ComEd Persistence and EUL Research – Phase 1 Findings

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DRAFT

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Prepared by:

Karen Maoz
Navigant Consulting, Inc.

Lucas Schroyer
Navigant Consulting, Inc.

www.navigant.com

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Submitted to:

ComEd
Three Lincoln Centre
Oakbrook Terrace, IL 60181

Submitted by:

Navigant Consulting, Inc.
150 N. Riverside Plaza, Suite 2100
Chicago, IL 60606

Contact:

Randy Gunn, Managing Director	Jeff Erickson, Director	Josh Arnold
312.583.5714	608.497.2322	608.497.2328
Randy.Gunn@Navigant.com	Jeff.Erickson@Navigant.com	Josh.Arnold@Navigant.com

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1. INTRODUCTION

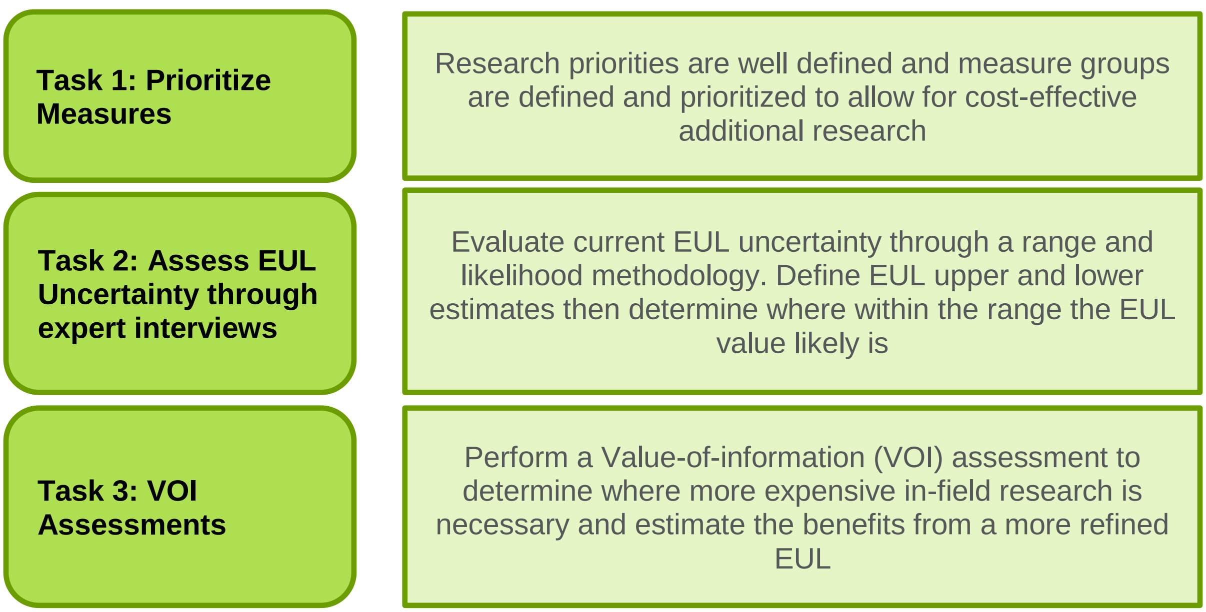
The evaluation research objective is to improve EUL estimates for priority measures that need higher quality EUL data and understanding of persistence. The purpose of this evaluation research is to better quantify the impacts that measure persistence has on measure lifetime savings in a manner consistent with the Illinois Future Energy Jobs Act (FEJA) legislation and the goals set out by this legislation for attaining cumulative persisting annual savings (CPAS) by electric utilities. CPAS goals are new for 2018 programs and CPAS targets are set through the legislation.

The two phases of the EUL research include the work presented in this report and field research. Phase I included reviewing current EUL and persistence estimates of high priority measures to identify Phase I measure categories that may have EULs that significantly differ from their current TRM value. Measures identified in Phase I will inform which EUL impact topics should be examined in subsequent field work in Phase II.

2. APPROACH

This report includes evaluation research findings for Phase I measures. Phase II will be conducted and reported on separately. Three tasks comprised the Phase I effort:

Figure 1. Phase I Tasks – Overview



Source: Navigant

2.1 Methodology

The uncertainty in these EUL values may under or overvalue measure savings over the measures' lifetime and in quantifying CPAS. However, field research for EUL and persistence is costly and may not result in any significant changes to the original values; therefore, this research activity is based on a learning process that builds on and improves existing EUL estimates.

The EUL research is conducted in two phases. This phased approach will help ensure that the evaluation research will be cost effective and produce meaningful results taking into account uncertainty around existing EUL estimates, and a layered approach for improving these estimates. Phase I is the initial analysis to provide inputs to Phase II. These inputs are further refining the measure list, identifying key years for conducting field research, and then providing sufficient data to develop a thoughtful primary data collection plan.

This analysis phase involved tasks that categorize and organize energy efficiency measures based on the completed secondary literature review. Key elements in this Phase I research included:

1. **Prioritize and Categorize Measures for the Evaluation Research Effort.** Research priorities were identified during a kick-off meeting with the ComEd team and stakeholders and measure groups were defined and prioritized to ensure for cost-effective additional research.
2. **Assess Uncertainty via Subject Matter Expert (SME) Surveys.** The uncertainty for current EUL estimates were evaluated and the drivers of this uncertainty were identified. This used a range and likelihood method where upper and lower bounds were determined for EUL estimates; then, additional information was used to determine where within this range the most likely values of the EUL might fall.
3. **VOI Assessments.** Value-of-information assessments will be used to determine where more expensive in-field research is likely to have the most value in terms of providing more reliable estimates of EUL.

This tiered research approach comprises the Phase I effort and helps identify which measures are at risk of having EULs that significantly differ from their current TRM value and will help to identify research hypotheses to be examined in subsequent field work.

2.1.1 Task 1: Prioritize and Categorize Measures for the Evaluation Research Effort

In the secondary research review, the research team identified 42 measures that were flagged for either EUL quantification or persistence research. Out of these 42 measures, the research team removed nine measures due to low savings in PY8, or because they were not included in current or planned ComEd programs. The team placed the remaining 33 measures into recommended research groupings for this study. The team decided to combine measures into measure groups to streamline the research efforts since many of the measures have the same persistence characteristics, SMEs, and potential field research methods. The eight research groupings and 15 measures in Table 1. Initial List of Measure Groups for Evaluation Research
resulted in the list of measures included in this study. Streetlighting was added later and this measure will be included as part of the Phase II work.

Table 1. Initial List of Measure Groups for Evaluation Research

Research Grouping	Sector	End Use	Measure Name
1. AC Tune-up	Commercial	HVAC	AC Tune-up
2. C&I Lighting	Commercial	Lighting	Lighting Controls
			Advanced Lighting Control Systems
			LED Fixtures
			LED Lamps
3. C&I Thermostat/HVAC controls	Commercial	HVAC	Thermostat Adjustment
			Programmable Thermostat
			HVAC Controls
4. Energy Management System	Commercial	Whole Building	Energy Management System
5. Compressed Air	Industrial	Compressed Air	Compressed Air – Leak Repair
6. Res Thermostat	Residential	HVAC	Programmable Thermostats
			Smart Thermostat
7. Residential Lighting	Residential	Lighting	LED Fixtures
			LED Lamps
8. Street Lighting[1]	Other	Lighting	Streetlighting

Source: Navigant

2.1.2 Task 2. Assess Uncertainty Based on Available Literature and Subject Matter Expert (SME) Interviews

Assessing the uncertainty around EUL measure estimates began with a literature review to gain insights into the reasonable ranges for measure EUL estimates; however, this was not necessarily representative of the uncertainty of an EUL. EULs found in literature reviews often turn out to be relatively close to each other. The EUL estimates found to be in use in different jurisdictions may be based on the same few studies resulting in the observed similar estimates. As a result, Navigant conducted a series of subject matter expert (SMEs) interviews to perform an initial assessment of measure EUL uncertainties. Specifically, the goal of these surveys was to develop range and likelihood values, i.e., a high-value/low-value range and some likelihood of where within this range the actual EUL might fall. A copy of the interview guide is in the Appendix - Section **Error! Reference source not found.**.

