SAFER, SMARTER, GREENER

Industrial O&M Persistence Study

Program Years 2010-17

Energy Trust of Oregon

April 28, 2020

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1.1.4 Key report specific terms

- "Participant" or "customer" refers to a unique organization, such as a company, that engaged with Energy Trust to complete energy efficiency projects.
- "Site" refers to a unique location. One participant may own or operate multiple sites.
- "Project" refers to the unique Project ID in Energy Trust's program tracking database and all measures or activities that were associated with the Project ID.
- "Measure" refers to the unique Measure ID in Energy Trust's program tracking database. A measure ID is the most granular level of detail stored in Energy Trust's program tracking database. Multiple measures are often associated with one Project ID.
- "Activity" is the specific O&M action taken by the participant at a given site to reduce energy consumption. Activities were identified by the research team through file review. Activities are not stored in Energy Trust's program tracking database. In some cases, there is a 1:1 between an activity and a measure. In other cases, one measure encompasses multiple activities.
- "Category" refers to seven different types of O&M activities. These categories are used to classify the O&M activities reviewed for this study.

EXECUTIVE SUMMARY

This report presents the results of DNV GL's research on the persistence and measure life of Energy Trust of Oregon's industrial Operations and Maintenance (O&M) energy savings delivered through its Production Efficiency program for program years 2010-2017.

Research results

DNV GL's analysis includes results for 252 unique activities associated with 120 electric and gas energy efficiency projects at 89 unique sites in Oregon. The activities were completed between 2010 and 2017, either as part of a stand-alone O&M project or through a strategic energy management (SEM) engagement. The 252 unique activities are not stored in Energy Trust's program tracking database as measures. In some cases, there is a 1:1 between an activity and a tracked measure. In other cases, one measure encompasses multiple activities. Table 1 summarizes the key research metrics and results.

The results show that the current 3-year measure life assumed for tracked O&M measures underestimates the total value of the energy efficiency savings acquired by the program and that most actions completed since 2010 continue to provide savings today. DNV GL's analysis supports the use of a 7-year measure life for these measures (both gas and electric) in the future. Other key findings include:

- Our analysis shows that the measure life is not significantly different for activities completed through the stand-alone O&M program and those completed through an SEM engagement.
- DNV GL does not have substantial recommendations for program improvement. Energy Trust has historically documented the actions necessary for savings to persist at each site. The research shows that the program successfully achieved its goal of getting the savings to persist.
- The factors driving the current measure life are the same as those that exist for all industrial persistence research: sites that close, sites that are sold, and sites that do not respond to interview requests.

Table 1. Key research metrics and results

Metric	Value or Result
Program years researched	2010-2017 (8 years)
Year interviews were completed	2019
Number of interviews completed	75
Number of activities discussed during interviews	212
Number of activities associated with closed/sold/non-response	40
Total activities in the final analysis	**252**
Are the standalone O&M and SEM results significantly different?	**No**
Modelled median measure life	**7 years**
Final survival analysis method used	**Kaplan-Meier**

Memo

To: Board of Directors

From: Erika Kociolek, Evaluation Sr. Project Manager
Kati Harper, Industrial & Agriculture Program Manager

Date: April 28, 2020

Re: Staff Response to Industrial O&M Persistence Study

Since the inception of Energy Trust's industrial program, a measure life of three years has been used for standalone operations and maintenance (O&M) and first-year strategic energy management (SEM), while a measure life of five years has been used for continuous SEM. Measure life, or the median number of years O&M activities are in place and functioning, has a tremendous impact on project- and program-level cost-effectiveness. Given that over or underestimating measure life may have a large impact on cost-effectiveness, in 2017 Energy Trust undertook a study[1] to characterize the types of O&M activities incentivtized by commercial and industrial programs. This involved a literature review of the lifetime of O&M activities in an attempt to assess the reasonableness of the three-year measure life. The literature review revealed a dearth of research on the lifetime of O&M activities, which led Energy Trust to undertake a study to assess the persistence of O&M activities. The primary objectives of the industrial O&M persistence study were to estimate the persistence of industrial O&M activities and assess the appropriateness of the three-year measure life used for standalone O&M and first-year SEM and the five-year measure life used for continuous SEM. The evaluator sampled industrial standalone O&M projects and SEM engagements completed between 2010 and 2017; that is, between one and seven years before data collection for the study was completed. The evaluator interviewed customers to understand if activities implemented as part of the standalone O&M projects and SEM engagements were still in place and functioning, and if not, when activities stopped and why. The evaluator then used the data collected through interviews to perform survival analysis to estimate measure life.

The evaluator employed a variety of approaches to estimate measure life and performed a sensitivity analysis to assess the robustness of the results. The estimated measure life ranged from five to seven years depending on the approach; the evaluator's preferred approach, Kaplan-Meier, resulted in an estimated measure life of seven years. There were no statistically significant differences in estimated measure life for standalone O&M and for first-year and continuous SEM. The evaluator concluded Energy Trust can assume a measure life of seven years for standalone O&M and for first-year and continuous SEM. The evaluator specifically called out the industrial program's inclusion of strategies to encourage long-term persistence in its program documentation and its emphasis on working with customers to revise their standard operating procedures, noting these are key to the persistence of O&M activities.

Starting in 2020, the industrial program will use a measure life of seven years for electric and gas savings from all standalone O&M projects and all first-year SEM and continuous SEM engagements.

[1] Persistence of O&M Energy-Efficiency Measures. 2017. https://www.energytrust.org/wp-content/uploads/2018/07/Energy-Trust-OM-Measure-Persistence-Report-final-with-staff-response.pdf.

1 BACKGROUND

Energy Trust evaluates the performance of its programs on a regular basis. DNV GL was contracted to research the persistence of Energy Trust of Oregon's industrial Operations and Maintenance (O&M) energy savings delivered through its Production Efficiency (PE) program for program years 2010-2017. Energy Trust intends to use the results of this research to inform the assumed measure lifetime of future measures supported by the program. The primary objectives of this research are to:

- Estimate the long-term persistence of industrial O&M measures, including reasons why O&M measures are no longer in place and/or no longer saving the amount of energy originally estimated.
- Assess the appropriateness of the 3-year measure life that is currently used for standalone O&M and SEM. Additionally, assess the appropriateness of the 5-year measure life that is currently used for SEM continuation participants. Continuation participants are those that engage with SEM over multiple years.
- Assess if measure persistence (including reasons why O&M measures are no longer in place and/or no longer saving the amount of energy originally estimated) differs for stand-alone O&M measures versus O&M measures implemented at sites that have participated in SEM.
- Provide recommendations for improving the persistence of industrial O&M measures.

1.1 Prior research

In 2017, DNV GL conducted a detailed literature review project for Energy Trust. The project characterized O&M measures and associated energy saving actions to identify the types of measures or activities that have reasonable persistence. Our research validated Energy Trust's current assumption of a 3-year average for persistence of O&M measures based on publicly available literature.[1] The research documented in this report utilizes primary research to estimate a measure life for the measures historically supported by the program.

1.2 Energy Trust background

Energy Trust is an independent nonprofit organization, selected and overseen by the Oregon Public Utility Commission, to lead Oregon utility customers in benefiting from saving energy and generating renewable power. The services, cash incentives and solutions support customers of Portland General Electric, Pacific Power, NW Natural, Cascade Natural Gas, and Avista. The cumulative impact of their programs since 2002 has been a contributing factor in the region's low energy costs and in building a sustainable energy future. More information about Energy Trust's background, funding sources, strategic and action plans, policies and programs are available on their website at www.energytrust.org/about.

1.3 Key definitions

This report uses the following terms when referring to the existence and value of energy savings over time. These terms are further defined and discussed in the Uniform Methods Project, Chapter 13[2] and the NEEP Glossary of Terms[3].

[1] Available online: https://www.energytrust.org/wp-content/uploads/2018/07/Energy-Trust-OM-Measure-Persistence-Report-final-with-staff-response.pdf

[2] Daniel M Violette. (2017). Chapter 13: Assessing Persistence and Other Evaluation Issues Cross-Cutting Protocol, The Uniform Methods Project: Methods for Determining EnergyEfficiency Savings for Specific Measures. Golden, CO; National Renewable Energy Laboratory. NREL/ SR-7A40-68569. http://www.nrel.gov/docs/fy17osti/68569.pdf

[3] Northeast Energy Efficiency Partnerships 2011. Regional Evaluation, Measurement and Verification Forum Glossary of Terms, Version 2.1. https://neep.org/sites/default/files/resources/EMV_Glossary_Version_2.1_0.pdf

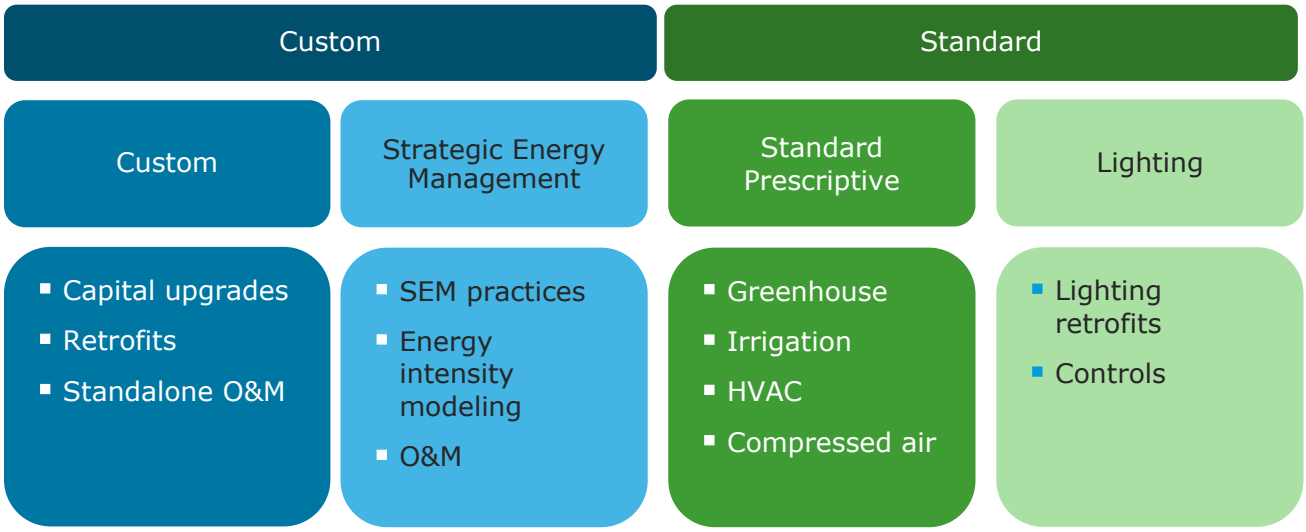
- "Persistence" - Persistence is defined as how long an energy-efficiency measure produces energy savings, which affects the value of the measure and its cost-effectiveness.
- "Measure life" – Measure life is synonymous with effective useful life (EUL) and is an estimate of the median number of years that the tracked energy efficiency measures installed under a program are still in place and operable.

1.4 Program description

The PE program provides electric and gas energy-efficiency solutions to all sizes and types of eligible businesses in the industrial, agriculture, wastewater, and water treatment sectors. The program is designed and managed internally by Energy Trust staff and delivered to the market by program delivery contractors and other market actors. The program achieves savings through two primary paths—Custom and Standard—as shown below in Figure 1. More information about Energy Trust's current offerings for industrial customers is available on their website at https://www.energytrust.org/programs/industry/. The Custom track includes, among other things, incentives for operations and maintenance measures. Industrial customers can receive incentives for "standalone" O&M measures; O&M measures are also often implemented as part of strategic energy management (SEM) engagements. While the activities completed as standalone or part of SEM may be the same, the savings calculation methodologies are different.

- Standalone O&M – Savings for standalone measures are estimated using engineering-based calculations. The savings may be estimated for one activity or for a group of activities completed on a single system, such an optimization the refrigeration system.
- SEM – Savings due to SEM engagements are estimated using a statistical regression methodology that provides an estimate of savings due to all activities completed within the engagement period. No savings estimate exists for any one activity completed.

Figure 1. Production Efficiency program overview[4]



[4] Source: https://www.energytrust.org/wp-content/uploads/2018/03/Production-Efficiency-Custom-and-Strategic-Energy-Management-RFP-Final.pdf

1.5 Sample frame overview

DNV GL sampled from the 509 unique standalone O&M and SEM projects recorded in program years 2010-2017. DNV GL used a stratified random sample tailored to the research objectives to select these projects from the population. Key stratifications included the type of project (e.g., standalone O&M and SEM) and the magnitude of savings claimed. A certainty stratum was used to ensure the largest projects were selected for inclusion in the study. Table 2 summarizes the number of sites, projects, and energy savings tracked by the program over these 8 years. Some unique projects claimed both electric and gas savings, so the sum of electric projects and gas projects is greater than the unique projects for the year. The frame included both gas and electric savings claims, but the frame was heavily weighted to electric projects due to measures completed at participating facilities.

Table 2. Sample frame summary by track and year

Track	Installation Year	Unique Site IDs	Unique Project IDs	Electric Projects	Gas Projects	Electric Savings (MWh)	Gas Savings (therms)
Standalone O&M	2010	40	47	47		22,208	
	2011	50	52	43	12	12,492	84,845
	2012	18	20	15	7	4,527	62,671
	2013	29	34	34	3	8,193	9,298
	2014	19	23	21	4	12,084	52,688
	2015	39	44	43	2	10,389	56,604
	2016	39	44	41	4	9,744	133,964
	2017	39	43	42	3	11,962	39,967
	Subtotal	**273**	**307**	**286**	**35**	**91,600**	**440,037**
SEM	2010	16	16	16		25,508	
	2011	15	15	15	2	20,582	163,000
	2012	15	17	17	1	28,696	59,800
	2013	39	37	34	8	43,705	118,043
	2014	37	37	36	5	35,915	38,039
	2015	23	22	22	1	10,259	12,376
	2016	33	31	30	9	15,957	69,085
	2017	24	27	27	3	15,914	8,685
	Subtotal	**202**	**202**	**197**	**29**	**196,536**	**469,028**
Study Total		**475**	**509**	**483**	**64**	**288,136**	**909,065**

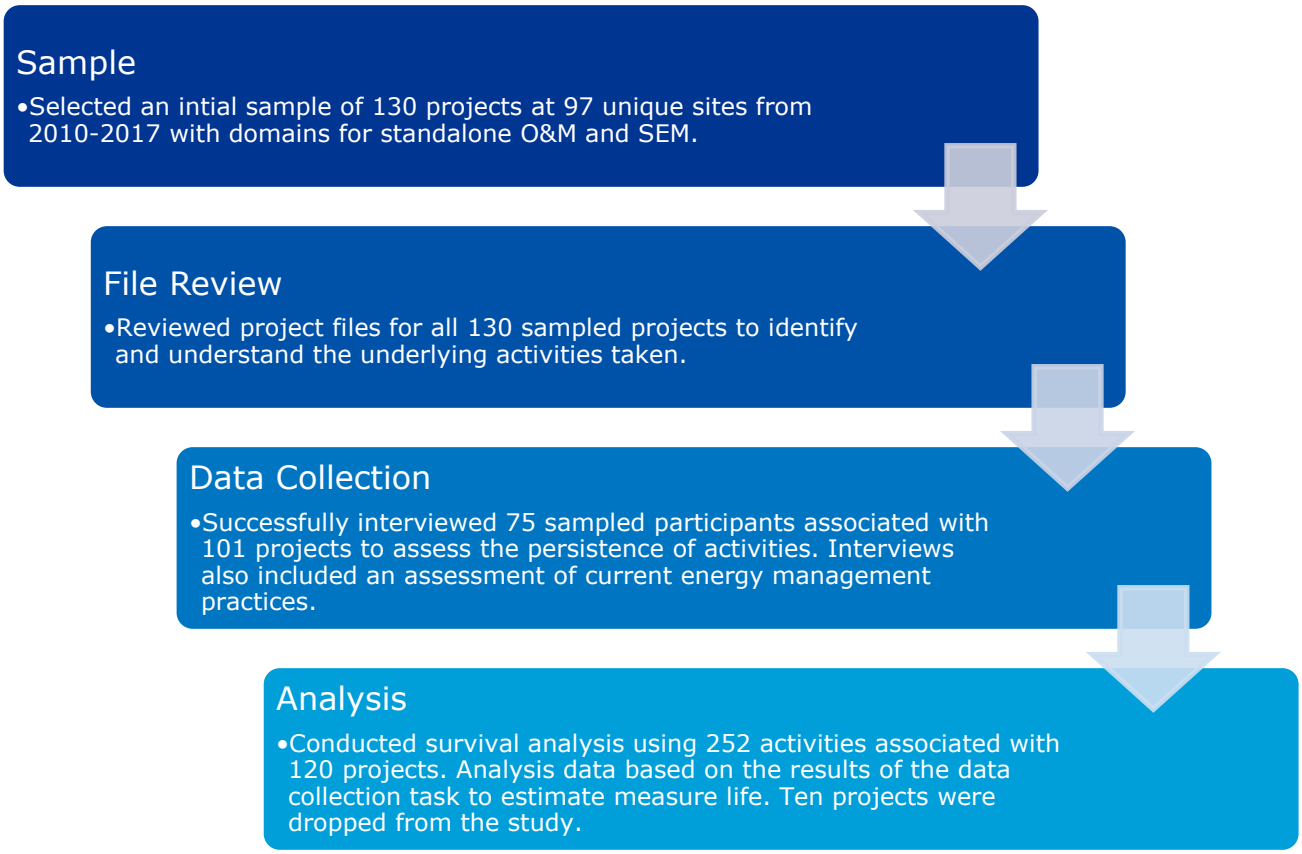
2 RESEARCH METHODOLOGY

This section summarizes the process and methods used for this research as well as decisions made by the researchers.

2.1 Overview

DNV GL assessed the persistence of O&M activities by performing the four primary research steps shown in Figure 2.

Figure 2. Primary research steps[5]



2.2 Sample design and final sample quotas achieved

Energy Trust provided DNV GL with a dataset of program activity along with other project documentation necessary to develop a sampling plan. DNV GL developed a sampling plan that detailed the expected number of sample points for different fuel types, program tracks, and measure categories. The final sampling plan is provided in Appendix A.

DNV GL used a stratified random sample tailored to the study's research objectives. The sampling plan was designed to support reliable, accurate estimates of O&M measure life as well as a comparison of between standalone O&M and SEM.

[5] A definition of survival analysis and description of its application in DSM evaluation is provided here: https://aceee.org/files/proceedings/1994/data/papers/SS94_Panel8_Paper02.pdf

The survival model approach puts a premium on model fit. This, in turn, defines the goal of the sample design. DNV GL designed a stratified sample that considers the following:

- Installation year to ensure the existence of different lengths of time since completion in the study.
- Whether the project was a standalone O&M or SEM project.
- The magnitude of savings claimed to increase the likelihood of selection for projects with high savings.

The sample and data collection approach were designed to facilitate the best possible model fit and therefore the highest precision estimates given the available data. For the initial design, we used a persistence curve that has its median at 3 years after measure implementation. Table 3 shows the final sample dispositions achieved by track and program year. Ten projects included in file review were dropped from the study and not included in the final analysis.[6] These 10 projects are excluded from Table 3 and all tables and charts that follow.

