EMV Group A, Deliverable 16 EUL Research – Residential Whole Building Retrofits

Final Report

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Executive Summary

Introduction and Objectives (pages 6-8)

This document outlines the effective useful life (EUL) research[1] conducted by Guidehouse, Inc. (Guidehouse) on behalf of the California Public Utilities Commission (CPUC) for energy efficiency residential whole building projects. EUL is defined as the median number of years since installation that an implemented measure is still in place and operable.[2]

Most California program administrators (PAs) offer incentives through the Home Upgrade Program (HUP) for whole building retrofit projects that incorporate a suite of measures[3] acting in concert to provide energy savings. While most HUP projects are prescriptive, one type of HUP project is called *Advanced* Home Upgrade (AHUP), which uses building simulation models to calculate the interactive savings effects of all measures acting together and report savings contributions for each project on a measure-level basis. Typical projects incorporate a mixture of building envelope, HVAC[4], lighting, controls, and other measure types—each with individually defined EUL values in the Database for Energy Efficiency Resources (DEER). The most commonly installed measures within the Advanced Home Upgrade population include duct sealing and insulation, central air conditioning, attic insulation, and air sealing.

DEER lists dozens of different EUL values for composite whole building upgrades. For example, the research team identified 48 separate whole building EUL records for Pacific Gas and Electric (PG&E) that range from 11.1 years to 19.8 years, with an average of 16.1 years. Similarly, the team found 48 whole building EUL records for Southern California Edison (SCE) that range from 14.0 years to 20.0 years, with an average of 17.7 years. These individual records differ according to the mix of measures implemented but their calculation depends on the availability of specific measure-level detail for each project. The sources underlying the current EUL estimates are not presented clearly, and the utility calculation process used to arrive at a single, composite EUL value is opaque.

As utility programs evolve to take advantage of advanced metering infrastructure (AMI) and normalized metered energy consumption (NMEC) analysis methods, it is likely that tracking and recording the specifics of individual energy-saving measures will be a lower priority for PAs. With this evolution, the EUL values for individual whole building projects in such programs will become increasingly difficult to estimate. Whole building projects are a current priority for EUL research because this detailed measure-level installation data is presently being collected and available to inform a data-driven analysis.

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[1] This research plan is part of the steps listed in the *Effective Useful Life (EUL) Study Work Plan* and accompanying *Measure Prioritization* document, https://pda.energydataweb.com/#!/documents/2191/view.

[2] California Public Utilities Commission, *California Energy Efficiency Evaluation Protocols: Technical, Methodological, and Reporting Requirements for Evaluation Professionals*, April 2006, http://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=5212.

[3] A measure is a specific offering targeted by California PAs to encourage energy or demand savings. Measures are often incentivized via some form of financial assistance, and are typically targeted towards specific building systems or components such as lighting, HVAC, or building shell.

[4] Heating, ventilation, and air conditioning

The primary objectives of this EUL research were to answer the following questions:

1. What is the estimated aggregate EUL of residential whole building projects?
2. Are there separate subsets within the whole building population that merit different aggregate EUL values? If so, what are those values?

Methodology (pages 9-13)

To estimate the aggregate EUL for whole building projects, the research team implemented an established industry standard approach.[5] The team first characterized the measure-level composition of the whole building population before calculating the savings-weighted whole building EUL values of the research sample using measure-level DEER data. The research plan consisted of the following steps:

1. Review each PA's population of residential whole home retrofit projects from 2017 and 2018
2. Sample from each PA to identify the specific measures implemented and the savings associated with each measure[6]
3. Calculate savings-weighted EUL values using measure-level savings data for each individual project in the sample and for the entire sample in aggregate
4. Analyze the calculated EUL values and produce EUL specific sub-groupings based on a project's proportion of electricity- and natural gas-derived savings

In most cases, the only sources of measure-level savings values were energy models created for AHUP projects; the team was able to pull measure-level savings data from each model's output files.

The research team requested a sample of 92 AHUP projects from the population of records in the 2017 and 2018 All Things Reported (ATR) databases.[7] The research team sampled randomly from each PA and each program year to ensure representation from all four PAs and from both program years.

The research team then extracted measure-level data from the sampled energy models and calculated a savings-weighted EUL for each individual project. This weighted EUL was based on the measure-level first-year savings and the corresponding EUL of individual measures within each project. That is, the EUL of each individual measure within a project was weighted

[5] Weighted Average Expected Useful Life Calculator. California Public Utilities Commission, "Rolling Portfolio Program Guidance," last accessed June 9, 2020, https://www.cpuc.ca.gov/General.aspx?id=6442456320

[6] The original sample size defined in the evaluation plan was designed to meet 90% confidence and 30% relative precision. The sample constituted just 28 projects, with an average of five projects requested from six different PAs. (Bay Area Regional Energy Network and SoCal Regional Energy Network were originally included in the sampling plan but did not have any Advanced Home Upgrade projects.) At the time the final data request was submitted, the research team decided to over sample (92 projects total among four PAs) in order to enable additional stratification.

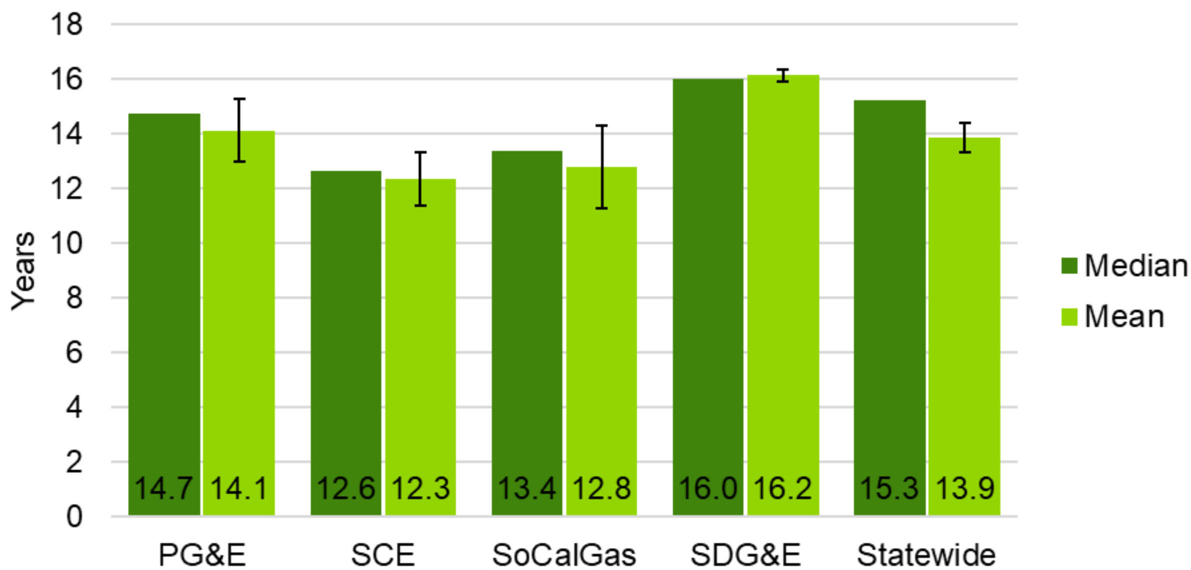
[7] Program implementers record savings and equipment specification details for every completed project in the All Things Reported (ATR) databases, which are subdivided by PA and by year.

by its contribution to the project's first year savings so that the weighted EUL is reflective of the measures accounting for the most first year savings.

Results (pages 14-21)

Figure ES1 shows the savings weighted average EUL values by PA, with weighting based on total energy savings (combined electric savings plus natural gas savings[8]). The median composite value across all PAs is 15.3 years, which falls near the middle of the existing spectrum of DEER values for individual projects[9]. The most commonly implemented measures across all PAs—each of which occurred in over 50% of projects—were duct sealing/insulation, central air conditioning, and attic insulation. Air sealing, gas furnace, and wall insulation upgrades were each implemented in over 25% of projects.

Figure ES1. Weighted EUL Based on Total (Electric plus Natural Gas) Savings



Source: Guidehouse

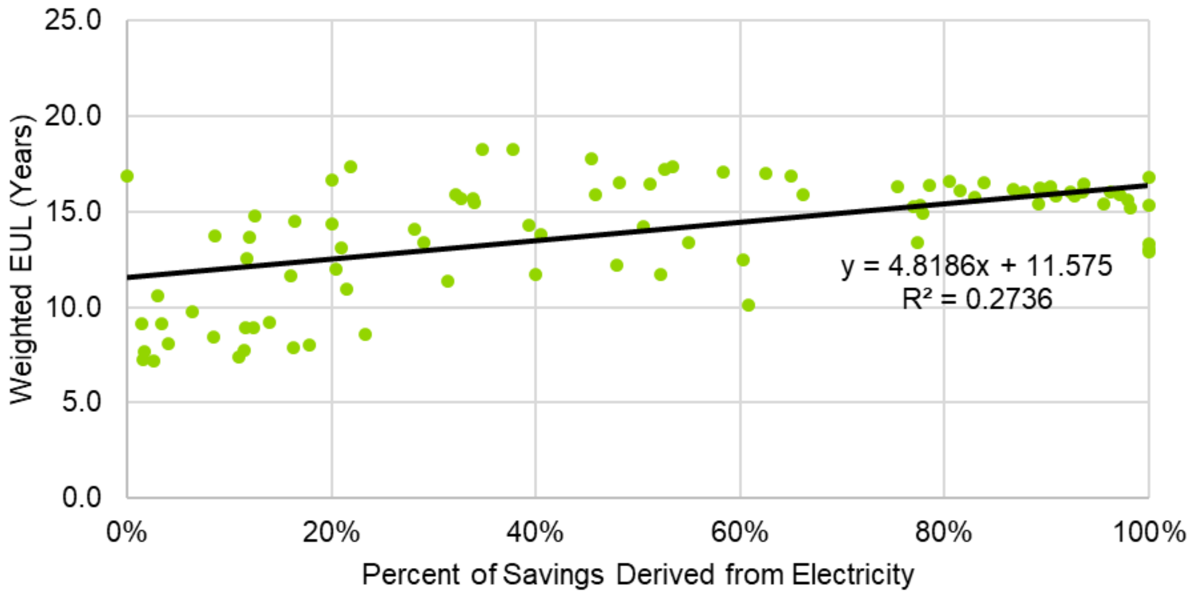
Accounting for the variability of measure prevalence between each PA's implemented projects, the results did not show an overwhelming trend relating to project region or climate zone, nor did the results reveal any standalone project 'archetypes.' However, Figure ES2**Error! Reference source not found.** shows that as a project's proportion of electricity-derived savings increases, the calculated aggregate EUL increases.[10]

[8] In order to combine fuel types, both electricity and natural gas usage were converted to British Thermal Units (BTUs).