Navigant recruited SMEs from across the industry to target a diverse set of experiences and opinions. This includes Navigant internal experts, program implementers, industry influencers such as TRM developers or policy makers, standard setting entities (e.g. ENERGY STAR®), installation contractors, and manufacturers.

To understand the uncertainty around these measure EUL estimates costs effectively, Navigant targeted three to six SME experts per measure to gain judgments on low and high EUL values that bracket the current best estimate with estimates of where within this range the true value might fall – i.e., might the true EUL value be greater or less than the current EUL estimate. The SME interviews represent extensive

[1] This was added after the initial list was set. Navigant has not been able to incorporate this measure into the results of Phase I.

industry experience on the technology in question and the use of a range and likelihood estimation process provides considerably more information on the risks of assuming one EUL value as correct, when there may be a high likelihood that another EUL value accurately represents the performance of this technology in the field.

The SME interview results help assess how likely it is for additional field research to produce EULs that are significantly different from the initial estimates. If the consensus is that the current EUL estimate is quite reliable, e.g., a tight range around the existing estimate across the SMEs; then, additional research may not be warranted. In this case, it is the view of the SME group that additional research is not likely to result in a substantively different value (e.g., additional research is unlikely to produce a value that is plus or minus 20% different than the initial estimate).

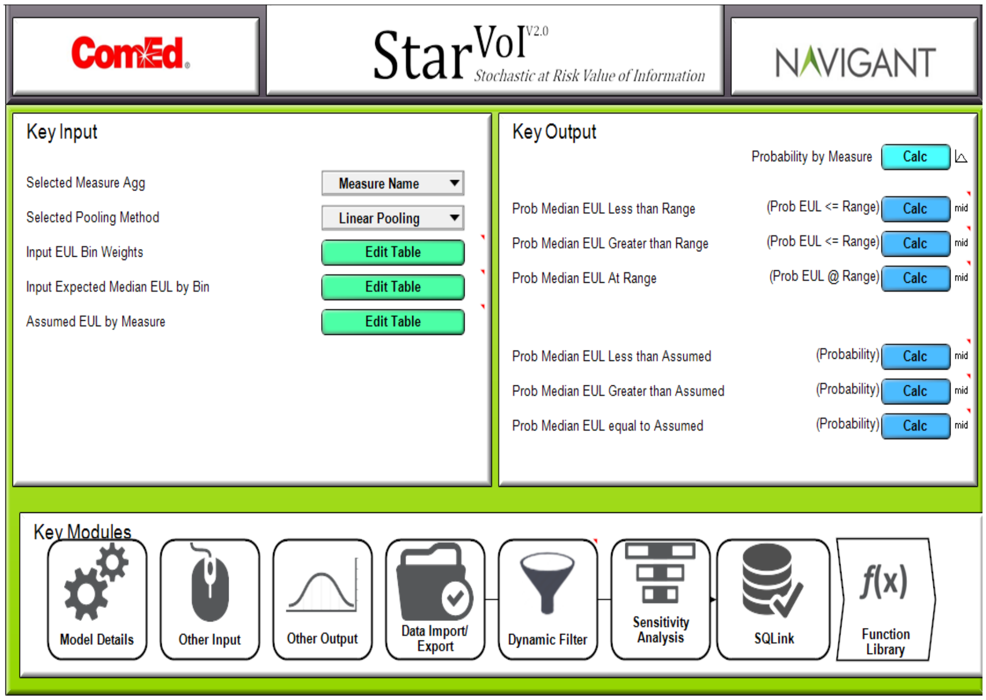
The distribution assessments by measure produces data for the use of value-of-information (VOI) approaches. These approaches are designed to meet the unique challenges of assessing EULs by leveraging initial estimates with different levels of in-field research. These approaches are commonly used when assessing research and development (R&D) priorities across many technical industries; and, Navigant has used the VOI approach in assessing the value of research on uncertain energy efficiency measure values used in cost-effectiveness analyses (e.g., EULs, Net-to-Gross Factors, and avoided costs).[2]

The VOI assessment is a simple approach using the distribution to represent the uncertainty around EUL estimates. This distribution represents the likely outcomes from an in-depth field study that produces more accurate estimates of EULs. EULs that are more uncertain are more likely to have additional field studies produce a result different from the initial EUL estimate. EUL estimates that are viewed as being accurate (i.e., have a tighter distribution) will have a lower probability of having additional research produce a revised EUL that is substantially different than the initial estimate (e.g., over 20% different). Navigant uses Monte Carlo approaches to more thoroughly address the VOI from additional research.

Navigant used the SME EUL range and likelihood data as inputs to Navigant's VOI (Star VOI™) model, which calculates EUL uncertainty across the various ComEd EE measures outlined in Table 1. Initial List of Measure Groups for Evaluation Research
. Figure 2. StAR VOI™ Model
below is a screenshot of the user interface for the Star VOI™ model.

[2] See: Navigant (2015). *Iowa Energy-Efficiency Net-to-Gross Report.* Prepared for the State of Iowa Department of Commerce Utilities Board. Link: https://efs.iowa.gov/cs/groups/external/documents/docket/mdax/mjax/~edisp/1201494.pdf ; and, "Navigant Consulting (2012), "Custom Free Ridership and Participant Spillover Jurisdictional Review," Prepared for the Sub-Committee of the Ontario Technical Evaluation Committee, Ontario, Canada, May. This approach is also addressed as Step 7: "Value of Information" in the Framework for addressing Gross and Net Savings policy decisions -- NEEP (2016). *Gross Savings and Net Savings: Principles and Guidance.* Submitted to the Northeast Energy Efficiency Partnerships: Evaluation, Measurement, and Verification Forum, by Dan Violette (Navigant) and Pam Rathbun (Tetra Tech), April. http://www.neep.org/gross-and-net-savings-principles-and-guidance .

Figure 2. StAR VOI™ Model



Source: Navigant

The following outlines the steps for the VOI analysis[3]:

Figure 3. EUL VOI Analysis Steps

Step 1: Import the Range and Likelihood Data	Import the Assumed EUL value (currently used in ComEd's EE programs) and the SME interviews dimensioning the EUL ranges and likelihood values.
Step 2: Generate Probability Distributions by Measure Observation	Use the data obtained from each individual SME to develop overall distributions for the range and likelihood values for EULs for each measure addressed.
Step 3: Uncertainty Analysis	Using the aggregated distribution curves by measure, determine if a measure's actual EUL is likely to be higher, lower, or similar to the currently assumed EUL

Source: Navigant

[3] See Appendix section **Error! Reference source not found.** for a detailed discussion of the VOI calculation methodology

Navigant originally planned to do a two-tier analysis of the EUL data but decided to only include the results of the first tier. The tier 1 uncertainty analysis illustrates the probability that a measure's EUL is different than the assumed value (Step 3 in Figure 3. EUL VOI Analysis Steps
).

The outcome from the VOI steps is a set of research priorities based on the likelihood that the evaluation research will, in fact, produce revised EUL estimates (i.e., the risks of assuming the current EUL value are high in terms of likelihood that research would produce corrected estimated EULs). The value of the evaluation research is based on the estimated difference (probability of uncertainty) in overall program savings using the initial EUL compared to a more accurate research-based EUL.[4]

3. Results

Navigant presents the findings based on the order of the analysis to further illustrate how this approach is based on the concept that it is a learning process and each layer provides more data and information to validate further research or not (except task 4 which defines additional research parameters to understand what effects the EUL). Therefore, the results are presented with SME interview findings and the modeling analysis VOI findings.

3.1 SME Interview Findings

Navigant targeted three to six interviews per measure. SMEs were recruited as indicated in the methodology section; however, the approach was to recruit SMEs from across the industry representing diverse experience and knowledge. Candidate SMEs included Navigant internal experts, program implementers, industry influencers such as TRM developers or policy makers, standard setting entities (e.g. ENERGY STAR®), installation contractors, and manufacturers. Navigant believes these interviews provide an appropriate range of views across a variety of measure applications.

The SME interviews went well with interview participants. Navigant found that the SMEs understood the process and were able to answer survey range and likelihood questions. This was particularly true for SMEs that had some familiarity with EE programs. In a few cases, there were some questions regarding the definition of measure EULs and how it differed from technical life (e.g. the rated hours of a LED vs the lamp EUL). This occurred primarily among manufacturers. Rather than push to get range and likelihood estimates from respondents that may not understand the EUL concept being addressed, these interviews focused on gaining insights into factors that might influence measure persistence characteristics.