Table 3. Number of projects in final analysis by track and program year

Track	Disposition	TOTAL	2010	2011	2012	2013	2014	2015	2016	2017
Standalone O&M	Completed Interview	52	6	4	4	5	4	6	11	12
	Incomplete - Facility Closed	5	2			1	2			
	Incomplete - Change in Ownership	2	1		1					
	Incomplete - No Response	4	1	2				1		
	Track Subtotal	**63**	**10**	**6**	**5**	**6**	**6**	**7**	**11**	**12**
SEM	Completed Interview	49	5	6	6	4	4	3	12	9
	Incomplete - Facility Closed	2			1			1		
	Incomplete - Change in Ownership	1				1				
	Incomplete - No Response	5			1	1	2			1
	Track Subtotal	**57**	**5**	**6**	**8**	**6**	**6**	**4**	**12**	**10**
All	Complete Interview	101	11	10	10	9	8	9	23	21
	Incomplete - Facility Closed	7	2		1	1	2	1		
	Incomplete - Change in Ownership	3	1		1	1				
	Incomplete - No Response	9	1	2	1	1	2	1		1
	Total	**120**	**15**	**12**	**13**	**12**	**12**	**11**	**23**	**22**

[6] Sampled projects were dropped from the study for the following reasons: multiple projects were sampled at a single site and completing interviews for all projects was determined to create excessive respondent burden so only a portion of the projects were discussed (n=3), the customer responded to recruitment and asked to be excluded due to recent evaluation history (n=1), the original project documentation was determined to be illegible (n=1), the collected data did not pass quality control for inclusion (n=2), or the site moved out of Energy Trust's service territory since participation (n=3).

Table 4 compares the population of projects sampled to the final analysis sample achieved for the study. The sum of electric projects and gas projects is greater than the unique projects for the year since some projects included both gas and electric savings. The final analysis sample was well aligned with the frame. It included both gas and electric savings claims but was heavily weighted to electric projects.

Table 4. Comparison of population to final analysis sample by track and year

		Population (N)			Final Analysis Sample (n)		
Track	**Installation Year**	**Unique Project IDs**	**Electric Projects**	**Gas Projects**	**Unique Project IDs**	**Electric Projects**	**Gas Projects**
Standalone O&M	2010	47	47		10	10	
	2011	52	43	12	6	5	2
	2012	20	15	7	5	3	3
	2013	34	34	3	6	6	
	2014	23	21	4	6	6	1
	2015	44	43	2	7	7	
	2016	44	41	4	11	10	2
	2017	43	42	3	12	10	4
	Total	**307**	**286**	**35**	**63**	**57**	**12**
SEM	2010	16	16		5	5	
	2011	15	15	2	6	6	2
	2012	17	17	1	8	8	
	2013	37	34	8	6	6	
	2014	37	36	5	6	6	
	2015	22	22	1	4	4	
	2016	31	30	9	12	11	7
	2017	27	27	3	10	10	2
	Total	**202**	**197**	**29**	**57**	**56**	**11**
Study Total		**509**	**483**	**64**	**120**	**113**	**23**

2.3 File review

Energy Trust provided DNV GL with all of the relevant project files associated with the selected sample.

- For standalone O&M, DNV GL reviewed the project files to gain a thorough understanding of the measures and energy-saving activities that were implemented. We used the Verification Report as the primary source of information.
- For SEM, DNV GL reviewed the project files, including opportunity registers and final reports, to identify what energy-saving activities were implemented. Unlike standalone O&M, savings for SEM were typically estimated using whole-facility regression models, so we did not have ex ante savings estimates for individual O&M activities implemented during the SEM engagement period. In those cases, we used the annual Completion Report as the primary source for SEM measures and activities. DNV GL recorded a maximum of five activities for a given SEM engagement.

The relevant information extracted from the project files was compiled into a spreadsheet. We recorded the following critical information for each activity:

- Description of the activity
- Date of initial activity adoption
- End-use primarily impacted by activity
- Expected frequency activity, if listed

- Individual, staff, or department responsible for implementation
- Contact name at the time of activity adoption
- Location of expected activity adoption within participant facility
- Setpoints, schedules, or strategies expected to be implemented

2.3.1 Classification of O&M activities

We then classified each identified activity as one of the seven O&M categories in Figure 3. DNV GL hypothesized that persistence might differ due to the cost and effort required to maintain the activity over time. For example, maintaining revised operating setpoints during a year requires less effort than maintaining a regular compressed-air leak detection program.

Figure 3. O&M categories

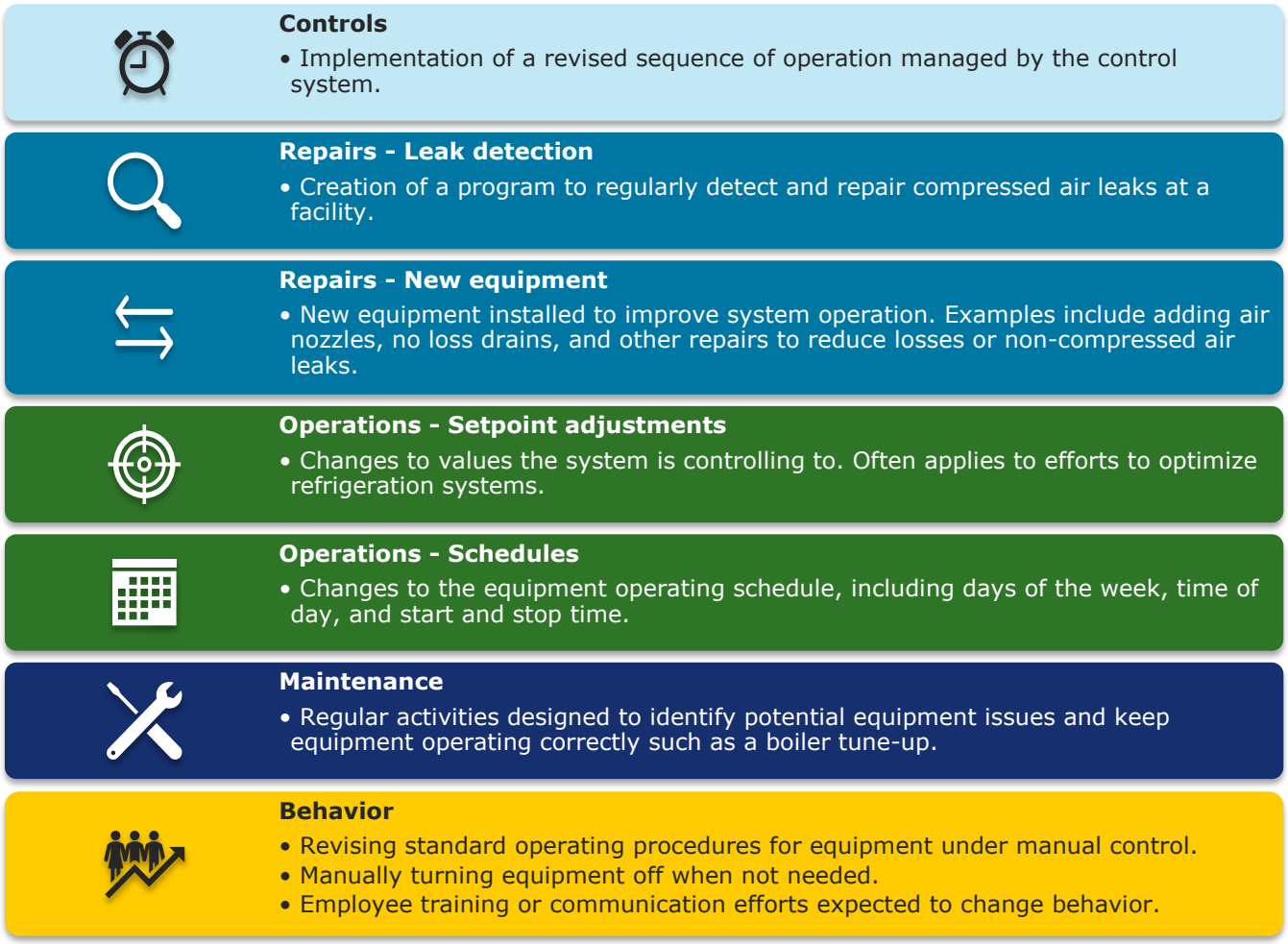


Figure 4 shows the number of activities by track and O&M category in the final analysis dataset. The analysis includes the number activities across all seven categories, with the top two categories being adjustments to controls and repairs of compressed air leaks. The distribution of categories in the sample cannot be directly compared to the population since the categorization was completed by the research team for only the sampled projects. No categorization exists for activities outside those sampled. Given the sampling methodology used, the chart shows what types of activities are either supported more regularly or were expected to achieve the highest savings.

Figure 5 shows the same information, but by program year instead of by program track. Other than a few exceptions, the final sample succeeded in including completed activities for each O&M category from each program year.

Figure 4. Count of activities included in analysis by O&M category and program track

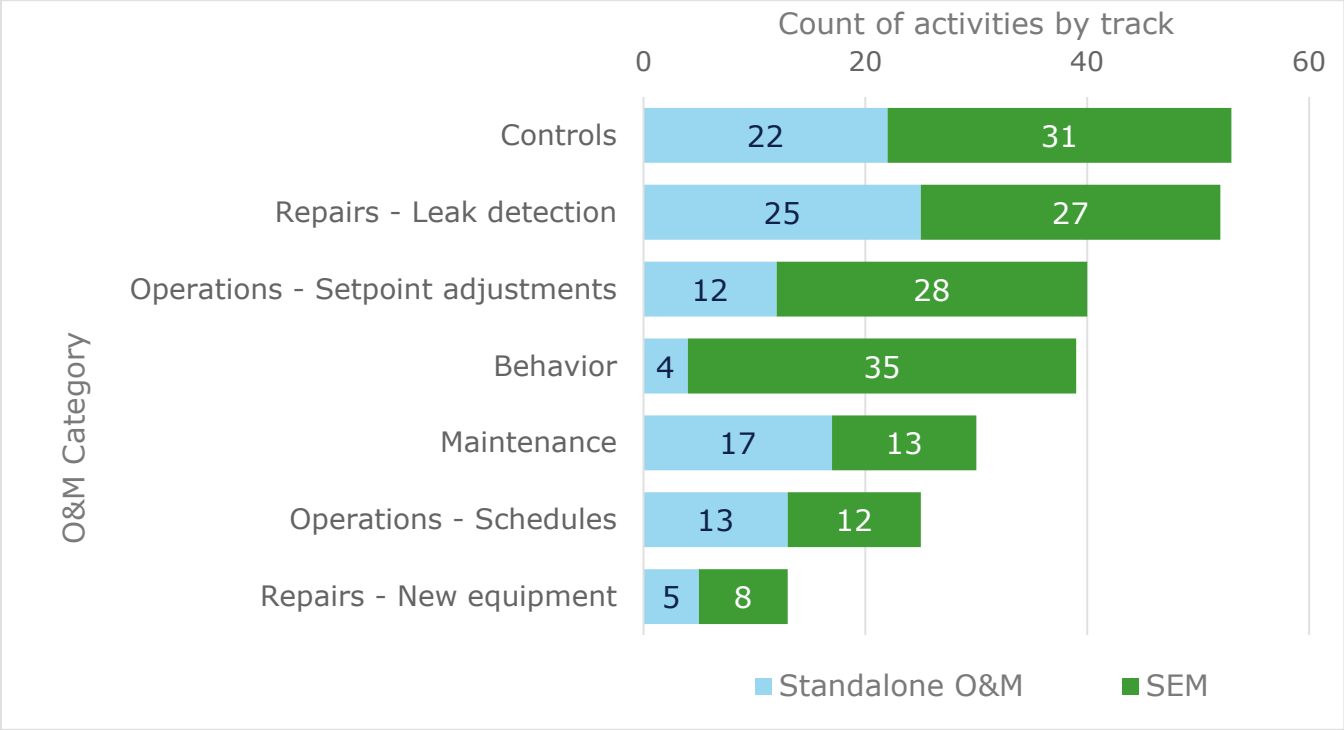
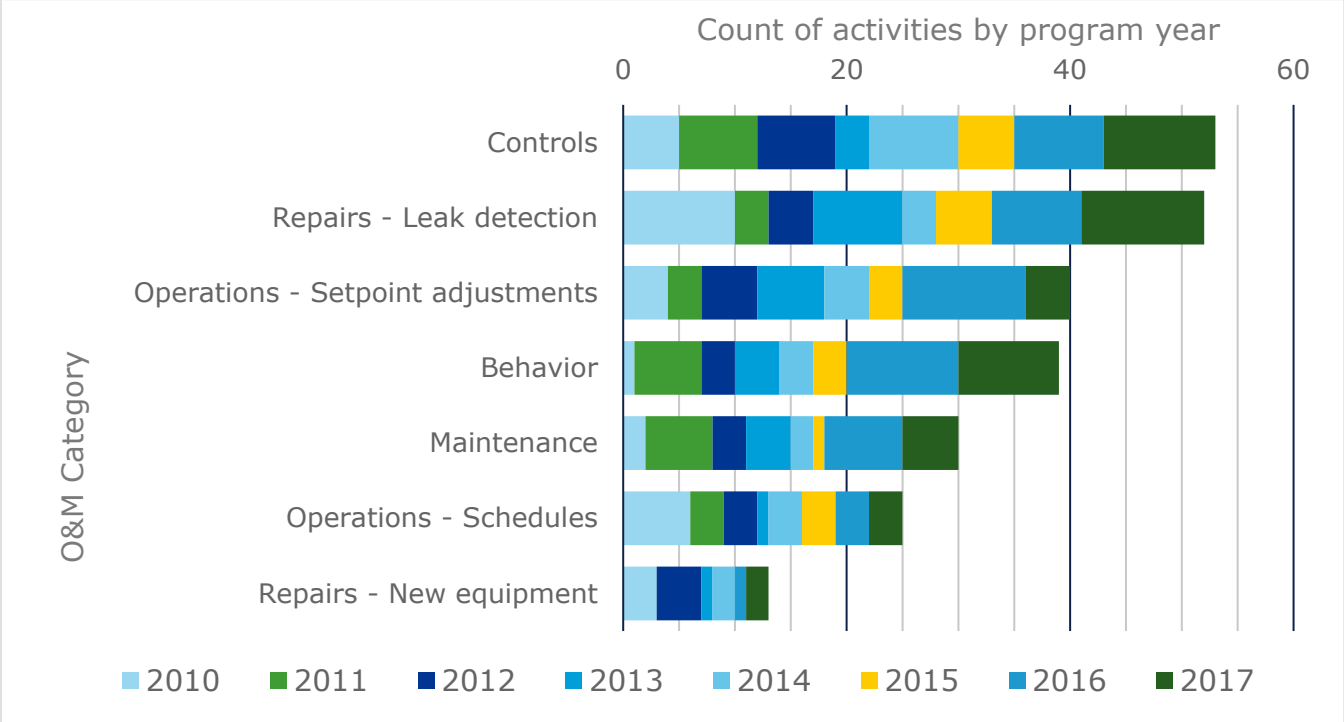


Figure 5. Count of activities included in analysis by O&M category and program year



2.4 SEM & O&M participant recruitment and interviews

DNV GL created an interview guides specifically for this research. The final interview guide is included in Appendix B.

Sampled participants were interviewed by three firms: DNV GL, David B. Goldstein and Associates (DBG&A), and Michaels Energy. Michaels Energy conducted the 2016-2017 PE program impact evaluation, so their engineers completed data collection for projects associated with participants also sampled for the 2016-2017 PE program impact evaluation.[7] DNV GL and DBG&A completed all other interviews.

The interviews with participants addressed the following key topics in four sections. The first section was completed once per interview. The second, third, and fourth sections were completed once per identified O&M activity:

- **Customer energy management practices**
  - Energy management practices, including tracking and monitoring energy use, goals and action plans, training, upper management engagement, and energy efficiency achievements.
  - These questions were designed around the Consortium for Energy Efficiency's (CEE) Strategic Energy Management Minimum Elements[8]
  - Practices that might be expected to improve persistence, such as predictive and preventative maintenance procedures, work order management, and use of standard operating procedures
- **Measure verification**
  - Confirmation of activity installation (or implementation) date
  - Whether the activity is currently installed or being implemented
  - If not currently installed or being implemented, when the activity stopped being implemented/failed
  - If still functioning beyond the 3-year measure life, expectations regarding how much longer site personnel expect the activity to last before being replaced, adjusted, etc.
- **Measure performance**
  - If the activity is still in place, whether it is performing as expected
  - Details regarding facility operations, control settings, maintenance schedules, and behavior (to better understand measure performance and related energy savings)
- **Customer insights**
  - For activities that ended or failed prematurely, why the activity failed
  - Whether anything has been done to prevent the failure and/or ensure the activity's persistence
  - Changes to operation, barriers, and suggestions for improvement/change

At the end of each interview, the interviewer assessed if the energy savings for each activity were persisting based on the responses provided. If the conclusion was that savings were not persisting and the respondent provided sufficient information, the interviewer estimated when the savings stopped persisting. See section 2.5.2 below for how DNV GL estimated when savings stopped persisting for those activities where the respondent did not provide an estimated end date.

[7] Interviews were completed in person by Michaels Energy only if they visited the site for the 2106-2017 PE Impact Evaluation. No site visits were completed specifically for this study.

[8] Available to the public at: https://library.cee1.org/system/files/library/11283/SEM_Minimum_Elements.pdf

2.5 Summary of analysis methodology

This section describes the decisions made and methods used by the research team to estimate measure life.

2.5.1 Activity-specific result determination

The research team assessed if savings continued to persist at the time of the interview based on all of the information collected during the interview. Actions were either assessed to continue to persist or not. It was determined that accurately assessing the percent persistence was infeasible and also overlapped with existing realization rate adjustments.

The interviews included multiple questions designed to acquire confirming information for each activity. In most cases the persistence of savings was clear from the responses provided. Customer staff easily articulated if an activity continued to be implemented or not. In a few cases, the research team was required to assess persistence based on the answers provided. For example, sites which communicated the existence of a compressed air leak detection program that checked, tagged and fixed leaks regularly resulted in persisting savings, even for cases where the interval between leak checks differed from the original project documentation. However, if the site stated that they fixed leaks when found and did not provide any indication of a regular program, then savings were determined to no longer persist.

During the interview, if the customer articulated that the activity was no longer implemented, then the interviewer asked when, if known, the activity stopped. The end date for savings persistence was recorded if provided by the site. If the site could not provide an estimate for when the activity stopped, a subjective decision was used (see below).

2.5.2 Subjective decisions

The research team was required to make multiple subjective decisions when determining if savings persisted, when savings stopped persisting, and how to treat activities for which the team lacked primary information. These decisions are described below, along with illustrative examples. Each decision was made with the intent to estimate savings persistence without bias. All identified activities not excluded from the study that required subjective decisions are included in the final analysis.

1. **Complete – Not persisting, No end date provided:** For 15 activities (12 SEM, 3 Standalone), DNV GL concluded that savings are not currently persisting due to the activity, but the site contact did not provide sufficient information to estimate when the activity savings stopped. For these 15 activities, DNV GL assessed the end of savings to be the year halfway between the installed year and 2019 (the year interviews were conducted).[9] For example, for an activity installed in 2013 that is not currently persisting, but for which no information is known regarding when savings stopped, the analysis assumes savings stopped in 2016. DNV GL believes this is a reasonable assumption given the information available.
2. **Incomplete - Facility closed:** For 13 activities (6 SEM, 7 Standalone), the site closed since the activity was installed. The analysis assumes the savings stopped persisting halfway between the installed year and 2019 (the year interviews were conducted), unless the facility closed before 2019. However, if the facility closed before the halfway point, then the savings were assumed to persist until the facility closed. For example, for an activity completed in 2013 at a facility that closed in 2017, the analysis assumes savings stopped in 2015. If the same facility had instead closed in 2014, then the analysis would assume the

[9] DNV GL concluded that using the median in this case was a reasonable treatment of the unknown for this research, the measures studied, and the timing of the study compared to the installation date. The results and sensitivity analysis show that the estimated measure life will not be significantly impacted by this method.

