment. Estimated lifetimes for urban buildings were generally shorter than more rural buildings (also similar to renovation rate estimates).

- Estimated lifetimes between efficient and less efficient equipment were generally similar with the exception of shorter lifetimes for efficient ballasts and HVAC controls.

Maintenance, Reasons for Change, and Equipment Disposal

- Equipment maintenance showed some patterns and exceptions. The majority of major equipment was reported to be maintained through contract arrangements or dedicated on-site staff, especially for heating, and water heating equipment. Refrigeration and motors tended to report less formal maintenance arrangements. Maintenance frequencies were known in only about 10-20% of cases.

- Contracted maintenance was reported with higher frequency in urban settings (and maintenance frequencies were also reported more often). Equipment in rural settings showed a somewhat higher percentage with dirt or rust.

- Renovation was given as a major reason for equipment changes for several equipment types, including HVAC controls, motors, ventilation systems, cooling, and heating equipment (in urban locations).

- Improving equipment efficiency was a key reason for change for a number of equipment and business types, including HVAC controls and indoor lighting. This was a key motivator for rural buildings and the retail sectors in particular.

- Equipment failure was seldom a significant factor for changes with a few exceptions, including cooling systems (in offices), water heaters (in offices and retail), and refrigeration (in groceries).

- Removed equipment is largely sent to the landfill or to an unknown destination. Little of the equipment is sent to secondary markets or re-used or stored elsewhere in the buildings, with a few exceptions.

Aggregate Equipment Results

Table 1 shows the useful lifetime assumptions used by Bonneville and various California utilities in designing commercial-sector programs. The last column represents a simple average for these measure lifetimes, assigning equal weights for each of the included lifetimes. Table 2 presents the results of the MLS II estimates of equipment lifetimes for broad equipment categories. Overall results are reported, as well as estimates for specific subsets of the data, including: geographic (urban/non-urban); business type (retail, grocery, and office); source of the original data (PNNonRES, CIPP, CAP); efficient and less efficient equipment; and large vs. small buildings. Differences between point estimates that are significantly different (at the 90% confidence level) are noted on the table.

The key results of this set of estimates follows. Point estimates are provided, but note that significant differences are denoted by symbols in the table.

- *All Category:* This column presents the results of the estimates aggregating all data across building types, database source, etc. The general results compare favorably, in terms of orders of magnitude with lifetimes used by BPA and other utilities. Equipment that are expected *a priori* to last longer in fact showed longer lifetimes (e.g., HVAC-related equipment).

- *Database Source:* Generally, the lifetimes for CIPP data show shorter lifetimes, especially for lighting equipment. The vast majority of installations under the CIPP program involved lighting equipment, so these results reflect the fact that the CIPP installations are, in fact, newer installations than the population at large. Note that the small sample size for the CAP program made it difficult to estimate lifetimes for some equipment. PNNonRES, which comes closer to representing the region, rarely had numbers that were significantly different from the “all” category, except in the case of a longer lifetime for water heating equipment.

- *Business/Building Type:* For several equipment types, notably cooling and heating equipment, office buildings demonstrate significantly longer lifetimes than similar equipment in retail establishments. Groceries showed significantly shorter lifetimes for outdoor lighting equipment. Few other significant patterns between business types were found.

- *Urban/Rural: The* point estimates for the rural buildings are generally longer; however, the relatively few sample points for the rural sites resulted in large confidence intervals. Therefore, none of the differences between urban and rural sites were significantly different.

- *Efficient vs. Less Efficient Equipment:* Generally, more efficient equipment was found to have shorter lifetimes. However, this is very much influenced by the fact that the more efficient equipment had generally been in the marketplace for a shorter period than standard equipment. The weakness of the estimation method used is that it assumes that equipment replacements are in a steady state, an assumption which is not very applicable for this stratification variable.

- *Building Size:* For almost every equipment category, large buildings showed shorter equipment lifetimes (or greater equipment turnover) than smaller buildings (by 5-6 years). Differences were significant for much of the important lighting equipment, as well as HVAC controls.