Navigant completed 49 range and likelihood EUL assessments with 14 coming from internal Navigant experts and 35 from external experts. **Error! Reference source not found.** shows the number of completed EUL assessments by measure and details the current program EUL and lowest and highest EUL bound captured from the interviews as described in section 0. The full SME responses are listed in the Appendix, section Appendix D.

[4] This can be further refined by examining the difference in life-cycle measure benefits assessed using cost-effectiveness modeling based on the initial EUL versus a revised research-based EUL. EUL research efforts are prioritized based on the value of conducting additional field research versus the costs incurred by the research.

Table 2. SME Interview Summary

Measure	Number of SME Interviews Completed	Lowest EUL Value	Current EUL Value	Highest EUL Value
AC Tune-up	4	<1 year	3	10
Advanced Lighting Control Systems	3	5	8	20
Compressed Air Leak Repair*	3	1	3	10
Energy Management System	2	1	15	20
HVAC Controls	3	5	15	30
Lighting Controls	3	1	8	22
Smart Thermostat	4	1	11	15
Thermostat Adjustment	3	<1 year	2	8
Programmable Thermostat (Com)	3	1	10	20
Programmable Thermostat (Res)	3	1	8	20
LED Fixtures (Com)	4	2	15	25
LED Lamps (Com)	4	<1 year	15	25
LED Fixtures (Res)	4	3	15	20
LED Lamps (Res)	4	1	10	>30 years

Source: Navigant

The key takeaways regarding measure EULs are based on both the range and likelihood data, as well as discussions regarding factors that might influence EUL. These are summarized for each measure below:

3.1.1.1 AC-Tune up

- A site's pre-existing HVAC practices can significantly impact the measure's EUL, (i.e. site-specific maintenance schedules may vary significantly).
- Maintenance issues occur more frequently (e.g. every few years) than repair related issues. For example, coil cleaning should occur every other year however these maintenance issues may not cause the measure's savings to significantly drop until issues begin to stack.

3.1.1.2 Advanced Lighting Control Systems

- These technologies are very new and as such there is a lot of uncertainty in evaluating the EUL.
- Lighting controls should be installed at the time of a lighting retrofit.
- Lighting controls don't fail in the same way that lighting products fail. Software incompatibility or the market demand for new features that require a hardware update drives the technologies replacement.

- Building managers who continue to monitor the effectiveness of the control system is essential to ensure the system remains tuned and the savings persist, however, the advanced control system savings likely will never significantly drop (i.e. below 50% compared to the base year savings) before the technology is removed or replaced for other reasons. These systems are expensive, so they are usually maintained.

3.1.1.3 Compressed Air Leak Repair

- Maintenance schedules and the skill of the technician are critical. If there is little maintenance, then small failures can stack and eventually cause the savings to significantly degrade.
- Having the education and right tools to routinely (continuous monitoring) maintain leaks are more significant.
- Leaks are progressive and endemic. A small leak can persist for a long time until it grows and becomes noticeable and is repaired in-house or via a contracted auditor or repair firm. That one leak may be permanently fixed, but there is a whole continuum of new leaks growing for the future.

3.1.1.4 Custom HVAC Controls

- The EUL upper limit of these HVAC controls is tied to the life of the controlled equipment (e.g. VFDs, CO2 sensors, etc.).
- There is a risk that facilities will bypass the controls if the space conditioning needs are not met.
- Properly trained technicians and experienced installers are necessary to ensure proper tuning (e.g. the sensors are working and DCV are properly set).

3.1.1.5 Energy Management Systems

- The savings for EMS are robust. New systems alert management if settings have been changed that impact energy, the ability to reset, tracks historic consumption.
- Maintaining the settings is critical to ensure the persistence of savings (EMS settings can be adjusted as quickly as every few months).
- Knowledge transfer and training for any new facility managers or owners is critical. Otherwise tenant and staff turnover may impact the EUL. If a building engineer doesn't understand, they might turn off a system at two to three years. Systems may need to be recalibrated well before the upper EUL limit (i.e. carbon monoxide sensors are required to calibrate twice a year). Generally, the technology lasts for a long time but savings persistence can be tied to the equipment life or performance.
- Savings persists well until about year five. If a site has highly trained staff, savings persist in a linear fashion until year 10. At that point, end uses are operated manually for the most part.

3.1.1.6 LED Fixtures

- Residential and commercial LED fixture EUL and performance are similar.
- Higher switch rates (i.e. the frequency with which a light is turned on and off) can significantly drop the LED fixture EUL.

- Installation practices might have a slight impact on EUL due to compatibility issues. Inexperienced or lower quality installers may install lamps that are not dimmer compatible, which may cause both the lamp and fixture life to decrease.

3.1.1.7 LED Lamps[5]

- ENERGY STAR® let in lower life products two years ago and so manufacturers now provide lamps with lower rated lifetimes.
- There is a lot of uncertainty around LED lamp EULs as they are very dependent on building type and installation application (e.g. switch rates, lamp temperature, operating hours, remodeling practices). In commercial facilities, new tenants are likely to retrofit the lighting.
- Installation practices likely have little impact in residential applications as these lamps are fairly easy to install, however they might have more of an impact in commercial applications, particularly for linear lamps (i.e. energy service companies (ESCOs) might install incompatible LED tube lamps with switching vs dimming ballasts).
- LED lamp operating hours have huge impacts on EUL. LED lamps operating nonstop might see their LEDs last only a few years. Commercial LED lamps seldom reach the assumed value of 15 years.

3.1.1.8 Lighting Controls

- Outdoor sensors (i.e. photocells) would have a significantly lower lifetime than indoor controls and sensors.
- These controls do not have hard failure like a switch or a relay does. It can be difficult to understand when the technology is no longer operating and providing savings.
- If the lighting controls are installed incorrectly, the user ends up not using them very quickly or if the system is not commissioned properly then the savings will quickly degrade.
- If controllers are wireless, then their lifetime may be limited if batteries are not routinely replaced.
- The fixture will likely become obsolete or burn out before the controls do.

3.1.1.9 Programmable Thermostats[6]

- Changing schedules or default settings is the biggest driver for savings degradation. In commercial spaces, occupants who are not aware of the facilities energy usage or are not responsible for the energy bills might be the ones who change the thermostats settings. Changes to operating hours, operating conditions, residents or occupants, and remodeling of the space might drive a user to change or not follow the initial schedule
- Changing of occupants or facilities' hours requires recalibration of thermostats.
- The EUL for programmable thermostats is often limited by the lifetime of the equipment it controls. Thermostats are often replaced when new HVAC equipment is installed. Even though

[5] Will these measures continue to be included in ComEd's EE portfolio after the Energy Independence and Security (EISA) Act 2020 Federal Light Bulb Efficiency Standard impacts?

[6] California technical forum is looking into thermostat EUL updates with results pending.

the thermostat can last for 10 years, this is very unlikely as the savings will degrade or the thermostat will be removed.

3.1.1.10 Smart Thermostats

- Smart thermostats have not been in the market for very long. Does a thermostat's savings or EUL differ between early adopters compared to recent or future users? Early adopters have had their thermostats for eight to nine years at this point so the upper end of the EUL is still largely unknown.
- Although the technology persists for a long time, these thermostats will likely be replaced as newer models with added features come out. Thermostats might also be replaced as HVAC equipment is replaced.
- Tenant usage of the thermostat may stop within a year if they are unhappy with the conditioning of their space.
- Qualified installers would be able to commission a thermostat more effectively than a homeowner could (e.g. compatibility issues exist with the existing HVAC).

3.1.1.11 Thermostat Adjustment[7]

- No specific comment to reference, except that it may not be considered any different than the other thermostat measures.

3.2 VOI Findings

Navigant decided to use a plus or minus- 20% bound around the current assumed EUL values used in ComEd's energy efficiency (EE) programs (shown in
Table 3. Range of EUL within +/- 20% of Assumed Value for Each Measures
) to determine whether a measure was at risk of overestimating or underestimating the EUL. If the results from the VOI assessment suggest that a measure's EUL value is within the range, then there is no need for further research. If the VOI shows that the likely actual value based on the range and likelihood data is outside of this range, then the assumed EUL value used in ComEd's EE programs may need to be updated or further research may be warranted to determine if a more accurate EUL number should be used.