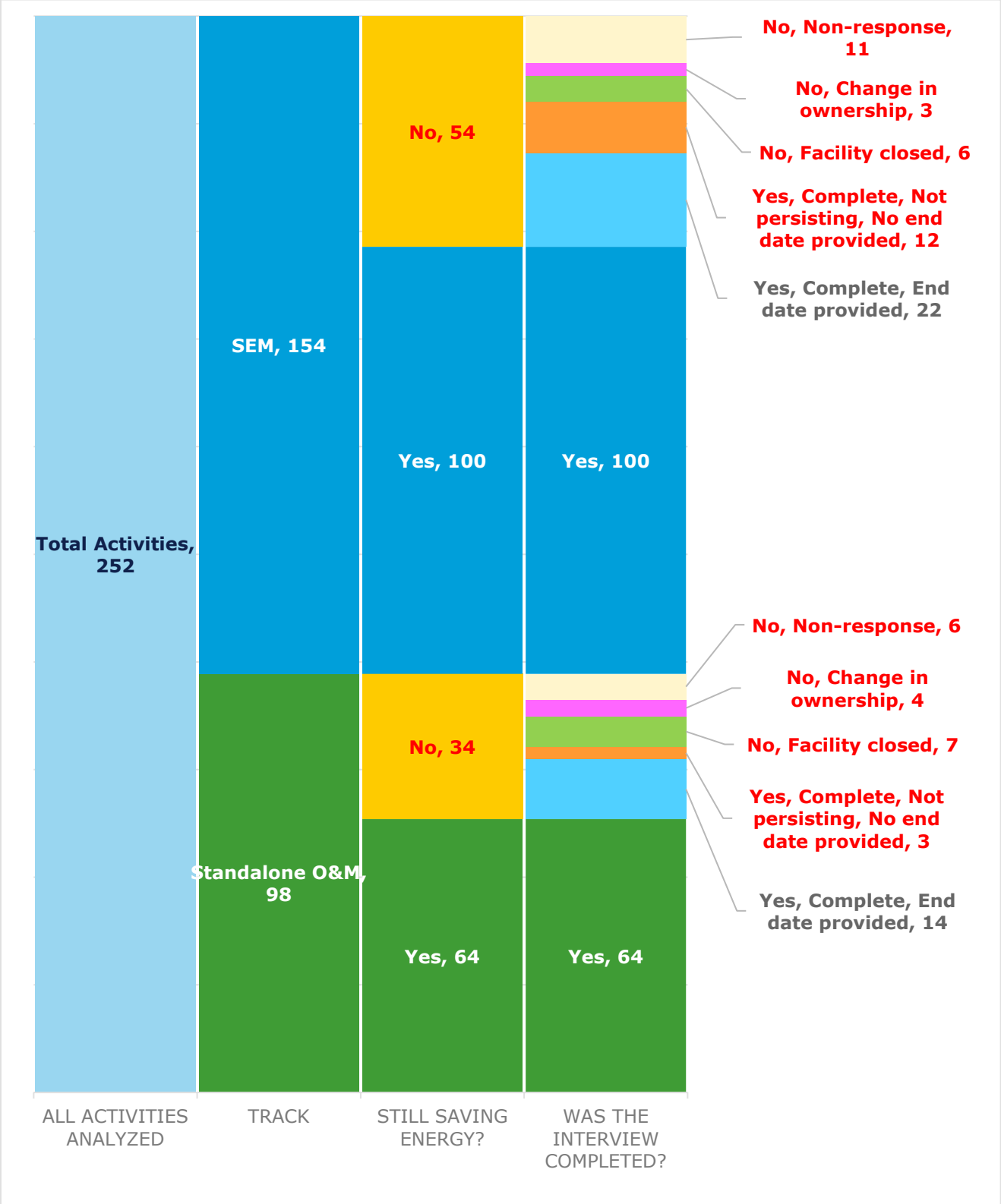
savings stopped in 2014. DNV GL believes this is a reasonable assumption given the information available. All identified activities at closed facilities are included in the results.

3. **Incomplete - Change in ownership:** For 7 activities (3 SEM, 4 Standalone), DNV GL was unable to speak with the facilities due to a change in ownership and the terms of the initial program participation agreement between Energy Trust and the customer. Similar to the previous example, the analysis assumes the savings are no longer persisting and that the savings stopped persisting halfway between the installed year and 2019 (the year interviews were conducted). However, if the facility was sold before the halfway point, then the savings were assumed to persist until the facility was sold. DNV GL believes this is a reasonable assumption given the information available. All identified activities at sold facilities are included in the results.
4. **Incomplete – Non-response:** For 17 activities (11 SEM, 6 Standalone), the research team was unable to recruit a customer after repeated attempts by the research team and program staff. The savings are assumed to not be currently persisting and the analysis assumes the savings ended halfway between the installed year and 2019 (the year interviews were conducted). DNV GL believes including these sites in the analysis controls for response bias in the study's results and it is reasonable to assume that savings are not persisting at sites unwilling to communicate with the research team. All identified activities associated with customers we were unable to recruit are included in the analysis.

Figure 6 shows the number of activities DNV GL determined were persisting in 2019 by program track. The final categories shown in red match the subjective decision categories discussed above. The persistence determination is summarized as follows:

- Energy savings from 164 of the 252 activities installed in 2010-2017 are persisting in 2019. These 164 activities are therefore right-censored in the survival analysis.
- The remaining 88 activities were determined or assumed to not be providing energy savings in 2019. Of these 88 activities,
  - 36 are the result of completed interviews during which the end date of the activity was provided.
  - 52 are the result of the subjective decision-making discussed above in section 2.5.2.

Figure 6. Activity persistence determination and subjective decisions by program track



2.5.3 Survival analysis

An activity's effective useful life (EUL), or measure life, is defined as its median retention time; that is, the time at which half the units of the measure installed during a program year are not retained. Energy efficient measure retention studies are commonly conducted on data from multiple program years and before half the units of a measure installed during any program year have failed or been removed. Therefore, it is necessary to employ statistical methods that can address survival up to the present time (right censoring) as well as projecting survival curves to a timeframe where 50% of units have failed or been removed.[10] To analyze retention, this study employs a methods commonly referred to as survival analysis.[11] These methods are widely employed in energy-efficiency savings persistence studies and address the challenges of short analysis data timeframes and censored data.

2.5.3.1 Kaplan-Meier estimator

Survival analysis of energy efficiency measures usually combines measure status data from multiple program years. While some measures may fail or be removed during the intervening years prior to the evaluation, many will still be in place at the time of the evaluation. The maximum age of known survival in the dataset cannot exceed the number of years between the program year and time of the evaluation. A survival analysis method must be able to deal with measures still installed at the time of evaluation, but that will experience a removal event at some unknown point in the future (right censoring). Life-test or Kaplan-Meier (KM) survival curves are a simple yet powerful way to summarize date-specific and right-censored data, which is data for activities still in place at the time of the evaluation.

If activities have been installed long enough that more than 50% of the activities are no longer in place for at least a subset of the population, a non-parametric approach such as a KM approach may offer a direct characterization of estimated useful life. The limitation to the non-parametric approaches is that they cannot be projected beyond the limits of the maximum elapsed years. In many cases where estimates of measure persistence are sought, over 50% of the measures are still in the field, thereby limiting the ability to use KM.

2.5.3.2 Parametric survival analyses

If there are not enough years of data to use the KM approach to estimate an EUL, a parametric approach is used. This approach assumes that the number of years an activity is retained, or the time to non-retention of a unit, follows some general path. Technically, this path is referred to as a distribution. Therefore, the general method of study is to collect data on the times to non-retention of units and use those data to estimate the specific path or parameters of the distribution. The estimated path or parameters of the distribution of the time to non-retention of a unit of a measure are then used to estimate the median retention time or EUL.

Given the variety of reasons a unit of a measure may not be retained, the general path the time to non-retention of a unit follows is unclear. Therefore, this study considered three distributional assumptions, including Weibull, log-normal, and log-logistic. These are common distributional assumptions made when conducting survival analysis.

For this analysis, the KM approach produced an EUL estimate under most scenarios. We included the parametric approaches to demonstrate how they work relative to the KM approach.

[10] In energy efficiency survival analysis data, there are typically units that have survived to the current time but for which we cannot know how much longer they will survive. This is referred to as right censoring. Moving left to right through time, the right end is censored at the point beyond which we have no information.

[11] A definition and description of its application in DSM evaluation is provided here: https://aceee.org/files/proceedings/1994/data/papers/SS94_Panel8_Paper02.pdf

2.5.3.3 Analysis scenarios

As discussed in Section 2.5.1, above, the data for this analysis are at the account – activity level. The data include weights for expanding the account-activity data back to the population. In addition to sample weights, it is common to account for differential energy savings across activities when estimating survival analysis models. The available energy savings data are at the project-level, making it impossible to fully account for energy savings at the project-level. For this analysis we model the data with varying treatments of unknowns, aggregation, and weighting to explore the sensitivity to these aspects of the data:

- **Activity-level, sample-weighted-only** – This model estimates the survival of activities without consideration for their relative contribution to savings. This model is sample-weighted, so it reflects the larger population of projects, but counts activities equal with respect to savings level.
- **Activity-level sample and savings-weighted** – This model gives greater weight to projects with greater savings. Ideally, weighting would be applied at the activity level, but accurate activity-level savings are generally not available for SEM engagements. Instead activities were weighted with project-level savings distributed equally across all the activities associated with the project.
- **Project-level sample and savings-weighted** – The lack of activity-level savings makes it impossible to fully account for differences in survival across activities with different levels of savings. Aggregating savings to the installed year and track level for each project provided an alternative way to apply both population and savings weights without distributing them across activities. In the aggregation process, we tested 3 scenarios.[12] Projects could be flagged as:
  - Surviving to the duration of the first failed activity (most conservative)
  - The last failed activity or age at right-censoring (most generous), or
  - A median level between these two extremes.

We modeled each of these approaches for all activities and distinguishing between standalone O&M and SEM.

[12] To avoid mixing activity and project-level savings, for this approach, all activities were rolled up to the project-level, whether activity-level savings were available or not.

3 FINDINGS

This section summarizes the information from each research step that was critical to our understanding of the program and methodology selected.

3.1 Summary of file review findings

Our file review was primarily a data gathering step to ensure sufficient information was available to interviewers for data collection. The research team learned the following during this research task:

- **Inconsistency exists in the number of activities that a single tracked standalone O&M measure represents.** DNV GL was unsure at the start of the project if a measure would represent one activity or multiple activities. We found that in many cases, one measure represents multiple activities. This information supported the decision to complete in-depth file review on all projects to identify specific activities.
- **Standalone O&M project documentation includes a persistence section**. DNV GL was impressed to see that the program has consistently included a section in their reports to customers documenting the actions necessary by the site to ensure long term savings persistence. This section was critical to understand what determines if the activity's savings are persisting. For example, DNV GL did not research if the compressed air leaks that were repaired remained repaired, instead, DNV GL researched if the site has maintained a regular compressed air leak detection program as discussed in the reports.
- **SEM participants regularly completed an extensive list of activities during an engagement**. DNV GL concluded that it was impractical to interview a customer about all activities identified, so the total number of activities recorded from one SEM engagement was limited to five. DNV GL staff used their judgement to select the activities likely to provide the largest savings.
- **23 customers participated in multiple sampled projects at different times over the research period.** This increased the number of activities that DNV GL could discuss with each customer. Again, DNV GL concluded that it was impractical to discuss all activities recorded. DNV GL limited the total number of activities to discuss with any one customer to five. DNV GL staff used their judgement to select the five activities completed by a customer over the entire research period likely to produce the majority of savings. DNV GL prioritized actions that were expected or could be expected to deliver the most savings, activities that resulted in multiple O&M categories being discussed, and activities that allowed for questions on multiple projects. In some cases, DNV GL dropped entire projects from the sample since it was impractical to discuss all projects sampled with one contact.
- **Overlap exists between standalone O&M and SEM participants.** 35 of the 63 standalone O&M projects analyzed occurred at sites that participated in SEM at some point between 2009 and 2020. Of the 23 customers with multiple sampled projects discussed above, 18 participated in both the standalone O&M track and SEM (some at different sites owned by the same customer). In 17 of the 18 cases, SEM enrollment occurred after the standalone O&M project, but in one case the SEM enrollment occurred prior to the standalone O&M project. Repeat participation across multiple tracks or program offerings is normal for industrial energy efficiency programs. However, the participation in both tracks prevents DNV GL from concluding that standalone O&M participants are different than SEM participants.

3.2 Summary of interview findings

3.2.1 Customer energy management practices

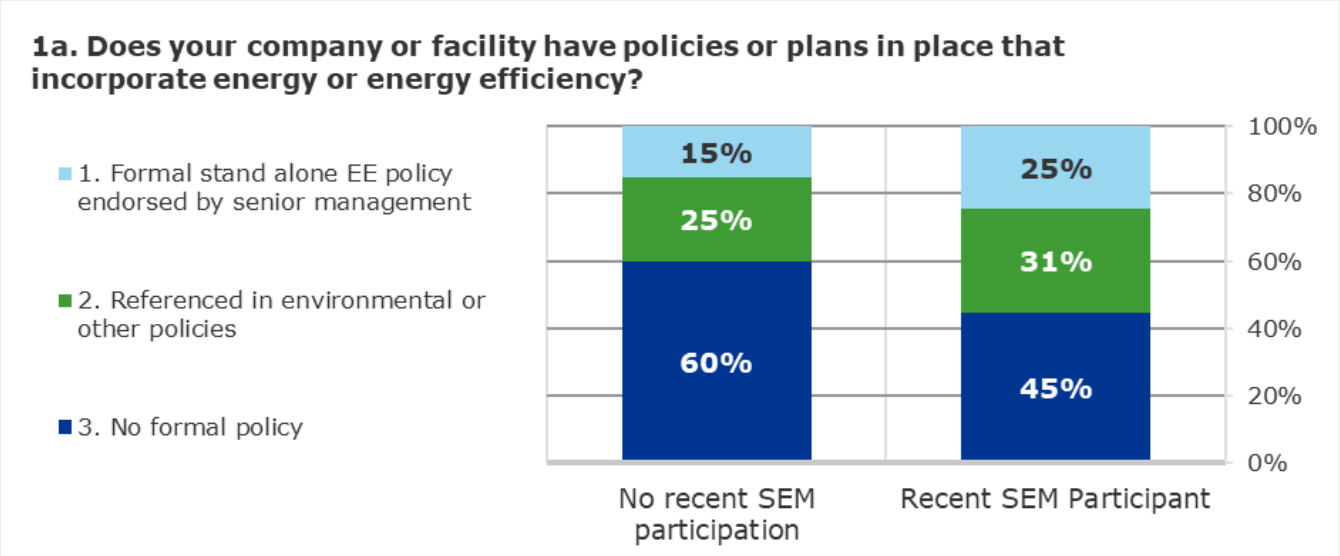
Each interview included questions specific to current energy management practices, such as the existence of an energy team, energy efficiency policy, and regular practices to review recent energy consumption. The responses to all questions are summarized in Appendix C.

Responses are divided into two distinct groups: customers who participated in SEM recently (between 2015 and 2020) and customers who have never participated in SEM or have not participated in SEM recently (before 2015). Note that in some cases, customers who completed standalone O&M projects completed SEM either before their standalone O&M project, or after their standalone O&M project.

Overall, DNV GL found that approximately half of customers are not implementing energy management practices and half are implementing energy management practices. However, the lack of energy management practices does not correlate with the persistence of energy savings. Even customers that communicated a lack of energy management practice were continuing to deliver savings from the discussed activities. DNV GL believes this suggests two conclusions:

1. The existence of energy management best practices is not necessary for the long-term persistence of O&M activities.
2. The existence of continued energy management best practices (recent SEM participation) does not result in longer savings persistence of specific O&M activities.

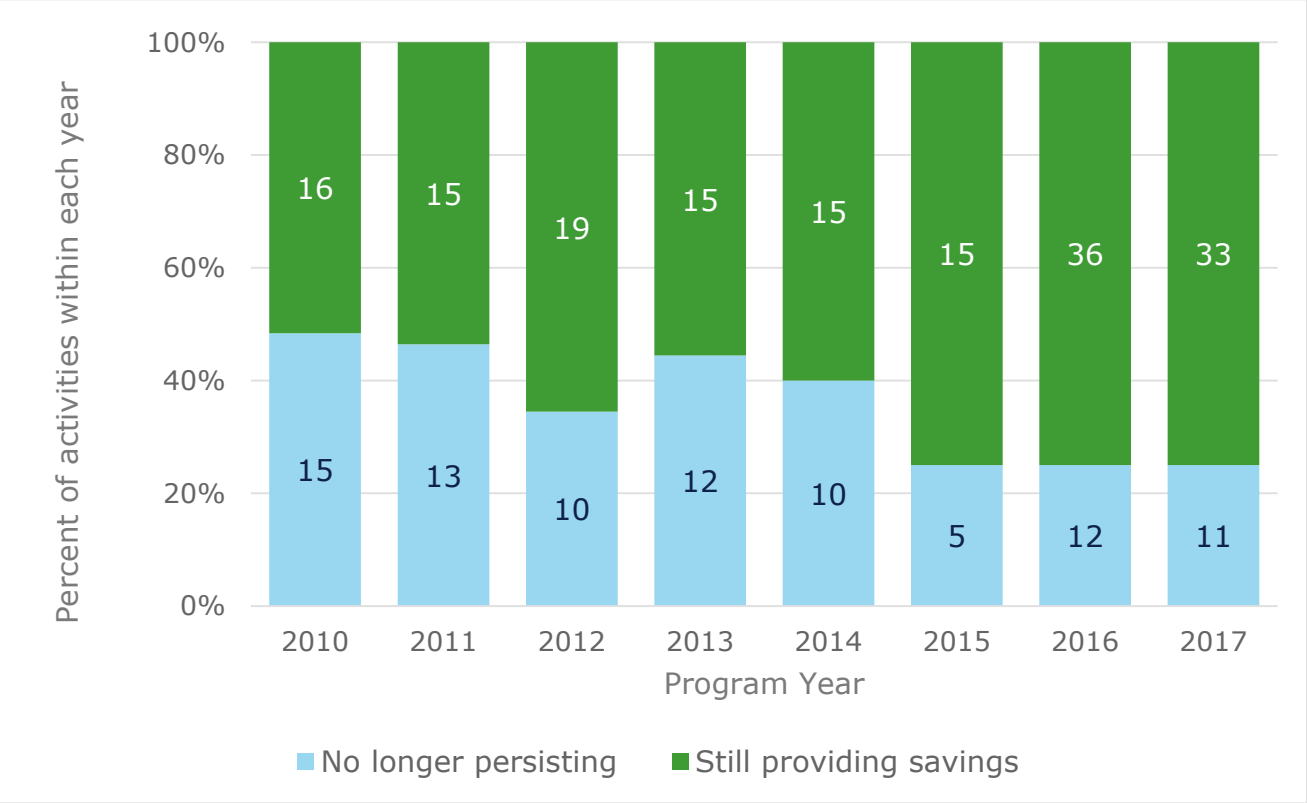
Figure 7. Example response summary, Energy management practices



3.2.2 Activity level persistence determination

Figure 8 shows the same 252 activities, but by the program year the measures were reported in. The chart shows that even for the activities implemented over 5 years ago (2010 – 2013), the research determined more than 50% of the activities are still providing energy savings in 2019. While the chart is unweighted, it supports the final conclusion that the current measure life of 3 years significantly underestimates the benefits achieved by the program.