[9] EUL values for whole building projects currently listed in DEER range from 11.1 to 20.0 years, and rely on knowledge of the specific measures comprising each individual project.

[10] This effect can also be shown to have the equivalent effect when plotting aggregate EUL versus percentage of savings derived from natural gas.

Figure ES2. Project-Level EUL vs. Percentage of Savings Derived from Electricity



Source: Guidehouse

This trend is influenced by the individual measures that contribute the most energy savings to a project and are therefore weighted more heavily. For projects in which the majority of savings are derived from natural gas rather than electricity, insulation and air sealing measures contribute a generally higher proportion of savings than they do for other projects. According to current rules, insulation measure retrofits are weighted using the Remaining Useful Life[11] (RUL) of 6.67 years rather than the full measure EUL of 20 years[12]. When the RUL is used, these insulation measures have the *lowest* useful life values of any individual measure, resulting in lower aggregate EUL values for the insulation-heavy projects that have most natural gas-derived savings.

By contrast, longer-lived measures like duct sealing, central air conditioning, and high-performance windows are most likely to be the predominant driver of savings in those projects that derive most savings from electricity. Consequently, this leads to higher aggregate EUL values for projects with a large proportion of savings derived from electricity.

Note, however, that the strength and direction of this trend is highly dependent upon the values used to weight individual measures. In particular, if insulation measures are weighted using the full measure EUL of 20 years rather than the RUL, the trend reverses entirely. That is, the aggregate EUL then *decreases* as a project's proportion of electricity-derived savings increases. This occurs because the insulation measures now have the *highest* useful life values of any individual measure. The insulation-heavy projects that have most savings derived from natural gas therefore have relatively high aggregate EULs. Furthermore, this *decreasing* trend found using the full insulation EUL of 20 years exhibits a considerably stronger correlation than the

[11] Remaining Useful Life serves the function of Effective Useful Life when a measure is installed on "host equipment", where the lifetime of the host equipment is a better indicator of how long the new measure will last. One example is a new high efficiency furnace fan installed on an older furnace. In this case, the life of the furnace is more likely to dictate how long the new fan is in service, since the furnace is likely to fail earlier.

[12] Decision15-12-002: http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M156/K191/156191759.docx

increasing trend found using insulation RUL values. 4.0Appendix D outlines the calculated whole building EUL values when alternate insulation EUL values are considered.

Conclusions (page 22)

After analyzing the data collected from 2017 and 2018 Home Upgrade Program participants, the research team concludes that it is valuable to specify different EUL values for different types of whole building projects, based on the electricity and fuel savings profile of each individual project. The team recommends forming three different project fuel savings profiles: one for projects that save predominantly electricity (75% or more of total project savings is derived from electricity), one for projects that save predominantly natural gas (75% or more of total project savings is derived from gas or other fossil fuels), and one for projects that fall in between, with a more even mixture of electricity and natural gas savings[13]. Such a structure will allow for an accurate characterization for each project's EUL value, even without future access to the individual measures that make up each retrofit.

Given these considerations, the calculated EUL for each profile is shown in Table ES-1. These values serve as the recommended profile names and assigned EUL values for whole building projects going forward.

Table ES-1: Recommended EUL Values, by Project Fuel Savings Profile

Whole Building Project Profile	Composite Project-Level EUL (years)
0%-25% Electric Savings	**10.6**
25%-75% Electric Savings	**15.7**
75%-100% Electric Savings	**15.9**

Source: Guidehouse

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[13] Note that the 25% and 75% electrically-derived savings cutoff values were chosen by observing gaps in the plotted sample data. There appear to be visible gaps around both 25% and 75% that form natural groupings. These boundary values were not analytically-derived, but appear to represent logical savings-type boundaries.

1.0 Introduction

This study details the process and findings of an investigation into the composite effective useful life (EUL) of residential whole building retrofits implemented by California program administrators (PAs). On an individual measure basis, EUL is defined as the median number of years since installation that an implemented measure is still in place and operable.[14] The primary focus of this EUL research is to determine whole building EUL values that may be used in the future as program delivery structures change and to update the existing default EUL values used in the statewide portfolio, including an update to the Database of Energy Efficiency Resources (DEER).[15]

Guidehouse (also referred to as the research team) prepared this study (EMV Group A, Deliverable 16 EUL Research, Whole Building Retrofit) for the California Public Utilities Commission (CPUC). In June 2019, the research team conducted a high impact measures analysis, ranking measures from two datasets. The first approach used the Uncertain Measure List, [16] which describes measure categories. The second approach used the measure-level detail in the California Energy Data and Reporting System (CEDARS) extract for 2017.[17] The prioritization process designated residential whole building retrofits as a high priority measure.[18]

1.1 Measure Background

Most PAs in California offer incentives for whole building projects through the Home Upgrade Program. The *Advanced* Home Upgrade Program (AHUP) implements residential whole building projects that incorporate a suite of measures acting in concert to provide energy savings.

The savings for each project are estimated using computer building simulation models[19] that calculate the interactive savings effects of all measures acting together and report savings contributions on a measure-level basis. Typical projects incorporate a mixture of building envelope, HVAC, lighting, controls, and other measure types—each with individually defined EUL values in DEER. The most commonly installed measures within the AHUP population include duct sealing and insulation, central air conditioning, attic insulation, and air sealing. Guidehouse identified a total of 16 unique measures within the sample of whole building retrofit projects. These measures have DEER EUL values ranging from 3 years to 20 years.

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[14] California Public Utilities Commission, *California Energy Efficiency Evaluation Protocols: Technical, Methodological, and Reporting Requirements for Evaluation Professionals*, April 2006, http://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=5212.

[15] DEER contains estimates of the energy savings potential of select energy efficient technologies and measures in residential and nonresidential applications. The database also contains information on the costs and benefits of energy efficient measures.

[16] Energy Division maps the thousands of measures in annual claims to 288 standardized measure groups for the purposes of aggregation and consistency across programs, PAs, and years. In a given program year, each measure associated with one or more claims is assigned a single measure group, allowing for application and comparison between evaluations of one year and claims of another. The Uncertain Measure List can be found here: http://www.cpuc.ca.gov/general.aspx?id=4137.

[17] CEDARS, "Confirmed Claims Dashboards for 2017 (Cost Effectiveness Output)," *California Energy Data and Reporting System*, 2018, online at https://cedars.sound-data.com.

[18] Measure prioritization for EUL research, https://pda.energydataweb.com/api/downloads/2191/Measure%20Prioritization.pdf.

[19] Individual PAs use different whole building simulation software. The research team encountered projects evaluated using EnergyPro, Snugg Pro, CakeSystems, and OptiMiser software.

Whole building projects are of particular interest for EUL research because of the current availability of detailed measure-level installation data. As utility programs evolve to take advantage of advanced metering infrastructure (AMI) and normalized metered energy consumption (NMEC) data, it is possible and perhaps likely that individual measure-level detail will become less readily available. In an environment where energy efficiency programs become less prescriptive and more results-based, the EUL values for individual whole building projects—which provide important decision-making inputs for PAs and are necessary to evaluate lifetime energy savings for planning and cost-effectiveness—will become increasingly difficult to estimate.

1.1.1 Literature Review

DEER has dozens of listed EUL values for whole building upgrades. These individual records differ according to the mix of measures implemented but their calculation depends on the availability of specific measure-level detail for each project. The sources underlying the current EUL estimates are not presented clearly, and the utility calculation process used to arrive at a single, composite EUL value is opaque. For example, the research team identified 48 separate EUL records for Pacific Gas and Electric (PG&E) that range from 11.1 years to 19.8 years, with a savings-weighted average of 16.1 years. Similarly, the team found 48 EUL records for Southern California Edison (SCE) that range from 14.0 years to 20.0 years, with an average of 17.7 years. These individual records differ according to the mix of measures implemented but depend on specific measure-level detail for each project.

To gauge the national consensus on the EUL of whole building projects, Guidehouse reviewed 11 state and regional technical reference manuals (TRMs), including those for California, Vermont, Massachusetts, Ohio, Pennsylvania, New York, Illinois, Wisconsin, Tennessee, Minnesota, and the Mid-Atlantic region. Notably, only the California, Massachusetts, Vermont, and Ohio TRMs include measures related to whole building retrofits. However, these manuals do not provide good references for the stated EUL values, nor the method used to calculate these values. Per Guidehouse's experience evaluating their programs, Ohio and Illinois utilities use a savings-weighted approach to determine whole building EUL. This methodology weights EUL by the savings achieved by each component of the whole building project. The CPUC has also published a draft calculator that calculates composite EUL values using a similar method. [20]

While individual measures are well-characterized in each TRM and in standalone research reports, there is no published study on the EUL of whole building retrofits. Lawrence Berkeley National Laboratory (Berkeley Lab)[21] defines 15 years as the EUL of whole building retrofits using data that was either reported directly from PAs or calculated by dividing lifetime savings (estimated by PA) by reported first-year savings.

Given the lack of consensus around whole building EUL values, this research effort aims to conduct an evaluation process that is transparent and presents updated California-specific whole building EUL values that can be used by future energy efficiency programs, regardless of the format of future impact evaluations.

[20] Weighted Average Expected Useful Life Calculator. California Public Utilities Commission, "Rolling Portfolio Program Guidance," last accessed 9, 2020, https://www.cpuc.ca.gov/General.aspx?id=6442456320

[21] Lawrence Berkeley National Laboratory, *Energy Savings Lifetimes and Persistence: Practices, Issues and Data. Technical Brief*, May 2015.

1.2 Study Scope and Objectives

This EUL research aims to address the following key questions:

- What is the EUL of the typical whole building project in California?
- Are there certain project archetypes or other distinctions that will allow for a logical subset of several different whole building EUL values? What are those values?

The research team analyzed data from four PAs for this study: PG&E, SCE, San Diego Gas & Electric (SDG&E), and Southern California Gas (SoCal Gas). AHUP projects from 2017 and 2018 provided the population from which the research sample was drawn.