The details of the statistical analysis are provided in the Appendix, section **Error! Reference source not found.**.

[7] It's unclear what the future of this measure in the context of future smart thermostat programs.

Table 3. Range of EUL within +/- 20% of Assumed Value for Each Measures

Measure Name	Assumed EUL (years)	EUL Bounds used for uncertainty assessment	
		Lower Bound (-20%)	Upper Bound (+20%)
AC Tune-up	3	2.4	3.6
Advanced Lighting Control Systems	8	6.4	9.6
Compressed air - Leak Repair	3	2.4	3.6
Custom HVAC Controls	15	12	18
Energy Management System	15	12	18
LED Fixtures (Com)	15	12	18
LED Fixtures (Res)	15	12	18
LED Lamps (Com)	15	12	18
LED Lamps (Res)	10	8	12
Lighting Controls	8	6.4	9.6
Programmable Thermostats (Com)	10	8	12
Smart Thermostats	11	8.8	13.2
Thermostat Adjustment	2	1.6	2.4
Programmable Thermostats (Res)	8	6.4	9.6

Source: Navigant

Table 4. Probability the Measure EUL is Higher or Lower than the Assumed EUL
shows how likely a measure is to either be higher or lower than the assumed EUL's bounds (i.e. the probability that the EUL is outside the plus or minus 20% bounds). If the measure lower and upper bound probability is less than ±50%, then the EUL is considered sufficiently accurate. Measures that have over a 50% probability, marked in green and orange, of being higher or lower, respectively, than the bounds were identified as potentially being at risk of having an incorrect EUL, while measures that have over a 75% probability, marked in red, were identified as needing additional EUL research or updating the assumed value. Advanced lighting controls, compressed air – leak repair, and commercial thermostat adjustment measures are likely to have EUL values that are higher than the assumed value, representing unclaimed lifetime savings for ComEd's EE portfolio. Commercial programmable thermostats and residential smart thermostats have over a 50% likelihood that their EULs are less than the low range of the assumed value. HVAC controls, LED fixtures, and LED commercial lamps are very likely (>75% probability) of being less than the low range of the assumed value.

Table 4. Probability the Measure EUL is Higher or Lower than the Assumed EUL

Measure Name	Currently Assumed EUL	EUL +/- 20% Bounds	Probability EUL is Less than Lower Bound	Probability EUL is Greater than Upper Bound	Energy Savings Impact Level[8]	EUL Uncertainty Assessment findings
AC Tune-up	3	2.4 - 3.6	48%	29%	3	Accurate
Advanced Lighting Control Systems	8	6.4 - 9.6	2%	77%	3	Likely too low
Compressed air - Leak Repair	3	2.4 - 3.6	17%	60%	2	Might be low
Custom HVAC Controls	15	12 - 18	81%	1%	3	Likely too high
Energy Management System	15	12 - 18	45%	22%	2	Accurate
LED Fixtures (Com)	15	12 - 18	77%	4%	1	Likely too high
LED Fixtures (Res)	15	12 - 18	73%	3%	1	Likely too high
LED Lamps (Com)	15	12 - 18	87%	3%	1	Likely too high
LED Lamps (Res)	10	8 - 12	43%	28%	1	Accurate
Lighting Controls	8	6.4 - 9.6	40%	32%	2	Accurate
Programmable Thermostats (Com)	10	8 - 12	63%	20%	2	Might be too high
Smart Thermostats	11	8.8 - 13.2	62%	1%	3	Likely too high
Thermostat Adjustment	2	1.6 - 2.4	20%	62%	2	Might be low
Programmable Thermostats (Res)	8	6.4 - 9.6	29%	32%	3	Accurate

Source: Navigant

4. Recommendations

Table 5. Research Recommendations Based on Uncertainty Assessment
Error! Reference source not found. outlines Navigant's recommended next steps based on Phase I evaluation research findings.

Recommendation 1. ComEd's current assumed EULs are likely to be a good approximation for:

- AC Tune-up
- Energy Management Systems

[8] The Energy Savings Impact Level illustrates which measures make up either a large, medium, or small amount of the PY2017 portfolio savings, an indicator of historical significance which may reflect forward looking savings. A rank of 3 indicates a measure that contribute less than 1% of the total kWh savings by customer class. A rank of 2 is for measures that make up less than 5% and a rank of 1 is for measures that contribute a large portion (>5%) of the PY 2017 kWh portfolio savings.

- Lighting controls
- Programmable thermostats - residential
- LED lamps - residential

Recommendation 2. However, the assumed EUL values for the following measures have a percent probability of being ±50% more than the current EUL values:

- **Programmable thermostat – commercial.** If ComEd continues to offer programmable thermostat related measures, then field research may lead to a better understanding of whether the savings for these thermostat measures persist in different applications.
- **LED fixtures and lamp – commercial.** EULs are very likely to be less than the assumed values. The impending EISA federal baseline standard update will significantly reduce the savings from LED lamp measures. Navigant proposes to conduct research if LED measures, in particular LED fixtures, will continue to be a significant focus for ComEd's EE programs.
- **Compressed air – leak repair.** The EUL for this measure is likely to be low. Additional field research may reveal that savings persist beyond the assumed value. ComEd should consider researching other compressed air measures simultaneously to cost-effectively understand the EUL of multiple measures at once.
- **HVAC controls, advanced lighting controls, smart thermostats.** These are all fairly new technologies and any field research should not be conducted until later years when these technologies have matured and research can target critical years for these. Even though HVAC controls may not be as new as the other two technologies, one of the questions associated with this measure that is similar to the other three is that the lifetime of these technologies are limited due to the lifetime of the associated HVAC or lighting equipment and the replacement of the controls with newer models when the controlled equipment is replaced (i.e. SME's believe smart thermostats won't last longer than 10 years).

Table 5. Research Recommendations Based on Uncertainty Assessment

Measure Name	Next Steps
AC Tune-up	No future research recommended
Advanced Lighting Control Systems	Possible future research; nascent technology
Compressed air - Leak Repair	Propose research, but consider aggregating with other compressed air measures for research cost efficiency
Custom HVAC Controls	Propose research, EULs are likely too high due to the HVAC controls performance and continued operation is tied to linked systems and the RUL of controlled equipment.
Energy Management System	No future research recommended
LED Fixtures (Com)	Propose research BUT first check planned research in other jurisdictions; consider tabling lamps due to pending standard change
LED Fixtures (Res)	"
LED Lamps (Com)	"
LED Lamps (Res)	No future research recommended
Lighting Controls	No future research recommended
Programmable Thermostats (Com)	Is this a viable future measure or transitioning to Smart Tstat/HVAC controller?
Smart Thermostats	Combine with existing Smart Tstat research; consider for future research since nascent technology, not installed long enough[9]
Thermostat Adjustment	Is this viable future measure or transitioning to Smart Tstat?
Programmable Thermostats (Res)	Is this viable future measure or transitioning to Smart Tstat?

Source: Navigant

Please note that the request to include streetlighting (a ComEd priority measure for EUL research) came in after Navigant began the interviews. Navigant plans to include streetlighting Phase 1 research in early 2019. As part of the next steps, Navigant will conduct field studies (either survey-based or site visits) to produce survival curves for the measures and a structural persistence assessment. This would be a structural engineering-based assessment to examine which persistence characteristics significantly impact which measure EUL in different situations and at what time periods.

[9] May consider initial research year over year to develop a survival curve analysis that will feed into a final assessed value.

5. Future Tasks – Phase II: Field Work

Phase II involves the field work that will be performed for those high priority measures that are also determined to have a high VOI relative to the cost of the evaluation research. A high VOI occurs when a measure that is viewed as being uncertain based on the analyses in Phase I, and a field study can be designed to produce updated EUL estimates that are viewed as reliable; i.e., it is a better estimate than what is currently available.