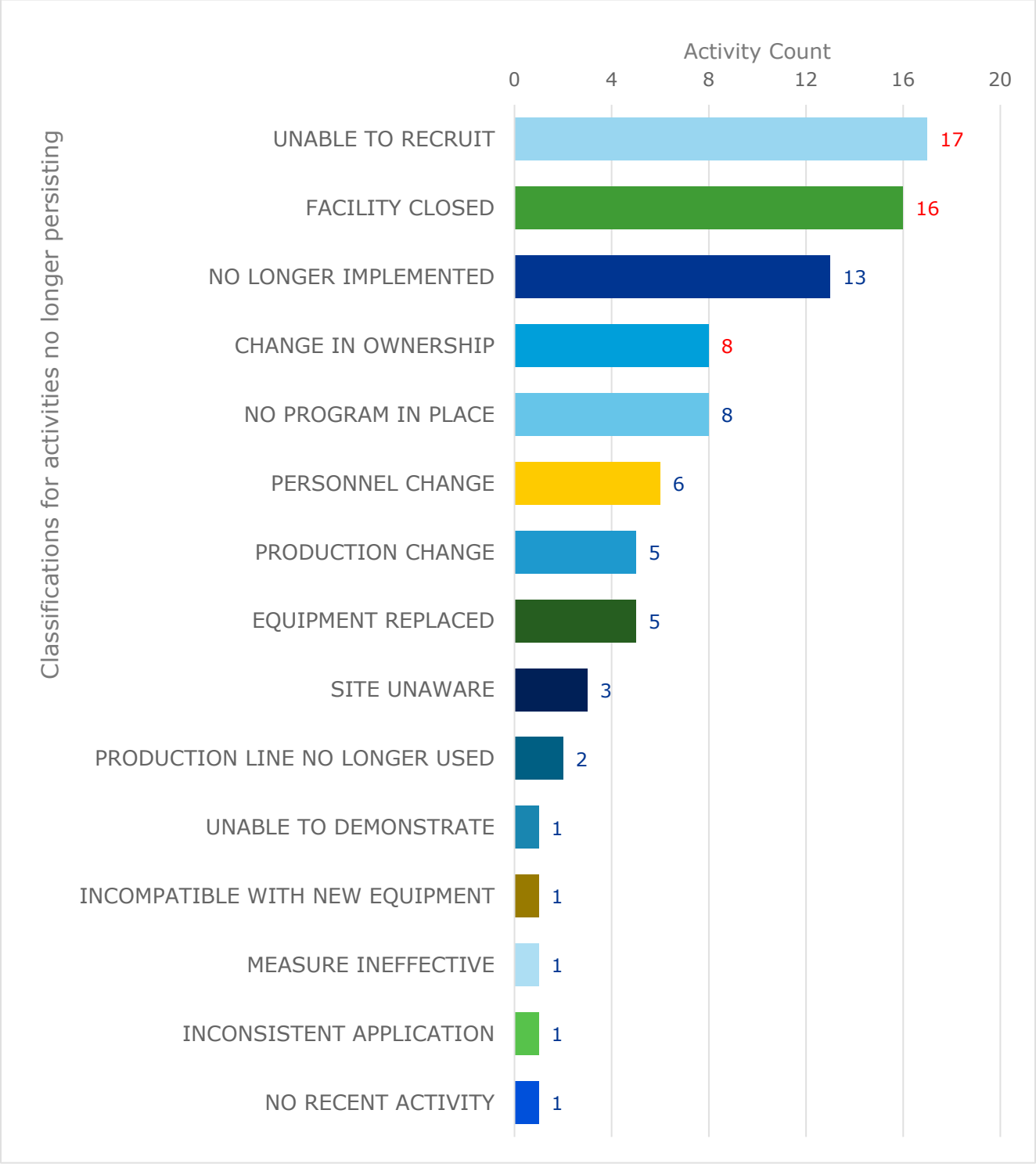
Figure 8. Count of activity persistence determination by program year



3.2.3 Reasons for end of persistence

DNV GL classified the 88 activities that did not persist by the reasons for no longer providing savings. Figure 9 shows the count of activities no longer persisting by reason. Each activity exists in only one classification. The figure shows two important aspects of the research. First, that the inclusion of activities associated with both non-responsive customers and locations that changed ownership in the analysis has a significant impact on the result (highlighted by the red numbers). Second, many of the reasons for no longer providing savings, such as closed facilities and changes in production volume, are not unique to O&M measures. Four of the of 5 activities classified as "Production Change" are due to increases in production that prevented the continued implementation of the activity. The final activity classified as "Production Change" occurred at the plant where a change in production resulted in the entire facility being shut down. The two "Production Line No Longer Used" activities occurred at operating facilities that no longer run the production line in the facility on which the energy savings were expected to occur.

Figure 9. Count of activities no longer persisting by classification



4 RESULTS & RECOMMENDATIONS

The survival analysis results provide an estimate of the EUL, that is, at what year 50% of the activities are still active. As discussed in section 2.5, the methods take into consideration both failure data and evidence of survival up to some number of years (still active at the time of the evaluation). Additional charts completed as part of the survival analysis are shown in Appendix D.

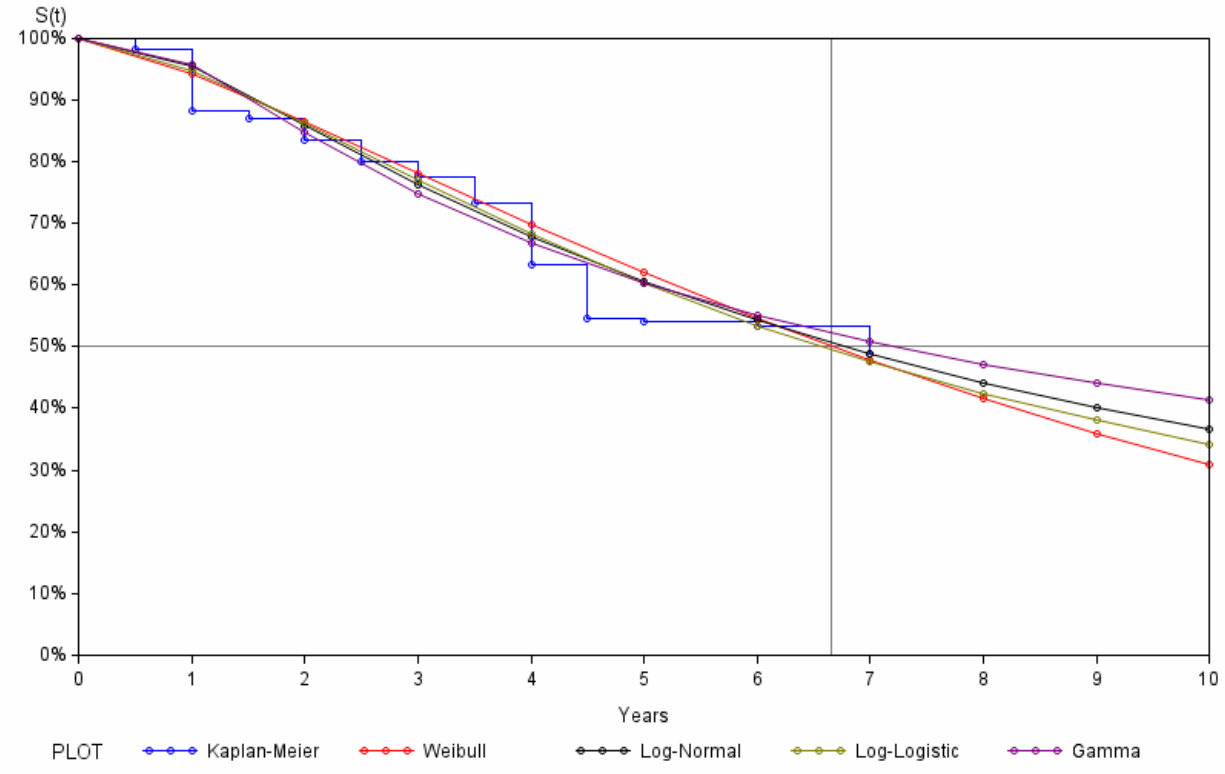
4.1 Survival analysis results

4.1.1 Overall results

Figure 10 provides a graph of the four survival analysis approaches applied to activity-level, sample-weighted-only data. The stepped line in blue is the KM approach. The other 4 lines are four parametric approaches representing 4 different distributional assumptions for the underlying hazard function--Weibull, log-normal, log-logistic and gamma.

Because there are failure data available for more than 7 years, the KM approach is able to provide an EUL estimate at 7 years. The parametric approaches closely follow the KM line, crossing the 50% line between 6 and 7 years. The KM method is the more transparent and direct representation of the underlying data. For the sample-weighted only survival curves, all five approaches are in close agreement with respect to the EUL.

Figure 10. Activity-level survival analysis curves, sample-weighted only



The activity-level, sample-weighted only models treat all activities equally regardless of their tracked savings. They provide an indication of the retention of activities regardless of their savings. This approach could, for example, underestimate retention if activities with greater savings have higher retention rates.

Figure 11 illustrates an activity-level, sample- and savings-weighted scenario, which is one way the analysis accounted for project-level savings in the survival curves. When we distribute project-level savings equally to activities, while still estimating the survival curve at the activity level, the KM approach shifts upward and only reaches 60% retention. The EUL as estimated by the parametric approaches is above 8 years.

Figure 11. Activity-level survival analysis curves, sample- and savings-weighted

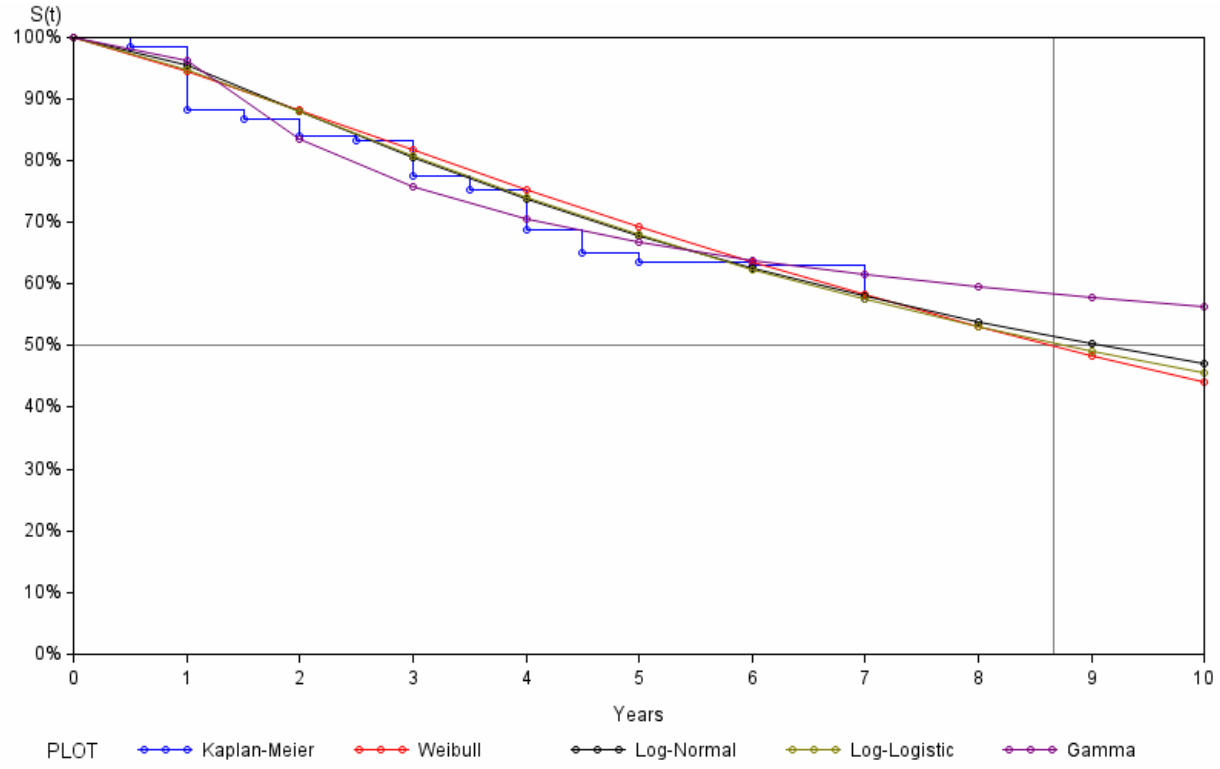
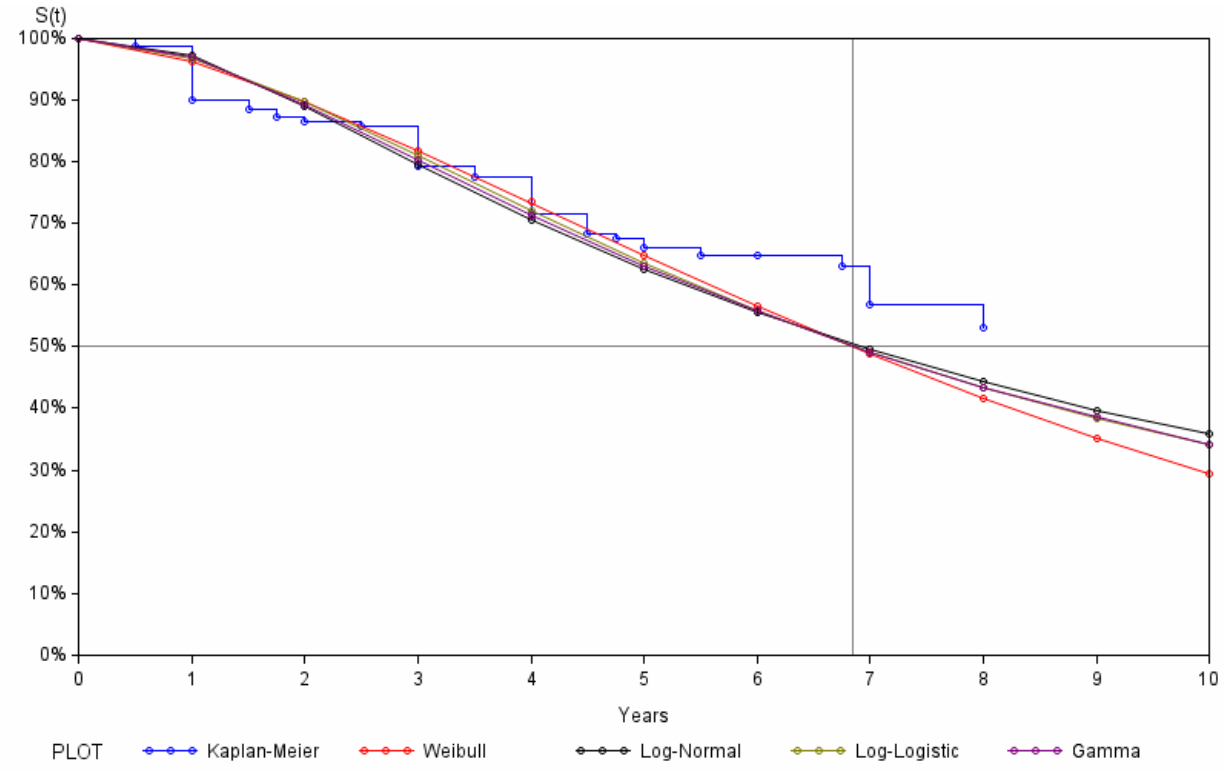


Figure 12 shows the other way of accounting for project-level savings, estimating a savings-weighted result at the project level rather than the activity level. The approach estimates the survival of the whole project with projects weighted by project-level savings. In this figure, projects take the status of their median activity.[13] This approach has the effect of increasing the weighting of shorter retention projects relative to longer retention projects. The parametric approaches are driven by the failure rate in the first 4.5 years. There are relatively few failures between 4.5 and 7 years allowing the KM EUL to occur at 9 years or greater. The parametric forms give less weight to these longer retention data points and produce a lower estimate of EUL at about 7 years. The agreement of the KM models across these different expressions of the data provides a solid argument for an overall EUL of at least 7 years. The parametric results also support an EUL of at least 7 years.

[13] Activities at a site were sorted by number of years survived. If the number of activities was odd, the years survived of the middle activity was attached to the site. If the number of activities was even, the average of those two years survived was used, rounding up, if necessary.

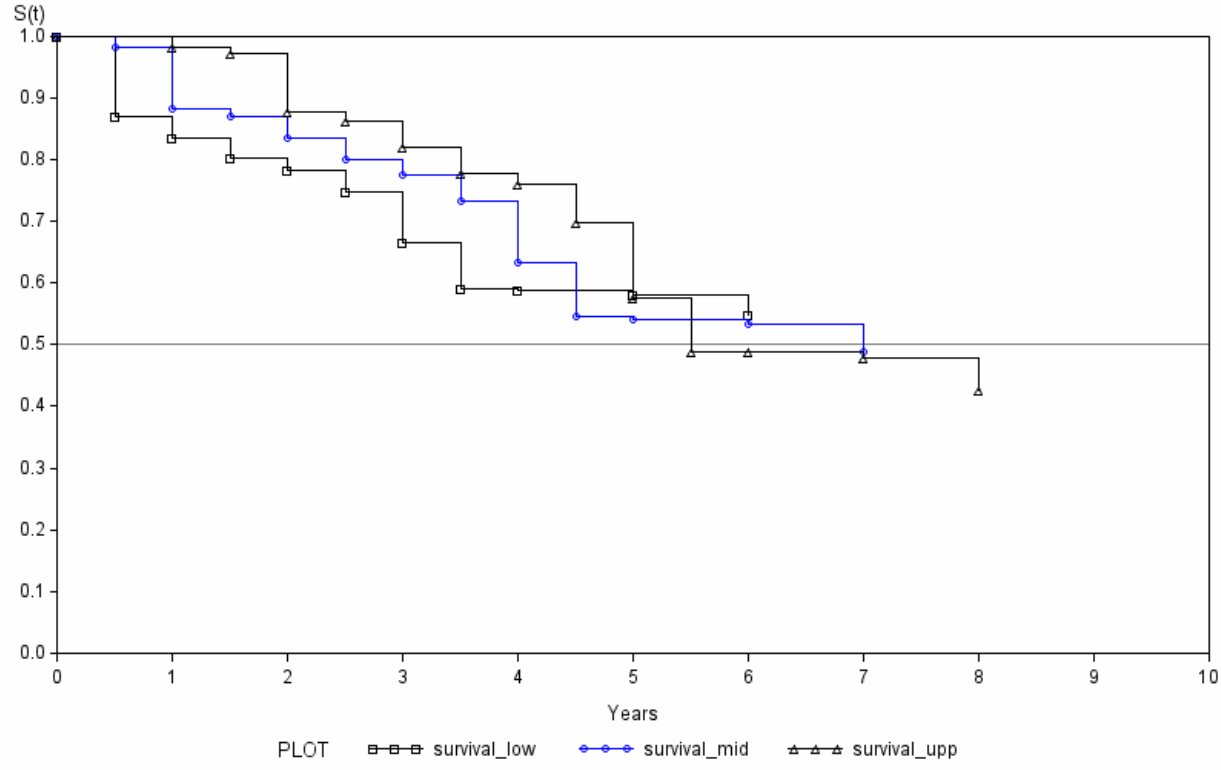
Figure 12. Project-level survival analysis curves, sample- and savings--weighted



4.1.2 Sensitivity analysis

Figure 13 shows the KM survival curve from Figure 10 with two additional curves representing higher and lower survival durations. As many of the durations are best estimates from site contacts or subjective estimates by the research team, it was informative to shift durations slightly up and down to demonstrate the sensitivity of the survival curves. For the lower survival estimate, activities that did not persist were said to have become inactive a year earlier with a lower limit of half a year retention. For the upper survival estimate, the activities that did not persist were said to have become inactive a year later with some upper limits based on facility closure or sold dates. In both cases, however, those activities still in place at the time of the evaluation (right-censored activities) remain at their original duration.

Figure 13. Activity-level survival analysis sensitivity, KM, sample-weighted only



The results of this plot are counterintuitive but illustrate an aspect of the KM algorithm:

- The lower survival estimate drops more quickly with more early failures. However, while there are more failures at lower durations, there are also relatively more activities still active as the right censored activities do not shift to the left. This means the lower survival estimate falls faster but also uses its failures up faster and never actually crosses the 50% line.
- To the contrary, increasing the time activities are still active means a greater number of failures remain relative to smaller numbers of remaining (not yet right censored) activities. As a result, the higher survival estimate decreases more slowly early but overtakes both the mid and lower survival curves crossing the 50% line at 5.5 years.

While these results are counterintuitive in their process, they still offer an understanding of the sensitivity of the survival curves around the median. While the higher survival estimate crosses at 5.5 years, it remains just below 50% until 7 years. The three curves converge on each other between 5.5 and 7 years, just at the median line. It is evident that no further adjustments will move the EUL below 5.5 years.