2.0 Study Methodology

This section describes the methodology used to determine aggregate whole building EUL values. The research plan consisted of the following steps:

1. Review each PA's population of residential whole building retrofit projects from 2017 and 2018
2. Sample from each PA to identify the specific measures implemented and the savings associated with each measure
3. Calculate savings-weighted EUL values using measure-level savings data for each individual project in the sample and for the entire sample in aggregate
4. Analyze the calculated EUL values and produce a subset of EUL bins to allow for additional EUL specificity based on a project's proportion of electricity- and natural gas-derived savings

2.1 Review of Tracking Database

Guidehouse reviewed All Things Reported (ATR) databases to obtain a list of residential whole home upgrade projects implemented in 2017 and 2018, by PA. The team examined projects that were flagged as Energy Upgrade California or EUC, which consists of projects in the Home Upgrade Program and AHUP.

The research team characterized the availability of measure-level data in the database and found that available details varied by PA. Some records contained only generic descriptors without any measure-level details, while others included descriptors listing the specific measures implemented. Table 2 shows the number of records found for each PA and the proportion of records that included specific measure details.

Table 2. Summary of Energy Upgrade California Projects in ATR Tracking Database

PA	2017 Records	2018 Records	Total Records	Proportion of Records with Measure-Level Detail
PG&E	6,017	5,627	11,640	11.3%
SCE	1,447	436	1,883	46.6%
SoCal Gas	3,648	15,781	19,429*	77.5%
SDG&E	393	384	777	0%

*The number of records for SoCal Gas is especially large in part because the database includes potential duplicate projects with descriptors indicating a connection to SCE and PG&E. See Appendix A.

Source: Guidehouse

Each ATR record listed the aggregate electricity and gas savings associated with each project but did not allocate the savings to individual measures within a project. However, Guidehouse was able to use the aggregate values to determine which measure descriptions were associated with the highest-saving projects as a consideration for later sampling. Appendix A lists the specific project descriptors found for each PA and the number of records and proportion of savings for each descriptor.

2.2 Project Sampling

Given the limitations in the ATR data and because no projects in the ATR contained data on the energy savings for individual measures, Guidehouse used a sampling approach to obtain the necessary project details for calculating savings-weighted EUL values.

The research team requested an initial small sample of projects to evaluate the data available in the program tracking documents for each PA and worked with PA staff to identify the availability of measure-level savings data. The team found that in most cases, the only source of measure-level savings values were energy models created for AHUP projects. These models were typically created using Snugg Pro or CakeSystems software, and the team was able to pull measure-level savings data from each model's XML output files.

After identifying and confirming the availability of measure-level savings data, the research team requested a sample of 92 AHUP projects with XML energy model outputs. The team drew the sample from the population of records in the ATR database with nonzero savings but excluded any non-AHUP project types that did not have energy models and measure-level savings. The research team sampled randomly from each PA and each program year to ensure representation from all four PAs and both program years.[22] Table 3 shows the number of projects sampled from each PA. Appendix A shows the breakdown of sampled projects by project descriptor in the ATR database.

Table 3. Sample Size Summary

PA	2017 Sample Size	2018 Sample Size	Total Sample Size
PG&E	12	12	24
SCE	16	12	28
SoCal Gas	10	6	16
SDG&E	12	12	28
Total	**50**	**42**	**92**

Source: Guidehouse

2.3 Analysis Methodology

2.3.1 Calculation of Weighted EUL Values

The research team extracted measure-level data from the sampled energy models and calculated a savings-weighted EUL for each individual project. This weighted EUL was based on the measure-level first-year savings and the corresponding EUL of individual measures

[22] Note that the original sample size defined in the evaluation plan constituted just 28 projects, with an average of five requested from six different PAs. (Bay Area Regional Energy Network [BayREN] and SoCal Regional Energy Network [SoCalREN] were originally included in the sampling plan but did not have any AHUP projects). At the time the data request was submitted, the research team decided to over sample with the hope of gaining more detail to enable additional stratification.

within each project.[23] That is, the EUL of each individual measure in a project was weighted by its contribution to the project's savings so that the weighted EUL is reflective of the measures that accounted for the most savings. This process is similar to the method used by the Weighted Average Expected Useful Life draft calculator published by the CPUC. To apply a weighting using the combined electricity (kWh) and gas (therms) savings for each measure and the entire project, Guidehouse converted all savings to a common thousand British Thermal Unit (kBtu) basis.[24] The research team developed overall PA-specific and California-specific EUL values by calculating the median of the sample's project-level composite EUL values.

Because some PAs provide only electric service or only natural gas service rather than both electric and natural gas, Guidehouse also performed separate EUL calculations using a weighting methodology based on electric savings alone and natural gas savings alone, in case individual PAs would benefit from the distinction. For example, weighting with electric savings alone meant ignoring any gas savings associated with each measure; each measure's contribution to the weighted EUL was based on its contribution to the total electricity savings for the project rather than the total combined electricity and gas savings. This analysis showed how weighted EUL values differ when using a strictly electric-only perspective and a strictly natural gas-only perspective.

2.3.2 Individual Measure EULs

The research team used individual measure EULs from DEER to calculate the weighted EUL values. Table 4 lists the measures found in the sample projects and their individual measure EULs.

Table 4. Measure EULs Used to Calculated Weighted EUL

Measure	DEER EUL ID	Measure EUL/RUL Weight (Years)	Version
Air Sealing*	BS-Wthr	11	DEER2014
Attic Insulation	BS-CeilIns	6.67 (RUL) ‡	DEER2014
Central Air Conditioning	HV-ResAC	15	DEER2014
Duct Sealing/Insulation†	HV-DuctSeal	18	DEER2020
Floor/Crawl Insulation	BS-FlrIns	6.67 (RUL) ‡	DEER2014
Gas Furnace	HV-EffFurn	20	DEER2014
Heat Pump	HV-ResHP	15	DEER2014
LED Lighting	ILtg-Res-LED-20000hr	16	DEER2014
Pool Pump	OutD-PoolPump	10	DEER2014
Wall Insulation	BS-WallIns	6.67 (RUL) ‡	DEER2014
Water Heater (Gas, Tank)	WtrHt-Res-Gas	13	DEER2014

[23] Projects sometimes included individual measures that had negative values for electricity or natural gas savings as a result of interactive effects. In these cases, the team calculated the weights for individual measures using the absolute value of savings. This is because it does not make sense to say that any given measure is expected to last for a negative number of years, which would be implied by the negative weights that would result from using negative savings values. Using this method, the EUL of a measure with negative savings is weighted according to the relative magnitude of that measure's effect on total project savings.

[24] Conversion factors: 1 kWh = 3.412 kBtu and 1 therm = 100 kBtu

Measure	DEER EUL ID	Measure EUL/RUL Weight (Years)	Version
Water Heater (Gas, Tankless)	WtrHt-Instant-Gas	20	DEER2014
Windows	BS-Win	20	DEER2014

* Air sealing is not specifically listed in DEER, so the team used the value for low-income weatherization and performed a sensitivity analysis to determine the impact of varying the air sealing EUL value upon calculated overall EUL values.

† The previous duct sealing EUL was 18 years prior to January 1, 2017. Classification of duct sealing as a BRO measure recently redefined the value as 3 years, but a proposed DEER scoping memo update in 2020 proposes that for all buildings built prior to 2006 (the year when duct sealing was required by code) the BRO classification should not apply.

‡ According to current CPUC rule, the lifetime of insulation retrofit measures is limited to the Remaining Useful Life (RUL), which is 1/3 of the current EUL value of 20 years.

Source: Guidehouse

Guidehouse notes special considerations for three of the measure-level weighting values.

- **Air sealing:** DEER did not contain an EUL record for air sealing. As a proxy, the research team used the 11-year value for low-income weatherization and performed a review of TRMs from other states to validate this assumption. The team found that 11 years, 15 years, and 20 years were all common values for the residential air sealing EUL. Table 5 summarizes the findings of this research. Guidehouse recommends using the 11-year value because it is used by the California publicly owned utilities (POUs) and was previously used in older versions of DEER. While the results presented in Section 3.0 use 11 years as the EUL for air sealing, Appendix B discusses the sensitivity of the final weighted whole building EUL to changes in the air sealing measure EUL.

Table 5. Comparison of Published Air Sealing EUL Values

Air Sealing EUL	State TRMs/Sources
11 years	California POU TRM, Arizona, New Mexico
15 years	Pennsylvania, Massachusetts, Missouri, New York
20 years	Wisconsin, Minnesota, Illinois

Source: Guidehouse and publicly available state TRMs

- **Duct sealing:** The DEER EUL for duct sealing—which has been in effect since January 1, 2017—is 3 years. Prior to 2017, the EUL from DEER2014 was 18 years. However, for houses constructed prior to 2006, duct sealing was not a code requirement. For these older houses, it may be more appropriate to consider duct sealing akin to a weatherization measure, and not subject to the 3-year BRO measure cap. A 2022 DEER scoping update memo proposes creating such a distinction and raising the duct sealing EUL to 18 years for homes built prior to 2006.[25] This analysis uses 18 years as the EUL value for duct sealing.

[25] Memo dated April 21, 2020: "Solicitation for Comments on Scope of Update for Database of Energy Efficiency Resources for program year 2022 (DEER2022) and error corrections for program years 2020 and 2021". Duct sealing discussion begins on page A-6.
All homes in the sample for this study were built prior to the January 1, 2006 cutoff, suggesting that duct sealing was more of a retrofit measure and less of a behavioral, retrocommissioning, and operational measure. It is reasonable to expect that future whole building projects may address a building stock of a similar vintage.

- **Residential attic, floor, and wall insulation:** The current EUL value for insulation measures is 20 years. However, according to current CPUC rules, the research team weighted insulation measures using their Remaining Useful Life (RUL) of 1/3 of EUL, or 6.67 years. The research team also notes that the pending Guidehouse study on the EUL of residential wall insulation calculated an overall EUL of 31 years for these measures. For reasons discussed in Section 3.3, the research team also investigated how results would change if the full EUL values were used. Appendix D shows these results.

The results presented in Section 3.0 weight air sealing with its measure EUL of 11 years, duct sealing with its measure EUL of 18 years, and insulation measures with the RUL value of 6.67 years. Guidehouse notes that any modifications to individual measure EULs may require an update to the weighted whole building EUL.