Specific Equipment and Measures

Table 3 below presents the results of the measure life estimations for a variety of specific equipment types and ECMs. In addition, 90% confidence intervals for the point estimates are also provided. The age distribution method used for the calculations requires relatively large sample sizes, so estimates could not be derived for a number of specific ECMs and equipment types. In addition, because the estimation needed relatively large sample sizes, the lifetimes could not, in general, be subsetted to show differences between different groups. Note also that for certain measures (indicated by a ** symbol) the measures are too new on the market to be considered in “steady state replacement”, and the measure lifetimes estimated via this method likely provide estimates of the length of time the technology has been in the market.

Summary of Equipment Lifetime Results and Differences

Table 4 provides a summary of the patterns of MLS II lifetime estimates compared with lifetimes assumed by utilities. The columns indicate that a number of measures demonstrate lifetimes in the field that are consistent with or longer than program assumptions (with some differences depending on which utility’s lifetime is considered). However, for a number of measures, specifically many that are most often considered in DSM programs, the apparent estimates lifetimes are shorter than program assumptions. Most of these results are denoted by stars in

Table 1. Useful Lives of Commercial and Industrial Energy Conservation Measures (years)

Equipment Type and Description	BPA Median	SCE	SDG&E	PG&E*	SCG	BPA ESD	AVG
Lighting							
Energy-efficient fluorescent lamp	5	3	5	6.5		5	4.9
Same as above with built-in ballast	2	2				2	2.0
Energy-efficient ballast	11	12	18			12	13.3
Electronic ballast	3	3	5			12	5.8
Metal halide lamp	10	12	5			3	7.5
Low-pressure sodium lamp	5	3				5	4.3
High-presure sodium lamp	5	3				5	4.3
Parabolic fixture	20	15	15	20			17.5
Dimming systems	20	20	15	20		20	19.0
On-off switching	7	20				7	11.3
Motion sensor	10	15	8	5		10	9.6
Compact fluor. w/detachable ballast						12	12.0
Energy efficient fixture (fluor, HID, etc.)						20	20.0
HVAC							
Economizer	11	15	15			11	13.0
Chiller strainer cycle system	15	15				15	15.0
Air-to-air packaged heat pump	10	15					12.5
Water-to-air packaged heat pump	15	15					15.0
Ice thermal energy storage	19	20	20			19	19.5
Water thermal energy storage	20	20	20			20	20.0
Plate type heat pipe recovery system	14	15			15		14.7
Rotary type heat recovery system	11			10			10.5
Heat recovery from refrig./condenser	11	15		10			12.0
Low leakage damper	9	10					9.5
Variable inlet vane VAV	11	10	20		15		14.0
Variable pitch fan for cooling tower	13	15	10				12.7
Make-up air unit for exhaust hood	10	10					10.0
Air destratification fan-paddle type	10	18					14.0
Air destratification fan-high inlet/low discharge	15	18					16.5
Air curtain	10	10					10.0
Deadband thermostat	13	15				13	13.7
Spot radiant heat	10	15				10	11.7
Radiant heat (hot water or steam)						25	25.0
Unit heaters (electric or gas)						13	13.0
Unit heaters (hot water or steam)						20	20.0
Valve actuators (hydraulic)						15	15.0
Valve actuators (pneumatic)						20	20.0
Valve actuators (self-contained)						10	10.0
Air washers						17	17.0

Table 1. (contd)

Equipment Type and Description	BPA Median	SCE	SDG&E	PG&E*	SCG	BPA ESD	AVG
Controls							
Computer logic EMS	13	20	15			13	15.3
Electronic controls	11	15	15			15	14.0
Electric controls						15	15.0
Pneumatic controls						20	20.0
Time clocks	10	9		5		10	8.5
Motors, Drives, and Transformers							
Standard electric motor	15	18				15	16.0
High-efficiency electric motor	17	18	17	17		17	17.2
Variable-speed DC motor	18	20				18	18.7
Variable-speed drive-solid state	15	15				15	15.0
Variable speed drive-belt type	10	10	10			10	10.0
Efficient AC electric transformer	15	30				15	20.0
Motor Starters						17	17.0
Reciprocating engines						20	20.0
Steam turbines						30	30.0
Domestic Hot Water							
Heat pump water heater	10	13				10	11.0
Point-of-use water heater	12	15				12	13.0
Solar water heater	15	15				15	15.0
Change electric to gas booster			15				15.0
Refrigeration							
Unequal parallel refrigeration	14	15	15			14	14.5
Condenser float head pressure control	10	15	15			10	12.5
Auto cleaning system for condenser tubes	15	15				15	15.0
Hot gas bypass defrost	10	15				10	11.7
Polyethylene strip curtain	3	10		3		3	4.8
Refrigeration case cover	11	15				11	12.3
Building Envelope							
Double glazing	20	20				20	20.0
Heat mirror	18	20				18	18.7
Low-emissivity coating	14	15		10		14	13.3
Solar shade film (retrofit)	7	5	7			7	6.5
Tinted and reflective coating	14	20		10		14	14.5
Blanket insulation						24	24.0
Molded insulation						20	20.0
Air curtain						10	10.0