4.1.3 Track-specific results

The overall results can be split into separate survival curves for the standalone O&M and SEM tracks. The standalone O&M and SEM measures could be assigned different EULs if there was evidence of distinct survival curves.

In fact, both track-level survival curves exhibit a similar pattern to the overall plot provided above. Between 4 and 7 years after installation, the rate of failure diminishes, causing the survival curves to flatten. Figure 14 shows the standalone O&M and SEM curves estimated with sample-weight only. Similar to the overall survival curve, this flattening occurs at survival levels just above 50%, leading to consistent evidence of a a 7 year

EUL. Across the tracks, there are slight deviations in the survival curves in the middle years. However, despite this, both tracks flatten prior to crossing the 50% line produce a 7-year EUL for standalone O&M and at least 7 years for SEM. This figure indicates that the standalone O&M and SEM tracks can confidently be assigned the same EUL.

Figure 14. Standalone, activity-level O&M vs. SEM survival curves, sample-weighted only

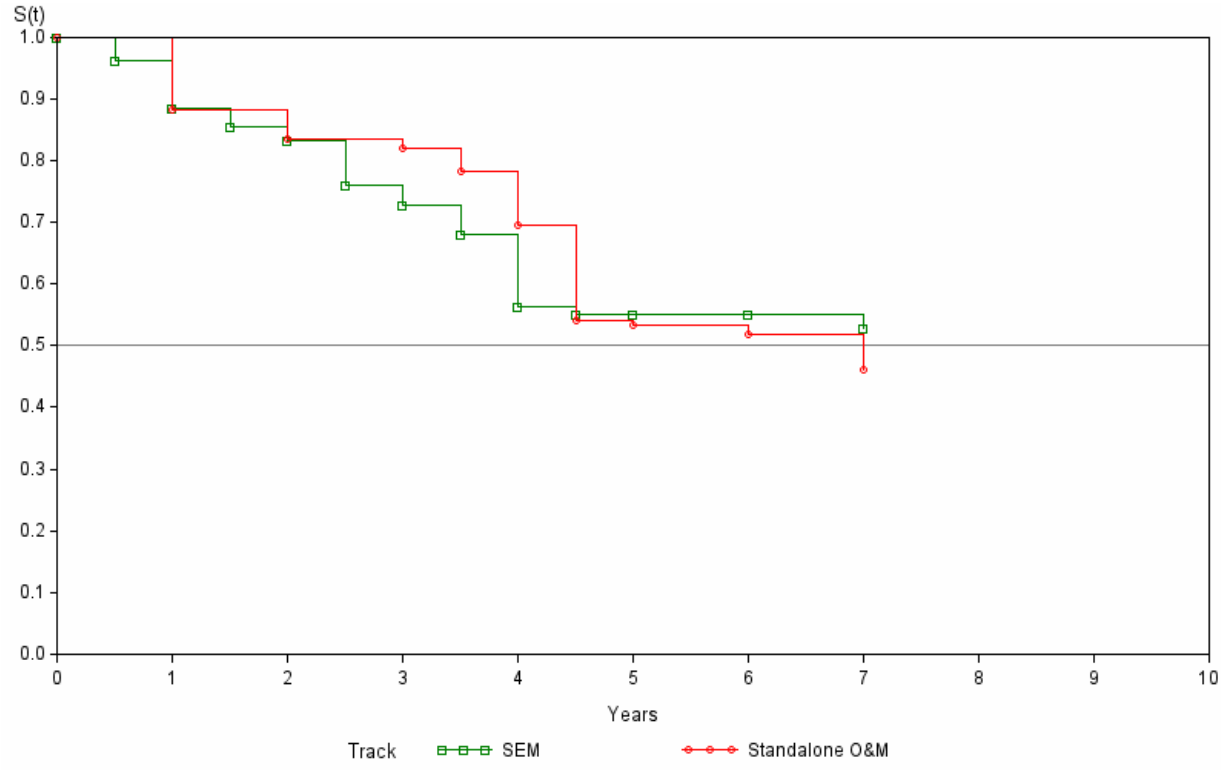
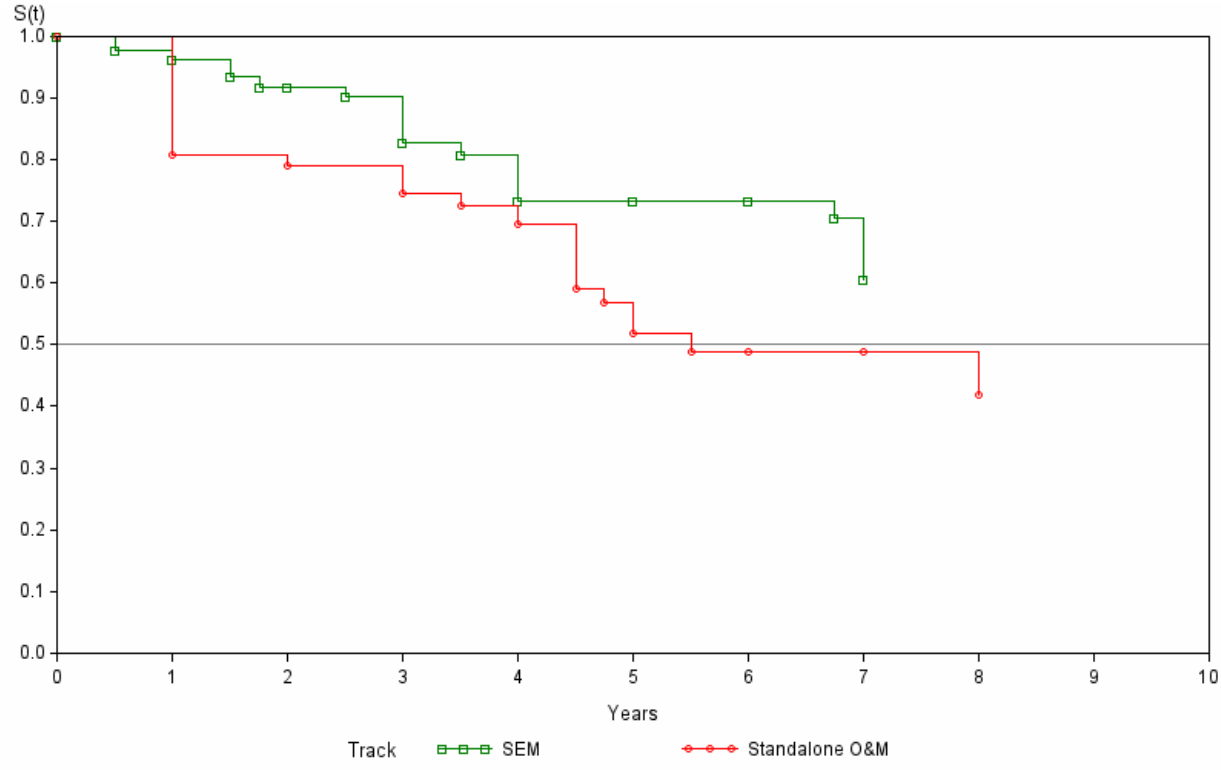


Figure 15 shows the track-level survival curves using aggregate project-level savings weights. The weighting shifts both survival curves a relatively small amount but to dramatic effect. SEM follows the same approximate shape as the prior plot but flattens out at a higher percentage, above 70%, and never actually crosses the 50% line. In contrast, the standalone O&M curve shifts downward so the flattening occurs below the 50% line after crossing the line at 5.5 years. Similar to the discussion above with respect to overall survival curve sensitivity analysis, the flat, low failure period between 4 and 7 years occurring close to the 50% line exacerbates the variability around the EUL estimates. The survival curves are not statistically different at any point along the curves. However, in contrast to the activity-level, sample-weighted-only results in Figure 14, this plot provides a visual suggestion that standalone O&M measures might prove to have a lower EUL than SEM.

Figure 15. Standalone O&M vs. SEM survival curves, aggregate-savings weighted



Because none of the results across any of the weighting schemes are statistically different than each other, the analysis does not support track-level EUL estimates. The seemingly different survival curves in the savings weighted schemes could potentially support track-level EUL estimates in the future if additional data support the same trends. Even with the differences as illustrated, the standalone O&M track persists at just below 50% through 8 years despite crossing the threshold at 5.5 years.

4.1.4 Survival analysis cofigurenclusions

The survival analysis described above provides ample evidence that the current EUL of 3 years is too low for standalone O&M and SEM measures. This analysis estimated EULs across a number of scenarios encompassing more and less conservative assigned project-level persistence levels and using different solutions to weighting challenges and track-specific survival curves. The EUL estimates mostly fall at or above 7 years.

- The strongest survival analysis approach (KM) provides an EUL of at least 7 years across all weighting scenarios.
- The sensitivity and track-level analysis reveal survival curves that can produce EULs of 5 years for one or both tracks under reasonable scenarios.
- The survival curves indicate that activities/projects that last at least 5 years have substantially lower failure rate in the subsequent years. The range of EULs reflect that the failure rate can flatten just above or just below the median retention level that defines the EUL.
- Updating the analysis dataset in a couple of years should provide a more exact estimate of the EUL as a greater number of activities/projects will be able to inform retention rates in the period after 5 years.

4.2 Recommendations and considerations for Energy Trust

Below are DNV GL's summary of the findings for each of the primary research objectives of this study.

Estimate the long-term persistence of industrial O&M measures, including reasons why O&M measures are no longer in place and/or no longer saving the amount of energy originally estimated.

- DNV GL recommends that Energy Trust calculate the cost-effectiveness of industrial O&M measures (implemented either as standalone O&M or as part of an SEM engagement) using a 5- or 7-year measure life. A 7-year lifetime would directly use the result of this study. Energy Trust could use a 5-year measure life if it wanted a value supported by the most conservative scenarios analyzed. See section 4.1 for more detail.
- The primary reasons for savings from O&M activities failing to persist are similar to the reasons why other industrial capital measures fail, such as site closures or sales and changes to production. In other cases, sites stopped implementing the required procedure or just stopped completing the activity and provided no specific reason why. No reason was typically provided when personnel have changed, they know they aren't doing it now, but do not know why and when it stopped.

Assess the appropriateness of the 3-year measure life that is currently used for O&M measures. Additionally, assess the appropriateness of the 5-year measure life that is currently used for SEM continuation participants.

- The current 3-year measure life used for O&M measures is inappropriate. This measure life has significantly underestimated the benefits achieved by industrial O&M measures.
- The 5-year measure life used for SEM continuation also underestimates the benefits achieved.

Assess if measure persistence (including reasons why O&M measures are no longer in place and/or no longer saving the amount of energy originally estimated) differs for stand-alone O&M measures versus O&M measures implemented at sites that have participated in SEM.

- Measure persistence does not significantly differ between sites that completed standalone O&M measures and those that participated in SEM. DNV GL believes this is due to the nature of the activities completed and the program's efforts specific to persistence risk management.
- Energy Trust can confidently assume a measure life for both tracks of 7 years.

Provide recommendations for improving the persistence of industrial O&M measures.

- DNV GL does not have significant recommendations for improving the persistence of the industrial O&M measures it supports. This research has demonstrated that the program is already achieving excellent levels of persistence. DNV GL believes the two items below are key to savings persistence. They were observed to be occurring in the sample interviewed and we believe the program influenced the occurrence of both.
  - The program should continue to include strategies for long term savings persistence in its program documentation.
  - The program should continue to promote the revision of standard operator procedures to include program activities, promote management of access to equipment control systems, and promote a regular energy consumption review of all systems within a facility at the appropriate interval.

APPENDIX A. SAMPLE DESIGN MEMO

APPENDIX B. INTERVIEW GUIDE

Interview Guides: Industrial O&M Persistence Study

Energy Trust of Oregon

FINAL submission on 3/6/2019

1 BACKGROUND

This interview guide is designed to complete an approximately 30 - 45 minute interview with participants in Energy Trust of Oregon's Production Efficiency program. The primary goals of this research are to:

- Estimate the long-term persistence of industrial O&M measures, including reasons why O&M measures are no longer in place and/or no longer saving the amount of energy originally estimated
- Assess the appropriateness of the three-year measure life that is currently used for O&M measures
- Assess if measure persistence (including reasons why O&M measures are no longer in place and/or no longer saving the amount of energy originally estimated) differs for standalone O&M measures versus O&M measures implemented at sites that have participated in SEM
- Provide recommendations for improving the persistence of industrial O&M measures

The objectives of this interview are to:

- Assess the energy management culture at each sampled location through a series of general questions.
- Investigate the persistence of energy savings from O&M measures and SEM activities by assessing if the action(s) completed continues to provide savings and/or if the measure's energy optimization intent is still in place at the organization. This will be assessed through measure-specific questions.
- For measures found to no longer be saving energy, assess when savings stopped and why. This will be assessed through measure-specific questions.

2 INTERVIEW RECRUITMENT

Recruitment is based on project recruitment protocol documented in the project work plan.

3 BACKGROUND MATERIALS

The following table provides the materials used to develop the general questions in this guide.

The general questions used to assess energy management practice were developed using an ENERGY STAR assessment matrix. We have mapped these areas of interest to the CEE SEM Minimum elements.[1] This is the original matrix which can be found here:	https://www.energystar.gov/buildings/tools-and-resources/energy-program-assessment-matrix-excel
The Guidelines for Energy Management document associated with this matrix can be found here:	https://www.energystar.gov/sites/default/files/buildings/tools/Guidelines%20for%20Energy%20Management%206_2013.pdf

4 INTERVIEW MATERIALS

The interview guide will be programmed into a form that will be completed by the interviewer. The results of each interview will be added a database at the conclusion of the interview.

[1] CEE Minimum Elements: https://library.cee1.org/system/files/library/11283/SEM_Minimum_Elements.pdf

5 INTERVIEW

Interview Date: _____

Interviewee Name(s): _____

Interviewer Name(s): _____

Interview Duration: _____

5.1.1.1 Interview Recording

If you record the interview, you must obtain explicit permission from the respondent(s).

5.1.1.2 Confidentiality

If respondents ask, tell them yes, their answers will remain confidential.

5.1.1.3 Legitimacy

If the respondent questions the legitimacy of the interview, give them the study manager's contact information:

Study Manager

[redacted]

5.1.1.4 Introduction

1. Hello, my name is _____ and I work for DNV GL. Thank you for taking the time to speak with me. Energy Trust of Oregon has contracted with us to help develop an understanding of the persistence of energy savings over time and provide recommendations to improve their programs. Today I'd like to speak with you about operations and maintenance practices related to equipment that was part of a previous Energy Trust of Oregon energy efficiency project.
2. If TRACK = SEM: Were you aware of or were you involved in the training and technical assistance provided by Energy Trust to track and improve energy performance, and identify and implement energy efficiency actions during [PROGRAM YEAR]? [If needed: Energy Trust refers to this as Strategic Energy Management, or SEM.]
    a. Yes
    b. No
3. If TRACK = Custom O&M: Were you aware of or were you involved in the energy efficiency projects completed in [PROGRAM YEAR] related to [EQUIPMENT DESCRIPTION]?
    a. Yes

   b. No

4. Are you the person who is most familiar with the current operation and maintenance of [EQUIPMENT DESCRIPTION] at your facility?

   a. Yes

   b. No

      i. [If NO, ask for the name and contact info for a person who would be familiar with the project and ask to speak with that person.]

5. I anticipate that the interview will take approximately 45 minutes. This interview is for research purposes only; your feedback will not affect the status of any other Energy Trust projects. Do you have any questions before we begin?

   Great. Let's get started.

6. What is your current title and responsibility?

   a. Record text response

7. How long have you worked for [COMPANY NAME]?

   a. Record response in years.

The next part of our interview will focusing on characterizing the energy management practices that exist at your facility, like tracking your energy use, forming an energy team and holding regular meetings. Do you mind if I record the interview, so I may return to it when reviewing my notes? [If no, start recording]

5.1.1.5 Assessment of energy management practices

Responses to these questions should be summarized in the provided workbook. The interviewer will then assess which option of the three responses best aligns with the response provided.

The four questions with numbers are also included in the interview guide for participants selected for impact evaluation of PY16 or PY17 SEM activities.

SEM Minimum Element	Evaluation Questions	Little or no evidence	Some elements	Fully implemented
1a. Policy and Goals	12. Does your company or facility have any policies or plans in place that incorporate energy or energy efficiency?	No formal policy	Referenced in environmental or other policies	Formal stand-alone EE policy endorsed by senior mgmt
1b. Resources	10. Do you have an "energy champion" or "energy manager," someone in charge of coordinating energy management activities and spearheading efficiency projects? [If SEM participant] Is this the same person (or people) who served as the energy champion during SEM in [SEM YEAR]?	No central or organizational resource; decentralized management	Central or organizational resource not empowered	Empowered central or organizational leader with senior management support
	11. Do you have an energy [management] team [dedicated staff for energy and energy efficiency]? a. Who makes up the team? [NOTE: explore the roles of the team members, cross-functionality, size] b. Does your energy team meet? i. [If yes] How frequently does it meet?	No company energy network	Informal organization	Active cross-functional team guiding energy program
2a. Energy Management Assessment	Have you compared your facility's energy consumption to other facilities in the company or other competitors? Please describe.	Not addressed or only same site historical comparisons	Some internal comparisons among company sites	Regular internal & external comparisons & analyses
2c. Metrics and Goals	13. Does your company or facility currently have goals related to energy or energy efficiency? 13a. [If yes] are these goals based on an analysis of energy consumption at the facility?	Not addressed	Loosely defined or sporadically applied	Specific & quantifiable at various organizational levels
2d. Project register	Describe how your facility identifies and prioritizes energy efficiency projects, documents planned actions, and tracks them to completion.	No audit conducted/No opportunity register or project planning	Internal facility reviews, minimal tracking	Reviews by multi-functional team of professionals; well-developed list of projects and active prioritizing and tracking

SEM Minimum Element	Evaluation Questions	Little or no evidence	Some elements	Fully implemented
2g. Reassessment	How often do you review and update your list of energy saving actions the team can take to achieve your goals?	No reviews	Informal check on progress (no specified interval)	Revise plan based on results, feedback & business factors (regular interval)
	How often does your team or facility review progress and determine if you are or are not on track to meet your goals?	No reviews	Historical comparisons (no specified interval)	Compare usage & costs vs. goals, plans, competitors (regular interval)
3a and b. Measurement, data collection and availability	Please describe any metering, tracking, or reporting your facility completes to understand how energy consumption and costs change over time or with production changes.	Little metering/no tracking	Local or partial metering/tracking/ reporting	All facilities report for central consolidation/analysis
3c. Analysis	Has your facility created a baseline that any changes to consumption can be measured against? Please describe.	No baselines	Various facility-established	Standardized organizational base year and metric established
	Have you experienced any spikes in energy consumption this past year? How did you identify them? What systems or processes do you have in place to identify when spikes in energy consumption occur?	Not addressed	Some attempt to identify and correct spikes	Profiles identifying trends, peaks, valleys & causes
3d. Reporting	How does your facility/organization determine if it is tracking towards its goals?	No system for monitoring progress	Annual reviews by facilities	Regular reviews & updates of centralized system

5.1.1.6 Measure-specific questions

These questions are specific to the energy efficiency projects or actions completed at this site during previous program years. The questions are grouped by categories; each sampled measure has been mapped to a category. Interviews may include questions from multiple categories. The interviewer will ask these questions and choose the response based on information provided by the interviewee. Limited probing will be used. If required, interviewers can read all responses to the interviewee to help determine the correct response. In some cases, the interviewer will summarize the response in text. The results of each interview (including the general questions) will be used to assess if measure savings exist at the time of the interview and if not, when savings stopped to exist.