Therefore, as a result of the Phase I research, Navigant recommends conducting Phase II research for the following measures in 2019 and beyond:

- Smart Thermostats
- Thermostat Adjustment and Programmable Thermostats (if these are viable future measures)
- LED lamps and fixtures (if these measures will still be included after the Energy Independence and Security Act 2020 Federal Light Bulb Efficiency Standard impacts)
- Compressed Air – leak repair (consider also researching other compressed air measures at the same time)

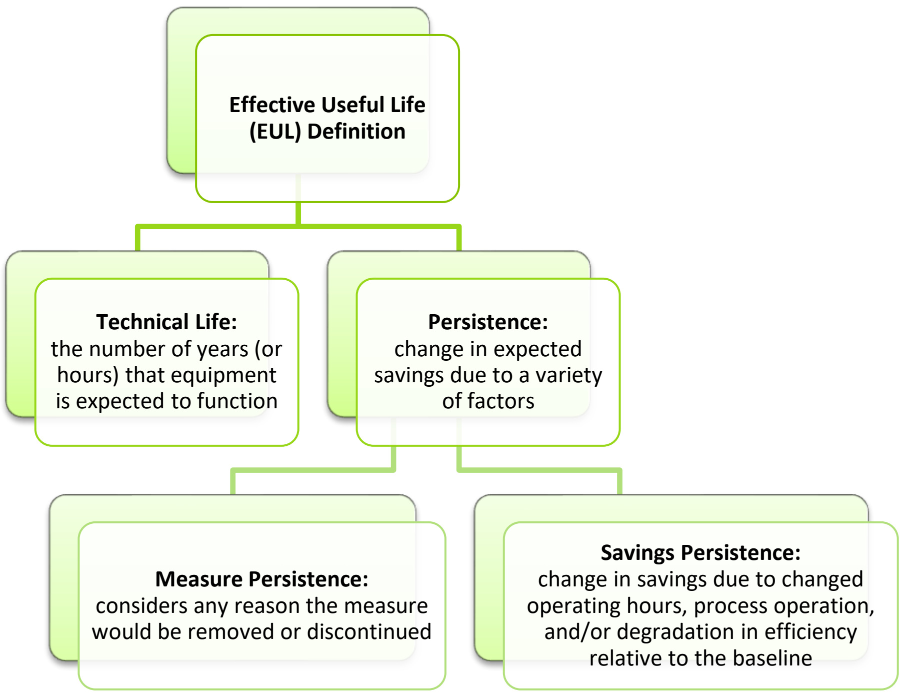
Navigant proposes delaying research for advanced lighting controls (consider researching normal lighting controls at the same time for efficiency purposes) until more is understood about the technology or the market matures.

The Phase II work will be comprised of four tasks addressed in the proposed Phase II Evaluation Research Plan (and in the appendix). Field research will be tiered such that initial research will be conducted on small samples that can produce information to assess the consistency of the initial EUL estimate against the initially collected field data. For those measure EULs where the field data shows that the initial estimate is not consistent with the small-sample field data, a larger, more in-depth survey will be conducted. As much as possible, the EUL research team will coordinate with other field work efforts to minimize customers impacted by research work and to have cost efficient budgets.

APPENDIX A. BACKGROUND

This research is designed to estimate EUL values that take into consideration its full definition, shown in Figure A-1. . Previous research for ComEd has made use of the best available literature to update technical resource manual (TRM) EUL estimates for 2018. The literature available on EULs is not complete and sources are not fully documented. As a result, it is important to conduct research on EULs for measures that are key components of ComEd programs.

Figure A-1. Defining EUL[10]



Source: Uniform Methods Project

Overall Study Goal

Navigant recently completed a thorough review of all the TRM and non-TRM measures and programs that ComEd has in its portfolio of programs. The review found that most EUL data is not supported by rigorous research. As part of that work, Navigant prioritized measures to research further for more accurate assessment of their EULs. These measures were selected since they have potential high impact to future portfolio savings and have poor quality sources for their EUL.

The evaluation research objective is to improve EUL estimates for the identified priority measures from the completed review that need higher quality EUL data and understanding of persistence. This research will allow for increased accuracy in the CPAS calculations as required by FEJA.

The overall project initiative (Phase I, presented here, and Phase 2, field research) will seek to answer the following key questions:

[10] Violette, Dan M., Uniform Methods Project - Uniform Methods Project (Uniform Methods Project: Methods for Determining EE Savings for Specific Measures. Ch. 13: Assessing Persistence and Other Evaluation Issues Cross-Cutting Protocols, 2013.

- What are the best estimates of EULs available from a practical cost-effective research agenda?
- Can significant persistence characteristics that impact measure EULs be identified to improve estimates and provide feedback into program planning and design?
- If there is quantifiable persistence, what is it and how does it vary through the measure's technical life?

APPENDIX B. INTERVIEW GUIDE

The following sections served as an interview guide to help capture the necessary EUL information to inform Navigant's Value of Information (VOI) model and help prioritize subsequent field collection efforts. Italic text provides instructions and background for the interviewer while normal text in quotes are questions for the interviewee to answer.

Project and Interviewee Background

Project Background:

- "The objective is to improve effective useful life (EUL) estimates for the selected measures that need higher quality EUL data and understanding of persistence to determine the following":
  - "The range of measure lifetimes observed in the market"
  - "The impacts that installation, behavioral, maintenance schedules, occupancy changes & conditions, and other persistence issues"
- "Measure EUL takes into consideration both the technical life and persistence"
  - "Technical life is number of years/hours equipment is expected to function"
  - "Persistence characteristic is the amount of change in savings as calculated for the first year. Ideally, we would have a year over year persistence characteristic."
- "The EUL is typically defined as the year in which 50% of the equipment savings have degraded compared to the base year savings. Persistence is the change in expected savings due to changes such as measure removal/discontinuation or changes in savings due to changed operating hours, process operation, degradation in efficiency, etc."

Interviewee Background:

- "Can you provide a brief description of your background with ____ (list measure group) measures?"

Measure Persistence Overview

Review the following table with the interviewee to the ensure they have a clear understanding of measure persistence and to stress that Navigant is trying to capture EUL/persistence impact data and not just manufacturing rated life or technical lifetime data. If there is a possibility to screen share, copy-paste this table to a blank document and show to the interviewee.

Table B-1. Persistence Impact Characteristics

Characteristic	Description
Program delivery method	Measures directly installed may last longer than measures delivered via mail for self-install, because self-installers may be less skilled and may not install according to manufacturer expectations, such as appropriate placement
Installation practices	Does the installation adhere to equipment manufacturer requirements for the class of equipment and comply with the product warranties? Adjustments may be needed to lifetimes originally estimated if they assumed practices not consistent with likely installation practices
Sizing and rating	Is the equipment sized and rated for the likely operating schedules and duty cycles, and are these consistent with the manufacturer's recommendations and warranty? Over and under sizing the equipment can change the lifetime of the measure
Maintenance	Is maintenance performed in a fashion that is consistent with the manufacturer requirements or best practices for the equipment and its associated controls or measure components? Is maintenance likely to be performed over the life of the measure? Deferred maintenance can decrease the lifetime
Region or climate zone	Region or climate may affect measure lifetime in many ways. For example, differences in climate zones may lead to changes in loading on the affected equipment
Operating conditions and practices	Adjustment to lifetime might be needed if operating conditions are "dirtier" than manufacturer recommendations or on/off switching occurs frequently
Occupancy Changes	Changes in occupancy, such as those caused by business turnover, may change lifetime. For example, measure lifetime estimated for all commercial applications may not be appropriate if the measure applies only to one sector, such as restaurants, where ownership and occupancy changes frequently
Remodeling practices	The lifetime should account for removal of the measure due to remodeling prior to its expected physical failure

Source: Regional Technical Forum

Value of Information Model: Interview Collection

The following bullet points serve as a guide to help capture measure EUL ranges and probabilities to help inform the VOI model.

- *Determine lower and upper bounds:*
    - "If you came across an EUL study for this measure was ____, what is the lowest EUL value you would expect to see before you became skeptical? What about the highest EUL?"
- *Repeat this process for every measure the interviewee has expertise on*
- *Split the EUL range into thirds. Ask the interviewee to rank these bins based on their probability that the EUL will fall into that range.*
    - ("if I had to quantify where the majority of measures lifetime in industry are …")

Field Work Prioritization: Interview Collection

The following bullet points serve as a guide to help better understand the impact measure persistence may have and to help prioritize later field EUL data collection efforts

- Our second goal of this interview is to refine our research approach for target measures and get a better understanding of the impact that persistence may have on a measure EUL across a measures lifetime and for different building types”
- *Identify how our persistence characteristics affect the EUL of C&I lighting measures*
  - *Record answers on a scale from 0-2 with 0 representing little EUL potential impact and 2 representing significant impact*
  - “Which persistence characteristics are applicable?”
- “Are there critical time frames in a measure life in which these characteristics have a large impact? Any variation of persistence impact by building type?”
  - “E.g. what can be learned in year 5 for a measure with an 8-year EUL?”
  - “E.g. Do certain building types reconfigure their controls after 1 year, 5 years, etc.?”
- “What suggestions would you have for field visits/customer survey data collection? What persistence characteristics have little to no information?”
- “Which areas could really benefit from additional research if we had to prioritize?”