Source: Compiled from Bonneville, Utility, and CEC sources.

Note: ESD = Energy Smart Design program.

Note: '(**) - Two changes made to PG&E information. Measure life of fixture.
20 years for HP-sodium lamp assumed an error, and assigned to parabolic.
Also, average of stated measure life of 5,8 assigned to efficient fluorescent lamps.
Average calculated as simple average of measure lifetimes present in table.

Table 2. Measure Lifetimes of Broad Equipment Categories - Age Distribution Method (in years, significant differences at 90% confidence noted)

	All	PNNonR	CIPP	CAP	Retail	Grocery	Office	Urban	Rural	Less Effic.[a]	More Effic.[a]	Small	Large(1)
Indoor Lighting													
Ballast	10.0	10.5	8.0	20.5~	9.5	15.6~	9.8	9.6	16.3	14.4*^	5.9*^	14.4*	9.7*
Bulb	4.2	3.9*	5.5*^	3.8~	4.5	4.1	4.1	4.3	3.8~	3.1*^	4.4*	4.2	4.3
Control	22.9	21.8	25.3		23.3	24.2	22.8	22.5	26.2	23.2	20.5~	26.2*	20.0*
Fixture	21.0	20.5	19.3	34.5~	21.3	20.5	21.5	20.5	25.0	19.9	21.3	24.9*	18.0*
Reflector	6.2	9.3					5.8	5.7		6.2			
Outdoor Lighting													
Ballast	15.7	17.8	7.3^				17.1~	15.6	16.0				
Bulb	6.1	6.4						6.9			5.8		
Control	22.7	22.8	16.1	24.4	25.2	16.2*^	24.1	22.6	23.9	23.2	22.4	24.2	20.8
Fixture	21.8	22.2*	12.2*^	26.3~	23.6	15.9*^	23.3	21.6	23.2~	22.1	21.8	23.0	21.0
Cooling Equipment	19.9	20.4*	15.2*	22.0	16.6	17.8	20.8	20.2	17.9	20.7	19.0	19.5	20.3
Cooling Compressors	15.4	15.4	16.9~	15.2	9.1*	13.1	18.2*		16.6	15.4			
Heating Equipment	18.2	17.9	17.3	24.5^	13.6*	19.4	20.3*	18.7	14.7	19.3	18.1	20.5	16.4
HVAC Controls	18.5	18.8	10.4*^		20.6	18.1~	17.9	16.9	26.7~	24.0*^	12.8*^	23.5*	14.8*
Refrigeration	16.5	16.1	21.9		14.2	19.3	19.5	16.5	20.9	18.7	16.0	15.6, 17.1	19.4, 15.2
Ventilation	23.4	22.9					24.1	23.3		24.7	21.6~	27.2	22.6
Water Heating	10.6	15.0^	8.2		15.2	13.2~	11.9	11.0	11.2	10.6			
Cooking	17.4	17.3	18.0		18.8	15.6	17.9	17.5		21.3*^	13.2*		
Motors	21.7	21.2					22.5	21.7		21.7			

Notes: significance tests at 90% confidence level
^ = significantly different from "all" category
* = significantly different from other entry within category
~ = no confidence interval could be calculated
(1) = large/small categories defined by median of building type
(a) = more and less efficient differences influenced by shorter marketplace tenure for "efficient" equipment