2.4 EUL Binning

Upon calculating project-level and whole-sample aggregate EUL values, Guidehouse scrutinized the data in order to identify any logical subsets. The team considered ‘bins’ arranged by typical measure groups, location or PA, and proportion of electrically-derived savings versus natural gas-derived savings. Identifying logical project bins with distinct EUL values would allow for greater accuracy in characterizing EUL values for future projects. Detailed discussion of stratified bins begins in Section 3.3.

3.0 Results

This section presents the results and key findings of Guidehouse's whole building EUL analysis, including the prevalence of specific measure types and the calculation of savings-weighted EUL values.

3.1 Measure Prevalence

From the sample of AHUP projects described in Section 2.2 and Table 3, Guidehouse identified the unique measures that were implemented in each retrofit project. Table 6 lists the different measures implemented for the projects in the sample, the number of projects for which each measure was present for each PA and in total, and the proportion of all sampled projects that contained each measure.

Table 6. Prevalence of Measures in Sample Projects

Measure	PG&E Count	SCE Count	SoCal Gas Count	SDG&E Count	Total Count	% of Sampled Projects with Each Measure
Total Number of Sample Projects	**24**	**28**	**16**	**28**	**92**	**-**
Air Sealing	19	12	10	3	44	47.8%
Attic Insulation	14	26	13		53	57.6%
Central Air Conditioning	17	14	6	24	61	66.3%
Duct Sealing/Insulation	21	26	15	24	86	93.5%
Floor/Crawl Insulation	1	1	4		6	6.5%
Gas Furnace	16	11	5	1	33	35.9%
Heat Pump	3	2	4		9	9.8%
LED Lighting	1				1	1.1%
Pool Pump	2				2	2.2%
Wall Insulation	3	12	10		25	27.2%
Water Heater (Gas, Tank)	3		1		4	4.3%
Water Heater (Gas, Tankless)	2	5	7	2	16	17.4%
Windows	3	7	3		13	14.1%

Source: Guidehouse

The most commonly implemented measures across all PAs—each of which occurred in over 50% of projects—were duct sealing/insulation, central air conditioning, and attic insulation. Air sealing, gas furnace, and wall insulation upgrades were each implemented in over 25% of projects. The remaining measures were included in less than 25% of projects. The measure mix for retrofit projects from SDG&E was especially homogeneous. Almost every SDG&E project consisted of central air conditioning and duct sealing/insulation; only a small proportion of projects included other measures.

3.2 Weighted EUL Values

3.2.1 Summary of Weighted EUL Values Based on Total Savings

Table 7 shows the savings-weighted EUL values by PA, with weighting based on total energy savings (combined electric savings plus natural gas savings). The composite value across all PAs is 15.3 years.

Table 7. Overall Weighted Whole Home Retrofit EUL

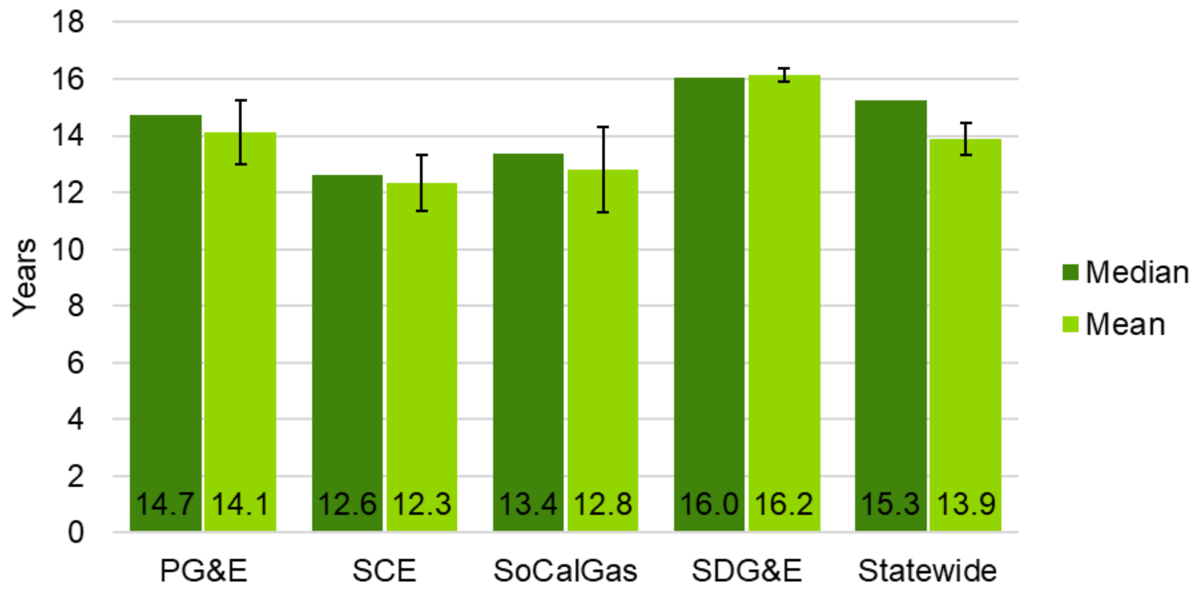
PA	Overall EUL Weighted Using Total Savings (Years)
PG&E	14.7
SCE	12.6
SoCal Gas	13.4
SDG&E	16.0
Combined	**15.3**

Source: Guidehouse

As discussed in Section 2.3.2, the research team used the 11-year EUL assigned to low-income weatherization as a proxy for air sealing but also found alternate values from published sources in other states. Appendix B shows how the overall whole building EUL results in Table 7 are impacted when these alternate air sealing EUL values are used. The research team also used the RUL value of 6.67 years for insulation measures. Appendix D shows how the results are impacted when attic, wall, and floor insulation EUL values of 20 years and 31 values are used.

Figure 1**Error! Reference source not found.** shows the overall **median** EUL values by PA based on weighting with total electric and gas savings (as previously listed in Table 7). The **mean** EUL is also shown with 90% confidence intervals to demonstrate the variability in individual savings-weighted EULs across the sample population.

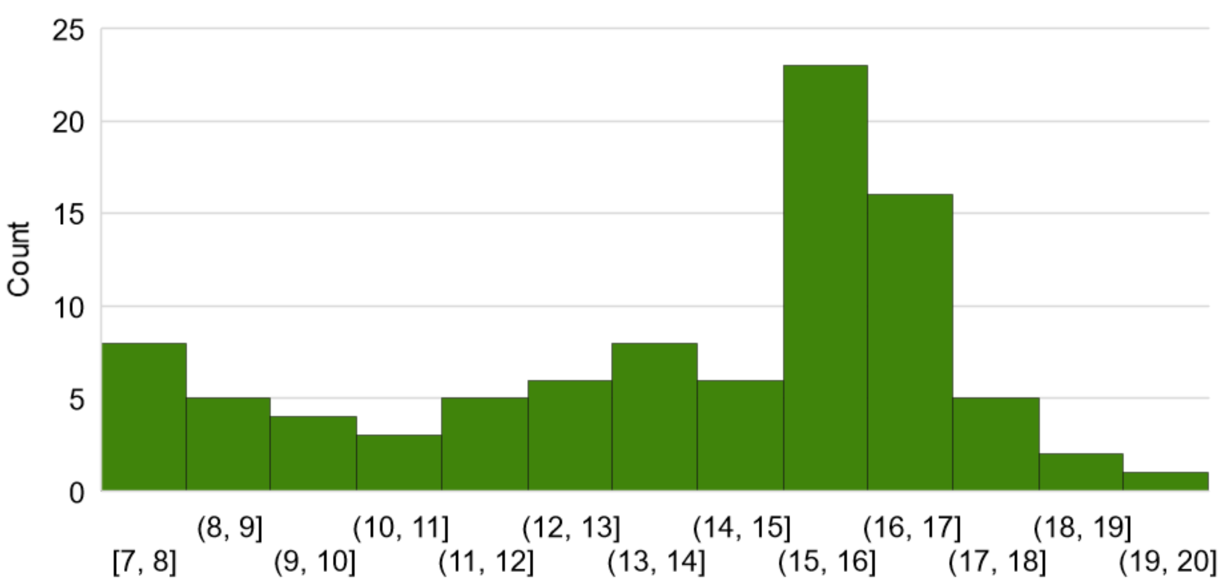
Figure 1. Weighted EUL Based on Total (Electric plus Natural Gas) Savings



Source: Guidehouse

Figure 2**Error! Reference source not found.** shows the distribution of composite EUL values calculated for each individual project. Note that no projects have composite EUL values higher than 20 years, with a relatively broad concentration between 7 and 17 years and a peak between 15 and 17 years.

Figure 2. Histogram of Weighted EUL Based on Total Savings for All PAs[26]



[26] Note that for this and all subsequent figures, histogram X-axis labeling uses "[" to denote inclusivity and "(" to denote exclusivity. For example: (7, 8] is the bin 7 < x ≤ 8.

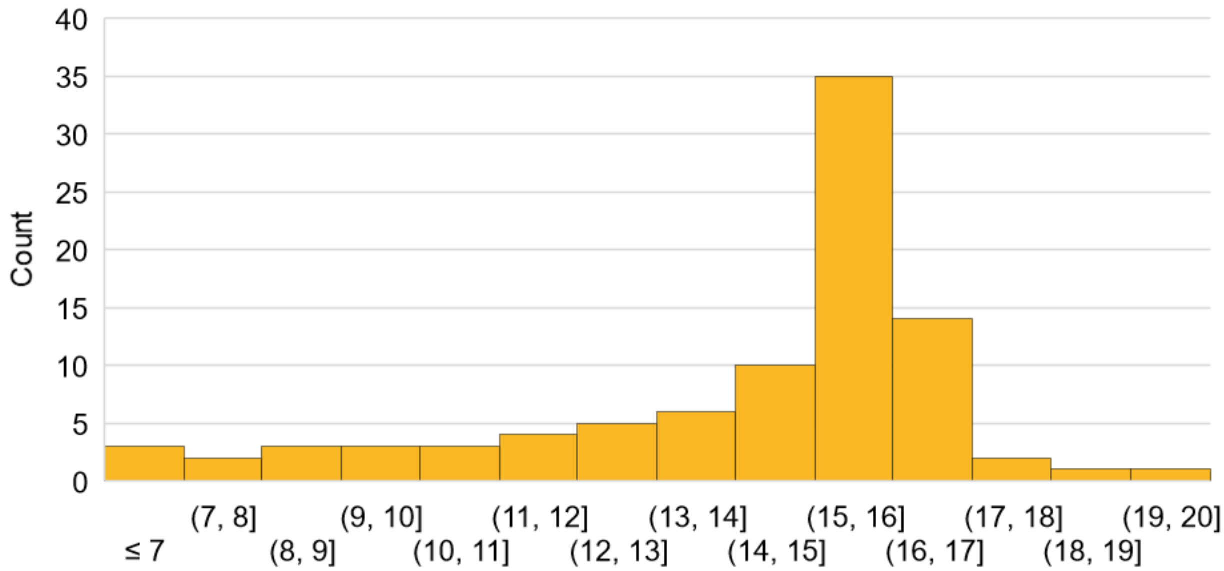
Source: Guidehouse

3.2.2 Weighting Using Electric and Gas Savings Alone

For PAs that deliver both electricity and natural gas service, savings weighted EUL should consider both electricity and natural gas savings. However, for PAs that deliver only electricity or only natural gas, an electric-only weighting or gas-only weighting may be more appropriate.