Follow-up

The following bullet points will help Navigant identify other EUL experts and data sources

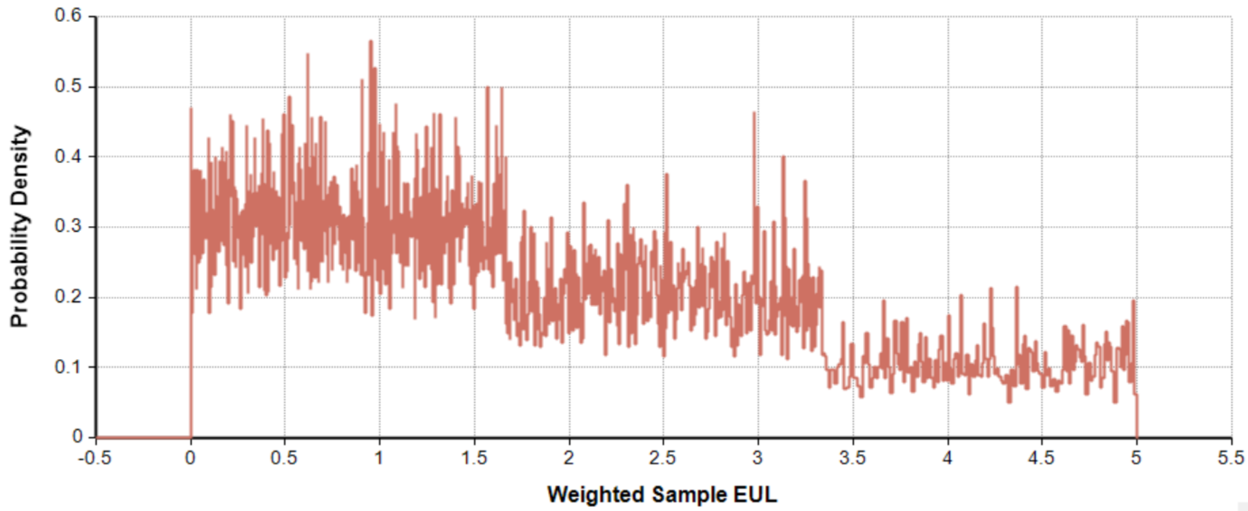
- “We are hoping to interview experts from a variety of perspectives (DOE labs, manufacturers, efficiency associations, evaluators, etc.). Do you have any contacts you could share with us for any of the above measures?
- “Do you have any recommended literature sources to gain more insight into how the persistence characteristics affect measure life?”

VOI METHODOLOGY – EXPANDED

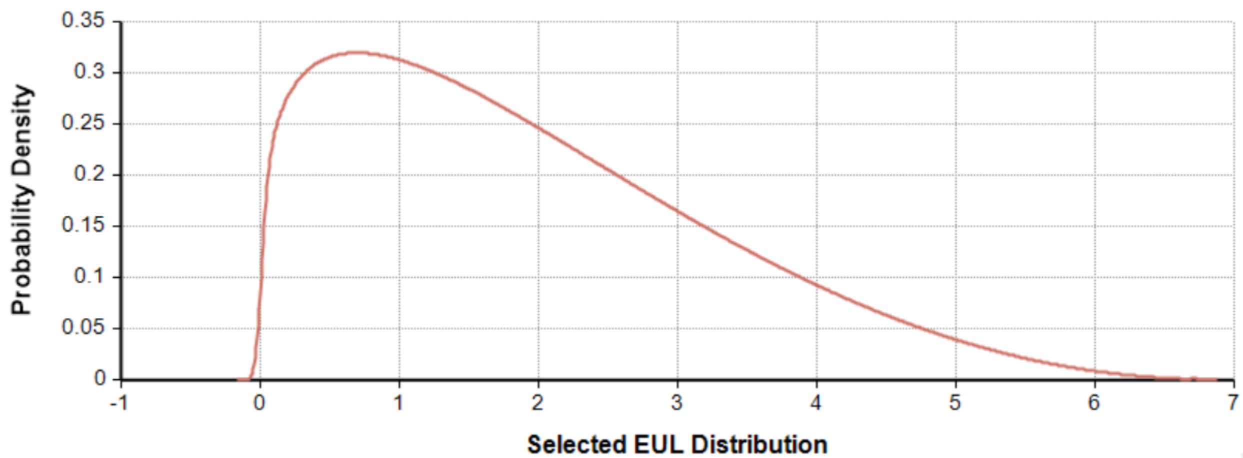
Navigant used a Monte Carlo approach within the Stochastic at Risk Value of Information (StAR VoI™) model to convert the elicited EUL range to a combined assessment of the uncertainty around EUL. The approach followed the protocol outlined below:

APPENDIX C

1. Convert elicited EUL range estimates to desired quantiles.
2. For each quantile, observation, and measure combination, draw *n* random sample from a uniform distribution within that quantile. These samples are in units of EUL.
3. Calculate quantile weights based on the elicited relative likelihood of each quantile and resample according to the weights calculated for each quantile.



4. Fit the weighted draws from the uniform quantile distributions to a scaled beta distribution using the shape and scale parameters *x*, and *y*.



5. The resulting fitted marginal EUL distributions are pooled to combine the multiple expert solicitations collected for each measure. Because the method for pooling observations can affect the uncertainty associated with the estimate, Navigant examined three different pooling methods, which are described below. Other methods, such as simple averaging, log-linear pooling, Bayesian pooling, or consensus estimation, are acknowledged but were not used in this study.

    a. Linear Pooling – Fur each measure, the probability density at each point *x* along the range of possible EUL values is summed over the index of experts and divided by the number of experts polled about the measure. Thus, the resulting probability densities reflect the arithmetic average of expert opinions about that measure along the range of potential EUL values. The linear method is the most common (and perhaps the most robust) method for combining expert opinions. Although it assumes independence of the expert opinions, it has the advantage of accumulating the plausibility of all outcomes across experts.

    b. Geometric Pooling – Similar to linear pooling, except that the probability density at each point *x* along the EUL range is multiplied, and then the *n*th root of this product is calculated. The geometric pooling method is favored when the influence of potential outliers should be minimized, or the solicited values are expected to span wide ranges, in order not to bias the pooled value toward the higher range, as is possible with linear pooling. Where ranges are very similar between experts and within one measure, geometric pooling and linear pooling will result in very similar outcomes. Like linear pooling, this method assumes independence of expert opinions, but to a weaker degree.

    c. Multiplicative Pooling – For each measure, the probability densities at each point along the EUL range are multiplied directly across the index of experts,and re-normalized such that the area under the curve is 1.0. Multiplicative pooling effectively weights the shared area of overlap between the expert opinions more heavily, decreasing the plausibility of outcomes where there is disagreement.

While Navigant examined the three pooling methods above in the StAR VOI ™ model, ultimately, linear pooling was selected as the method for combining the expert opinions into one EUL distribution for each measure in the study.

6. Once the expert distributions were combined into a single distribution for each measure, summary statistics including confidence intervals, and the likelihood of the assumed EUL given the final solicited distributions could be calculated directly by cumulating the probability of the marginal distribution up to a desired value.