Table 3. Estimated Measure Lifetimes - Measure Life Study II

	Measure Life (in years)		90% Confidence Interval			ESD ML	Utility ML Avg.	Utility ML Range
Indoor Lighting								
Ballast	10.0	[	8.7	12.0	]			
Std. Magnetic Ballast	18.5	[	17.5	19.5	]			
Efficient Magnetic Ballast*	8.2	[	6.6	9.6	]	12	13.3	(11-18)
Electronic Ballast**	4.6	[	3.8	5.1	]	12	5.8	(3-12)
Bulb	4.2	[	3.7	4.5	]			
Incandescent	2.8	[	2.3	3.6	]			
Compact Fluorescent	3.3	[	2.6	4.1	]	5	4.9	(3-6.5)
Fluorescent	4.5	[	4.1	4.8	]			
Control	22.9	[	21.8	23.9	]			
Mechanical On/Off	23.2	[	22.4	24.1	]	7	11.3	(7-20)
Mechanical/Multi Switch	28.7	[			]			
Timer Switching	22.9	[			]			
Fixture	21.0	[	20.0	21.9	]			
General Lighting	21.0	[	18.7	22.8	]			
Recessed Can	20.4	[	18.7	23.3	]			
Spots/Display	22.6	[	19.5	25.6	]			
Floods	21.8	[	19.3	24.9	]			
Strip Lighting	22.0	[	20.3	25.1	]			
Reflector	6.2	[	4.3	8.8	]			
Outdoor Lighting		[			]			
Ballast	15.7	[	13.1	18.0	]			
Standard Magnetic Ballast	15.0	[			]			
Bulb	6.1	[	5.2	7.2	]	3.5	(4.3/7.5)	(3-12)
Control	22.7	[	21.2	24.3	]			
Mech. On/Off	23.8	[	20.6	26.2	]			
Photocell On/Off	18.3	[	16.2	19.6	]			
Timer Switching	26.1	[	23.0	28.5	]			
Fixture	21.8	[	20.4	23.3	]			
General Lighting	19.2	[	17.8	21.3	]	20		
Floods	20.0	[	18.2	22.0	]			
Strip	27.6	[			]			
Cooling Equipment	19.9	[	18.6	21.3	]			
Central Heat Pump	17.4	[	14.5	19.7	]		12.5	
Central Packaged	19.7	[	16.2	23.7	]			
Central A/C Unit	20.8	[	17.0	24.0	]			
Chilled Water System	23.2	[	19.8	26.4	]	15	15	(15)
Cooling Compressors	15.4	[	13.3	17.0	]			
Heating Equipment	18.2	[	17.1	19.7	]			
Central Steam/HW	24.2	[	18.0	28.1	]			
Force Air Furnace	25.2	[	16.0	26.3	]			
Pkg-Gas Ht/El Cool	9.9	[	6.1	19.8	]			

Table 3. (contd)