The categories were created based on DNV GL's review of project files associated with each measure:

- Maintenance – Replacing consumable parts; cleaning equipment; calibration
- Repairs – Detect and repair compressed air leaks
- Repairs – Fixing or installing new equipment installed to improve system operation (e.g., to allow new control strategies)
- Operations – Schedule changes
- Operations – Setpoint adjustments
- Controls – Control strategy changes or process optimization efforts
- Behavior – Responding to tracked energy use; performing audits; revising standard operating procedures; observing and stopping waste; forming teams to improve energy awareness

SEM Interviews

DNV GL has identified up to 5 unique measures completed by each SEM participant as noted in the opportunity register (or similar list) in the completion report (or final analysis report). This was done for each SEM site sampled for this study (in cases where an SEM participant had multiple sites). Each of these measures has been classified according to the interview question categories. The interviewer will complete the measure-specific questions for each SEM measure identified. DNV GL chose and prioritized the measures based on either discussions in the document specific to the expected measure impact or our judgement of the measure impact compared to the other actions listed.

Table 1: Custom O&M – Measure-Specific Questions

Questions by Category:
Maintenance - Replacing consumable parts; cleaning equipment; calibration
Our records show you completed [MEASURE DESCRIPTION] on your [SYSTEM] under the program in [YEAR]
When was the last time you completed this maintenance activity on this equipment or system?
1. Within A Month
2. Within A Year
3. Within Two Years
4. Don't Know
5. Other (Add Note)
How often do you perform this maintenance activity?
1. More Than Once a Year (e.g. bi-annually, quarterly, monthly, etc.)
2. Annually
3. Every 2 Years
4. Other (Add Note)
5. Not On A Schedule
Please describe your maintenance approach for this equipment.
1. Predictive, Or Preventative Maintenance Practiced (That Is, Are Some Maintenance Activities Planned And Scheduled Regularly, Such As Cleaning, Checking/Replacing Filters And Parts)
2. Responsive (We Check On The System When Something Happens)
3. Don't Know
4. Other
Have you incorporated these maintenance activities into standard operating procedures or other written instructions to operators?
1. Yes
2. No
3. Don't Know
What percentage of your facility's work orders are generated due to predictive or preventative maintenance compared to responding to problems?
1. 70% Or More
2. 50 To 70%
3. 20 To 50%
4. Less Than 20%
5. None
How do you track work orders? (open ended, then categorize as below)
1. Active Management: E.g., Use Maintenance Scheduling Software (CMMS - Computerized Maintenance Management System) To Organize Track, And Schedule Maintenance Activities
2. Some Management: Periodically Review Records, Some Prioritization, Only Some Activities Managed
3. Minimal Management: Historical Records Maintained, Minimal Planning
How often do you review maintenance processes with or train operators so they can maintain the equipment as recommended?
1. Once
2. Annually
3. Never
4. Other Frequency (Specify)
[If interviewer responses suggest savings have not persisted] Why do you believe maintenance is not occurring regularly? [Probe for when maintenance practice stopped and why]

1. Record response.
Repairs - Detect and repair compressed air leaks
I'm going to ask you a few questions about your current air compressor operation. Under the program, you detected and repaired leaks to your compressed air system in [YEAR]
When was the last time the compressed air system was checked for leaks?
1. Within A Year
2. Within Two Years
3. More Than Two Years Ago
4. Other (Add Note)
How do you identify leaks at your facility?
1. Leaks Are Reported Individually When Detected By Production Or Maintenance Staff During The Course Of Their Duties (Skip Next Question)
2. We Have A Regular Leak Detection Program (Go To Next Question)
3. We Hire A Leak Detection Service (Go To Next Question)
4. We Have An Ultrasonic Detector (Go To Next Question)
Please describe your current plan to regularly monitor, detect and repair leaks for your compressed air systems?
1. Yes, We Perform Leak Detection Across The System On An Annual Schedule
2. Yes, We Perform Leak Detection Across The System On A Regular Schedule (Specify Frequency)
3. Yes, We Perform Leak Detection Across The System Sometimes
4. No, We Do Not Have A Plan To Detect Air Leaks
How many years have you been doing this, roughly?
1. Since (Program Year)
2. More Than 5 Years
3. 3-5 Years
4. 1-2 Years
5. Started This Year
Please describe your leak detection approach. In particular, describe the identification and tagging process, tracking, repair, verification and employee involvement aspects.
1. All Components Of A Leak Detection
2. Some components, no employee involvement
3. Some Components, Including Employee Involvement
4. No Actions Beyond Identification And Repair (if no program is present, probe for why)
[If interviewer responses suggest savings have not persisted] Why do you believe repair is not occurring regularly? [Probe for when maintenance practice stopped and why]
1. Record response.

Repairs – Fixing or installing equipment to improve system operation (e.g. to allow new control strategies)
Our records show you also added (XX - no-loss drains, dew point control for dryer) to improve the operation of your (XX system - air compressor) system.
Is this equipment still in place?
1. Yes
2. No
3. Don't Know
Is this equipment operating effectively?
1. Yes
2. No
3. Don't Know
4. Other (Add Note)
(if no to either above) When was it removed or when did it fail?
1. Insert Text
Have you implemented training for operators on the proper use of this equipment?
1. Yes
2. No
3. Don't Know
Have you included operation of this equipment in standard operating procedures or other written instructions to operators?
1. Yes
2. No
3. Don't Know
How often do you maintain this new equipment?
1. More Than Once a Year (e.g. bi-annually, quarterly, monthly, etc.)
2. Annually
3. Every 2 Years
4. Other (Add Note)
5. Not On A Schedule
Please describe your maintenance approach for this equipment.
1. Predictive (Or Preventative) Maintenance Practiced (That Is, Are Some Maintenance Activities Planned And Scheduled Regularly, Such As Cleaning, Checking/Replacing Filters And Parts)?
2. Responsive (We Check On The System When Something Happens)
3. Don't Know
4. Other
[If interviewer responses suggest savings have not persisted] Please describe why this equipment is no longer in use or not operating as intended.
1. Record response.

Operations – Schedule changes
Our records show you adjusted the schedule of your (XX system, e.g., air compressor system or more detailed - shut-down XX equip, made changes to 19 furnaces to only use air when the doors where open, valved off from areas not in use, etc.) under the program.
Have you maintained the schedule implemented (described above)? Explain if not.
1. Yes
2. No [Include explanation in final measure question]
3. Don't Know
4. Other [Include explanation in final measure question]
Are there changes in plant operations that have required changes to the (equipment, e.g. air compressor) schedule?
1. Yes
2. No
3. Don't Know
(if yes) Are they using the equipment more or less?
1. Insert Text
Have you implemented training for operators on why and how to keep the schedule for the (equipment – e.g. compressors)?
1. Yes
2. No
3. Don't Know
Have you incorporated these changes into standard operating procedures or other written instructions to operators?
1. Yes
2. No
3. Don't Know
Have you done other actions to make sure the schedule stays efficient? E.g., adjustments to controls, signs, etc.
1. Yes, Probe For Details
2. No
3. Don't Know
[If interviewer responses suggest savings have not persisted] Please describe why the schedule changed and when the schedule was changed from the project recommendations in [PROGRAM YEAR]?
1. Record response.

Operations - Setpoint adjustments
Our records show you (XX - reduced pressure from 125 to 117 psi, i.e. made changes to the operation of your equipment/system)
Do you still operate with these conditions?
1. Yes
2. No
3. Don't Know
4. Other- Explain
(if no) How do you operate now?
1. Insert Text
(if no) When did you make this change?
1. Insert Text
(if no) Why did you make this change?
1. Insert Text
Have you implemented training for operators on maintaining the improvements made to the operation?
1. Yes
2. No
3. Don't Know
Have you incorporated these changes into standard operating procedures or other written instructions to operators?
1. Yes
2. No
3. Don't Know
Have you done other actions to make sure the equipment/system stays efficient? E.g., Maintenance checks?
1. Yes, Probe For Details
2. No
3. Don't Know

Controls - Control strategy changes or process optimization efforts
Our records show you also made these adjustments to your (XX - Measure description) system
Do you still operate your controls this way?
1. Yes
2. No
3. Don't Know
4. Other- Explain
(if no) How do you operate now?
1. Insert Text
When did you make this change?
1. Insert Text
Why did you make this change?
1. Insert Text
Have you implemented training for operators on why and how to keep the schedule for the (XX - Measure description) system?
1. Yes
2. No
3. Don't Know
Have you incorporated these changes into standard operating procedures or other written instructions to operators?
1. Yes
2. No
3. Don't Know
Have you done other actions to make sure the equipment/system stays efficient? Maintenance checks?
1. Yes, Probe For Details
2. No
3. Don't Know

Behavior - Responding to tracked energy use; performing audits; revising standard operating procedures; observing and stopping waste;
Under the program, your company changed how you and your staff monitored, operated, and maintained your energy-using equipment. The action is described as (measure description).
Does your staff regularly complete this action as expected?
1. Yes
2. No
3. Don't Know
4. Other- Explain
(if no) What tends to happen now?
1. Insert Text
When did you make this change?
1. Insert Text
Why did this change?
1. Insert Text
Have you incorporated this action into standard operating procedures or other written instructions to operators?
1. Yes
2. No
3. Don't Know
How often do you review or train operators so they can maintain the equipment as recommended?
1. Once
2. Annually
3. Never
4. Other Frequency (Specify)

5.1.1.7 Measure Questions Repeat

If the interview includes multiple measures or multiple projects:

Now I'd like to ask you similar questions about a different measure [PROJECT]. This was completed in [PROJECT YEAR].

Are you also familiar with the current operation for [EQUIPMENT DESCRIPTION]?

5.1.1.8 Wrap up

Thank you again for your time. That's all the questions I have today.

Is there anything else you'd like us to know or anything you'd like Energy Trust to get back to you about?

APPENDIX C. ENERGY MANAGEMENT PRACTICES

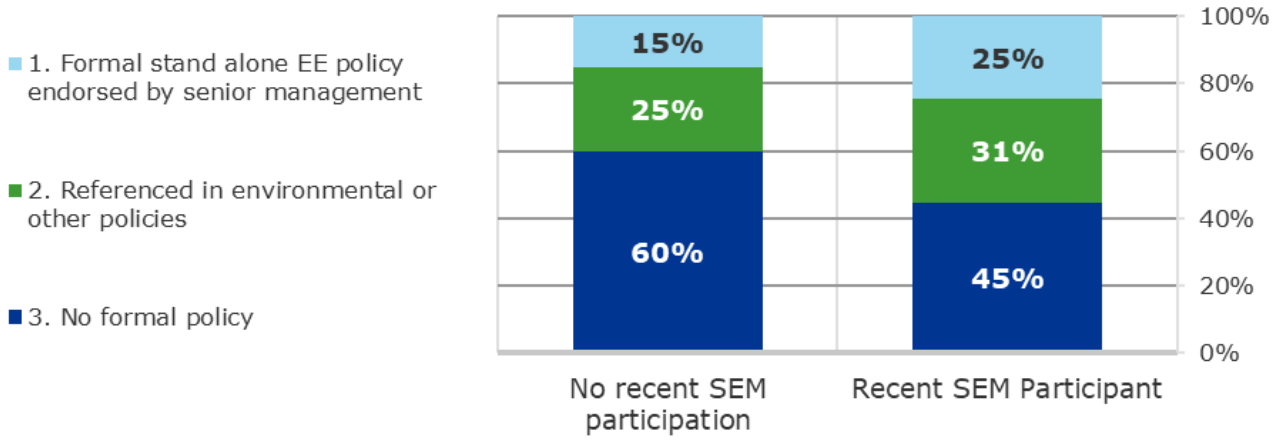
This appendix contains the results of the customer energy management practices portion of the interview. These questions were asked once per interview, even for cases when one interview was used to review activities completed at multiple facilities managed by a single organization. The results have been weighted based on the most recent project's site weight from the sample design. For example, if an interview discussed activities completed in 2011 and 2016, the sampling weight associated with the 2016 activities was used. All charts exclude any non-responses.

Each chart shows two distinct groups, those from recent SEM participants and those from participants with no recent SEM participation. Recent SEM participation is defined as customers with at least one site (determined using site CRM number) that participated in an SEM program in 2015 or later. In some cases, DNV GL sampled standalone O&M measures at sites that are associated with customers with recent SEM participation.

The questions were asked as open-ended with no answer options provided. Interviewers listened to the response and then assessed which of the options best fit the response provided.

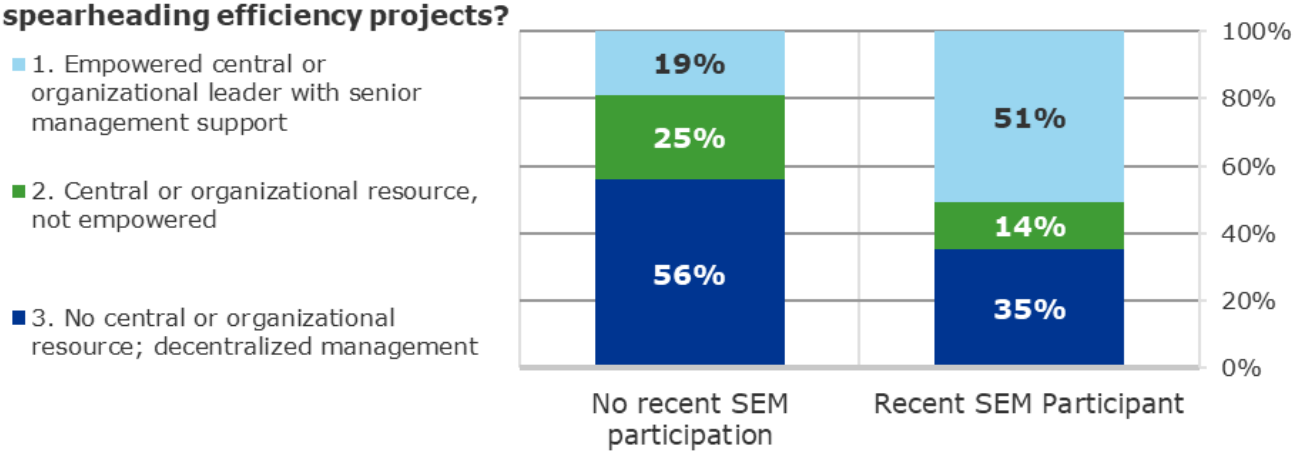
These responses improve Energy Trust's understanding of the current state of energy management at its historic program participants. The questions were designed around the Consortium for Energy Efficiency's (CEE) Strategic Energy Management Minimum Elements[14].

1a. Does your company or facility have policies or plans in place that incorporate energy or energy efficiency?

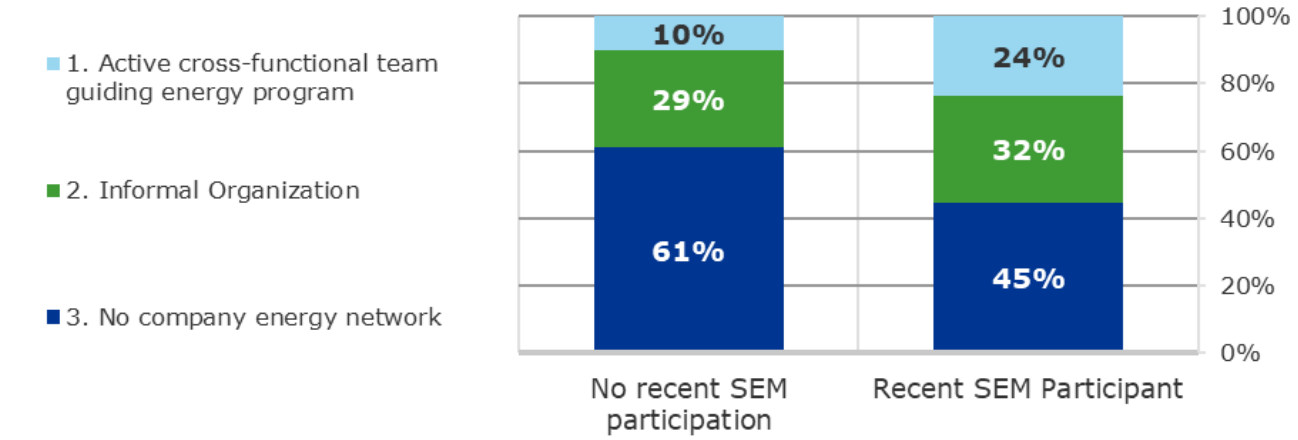


[14] Available to the public at: https://library.cee1.org/system/files/library/11283/SEM_Minimum_Elements.pdf

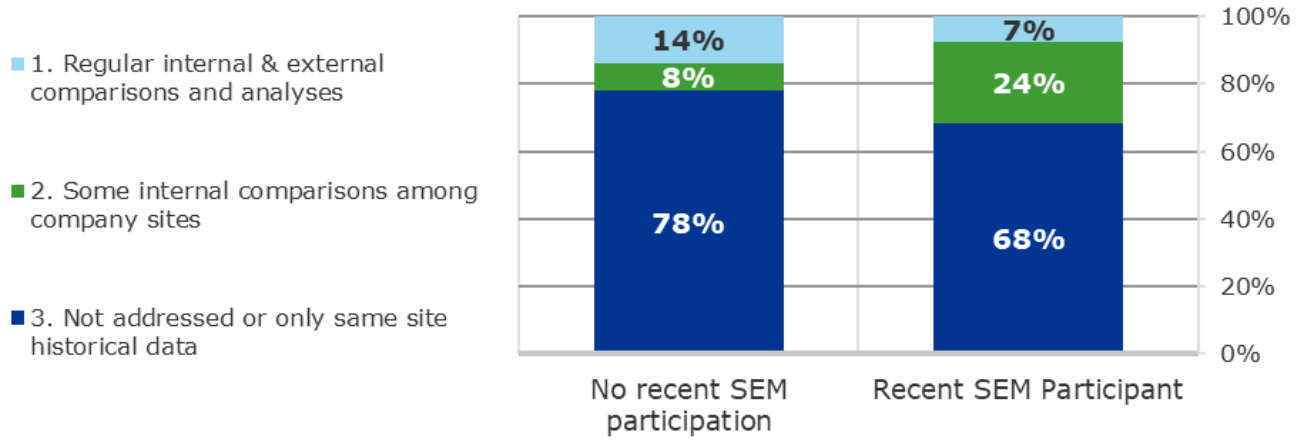
1b. Do you have an "energy champion" or "energy manager", someone in charge of coordinating energy management activities and spearheading efficiency projects?



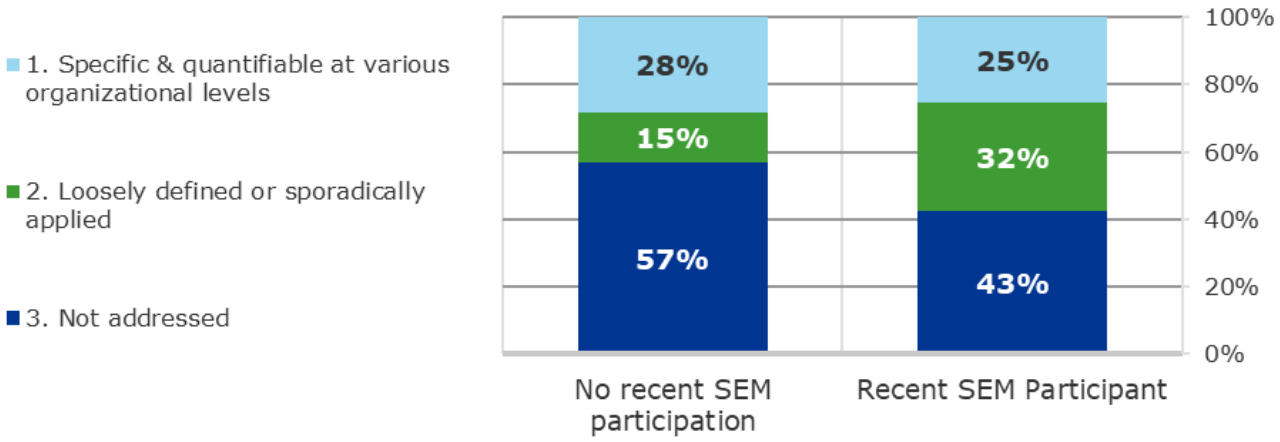
1b. Do you have an energy (management) team (dedicated staff for energy and energy efficiency)?