APPENDIX D. SME RESULTS – VOI INPUTS

End Use	Measure Name	Lower Bound	Upper Bound	Bin 1 (Low)	Bin 2 (Mid)	Bin 3 (High)	Least Likely Bin	Middle Likely Bin	Most Likely Bin
Compressed Air	Compressed air - Leak Repair	1.0	8.0	1:3.3	3.3:5.7	5.7:8	1	3	2
Compressed Air	Compressed air - Leak Repair	1.0	10.0	1:4	4:7	7:10	1	3	2
Compressed Air	Compressed air - Leak Repair	1.0	5.0	1:2.3	2.3:3.7	3.7:5	3	1	2
HVAC	AC Tune-up	0.0	5.0	0:1.7	1.7:3.3	3.3:5	3	2	1
HVAC	AC Tune-up	0.0	8.0	0:2.7	2.7:5.3	5.3:8	3	2	1
HVAC	AC Tune-up	1.0	3.0	1:1.7	1.7:2.3	2.3:3	3	2	1
HVAC	AC Tune-up	1.0	3.0	1:1.7	1.7:2.3	2.3:3	3	2	1
HVAC	AC Tune-up	1.0	5.0	1:2.3	2.3:3.7	3.7:5	3	1	2
HVAC	AC Tune-up	1.0	5.0	1:2.3	2.3:3.7	3.7:5	1	2	3
HVAC	AC Tune-up	1.0	5.0	1:2.3	2.3:3.7	3.7:5	3	1	2
HVAC	AC Tune-up	5.0	10.0	5:6.7	6.7:8.3	8.3:10	3	2	1
HVAC Controls	Custom HVAC Controls	5.0	15.0	5:8.3	8.3:11.7	11.7:15	1	3	2
HVAC Controls	Custom HVAC Controls	5.0	20.0	5:10	10:15	15:20	3	1	2
HVAC Controls	Custom HVAC Controls	1.0	10.0	1:4	4:7	7:10	1	3	2
HVAC Controls	Custom HVAC Controls	8.0	10.0	8:8.7	8.7:9.3	9.3:10	1	2	3
HVAC Controls	Energy Management System	5.0	30.0	5:13.3	13.3:21.7	21.7:30	1	3	2
HVAC Controls	Energy Management System	10.0	20.0	10:13.3	13.3:16.7	16.7:20	3	1	2
HVAC Controls	Energy Management System	5.0	10.0	5:6.7	6.7:8.3	8.3:10	2	1	3
HVAC Controls	Programmable Thermostats (Com)	5.0	20.0	5:10	10:15	15:20	3	2	2
HVAC Controls	Programmable Thermostats (Com)	3.0	10.0	3:5.3	5.3:7.7	7.7:10	3	1	2
HVAC Controls	Programmable Thermostats (Com)	1.0	8.0	1:3.3	3.3:5.7	5.7:8	3	1	2
HVAC Controls	Programmable Thermostats (Com)	1.0	15.0	1:5.7	5.7:10.3	10.3:15	3	2	1
HVAC Controls	Programmable Thermostats (Res)	5.0	10.0	5:6.7	6.7:8.3	8.3:10	3	2	1
HVAC Controls	Programmable Thermostats (Res)	7.0	20.0	7:11.3	11.3:15.7	15.7:20	1	3	2
HVAC Controls	Programmable Thermostats (Res)	5.0	10.0	5:6.7	6.7:8.3	8.3:10	3	1	2

End Use	Measure Name	Lower Bound	Upper Bound	Bin 1 (Low)	Bin 2 (Mid)	Bin 3 (High)	Least Likely Bin	Middle Likely Bin	Most Likely Bin
HVAC Controls	Programmable Thermostats (Res)	1.0	15.0	1:5.7	5.7:10.3	10.3:15	3	1	2
HVAC Controls	Smart Thermostats	5.0	10.0	5:6.7	6.7:8.3	8.3:10	3	1	2
HVAC Controls	Smart Thermostats	3.0	10.0	3:5.3	5.3:7.7	7.7:10	3	1	2
HVAC Controls	Smart Thermostats	3.0	12.0	3:6	6:9	9:12	1	3	2
HVAC Controls	Smart Thermostats	9.0	11.0	9:9.7	9.7:10.3	10.3:11	3	1	2
HVAC Controls	Smart Thermostats	1.0	15.0	1:5.7	5.7:10.3	10.3:15	3	1	2
HVAC Controls	Thermostat Adjustment	0.0	5.0	0:1.7	1.7:3.3	3.3:5	3	2	1
HVAC Controls	Thermostat Adjustment	1.0	5.0	1:2.3	2.3:3.7	3.7:5	3	2	1
HVAC Controls	Thermostat Adjustment	1.0	8.0	1:3.3	3.3:5.7	5.7:8	3	1	2
Lighting	Advanced Lighting Control Systems	5.0	20.0	5:10	10:15	15:20	1	3	2
Lighting	Advanced Lighting Control Systems	5.0	20.0	5:10	10:15	15:20	1	3	2
Lighting	Advanced Lighting Control Systems	5.0	15.0	5:8.3	8.3:11.7	11.7:15	1	2	3
Lighting	LED Fixtures (Com)	5.0	15.0	5:8.3	8.3:11.7	11.7:15	3	3	2
Lighting	LED Fixtures (Com)	1.70	25.0	1.7:9.5	9.5:17.2	17.2:25	3	1	2
Lighting	LED Fixtures (Com)	3.0	10.0	3:5.3	5.3:7.7	7.7:10	1	3	2
Lighting	LED Fixtures (Com)	3.0	10.0	3:5.3	5.3:7.7	7.7:10	1	3	2
Lighting	LED Fixtures (Res)	4.0	20.0	4:9.3	9.3:14.7	14.7:20	3	1	2
Lighting	LED Fixtures (Res)	4.0	20.0	4:9.3	9.3:14.7	14.7:20	3	1	2
Lighting	LED Fixtures (Res)	3.0	15.0	3:7	7:11	11:15	3	1	2
Lighting	LED Fixtures (Res)	3.0	15.0	3:7	7:11	11:15	3	1	2
Lighting	LED Lamps (Com)	3.0	10.0	3:5.3	5.3:7.7	7.7:10	3	2	1
Lighting	LED Lamps (Com)	5.0	15.0	5:8.3	8.3:11.7	11.7:15	3	2	1
Lighting	LED Lamps (Com)	1.7	25.0	1.7:9.5	9.5:17.2	17.2:25	3	1	2
Lighting	LED Lamps (Com)	2.0	16.0	2:6.7	6.7:11.3	11.3:16	3	1	2
Lighting	LED Lamps (Com)	1.0	5.0	1:2.3	2.3:3.7	3.7:5	3	1	2
Lighting	LED Lamps (Com)	0.5	10.0	0.5:3.7	3.7:6.8	6.8:10	3	2	1
Lighting	LED Lamps (Res)	5.4	27.0	5.4:12.6	12.6:19.8	19.8:27	3	1	2

End Use	Measure Name	Lower Bound	Upper Bound	Bin 1 (Low)	Bin 2 (Mid)	Bin 3 (High)	Least Likely Bin	Middle Likely Bin	Most Likely Bin
Lighting	LED Lamps (Res)	5.4	27.0	5.4:12.6	12.6:19.8	19.8:27	3	1	2
Lighting	LED Lamps (Res)	10.8	37.8	10.8:19.8	19.8:28.8	28.8:37.8	3	1	2
Lighting	LED Lamps (Res)	7.0	15.0	7:9.7	9.7:12.3	12.3:15	3	1	2
Lighting	LED Lamps (Res)	7.0	15.0	7:9.7	9.7:12.3	12.3:15	3	1	2
Lighting	LED Lamps (Res)	7.0	15.0	7:9.7	9.7:12.3	12.3:15	3	1	2
Lighting	LED Lamps (Res)	2.0	15.0	2:6.3	6.3:10.7	10.7:15	3	1	2
Lighting	LED Lamps (Res)	2.0	15.0	2:6.3	6.3:10.7	10.7:15	3	1	2
Lighting	LED Lamps (Res)	2.0	15.0	2:6.3	6.3:10.7	10.7:15	3	1	2
Lighting	LED Lamps (Res)	1.0	5.0	1:2.3	2.3:3.7	3.7:5	3	1	2
Lighting	LED Lamps (Res)	1.0	7.0	1:3	3:5	5:7	3	1	2
Lighting	LED Lamps (Res)	1.0	7.0	1:3	3:5	5:7	3	1	2
Lighting	Lighting Controls	7.0	22.0	7:12	12:17	17:22	3	2	1
Lighting	Lighting Controls	1.0	8.0	1:3.3	3.3:5.7	5.7:8	3	1	2
Lighting	Lighting Controls	1.0	15.0	1:5.7	5.7:10.3	10.3:15	1	3	2
Lighting	Lighting Controls	3.0	12.0	3:6	6:9	9:12	3	1	2

Source: Navigant

Phase II Research Plan

Phase II is comprised of four tasks. Each are discussed below.