	Measure Life (in years)	90% Confidence Interval		ESD ML	Utility ML Avg.	Utility ML Range
Heating Equipment (contd)						
Pkg-El Ht/Cool	21.6	[14.8	27.2]			
Pkg-E heat Pump	18.6	[16.8	20.3]			
Unit Heaters	21.1	[16.7	25.1]	13,20		
Individ. Heat Pumps	17.5	[	]			
Duct Heater	21.0	[18.9	24.6]			
Start/Stop	13.6	[9.7	18.0]			
Economizer**	8.1	[5.4	13.0]	11.0	13.0	(11-15)
HVAC Controls	18.5	[16.5	20.2]			
Std. Thermostat	24.1	[19.4	27.0]	15-20	15-20	
Programmable	9.0	[5.5	13.2]	10.0	8.5	(5-10)
Computer EMS	12.7	[9.0	15.6]	13.0	15.3	(13-20)
Dead Band Thermostat	10.6	[5.9	16.4]	13.0	13.7	(13-15)
Refrigeration	16.5	[14.8	18.6]			
Res. Upright	16.3	[10.9	22.0]			
Commercial Closed In	14.6	[10.7	18.6]			
Open Vertical	21.5	[	]			
Open Horizontal	20.1	[15.9	24.9]			
Walk in	19.9	[16.7	22.4]			
Glass door/cover	13.7	[12.4	14.7]	11.0	12.3	(11-15)
HE Evap. Fan Motors	18.8	[18.3	19.3]			
Floating Head	18.5	[10.5	27.7]	10.0	12.5	(10-15)
Parallel Unequal	25.4	[23.9	26.6]	14.0	14.5	(14-15)
Curtains	11.5	[10.8	12.4]	3.0	4.8	(3-10)
Ventilation	23.4	[21.6	25.6]			
Constant Volume	24.4	[21.6	27.4]			
Variable Air Volume	21.7	[	]		14.0	(10-18)
Water Heating	10.6	[9.3	12.4]			
Water Heater Tanks	11.0	[9.1	13.9]	10-15	10-15	
Cooking	17.4	[15.2	18.8]			
Motors	21.7	[19.4	24.4]			
Variable Speed Drive**	6.1	[3.9	13.0]	10-18	10-20	
Non-VSD	23.4	[21.8	24.9]	~15	~15	
AC Motors	19.7	[18.0	24.4]	15?	20.0	
DC Motors	26.1	[23.9	28.7]			
Window Tinting	10.8	[7.8	14.6]			
Tinted coatings*	17.5	[	]	14.0	14.5	(10-20)
Low-e coatings*	10.3	[	]	14.0	13.3	(10-15)
Heat mirror*	5.7	[	]	18.0	18.7	(18-20)
All coatings aggregate*	16.3	[	]			
Double glazing*	19.0	[	]	20.0	20.0	(20)

Note: Reported Measure Lives (ML) estimated using age distribution method. Additional equipment and ECMs had small sample sizes that could not support estimation of measure lifetimes. Sample sizes in some cases could not support calculation of confidence intervals for some measures.

(*): These measure lifetimes were calculated with the less reliable "reported rates of change" method.

(**): These measure lifetime estimates more likely represent the length of time this measure has been in the marketplace. Problem of estimation method and the fact that there has not been sufficient time to track failures for newer technologies.

Table 4. Measure Life - Analysis of Differentials - Measure Life Study II

Equipment with Shorter Estimated MLS II Lifetimes than Assumed Program Lifetimes	Equipment with Longer Estimated MLS II Lifetimes than Assumed Program Lifetimes	Equipment with No Significant Differences from Assumed Program Lifetimes
• efficient magnetic ballasts (8 years vs. 12-13 years; ESD= 12 years);*** • electronic ballasts (4.6 years vs. avg. 5.8 years; ESD= 12 years);***; not significantly different from BPA median or SCE 3-year estimates • economizer lifetimes used by BPA and many utilities are not significantly different, but the MLS II estimates (8.1 vs. 11 years for ESD) were significantly shorter than the lifetimes used by SCE and SDG&E (8.1 vs. 15 years);*** • variable speed drives for motors (at least 6 years shorter than ESD lifetimes of 10-18 years and all utility lifetimes of 18-20 years).***	• mechanical on-off switches (23 years vs. 7 years, for ESD, 11 years average or 20 years for longest lifetime);** • metal halide lamps, using a less reliable estimation method, showed lifetimes of 7.9 years, which is considerably longer than the 3 years used by ESD (although it is close to the 7.5 years assumed by other utilities);** • heat pumps showed longer lifetimes than ESD estimates (17.4 years compared to 10 years for ESD, but not different from the SCE figure of 15 years); • unit heaters (MLS II showed 21 years compared to ESD estimates of 13 years);** • unequal parallel refrigeration equipment (25 years compared to 14 for ESD and 15 years from BPA median and other utilities); • case covers (glass) for refrigeration (13.8 years compared to 11 years for ESD and 12.3 average (but the estimate is shorter than planning numbers used by SCE); • strip curtains for refrigerators (11.5 years compared to ESD 3 years, utility average 4.8, or SCE's 10 year lifetimes). • floating head technology in refrigeration (18.5 vs. 10 ESD, <u>diff</u>.) • floating head technology refrigeration not significantly different from utility average lifetimes (18.5 vs. 12.5 average)	• electronic ballasts 4.6, not significantly different from BPA median or SCE 3-year estimates. Shorter than others. • economizers (compared to BPA lifetimes); 8 years (11 ESD) • window double glazing and window tinting/treatments; (19 vs. 20 ESD; 10.8 chg.; 10-17 vs. 14 pgm.; 16 avg.) • compact fluorescent bulbs, (3.3 vs. 2-5 ESD); energy efficient lighting fixtures, (21 vs. 20 ESD); high pressure sodium lamps (lower reliability method (5 yrs vs. ESD 5); • time clocks (match) 10.1; 9 ESD (5-10); • individual heat pumps (water-to-air); (17.5 vs 15 avg.); • deadband thermostats; 10.6 vs. 13 ESD (13-15); • computer logic EMS; (12.7 vs. 13 ESD).