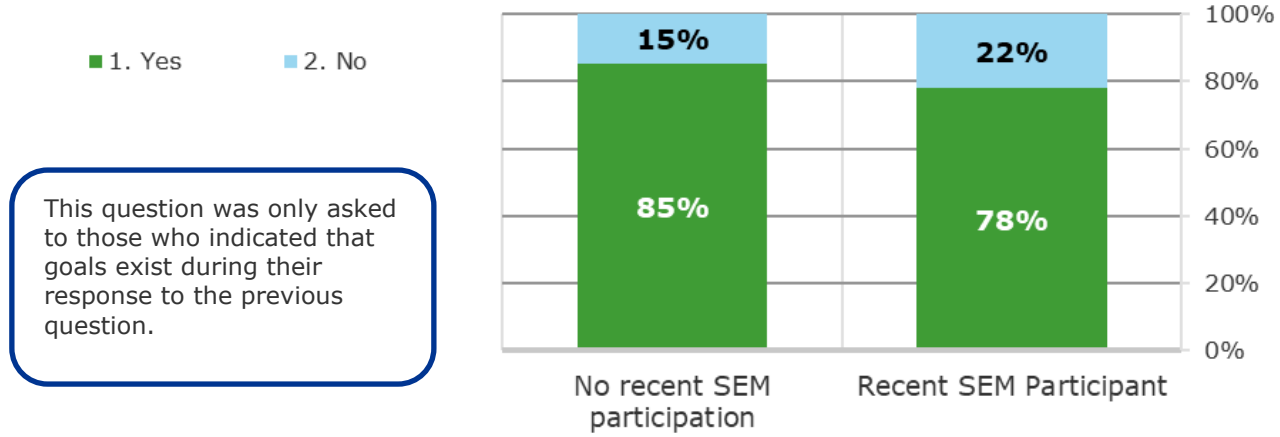
2b. Have you compared your facility's energy consumption to other facilities in the company or other competitors? Please describe.



2c. Does your company or facility currently have goals related to energy or energy efficiency?

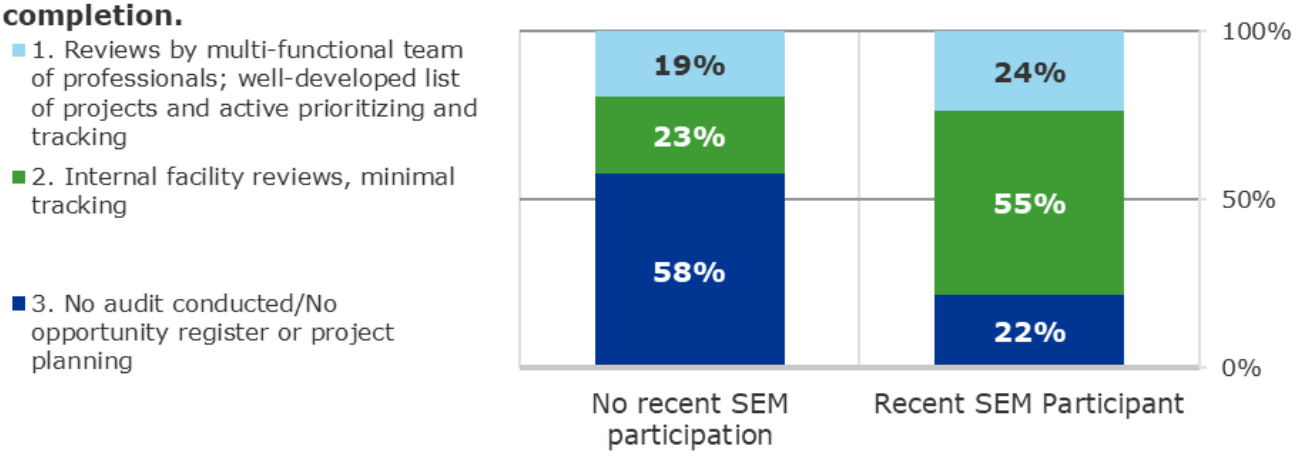


2c. Are these goals based on an analysis or energy consumption at the facility?

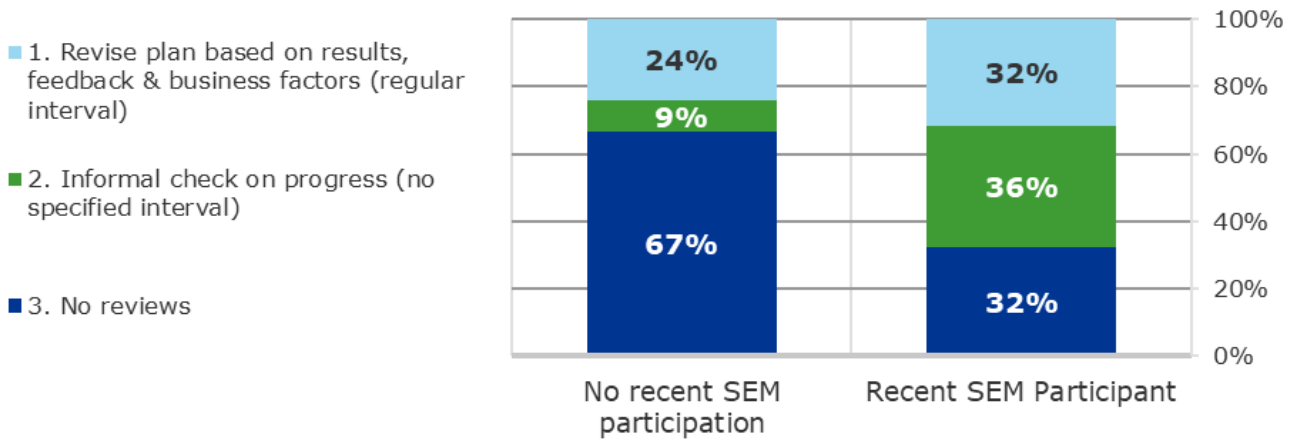


This question was only asked to those who indicated that goals exist during their response to the previous question.

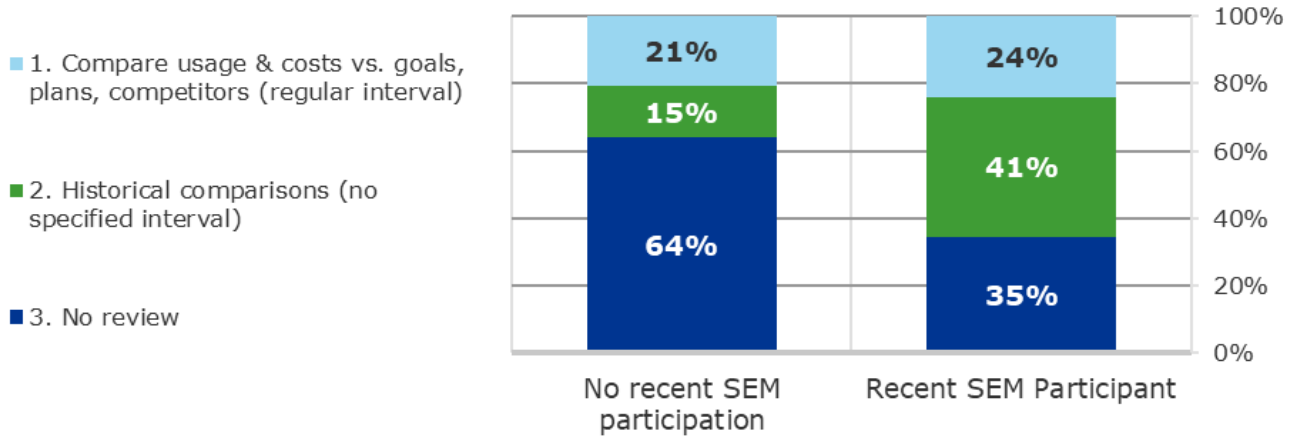
2d. Describe how your facility identifies and prioritizes energy efficiency projects, documents planned actions, and tracks them to completion.



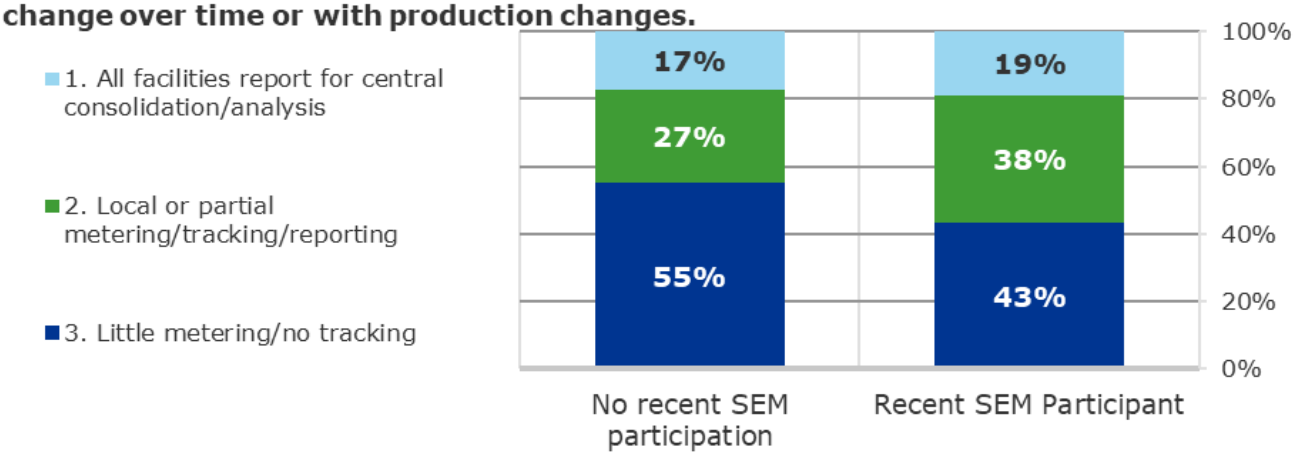
2g. How often do you review and update your list of energy saving actions the team can take to achieve your goals?



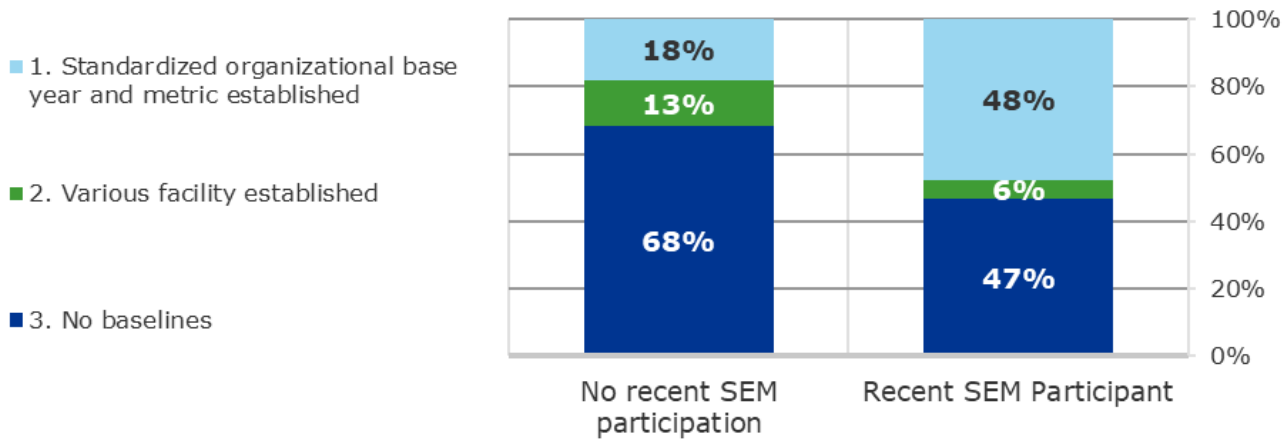
2g. How often does your team or facility review progress and determine if you are or are not on track to meet your goals?



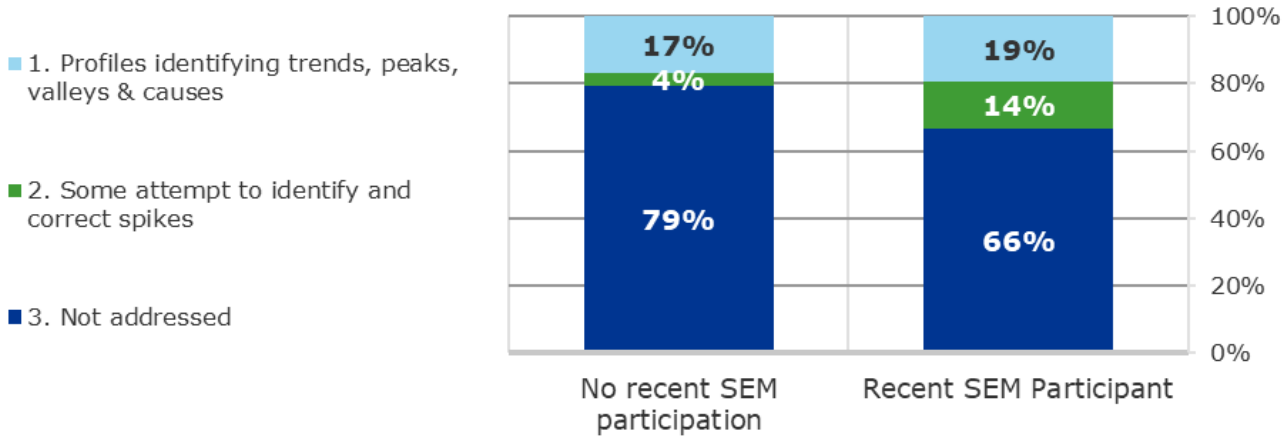
3a/b. Please describe any metering, tracking, or reporting your facility completes to understand how energy consumption and costs change over time or with production changes.



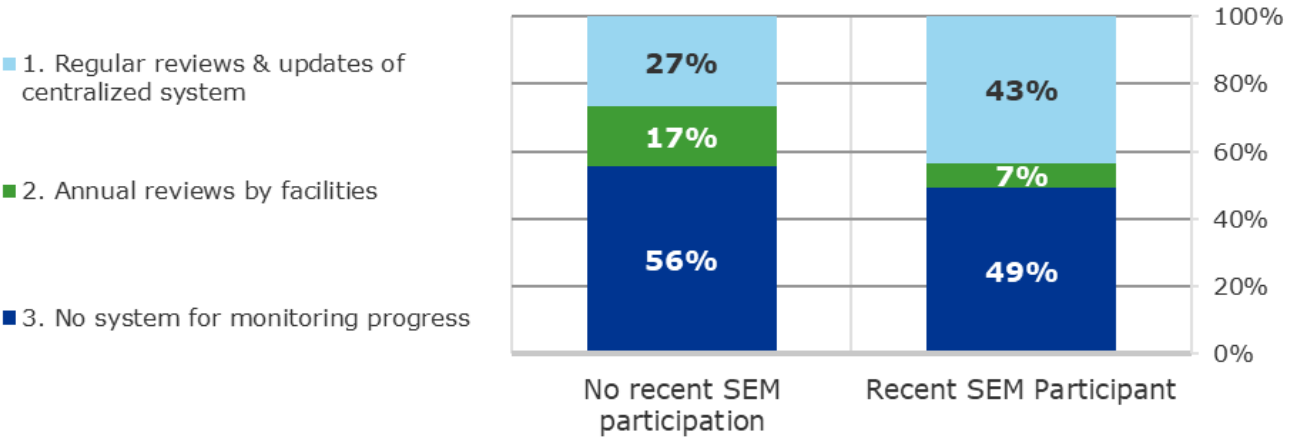
3c. Has your facility created a baseline that any changes to consumption can be measured against? Please describe.



3c. Have you experienced any spikes in energy consumption this past year?

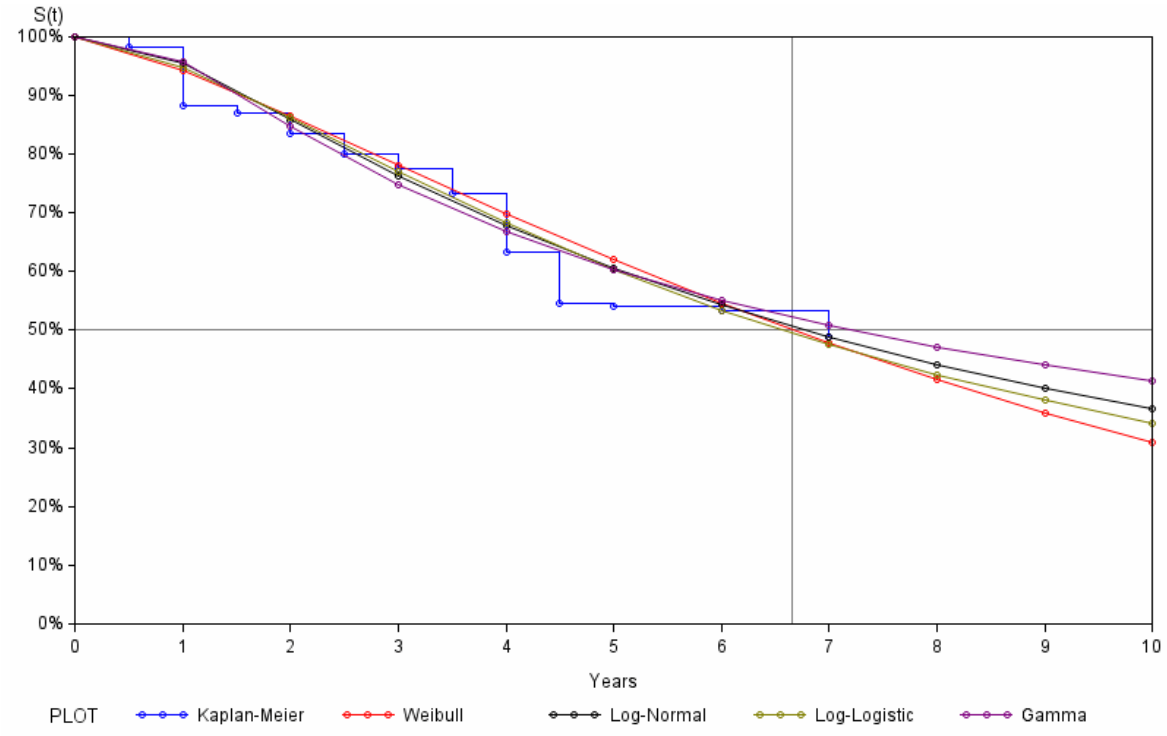


3d. How does your facility/organization determine if it is tracking towards its goals?