Notably, when weighting via one fuel exclusively, the EUL distribution takes a different shape. The distribution in Figure 3 shows fewer values below 10 years and a larger peak between 14 and 17 years when considering electricity weighted EUL.

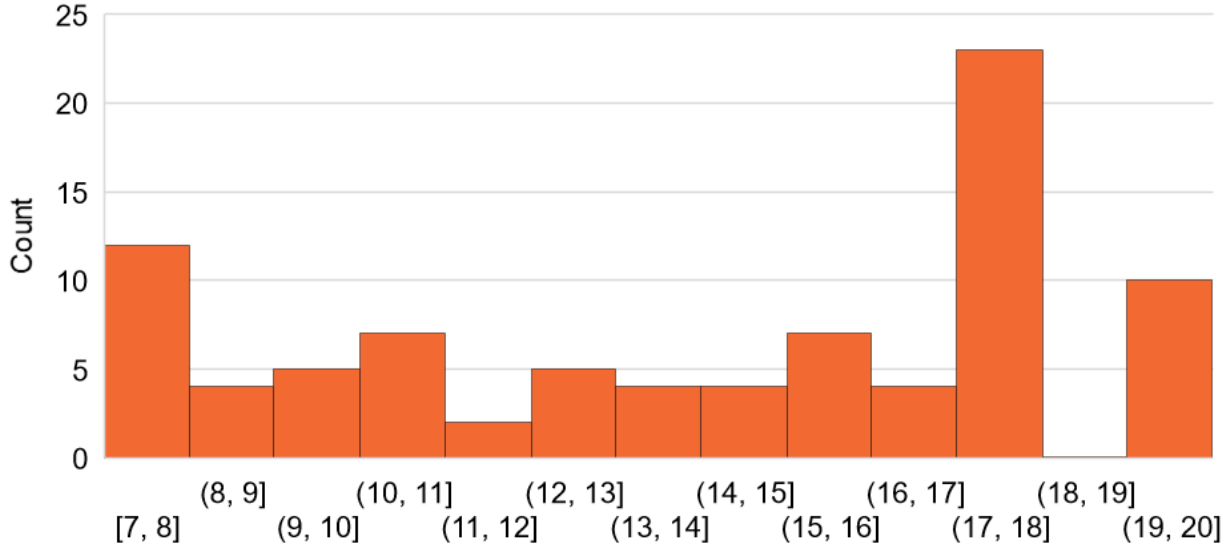
Figure 3. Histogram of Weighted EUL Based on Electric Savings Only



Source: Guidehouse

When EUL values are weighted with natural gas savings as shown in Figure 4, the sample shows a much broader distribution. Projects with lower weighted values are driven by insulation measures while projects with higher weighted values are driven by HVAC measures.

Figure 4. Histogram of Weighted EUL Based on Gas Savings Only



Source: Guidehouse

In most cases, the combined fuel EUL calculation should be used. However, Table 8 shows EUL values weighted by a single fuel.

Table 8. Weighted Whole Home Retrofit EUL, by Fuel Type

PA	EUL Weighted with Total Savings	EUL Weighted with Electric Savings Only	EUL Weighted with Gas Savings Only
PG&E	14.7	14.9	15.6
SCE	12.6	14.3	11.0
SoCal Gas	13.4	14.0	13.3
SDG&E	16.0	15.8	18.0
Combined	**15.3**	**15.2**	**15.2**

Source: Guidehouse

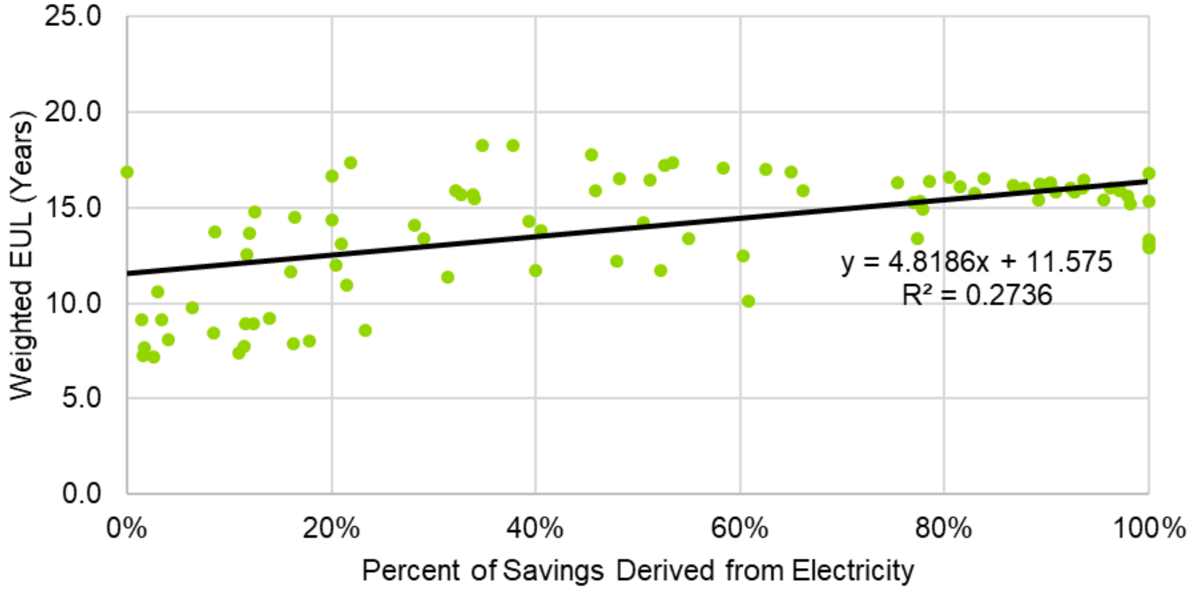
3.3 Binning Based on Proportion of Electric and Gas Savings

Guidehouse planned to create subsets within the sample population to accurately characterize unique project archetypes or trends in savings weighted EUL values based on common project characteristics. While examination of both the population and sample data did not lead to any obvious project archetypes based on specific measure combinations,[27] plotting the calculated project-level EUL versus the proportion of project savings derived from electricity[28] did reveal a subtle trend in which EUL values increase as the proportion of electricity savings increases, as Figure 5 shows.

[27] The research team analyzed the sample population to identify if projects could be grouped together based on the specific combination of measures performed but found that there were no clear groupings of projects that could be created; among the 92 projects in the sample, there were 46 unique combinations of different measures.

[28] This effect can also be shown with a plot of calculated EUL versus percentage of savings derived from natural gas.

Figure 5. Project-Level EUL vs. Percentage of Savings Derived from Electricity



Source: Guidehouse

To analyze and capture this fuel-related effect, the research team segmented projects into three bins based on the proportion of total first-year savings derived from each fuel. Table 9 shows these three bins and the number of sampled projects from each PA that fit into each bin. Note that bins are defined here in terms of electrical savings but could be equivalently described by the proportion of natural gas savings.

Table 9. Number of Sample Projects by Fuel-Related Savings Bin

Bin	PG&E	SCE	SoCal Gas	SDG&E	Total
0%-25% Electric Savings	9	15	9	0	**33**
25%-75% Electric Savings	11	9	4	4	**28**
75%-100% Electric Savings	4	4	3	20	**31**

Source: Guidehouse

Across all PAs, the plurality of projects populated the 0%-25% Electric Savings bin. This was also the case for SCE and SoCal Gas projects but not so for PG&E and SDG&E. The sample projects from PG&E had more balanced electric and natural gas savings, while most projects from SDG&E contributed predominately electric savings.[29]

Table 10 shows the whole building EUL values for each savings bin. The presence and strength of the trend in which the weighted EUL increases as the proportion of electric savings increases varies across the PAs.

[29] As discussed in Section 3.1 and Table 6, the measure mix was especially homogeneous for SDG&E. For most projects, the measure that accounted for the largest proportion of savings was electric central air conditioning. This is why most projects are in the 75%-100% Electric Savings bin.

Table 10. EUL for Projects in Each Fuel-Related Savings Bin

Bin	PG&E EUL	SCE EUL	SoCal Gas EUL	SDG&E EUL	Combined EUL
0%-25% Electric Savings	12.5	9.7	8.9	N/A	**10.6**
25%-75% Electric Savings	15.4	13.4	15.8	17.2	**15.7**
75%-100% Electric Savings	14.4	15.1	16.4	16.0	**15.9**

Source: Guidehouse

The reasons for this trend are nuanced and generally have to do with the individual measures that are weighted more heavily. In other words, it has to do with which measures, on average, contribute the most to total savings when they are present. For projects in the first bin in which most savings are from natural gas, shorter-life measures like insulation (which uses an RUL value of 6.7 years for this analysis) and air sealing contribute a generally higher proportion of savings than they do for projects in other bins. Because these measures have relatively low EUL or RUL weights, the resulting weighted EUL values for these projects are lower.

Alternatively, for projects in the third bin in which most savings come from electricity, measures like duct sealing, central air conditioning, and high-performance windows contribute a higher proportion of savings on average. Compared to insulation and air sealing, these measures have higher EUL values, resulting in higher weighted EUL values. Appendix C presents additional detail on the reasons for the fuel related EUL trend by examining how average measure weights vary across the three bins.