**: This is no longer an ESD measure.

***: Note that this figure more likely represents the length of time this measure has been in the marketplace. This is a weakness of the estimation method, and also reflects the fact that there has not been sufficient time to track failures on the newer technologies.

the table. This indicates that these measures do not generally meet the underlying analytic assumption of "steady state replacement." Therefore, much of the equipment that appears to have shorter lifetimes is actually reflecting the amount of time that the measure has been "in the field." Much of this equipment is expected to have relatively long lifetimes, and the results in the table indicate that these measures have not had widespread early failures. However, additional in-field time will be needed to determine the ultimate lifetime of these measures.

Implications of Results for Program Design

The MLS II results from this report have direct implications for Bonneville's ESD program and other utility conservation efforts.

- *Cost effectiveness calculation:* An examination of the sensitivity of the payback/cost-effectiveness calculations to the direction and magnitude of changes in lifetime assumptions for particular measures found in this study may be appropriate.

- *Program targeting:* For those measures with significant reductions in measure lifetimes, re-evaluation may be needed before recommending installation of certain equipment types. In addition, targeting of (or marketing to) certain business types may be appropriate.

Implications for Measure Life Studies and ECM Lifetime Analysis

Finally, the results offer advice and direction to future efforts in deriving measure life estimates. Analytical methods, like survival analysis, that depend on "matching" equipment, may be difficult to conduct unless the databases include (1) date of installation; (2) detailed information about location including possibly stickers on equipment; instant photos of the equipment on-site; marked-up floor plans; or detailed notations. Periodic follow-up, either through on-sites or phone calls or call-backs, will help identify removal dates.

If a database of this nature is not available, the results of this study may indicate that a one-time audit can provide fairly good information, suitable for estimating measure lifetimes for equipment that is "mature" in the marketplace. The results of this study tend to validate the lifetimes used for much of the mature equipment.

However, this type of one-time visit will not be sufficient to provide measure life estimates for newer equipment—and, unfortunately, it is this "newer" equipment that is generally installed as part of program efforts. Program planners will either need to wait until steady state is reached; or will need to be willing to track items fairly thoroughly for a number of years and then be willing to accept "standard" assumptions (e.g., exponential decay functions) for estimating measure lifetimes.

It is too soon after market introduction to reliably determine whether newer, efficient equipment displays longer and shorter lifetimes than historical equipment. In determining what assumptions to make for measure lifetimes for ECMs, similar lifetimes may be appropriate as long as the following assumptions hold: (1) if the measure lifetimes in this study accurately affect the amount of change out incorporating the impacts of renovation, remodeling, and changes related to functional needs; (2) if the technical lifetimes of "old technology" for the same function are similar to the technical lifetimes of the "new technology" (if manufacturers believe that customers will require approximately the same lifetimes for certain end-uses, or if the technology lends itself to similar lifetimes); (3) if maintenance and operation procedures are approximately the same complexity, and are understood and followed to approximately the same degree as historical equipment.

This study provides some detailed quantitative and some indicative results related to measure lifetimes of a wide variety of equipment, as well as information on a number of factors that influence persistence of savings. The study provides findings that can be used to confirm or modify anticipated lifetimes, examine program design and cost-effectiveness calculations, and provide guidance for program and measure targeting. As more detailed databases become available, and newer equipment is followed more closely (and has time to gain a failure track record), the measure lifetimes for newer equipment and ECMs will continue to be refined.

Reference

Skumatz, L. A., et. al., 1991. *Bonneville Measure Life Study: Effect of Commercial Building Changes on Energy Using Equipment,* Bonneville Power Administration, Portland, Oregon.