APPENDIX E.

Task 1. Structural Persistence Assessments for Measure Groupings

The evaluation research team will complete a structural assessment of persistence characteristics for measures, e.g., failure of equipment, remodeled space, changes in operations, etc. The team can then examine which persistence characteristics are believed to be most important in persistence and design the evaluation research study to address these characteristics. The interviewed SMEs also provided their input on the persistence characteristics.

Estimated measure persistence is based on both estimated measure life and savings persistence (i.e., the degradation of the energy savings, see Figure 1). Each measure grouping will have a mix of persistence characteristics.

This structural assessment will examine the influence of key characteristics on persistence for prioritized measures. For example, the NW Council's Regional Technical Forum (RTF) identified 9 characteristics that might impact an EUL by +/- 20% (See Table E-1 below).[11] Identifying the key characteristics that may affect savings persistence for a measure is a critical first step in the analysis. Assessment of these characteristics may show that a measure's EUL is likely to vary by characteristics that are linked to the type of installation, e.g., commercial lighting EULs may vary by building type and use. The appendix provides more details on these characteristics.

Table E-1. Measure Lifetime Influencing Characteristics

RTF Characteristics Influence Measure Lifetimes[12]	
1. Program delivery method	6. Operating hours
2. Installation practices	7. Operating conditions and practices
3. Sizing and rating	8. Occupancy changes
4. Maintenance	9. Remodeling practices
5. Region or climate zone	

Source: Regional Technical Forum

Each measure will undergo a review of the characteristics that influence persistence.

The structural assessment will examine key characteristics that impact EULs using propagation-of-errors analyses. This includes defining an engineering-based algorithm for estimating savings for each measure or measure grouping at a point in time (e.g., after 3 years, after 6 years or after 10 years). For example, a simple algorithm for lighting might be:

$$\text{Quantity} \times \triangle \text{ Watts} \times \triangle \text{Operating Hours} = \text{Savings}$$

[11] Guidelines for the Estimation of Measure Lifetime, Regional Technical Forum. December 8, 2015. https://rtf.nwcouncil.org/subcommittee/guidelines

[12] Refer to Appendix section **Error! Reference source not found.** for the full description for the RTF persistence characteristics.

Each input into this calculation may be influenced by characteristics that might result in a loss of savings (e.g., remodeling that changes the △Watts or quantity, number of bulbs or fixtures). The structural analysis may rely on the different components of the savings calculation to quantify the impact of key characteristics of savings and measure persistence with different levels of incidence over time. It will also help insure consistent data collection across projects or sites and identify areas of high sensitivity that require more research. For example, in reviewing lighting, this step will identify if the rate of owner/occupant turnover and remodeling impacts savings persistence by how much and in what year.

For each input reviewed, the yearly potential for one of these characteristics to influence energy savings will be examined based on scenarios and judgment. The assessment will look at intervals of time (e.g., every two or four years), and examine high and low brackets on the EUL impacts of different characteristics to assess the potential magnitude of effect that specific characteristic may have. This data identifies how many years post installation to conduct field studies and what should be addressed. By performing this analysis stepwise over time, it can illustrate how the incidence of characteristics can influence persistence – e.g., it sets out information to be gathered that can help the researcher assess what can be learned in year 5 for a measure with an 8-year EUL.

Measure specific assessment characteristics will be developed as structural assessments will include programmatic and technical considerations unique to the measure category. For example, thermostat persistence assessment will need to consider:

- Program factors:
    - Out of the box pre-programmed thermostat settings
    - Direct install where the installer programs the device and trains the user versus self-installed BYOT programs.
- Other non-program factors:
    - Changes in household occupancy schedule
    - Changes in household number of occupants
    - Device software upgrade schedule

The deliverable for this task will be a table for each measure similar to **Error! Reference source not found.**E-2 shown below. For these assessments, it will be important to gather data from program implementation tracking systems on specific participating segments such as building types for commercial measures and types of participants for residential measures.

Table E-2. Template for Identifying Persistence Characteristic Influence

Year	Relevant Characteristic	Relative Influence
1	NA	-
2	NA	-
…	NA	-
N-4	Maintenance	>20%
N-2	Remodeling, Occupancy Changes	>20%
N = technical life	NA	-

Source: Navigant

Task 2: Develop Research Plans per Measure

Each measure will have a unique approach to the primary data collection. Some measures will need on site data collection with or without metering and others can rely on phone or web survey. As a result of the SME interviews, the Navigant team has sufficient information to develop an appropriate research plan and assess cost to implement per measure.

- **Structural Persistence Assessments for Measure Groupings**. A primary structural engineering-based assessment examined characteristics (see Table E-1.E-1 for a list of characteristics) that influence EULs such as remodeling of space, changes in use, changes in operating hours, maintenance, and other topics that are known to affect measure persistence. This structural assessment examined how identified characteristics can impact EULs for measures in different situations; and, the likelihood of this occurring at different time periods, e.g., 3 years, 6 years and 10 years.

Task 3: Small-Sample Verification

In this task, Navigant may visit or survey 10 to 20 customers or sites to assess EULs and influential characteristics. This will build on the structural assessments performed in Task 2 and will include:

- A survey of a small set of customers can more quickly estimate the “common practice” and infield realization rates for the key influence characteristics identified in Phase I, Task 4. Building on the example of owner (or tenant) turnover and remodeling, common practice will be identified pertaining to changing out fixtures when a move or remodel has taken place. These results will have a mean and sample distribution and will be used to examine how consistent these data are with the initial EUL estimates. These small sample studies are used as tests for the consistency of the initial EUL estimates with the collected field data.

- Where the EULs are found to be inconsistent with these data at a given level of confidence; then, a larger data collection effort may be warranted. This tiered approach helps ensure the overall cost-effectiveness of the evaluation research, and the small sample studies can be used as an initial pre-test of challenges that might be incurred when moving to a larger data collection effort.

- The small sample tests can show which of the currently assumed values have a high likelihood of being incorrect by a given *delta* (+/- 10%).[13,14] They show where the field data is inconsistent with the currently assumed EUL.

The research groupings included in this small sample survey will also depend on the uncertainty in current estimates of measure persistence and the likelihood that further research can help revise persistence values appropriately (as opposed to not learning enough from the persistence evaluations to allow the research team to confidently revise the values).

[13] Tiering or staging the research in this manner would help ensure we are addressing estimation and validation of persistence in a cost-effective manner and help ensure that the value of the research exceeds its costs in terms of producing accurate CPAS validated estimates. That is, we are reducing the risk of expensive field research that may be unnecessary.

[14] This range estimation uses a 0 – 1 binominal distribution. It is a 1 if it falls in the +/- 10% range (e.g., for an EUL of 10, the range is 9 to 11), and a value of zero if it falls outside this range. It does not give us a new median value but tells us where large-scale research is most important.

Task 4: Large Scale Surveys and In-field Research

Building on the Task 3 results, larger survey and in-field evaluations for measures will be undertaken where the small sample data shows that the initial field data are inconsistent with the current EUL estimate.

- Larger in-field studies will be designed for the measures that are most likely to benefit from the more expensive research efforts.
- Each of these studies will leverage all the existing data collection and model development. The evaluation research will be designed to leverage the existing EUL estimates, incorporate data collected for other evaluation tasks, and use the influential characteristic analyses from Phase II above to determine what information should be collected in the field (e.g., a focus on changing operating conditions or frequency of remodels, etc.).

The final deliverable will be a table, using the template in Table E-3. E-3, for each measure category that quantifies the measure and savings persistence annually. This amount of detail must be collected as part of a field data collection effort. If a varying persistence value per year is not quantified or no survival curve is developed, then an overall EUL value will be the defined value used for CPAS.

Table E-3. Template for Quantifying Measure and Savings Persistence

Year	Savings	Measure Persistence	Savings Persistence
1	kWh	1 = yes installed & operating	1
2		1	1
…		1	$1\text{-}d_1$*
N-1		1	$1\text{-}d_2$
N = technical life		0 = removed from operation	$1\text{-}d_3$

d = the reduction in savings from characteristics affecting persistence. This value may vary year over year.
Source: Navigant