This method of segmenting projects into bins based on the proportion of savings derived from each fuel has the advantage of retaining its utility even as future evaluations lose measure-level detail. While future projects may not capture information on specifically implemented measures, they will include the proportion of energy savings by fuel type.

The research team notes that the direction and strength of this trend is highly dependent on the values that are used to weight individual measures. In particular, the trend is influenced by the weighting values used for attic, wall, and floor insulation measures. According to current rule, these insulation measures are weighted using their Remaining Useful Life (RUL) of 6.7 years rather than their measure EUL of 20 years. When this is done, these measures have lower weights than any other measure.

A finding from Guidehouse's 2020 EUL study of attic, wall, and floor insulation is that using the full EUL for insulation retrofits may be more appropriate than using the RUL value given the nature of the upgrades. Because new insulation work restores the original or existing insulation up to a brand new state and fixes any gaps or flaws, the retrofit likely pushes the failure or end-of-life date back to the full EUL value rather than being limited to the RUL of the original or existing insulation. Therefore, Guidehouse believes using the full EUL value to weight insulation measures is preferable to the current rule which requires weighting with RUL values.[30]

[30] Guidehouse notes that it appears that the current whole building EUL values in DEER that are calculated on a per-project basis did *not* follow the RUL convention, and instead use an insulation EUL value of 20 years.

Appendix D shows how the overall weighted EUL results, including the binning trend, would change if a full measure EUL of 20 years or 31 years were used to weight insulation measures.[31] Notably, weighting using the full measure EUL causes the trend in Figure 5 to reverse entirely. That is, the aggregate EUL now *decreases* as a project's proportion of electricity-derived savings increases. This occurs because the insulation-heavy projects in which most savings are derived from natural gas now have the highest EUL values of any individual measure, resulting in higher aggregate EULs. Furthermore, this *decreasing* trend found using the full insulation EUL of 20 years exhibits a considerably stronger correlation than the *increasing* trend found using insulation RUL values.

[31] Guidehouse conducted a 2020 EUL study for residential attic, floor, and wall insulation and calculated an overall EUL value of 31 years. This research had not been published as of April 2021.

4.0 Conclusions

Anticipating a shift toward performance-based AMI data evaluation of energy efficiency projects, Guidehouse provided a simple means of estimating EUL for future whole building projects, even as specific measure-level detail becomes more difficult to obtain. The values presented are California-specific, representative of recent real-world projects, and the process is less complex than the current suite of whole building EUL values in DEER.

The updated values presented in this study are not drastically different from the existing values that are individually calculated with each implemented project, but they provide flexibility for an AMI-enabled future. Because future projects will still provide a breakdown of electricity versus natural gas savings—as long as the typical measure mix within whole building projects does not drastically change—the estimated EUL values for projects that contribute predominantly electric savings or predominantly natural gas savings will still be accurate.

Whole building projects deriving savings predominantly from natural gas tend to have shorter composite EUL values than those deriving from electric savings. The shorter EUL for natural gas projects is derived from such projects being more likely to draw a higher proportion of savings from shorter-lived measures like air sealing and insulation than from relatively longer-lived measures like air conditioning, duct sealing, or high-performance windows. The research team feels that this distinction provides additional alternatives for characterizing EUL when a project derives savings predominantly from electricity or from natural gas, and provides utility and flexibility moving forward.

Appendix A. Additional Project Information from ATR Database

The following tables detail the different types of Energy Upgrade California residential retrofit projects found in the ATR tracking data for each PA. Each table lists the unique project descriptors and the number of projects from 2017 and 2018 that were found for each descriptor. The tables also show the proportion of total first-year savings that projects with each descriptor accounted for. The rightmost column of each table indicates the number of sample projects of each type used to calculate weighted EUL values.

These tables do not include multifamily projects because those projects were out of the study scope. They also exclude any descriptors for which the collective first-year total savings were equal to zero. If applicable, the line item “Specific Measure Descriptors” is used to count projects that listed the specific measures performed, rather than a category descriptor; the percentage of projects with these specific measure descriptors is what is shown in Table 2. Summary of Energy Upgrade California Projects in ATR Tracking DatabaseTable 2 (in the report body) as the proportion of records with measure-level detail.

Table A-1. Additional ATR Project Statistics for PG&E

PG&E ATR Project Descriptor	Total Count	% of Total First-Year Savings	Count in Sample
Retrofit-Res-Whole House-Heating	3,200	64.0%	11
Retrofit-Res-Whole House-Cooling	2,466	21.2%	8
Specific Measure Descriptors	1,311	5.2%	-
Retrofit-Res-Whole House-Water Heating	516	2.8%	-
Retrofit-Res-Whole House-Base Load	632	2.2%	-
Retrofit-Res-Whole House-Lighting	126	0.3%	1
Total	**10,289**	**100%**	**20**

Source: Guidehouse

Table A-2. Additional ATR Project Statistics for SCE

SCE ATR Project Descriptor	Total Count	% of Total First-Year Savings	Count in Sample
Comprehensive Whole House Retrofit – Weatherization	926	74.88%	28
Specific Measure Descriptors	877	24.96%	-
Other	80	0.16%	-
Total	**1,883**	**100%**	**28**

Source: Guidehouse

Table A-3. Additional ATR Project Statistics for SoCal Gas

SoCal Gas ATR Project Descriptor	Total Count	% of Total First-Year Savings	Count in Sample
Specific Measure Descriptors	15,065	33.9%	-
SCE Advanced Home Upgrade*	1,242	27.0%	-
SCE Home Upgrade* †	1,465	13.8%	-
LADWP Advanced Home Upgrade	356	7.9%	-
Burbank Home Upgrade†	630	5.0%	-
Muni Home Upgrade†	192	2.7%	-
SoCal Gas Home Upgrade- Whole Building (IOU) Gas Only* †	3	2.4%	-
LADWP Home Upgrade†	194	2.3%	-
PG&E Advanced Home Upgrade*	61	1.8%	-
Muni Advanced Home Upgrade‡	54	1.7%	16
Pasadena Home Upgrade†	158	1.3%	-
PG&E Home Upgrade* †	6	0.1%	-
Total	**19,426**	**100%**	**16**

* Projects from other PAs.

† Home Upgrade projects do not involve energy modeling, so measure-level savings data is unavailable.

‡ SoCalGas database referenced projects associated with many other PAs. In addition, many whole building projects were regular Home Upgrade projects, which did not include energy models with measure-level detail. Muni Advanced Home Upgrade was the umbrella used to describe SoCalGas-associated Advanced Home Upgrade projects that included measure-level savings details.

Source: Guidehouse

Table A-4. Additional ATR Project Statistics for SDG&E

SDG&E ATR Project Descriptor	Total Count	% of Total First-Year Savings	Count in Sample
Home Upgrade 2016*	235	58.1%	-
Home Upgrade 2016 SDG&E/SoCal Gas*	35	12.3%	-
Advanced Home Upgrade 20%	20	8.5%	3
Advanced Home Upgrade 10%	76	8.4%	10
Advanced Home Upgrade 15%	42	7.3%	10
Advanced Home Upgrade 25%	6	3.8%	1
Advanced Home Upgrade 45%	1	0.8%	-
Advanced Home Upgrade 30%	2	0.8%	-
Total	**417**	**100%**	**24**

* Home Upgrade projects do not involve energy modeling, so measure-level savings data is unavailable.

Source: Guidehouse

Appendix B. Sensitivity Analysis for Air Sealing Measure EUL

As discussed in Section 2.3.2, Guidehouse used the 11-year EUL for low-income weatherization from DEER as a proxy for air sealing but also identified values of 15 years and 20 years from other state TRMs.

Table B-1 shows the results of a sensitivity analysis where the research team examined the effect of varying the air sealing EUL on the final whole building EUL. These values are weighted using total electric and natural gas savings, RUL values of 6.67 years for weighting insulation measures, and an EUL value of 18 years for weighting duct sealing. Increasing the air sealing measure EUL from 11 years to 20 years increases the whole building EUL for all PAs by only 0.2 years.

Table B-1. Air Sealing Measure EUL Sensitivity Analysis – Insulation Weight of 6.67 years

Air Sealing EUL	PG&E EUL	SCE EUL	SoCal Gas EUL	SDG&E EUL	Combined EUL
11 years	14.7	12.6	13.4	16.0	**15.3**
15 years	15.3	13.4	13.5	16.1	**15.4**
20 years	15.7	14.0	13.7	16.1	**15.5**

Source: Guidehouse

Table B-2 and Table B-3 show the results of the same sensitivity analysis when insulation measures are weighted using a measure EUL value of 20 years and 31 years respectively.

Table B-2. Air Sealing Measure EUL Sensitivity Analysis – Insulation Weight of 20 years

Air Sealing EUL	PG&E EUL	SCE EUL	SoCal Gas EUL	SDG&E EUL	Combined EUL
11 years	17.2	18.7	18.4	16.0	**17.4**
15 years	17.5	19.1	18.9	16.1	**17.8**
20 years	18.2	19.3	19.5	16.1	**18.2**

Source: Guidehouse

Table B-3. Air Sealing Measure EUL Sensitivity Analysis – Insulation Weight of 31 years

Air Sealing EUL	PG&E EUL	SCE EUL	SoCal Gas EUL	SDG&E EUL	Combined EUL
11 years	18.4	22.6	22.1	16.0	**19.7**
15 years	18.8	22.8	22.4	16.1	**20.1**
20 years	19.8	23.7	23.1	16.1	**20.3**

Source: Guidehouse

Appendix C. Additional Detail on Reasons for EUL Trend in Binning

As discussed in Section 3.3, the trend in which the weighted whole building EUL increases as the proportion of electricity savings increases occurs because projects with a low proportion of electricity savings are more likely to draw a higher proportion of savings from shorter-lived insulation or air sealing measures than from longer-lived measures like duct sealing or windows.

Table C-1 lists each measure found in the sample of projects, sorted in descending measure EUL order. The second column shows the proportion of the 92 projects in which the measure was present. The three rightmost columns show the average proportion of total electricity and natural gas savings that each measure accounted for, broken down into the three bins defined in Section 3.3. Color coding indicates the bin for which each measure contributes the highest proportion of savings on average (darker shading indicates a higher proportion of savings).

