GROUP A

Residential HVAC and DHW Measure Effective Useful Life Study Final Report

California Public Utilities Commission
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Glossary of terms

C-20 Licensed Contractor – The C-20 HVAC License is a Class C Specialty Contractor License offered by the state of California, required to conduct legal operations in air conditioning projects, heating ventilation, and other climate control projects. A C-20 licensed contractor is a warm-air heating, ventilating, and air-conditioning contractor that fabricates, installs, maintains, services, and repairs warm-air heating systems, air conditioning systems, and water pumps.

C-36 Licensed Contractor – The C-36 Plumbing License is a Class C Specialty Contractor offered by the state of California, required to conduct legal operations in plumbing design, installation, repair, and inspection and maintenance. A C-36 plumbing contractor provides a means for a supply of safe water, ample in volume and of suitable temperature for the purpose intended, and the proper disposal of fluid waste from the premises in all structures and fixed works.

Effective Useful Life (EUL) – Effective useful life (EUL) is defined as an estimate of the median number of years that the measures installed under a program are still in place and operable.[1]

Measure – A product whose installation and operation at a customer's premises results in a reduction in the customer's on-site energy use, compared to what would have happened otherwise.[1]

Participant – An individual, household, business, or other utility customer that received a service or financial assistance offered through a particular utility program, set of utility programs, or aspect of a utility program in a given program year.[1]

Performance Degradation – Any over time savings degradation (or increases compared to standard efficiency operation) that includes both (1) technical operational characteristics of the measures, including operating conditions and product design, and (2) human interaction components and behavioral measures.[1]

Persistence Study – A study to assess changes in net program impacts over time (including retention and degradation).[1]

Precision – The indication of the closeness of agreement among repeated measurements of the same physical quantity. In econometrics, the accuracy of an estimator is measured by the inverse of its variance.[1]

Reliability – When used in energy evaluation refers to the likelihood that the observations can be replicated.[1]

Retention (Measure) – The degree to which measures are retained in use after they are installed.[1]

Rigor – The level of expected reliability. The higher the level of rigor, the more confident we are that the results of the evaluation are both accurate and precise, i.e., reliable.[1]

Sample Design – The approach used to select the sample units.[1]

Survival Analysis – Survival analysis is a class of statistical methods for studying the timing of events or time-to-event models. Originally these models were developed for medical research where the time to death was analyzed, hence the name survival analysis. These statistical methods are designed to work with time-dependent covariates and censoring. Time-dependent covariates are independent variables whose impacts on the dependent variable vary by not only their occurrence but also their timing. Censored data refers to not knowing when something occurred because it is before your data collection (left-censored) or has yet to occur at the time of data collection (right-censored).[1]

[1] CPUC. "California Energy Efficiency Evaluation Protocols: Technical, Methodological, and Reporting Requirements for Evaluation Professionals. Appendix B: Glossary of Terms." April 2006.

1 EXECUTIVE SUMMARY

This report presents the findings of the effective useful life (EUL) evaluation study conducted by DNV on behalf of the California Public Utilities Commission (CPUC) of five residential heating, ventilation, and air conditioning (HVAC) and domestic hot water (DHW) heating technologies. This is the second of the two residential EUL studies with measure technologies selected by the joint staff (DNV and CPUC). For this study, DNV classified the residential HVAC and DHW technologies into two groups: nascent heat pump and established gas technologies. The nascent heat pump technologies include heat pump HVACs and heat pump water heaters, whereas the established gas technologies include gas furnaces, gas storage water heaters, and gas tankless water heaters.

1.1 Study background and objectives

An EUL is the estimate of the median number of years that a measure, or energy-efficient technology, installed under a program is still in place and operable. EUL values are critical in reliably estimating the lifetime energy savings that are used for program planning and evaluation activities, and therefore, need to be periodically re-assessed. The current Database for Energy Efficiency Resources (DEER) EUL values of residential HVAC and water heating technologies come from studies that were conducted 15 to 20 years ago. These EUL values need to be updated to reflect the impact of technology advancement, maintenance practices, occupancy, space remodeling, human interaction components, climate change, and many other factors that have shifted in recent years. Moreover, there is strong interest from stakeholders as the HVAC and DHW technologies, particularly the nascent technologies, support California's decarbonization and savings goals.