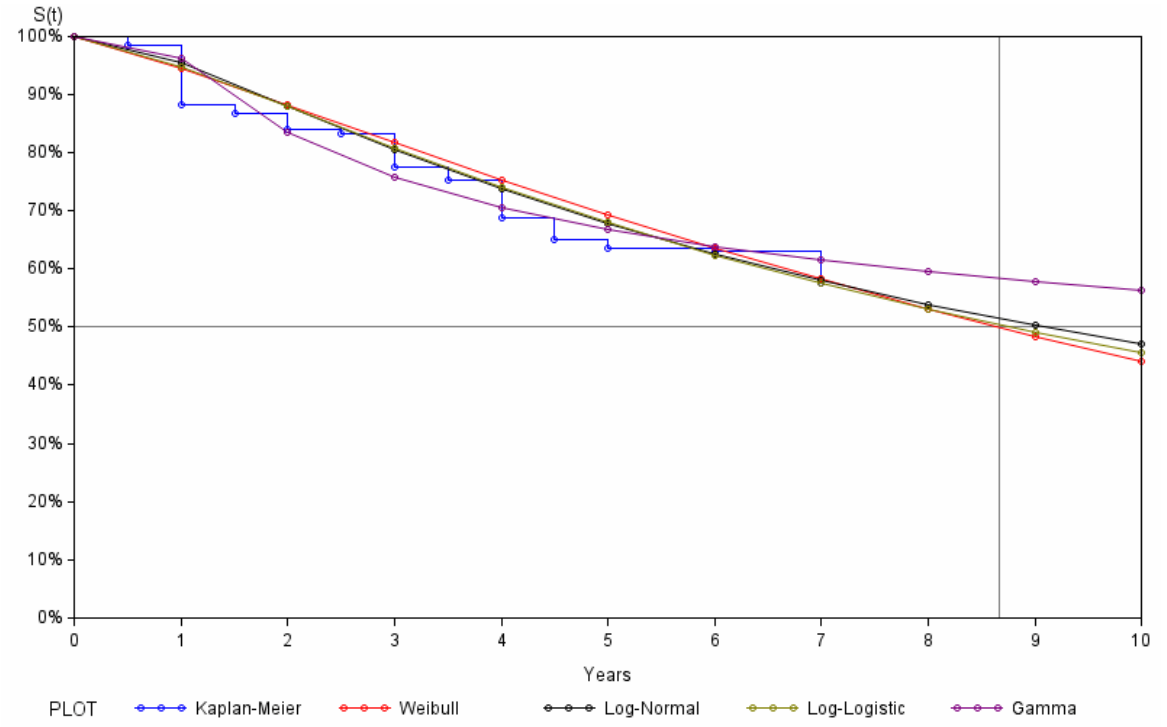


APPENDIX D. ADDITIONAL SURVIVAL ANALYSIS FIGURES

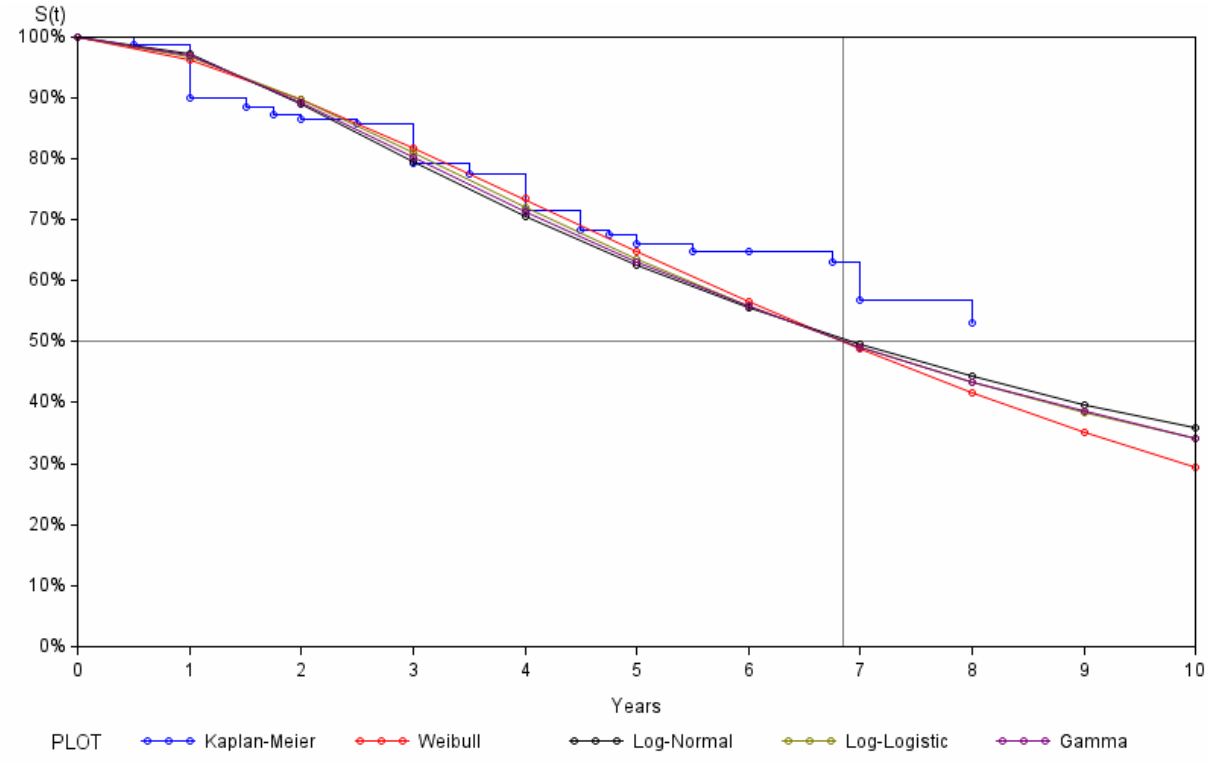
Survival plot: Activity-level, sample-weighted only,



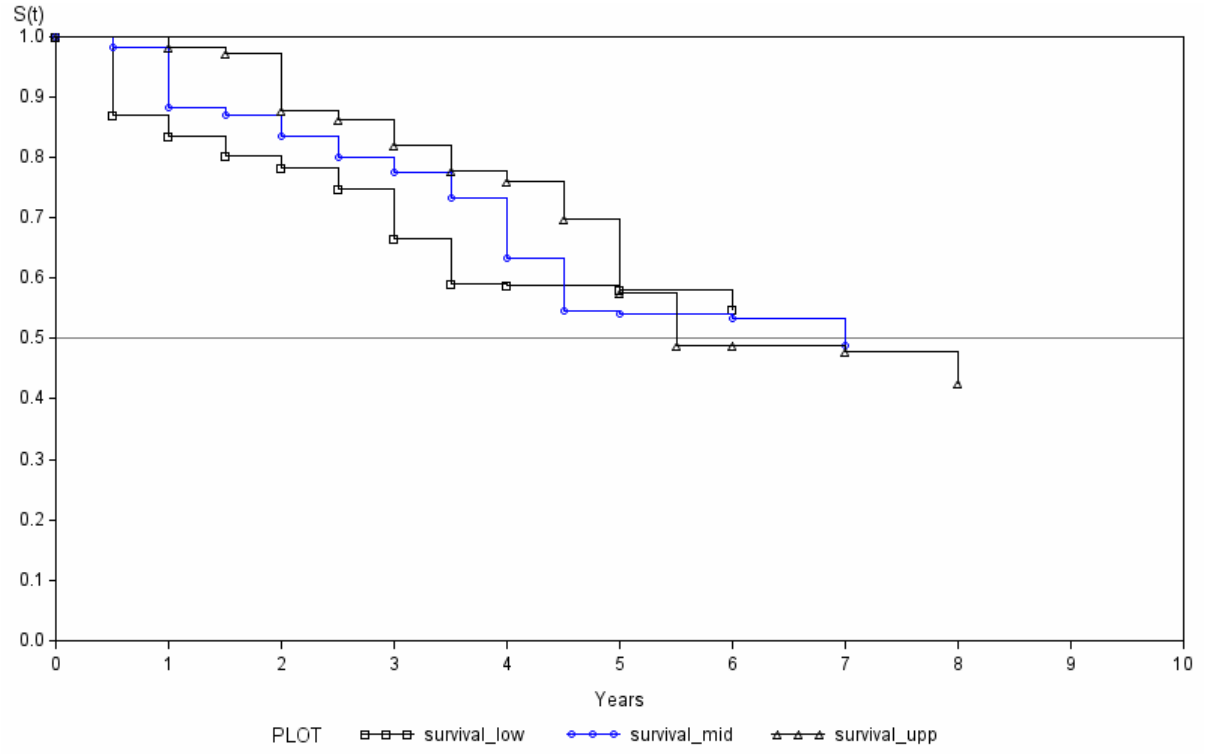
Survival plot: Activity-level, sample- and savings-weighted



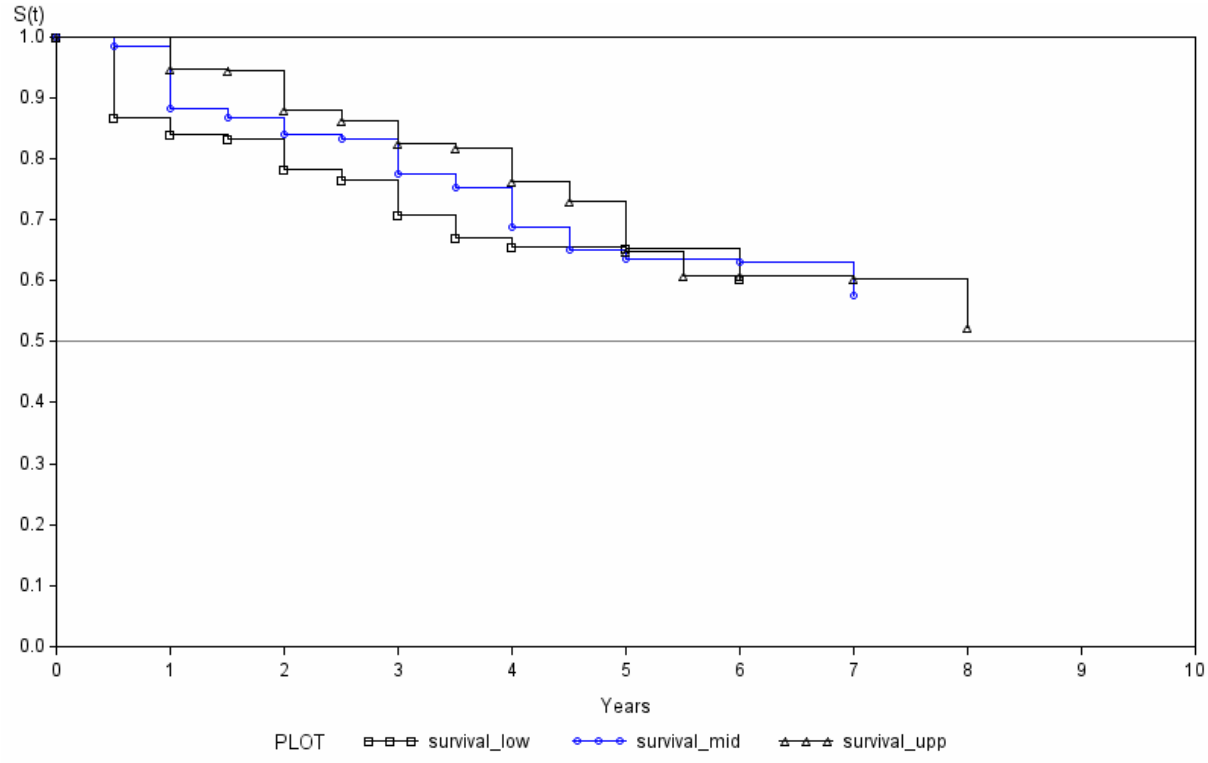
Survival plot: Project-level, sample- and savings-weighted



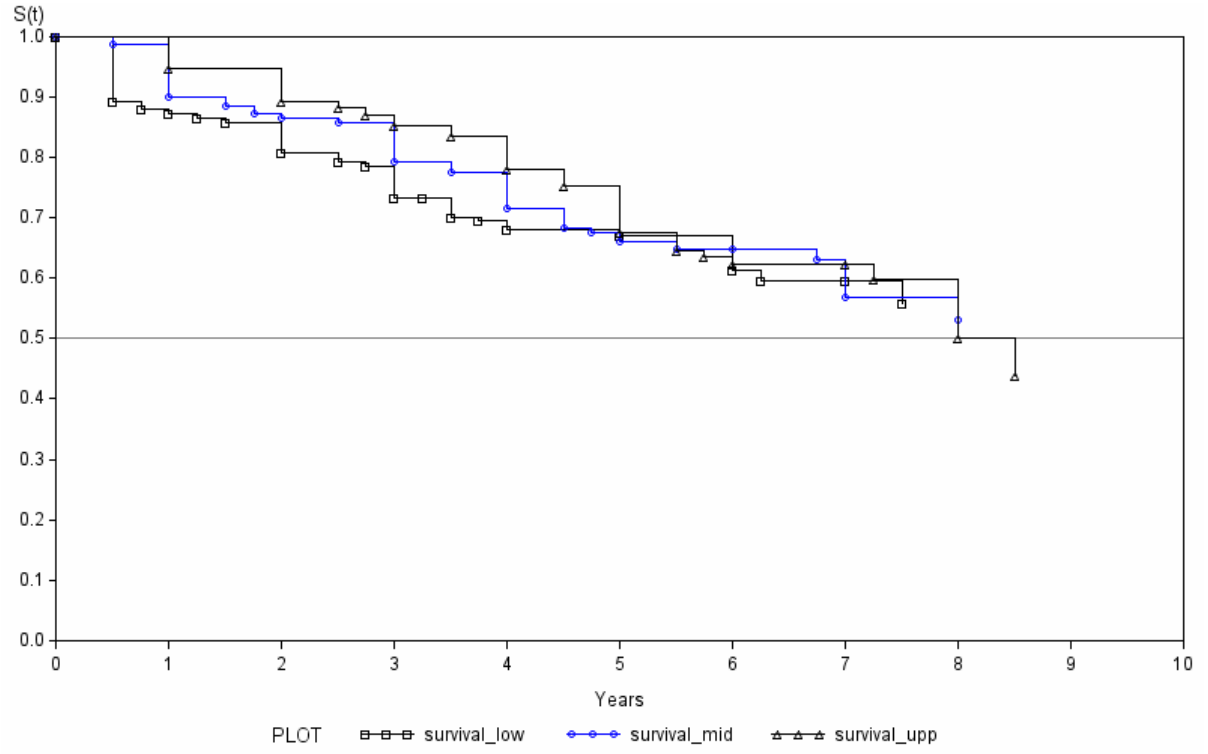
KM survival sensitivity: Activity-level, sample-weighted only,



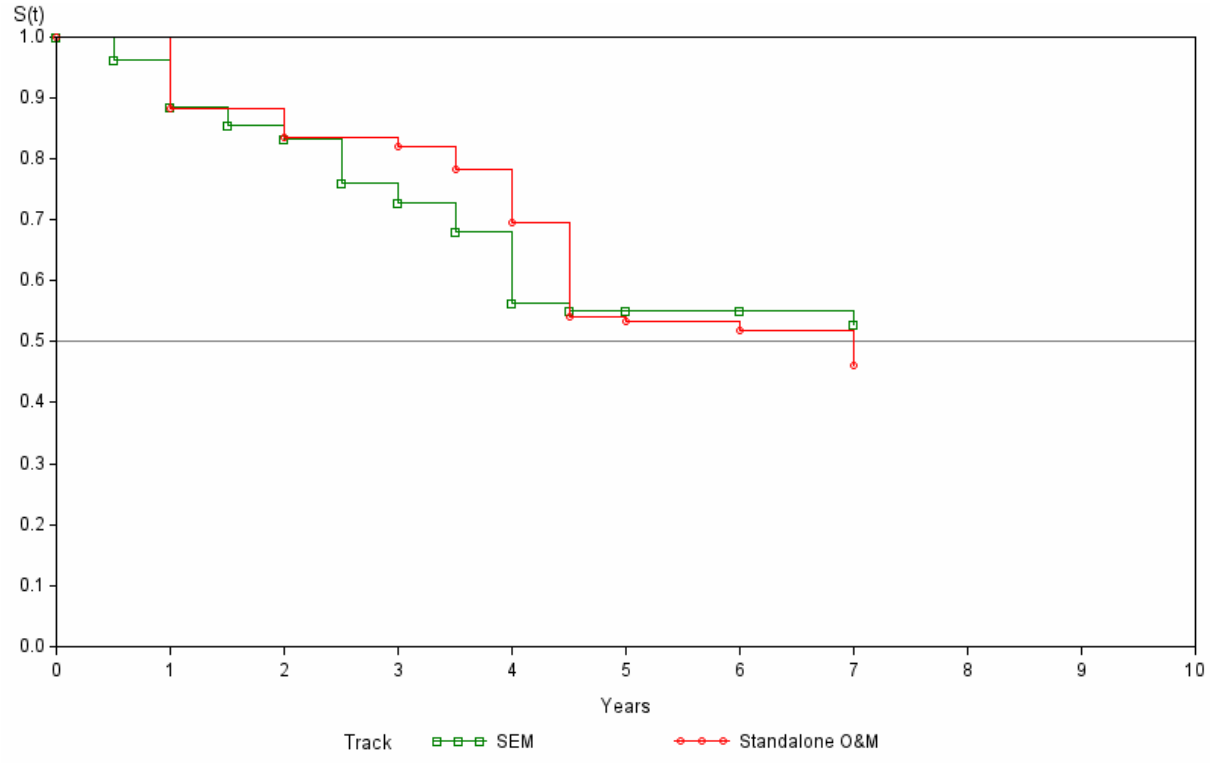
KM survival sensitivity: Activity-level, sample- and savings-weighted



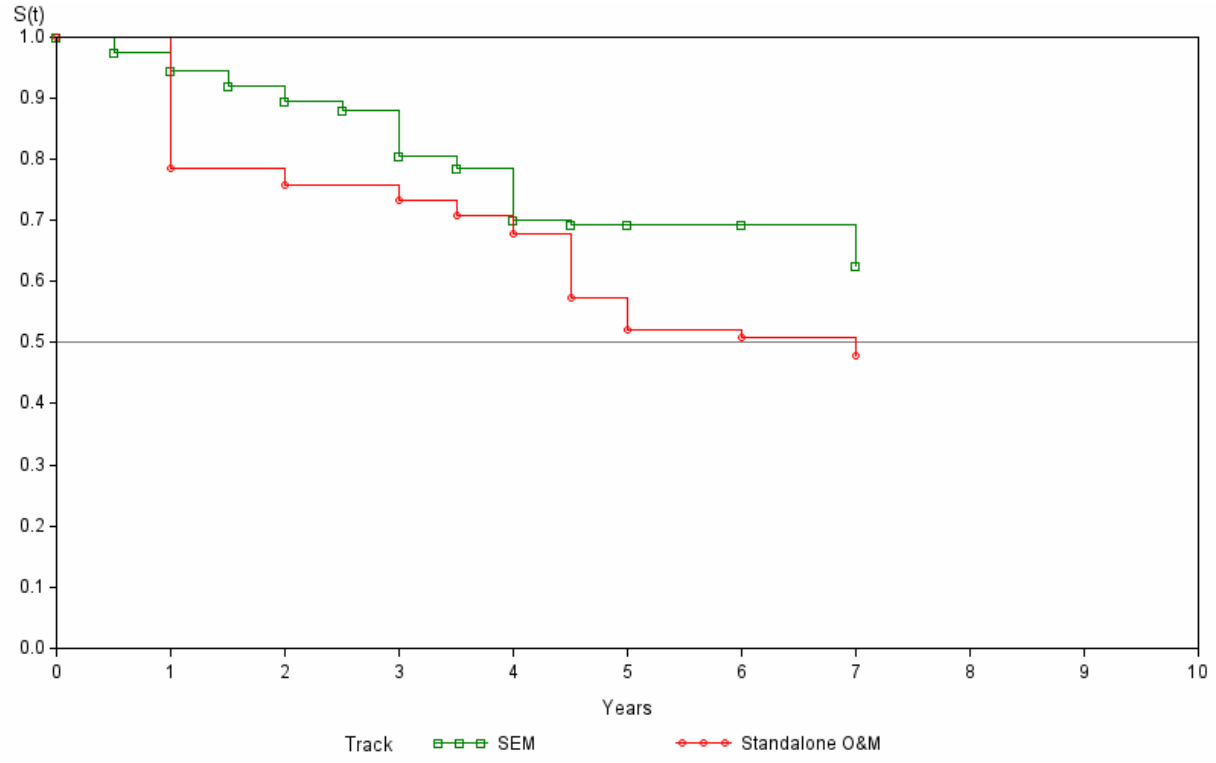
KM survival sensitivity: Project-level, sample- and savings-weighted



Standalone O&M vs. SEM survival curves: Activity-level, sample-weighted only,



Standalone O&M vs. SEM survival curves: Activity-level, sample- and savings-weighted



Standalone O&M vs. SEM survival curves: Project-level, sample- and savings-weighted