Table C-1. Average Weight by Measure Across Fuel Proportion Bins

Measure	Measure Prevalence*	EUL or RUL	Average Weight (Proportion of Total Project Savings)		
			0%-25% Electric Bin	25%-75% Electric Bin	75%-100% Electric Bin
Attic Insulation	58%	6.67	28%	25%	18%
Floor/Crawl Insulation	7%	6.67	23%	11%	-
Wall Insulation	27%	6.67	42%	24%	14%
Pool Pump	2%	10	-	25%	54%
Air Sealing	48%	11	15%	13%	8%
Water Heater (Gas, Tank)	4%	11	19%	12%	-
Central AC	66%	15	5%	32%	61%
Heat Pump	10%	15	-	31%	26%
LED Lighting	1%	16	5%	-	-
Duct Sealing/Insulation	93%	18	13%	24%	29%
Gas Furnace	36%	20	27%	16%	14%
Water Heater (Gas, Tankless)	17%	20	35%	33%	-
Windows	14%	20	12%	23%	37%

* Measure prevalence is the proportion of the 92 sample projects that contained the given measure.
Source: Guidehouse

Error! Reference source not found. illustrates the underlying trends that are responsible for the overall trend of lower weighted EUL values for projects with a higher proportion of electricity savings. The measures at the top of the table with the shorter lifetimes, on average, make up a greater proportion of savings for projects in which savings are primarily from natural gas. Although less pronounced, measures as the bottom of the table with longer lifetimes, on average, make up a greater proportion of savings for projects in which savings are primarily from electricity with the exception of gas furnaces and water heaters.

A notable result is that while duct sealing is generally a fuel-agnostic measure (it can reduce HVAC losses for both natural gas furnaces and electric central air conditioners), in the sample of projects for this study it contributed a larger proportion of savings (29% versus 13%, on average) for projects with savings primarily from electricity (air conditioners) than from natural gas (furnaces). Modifications to the duct sealing measure EUL value could therefore have a considerable effect on the strength of the observed trend.

As shown in Appendix D, the research team notes that if insulation measures were weighted using EUL values of 20 years or 31 years rather the current RUL value of 6.67 years, the three insulation measures currently at the top of the table would move to the bottom. This would result in a reversed and stronger trend in which the longest-lived measures—insulation, gas furnaces and water heaters—all make up a greater proportion of savings for projects in the 0%-25% electric bin and cause that bin to have the highest weighted EUL value rather than the lowest.

Appendix D. Results Using Full Measure EUL for Insulation Measures

As discussed in Section 3.3, the research team analyzed how the overall weighted EUL results would vary if full measure EULs of 20 years or 31 years were used to weight attic, wall, and floor insulation measures. This was motivated in part due to a finding from Guidehouse's 2020 EUL study of attic, wall, and floor insulation. That study found that using the full EUL for insulation retrofits is preferable to using RUL values given the nature of the upgrades, because new insulation work brings the original or existing insulation up to a brand-new state and fixes any gaps or flaws.

D.1 Insulation EUL of 20 Years

Table D-1 shows the savings-weighted EUL values by PA when measure EULs of 20 years are used to weight attic, wall, and floor insulation. Weighting is based on total energy savings (combined electric savings plus natural gas savings). The resulting composite value across all PAs is 17.4 years. The combined weighted EUL value is 2.1 years higher than the comparable result in Table 7 which uses the current RUL value of 6.67 years to weight insulation measures.

Table D-1. Overall Weighted EUL with 20-year Insulation EUL

PA	Overall EUL Weighted Using Total Savings (Years)
PG&E	17.2
SCE	18.7
SoCal Gas	18.4
SDG&E	16.0
Combined	**17.4**

Source: Guidehouse

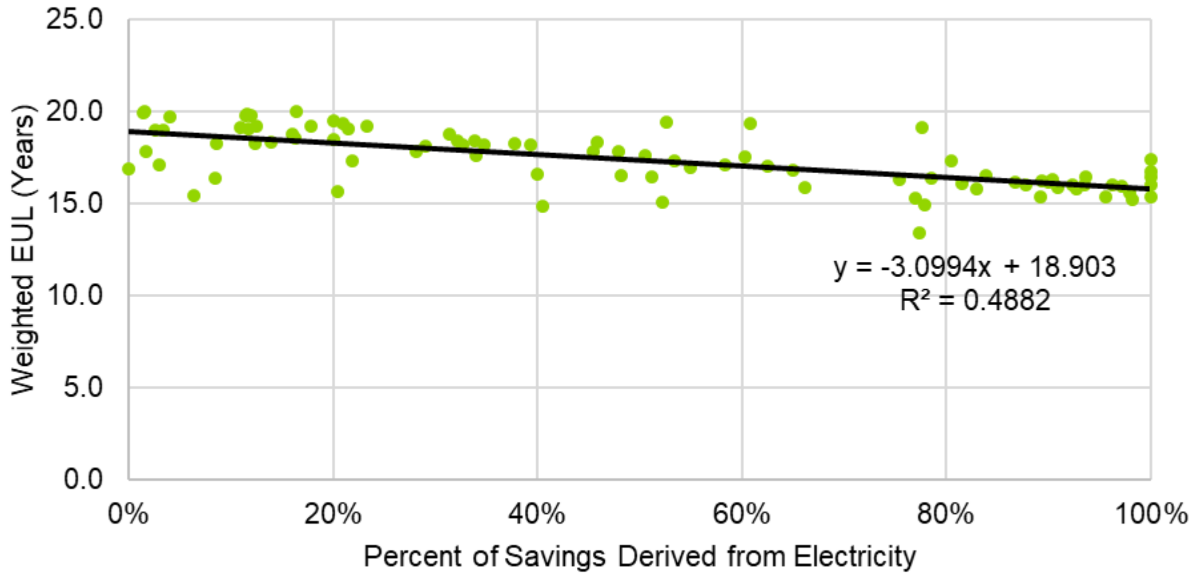
Figure D-1 plots the calculated project-level EUL versus the proportion of project savings derived from electricity when insulation measures are weighted using the full 20-year EUL value. This is analogous to Figure 5 in the main body. Unlike the positive correlation in Figure 5,

Figure D-1 shows a negative correlation. That is, the aggregate EUL now *decreases* as a project's proportion of electricity-derived savings increases. The insulation-heavy projects in which most savings are derived from natural gas now have the highest EUL values of any individual measure, resulting in higher aggregate EULs.

The team also notes that the negative correlation in

Figure D-1 (R^2 of 0.49) is stronger than the positive correlation in Figure 5 (R^2 of 0.27).

Figure D-1. EUL vs. Percent of Electricity-Derived Savings with 20-year Insulation EUL



Source: Guidehouse

Table D-2 shows the weighted EUL values for each bin and each PA when an insulation EUL of 20 years is used. This is analogous to Table 10 in the main body.

Table D-2. EUL for Fuel-Related Savings Bins with 20-year Insulation EUL

Bin	PG&E EUL	SCE EUL	SoCal Gas UL	SDG&E EUL	Combined EUL
0%-25% Electric Savings	17.9	19.2	19.1	N/A	**19.0**
25%-75% Electric Savings	17.1	18.2	18.4	17.2	**17.7**
75%-100% Electric Savings	15.3	16.7	16.8	16.0	**16.0**

Source: Guidehouse

D.2 Insulation EUL of 31 Years

Table D-3 shows the savings-weighted EUL values by PA when a measure EUL of 31 years is used for attic, wall and floor insulation. The 31 year value comes from the Guidehouse 2020 EUL study for residential attic, floor, and wall insulation which had not yet been published as of April 2021. The reuslting composite value across all PAs is 19.7 years.

Table D-3. Overall Weighted EUL with 31-year Insulation EUL

PA	Overall EUL Weighted Using Total Savings (Years)
PG&E	18.4
SCE	22.6
SoCal Gas	22.1

SDG&E	16.0
Combined	**19.7**

Source: Guidehouse

Figure D-2 plots the calculated project-level EUL versus the proportion of project savings derived from electricity when insulation measures are weighted using a 31-year EUL value. This is analogous to Figure 5 in the main body and

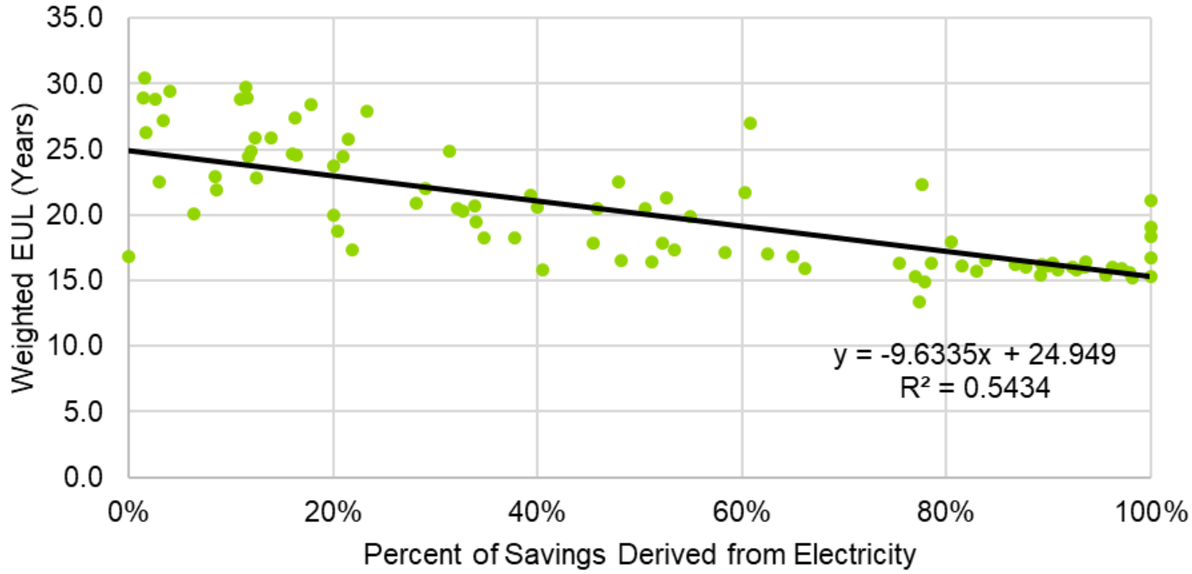
Figure D-1 above. Like

Figure D-1, Figure D-2 shows a negative correlation in which the aggregate EUL *decreases* as a project's proportion of electricity-derived savings increases.

When an EUL of 31-years is used for insulation, the negative correlation in Figure D-2 (R^2 of 0.54) is even stronger than the correlation in

Figure D-1 (R^2 of 0.49) where an EUL of 20 years is used.

Figure D-2. EUL vs. Percent of Electricity-Derived Savings with 31-year Insulation EUL



Source: Guidehouse

Table D-4 shows the weighted EUL values for each bin and each PA when an insulation EUL of 31 years is used. This is analogous to Table 10 in the main body.

Table D-4. EUL for Fuel-Related Savings Bins with 31-year Insulation EUL

Bin	PG&E EUL	SCE EUL	SoCal Gas UL	SDG&E EUL	Combined EUL
0%-25% Electric Savings	22.5	25.8	24.8	N/A	**24.6**
25%-75% Electric Savings	17.8	21.5	20.8	17.2	**20.1**
75%-100% Electric Savings	15.3	18.2	16.8	16.0	**16.1**

Source: Guidehouse

Appendix E. Stakeholder Comments and Research Team Reponses

The research team received the following stakeholder comments and questions during the official comment period. This appendix documents the research team's responses.

E.1 SDG&E Comments

1. *We understand that the CPUC's Ex-Ante Workpaper Team is soliciting feedback from PAs regarding "EUL_IDs for expiration consideration 2021-04-29_all IOUs." Many of the EULs used in the Residential Whole Building EUL Study are flagged for expiration for*

DEER2023. How will Guidehouse coordinate with the Ex Ante Team on this? Will the expiration of EULs impact the results of this study? Recommend coordinating with the CPUC's Ex-Ante Workpaper Team to help with this study's results.

Response: It is the research team's understanding that the aforementioned EUL codes are being retired in the near future, but this does not indicate that the underlying EUL values are changing. This whole building research and its conclusions will remain unaffected, since the EUL values for the individual technologies – which still remain operable in practice – are unchanged. Additionally, if any of the underlying EUL values change, the methodology for the whole building EUL determination is unchanged. The resulting value can be updated with the same methodology.

2. *Will the recommended EUL values from the study be included in the DEER updates? If so, when will these the updates take effect? Again, recommend for coordination with the CPUC Ex-Ante Workpaper Team as their deliverables could be at different DEER cycles.*

   Response: The upcoming DEER resolution will consider the new whole building EUL values for adoption.

3. [Comments 3 and 4 are combined here.] *In Table 4, the EUL/RUL DEER ID for residential gas tank water heaters is referencing an electric tank water heater. We recommend changing the DEER 2014 ID for residential gas tank water to correctly reference " WtrHt-Res-Gas" so that it aligns with the 11 year EUL, because the EUL for residential electric water heaters is 13 years.*

   In Table 4, the EUL/RUL DEER ID for residential gas tankless water heaters is referencing a gas tank water heater. We recommend changing the DEER 2014 DEER ID for residential gas tankless water to correctly reference "WtrHt-Instant-Res" so that it aligns with 20 year EUL.

   Response: Thank you for flagging. These were reporting errors/typos in Table 3. We confirm that the EUL values used in the analysis are 13 years for gas tank and 20 years for gas tankless water heaters. We have corrected the EUL IDs and values listed in Table 3 (which also listed the incorrect ID for Windows). Results for weighted EUL values are unchanged, since the correct values were used in the underlying analysis.

4. *The study needs to clarify the "Measure Application Type" (MAT) it used for determining the EUL/RUL years. * Table 4 (pages 11-12) list several "Measures" types, but omits the MAT logic that is needed to determine if EUL or RUL years are to be referenced in the study. * DEER EUL Basis support table lists both the EUL and RUL and the "MAT" is a prime indicator as to determine which of the two values (EUL or RUL years) are to be referenced and used. * Per CPUC guidance, the following are examples to determine if EUL or RUL years are to be used: * for Normal Replacement (NR) EUL years are used * for Add-on Equipment (AOE) RUL years are used * for New Construction (NC) EUL years are to be used * for Behavior, Retro-commissioning, and Operational types EUL years are used Additionally, the study needs to clarify that those insulation only measures (attic/floor/crawl/wall) listed in Table 4 are considered Add-on Equipment (AOE) as stated in DEER 2020 CPUC Resolution E4952, page A-37, for Add-On Equipment (AOE) measures.*

   Response: Measure application type (resulting in the use of effective useful life vs remaining useful life) is discussed in Sections 2.3.2 and 3.3, as well as in Appendix B. As a result of this comment, the research team has included additional mention of which measures use RUL, in Table 3.

E.2 SCG Comments

1. *Page 27 of the report mentions "…These tables do not include multifamily projects because those projects were out of the project scope…" Please explain the reason for this exclusion.*

   Response: Multifamily residential buildings have inherently different energy consumption and savings drivers as compared to single family residential buildings. In order to provide quality research within the intended budget and timeline, the research team focused this round of research on single family buildings only. This focal point was outlined in the research plan, which was approved prior to starting any data collection or analysis.

2. *Page 5 of the report mentions that the primary objective of this EUL research was to answer the question of "What is the estimated aggregate EUL of residential whole building projects?" In table 8 on page 22, the combined EUL is mentioned as 15.2. Is this what the report is suggesting that future programs use as whole house weighted aggregate EUL?*

   Response: While the Guidehouse team role in this effort is to present research results and commentary on the conclusions that can be derived from that research, it is ultimately up to the DEER team to publish official values and direction for their use. What we are implying from this research is that several "bins" (by savings type) would provide more nuanced EUL values moving forward, even without detailed information on measure mix. These values can be found in Table 9 (or Table D-2, if full 20-year insulation EUL/RUL values are approved in the future.) For projects that have 0-25% of the savings provided be electricity (in other words, 75-100% of savings come from natural gas), we have an average value of 10.6 years, as seen in Table 9. In Table 7, the gas savings (ie: the value most pertinent to SCG) does not include any measures in projects with electrical savings, and some amount of real electrical savings data is being discarded. Therefore, these gas-only values may not accurately represent the real whole building projects that were analyzed for this study. Therefore values in Table 9 are preferable to those found in Table 7, because no data is being thrown out or ignored.

   Note, however, that although the 0-25% electrical savings bin values are low (10.2 years), the use of insulation RUL (6.7 years) is a main factor. We have also included a scenario that uses a 20-year value of insulation and greatly increases composite EUL values across-the-board. Concurrent EUL research on insulation points towards using 20 years even for insulation retrofit projects, but that report has not yet been finalized. We included detailed information on this scenario in Appendix D, however, so that the new values may be adopted if/when the insulation conclusions are accepted.

3. *On Page 13 of the report, table [2] shows that SoCalGas has many projects as compared to the other utilities. However, in the sampling process mentioned in table 3 on page 14, and in table 6 on page 18, the number of samples taken from SoCalGas is the least amount amongst all the utilities. The number of samples has a direct relationship with any conclusion. Please elaborate how the research team arrived at the total number of samples from each utility.*

Response: The sample sizes from each PA were derived directly from the population of *Advanced* Home Upgrade projects that had modeled, measure-level savings available for analysis as a result of late 2019 / early 2020 data requests. As shown in Table A-3, a large majority of the SCG records found in the ATR were not grouped into projects with modeled savings, were associated with other PAs or Publicly Owned Utilities (POUs), or were regular Home Upgrade projects. Because *Muni Advanced Home Upgrade* was the umbrella term used to describe SCG-associated Advanced Home Upgrade projects that included measure-level savings details, SCG had a much smaller population of projects with the requisite data for this analysis, especially as compared to other PAs. (SCG had 50 projects total, as compared to ~1,500 for the next smallest PA, and ~16,000 for the largest PA). We achieved a relative precision of ~25% for each stratum (PA+year), including SCG.

4. *Page 26 section 4 mentioned "…Whole building projects deriving savings predominantly from natural gas tend to have shorter composite EUL values than those deriving from electric savings. The shorter EUL for natural gas projects is derived from such projects being more likely to draw a higher proportion of savings from shorter-lived measures like air sealing and insulation than from relatively longer-lived measures like air conditioning, duct sealing, or high-performance windows…" SoCalGas has measures such as water heater with an EUL of 11 years and gas furnace with an EUL of 20 years. Please elaborate how this report arrived at this conclusion. Would this conclusion change if more sampling had been done from the SoCalGas projects?*

   Response: The largest driver of a short gas EUL is the requirement to use RUL for insulation projects. This yields a calculation with a strong emphasis on the 6.7-year RUL of insulation. Insulation EUL research is currently in the process of being finalized, and will propose *not* using the RUL in the case of retrofit projects, but rather the full 20-year EUL, since an insulation retrofit project typically brings the whole assembly up to new condition. We have included supplemental calculations in Appendix D to attempt to expedite an update to the whole building EUL value if/when the insulation research is approved.

   Regarding sample sizes, we were able to achieve comparable relative precision values among different PAs with the existing sample. We do not think that additional sample for SCG would dramatically impact the results, especially since the results (Table 9) are framed by project savings type, and SCG whole building projects are most likely to fall into the 0-25% electrical savings bin, which was itself most strongly influenced by SCG data.

E.3 IGSD Comments

1. [Abbreviated] *I would like to share and observation: many central AC and heat pump units in California last longer than the 15 years assumed in this study and the DEER database. These old units use a disproportionate amount of energy, and contribute a disproportionate amount of peak demand. But because California uses "average" life instead of a distribution of average lifetimes, these older units (16 years and older) are essentially phantoms or vampires--out there sucking energy, but assumed to be gone per CA's assumptions, and less eligible for rebates and incentives because they are beyond their useful lifetimes, when we believe CA should be targeting even MORE resources to get them off the grid (i.e. higher incentives).*

Response: We agree that heat pumps are of high importance for future EUL research, and their position as a large user of household energy weighs heavily in prioritization of future measures. The team did evaluate the feasibility of studying residential heat pump EUL during this cycle—even submitting a formal heat pump research plan—and requested data on installed or removed heat pumps, but did not receive the quantity of sufficiently old heat pump units to be able to draw strong conclusions.

Heat pumps remain a strong priority for study, and the EUL team has considered alternative options for research. Ultimately, the heat pump question is outside of the scope of this whole building research, however.

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