The objectives of this residential HVAC and DHW EUL Study were to:

- Revise or verify EUL estimates for the five residential nascent and established HVAC and DHW technologies.
- Conduct a retention study for residential nascent heat pump HVAC and heat pump water heaters. A retention study is performed through the development of a retention rate to assess what percent of impacted technologies installed over the last 15-20 years are still in-place and working.

1.2 Study methods and results

To arrive at EUL estimates, DNV adopted a primary data collection and analysis method that assessed the current status (if still in place), working condition (operable or not), and the age of a sample of impacted equipment. The sampled equipment was selected from a distribution of installation ages, ranging between 2006 and 2023, occurring through energy programs in California and from a subset of equipment, with ages ranging from 11 to 40 years, that DNV observed via non-participant surveys. Table 1-1 summarizes our targeted and achieved sample size for different age groups of the impacted HVAC and DHW technologies.

Table 1-1. Targeted and achieved sample size by age and technology

Age (Years)	Nascent heat pump technologies				Established gas technologies					
	Heat pump HVAC (central and ductless)		Heat pump water heater		Gas furnace (Central and wall)		Gas storage water heater		Gas tankless water heater	
	Target sample	Final Sample	Target sample	Final Sample	Target sample	Final Sample	Target sample	Final Sample	Target sample	Final Sample
1-3	150	123	153	264	30	139	20	232	20	1,108
4-5	12	5	42	65	30	43	20	170	20	480
6-7	4	1	62	95	93	72	20	67	20	112
8-10	17	14	44	35	101	43	20	-	20	1
11	7	8	-	-	3	206	3	2	3	-
12	6	9	1	3	5	251	6	2	6	-
13	3	3	-	-	-	507	2	2	2	4
15-17	-	-	-	-	125	516	-	-	-	3
11-40	4	4	-	-	29	10	68	62	68	3
Total	**201**	**167**	**302**	**462**	**416**	**1,787**	**163**	**537**	**163**	**1,711**

As the primary data collection approach, DNV conducted email surveys followed by phone calls and site inspections. We gathered in place and operable status information of the installed impacted equipment, and documented nameplate pictures. The nameplate photos in conjunction with customer-reported age information were used to estimate the age of impacted equipment. This information was then used to develop and predict the probability of survival of the impacted equipment – a survival analysis. An EUL is the amount of time that passes until 50% of the impacted equipment is still in place and working (surviving). Table 1-2 summarizes our data collection findings and our primary analysis results.

Table 1-2. Primary data collection and analysis summary

Residential technology	Total units observed	Count of units that were still in-place & working	Count of units that had failed/ were removed	Estimated EUL (years)
Nascent heat pump technologies				
Heat pump HVAC (ductless & central)	167	162	5	23
Heat pump water heater	437	437	25	38
Established gas technologies				
Gas furnace (central & wall)	1,787	1,652	135	36
Gas storage water heater	497	497	54	25
Gas tankless water heater	1,711	1,682	29	20

Because the heat pump technologies (heat pump HVAC and heat pump water heater) are nascent technologies, only a limited number of installations through energy programs between 2006 to 2023 were old enough to provide a good basis for a precise estimate of the EUL. So, we pursued a secondary method that assessed the age of a sample of equipment replaced by licensed C-20 HVAC and C-36 plumbing contractors and program implementors of the investor-owned utilities (IOUs), regional collaboratives (BayREN), public utilities (MCE), and local government joint power authorities (RCEA) during this study. This involved gathering nameplate pictures and age information of heat pump technologies removed between July to October 2023 through the current heat pump programs offered by the utilities in California and through C-20 and C-36 licensed contractors in California. The program implementors could not accommodate providing appropriate baseline equipment data, so we only relied on data gathered through C-20 and C-36 contractors to establish the age of heat pumps replaced during this study.

DNV reached out to 691 C-20 and C-36 licensed contractors and was able to recruit 43 contractors that had either replaced heat pump technologies in the past or anticipated replacing heat pumps. Among the recruited 43 contractors, only 5 contractors followed up with 10 nameplate photos of heat pump HVACs. No nameplate pictures for heat pump water heater replacements were provided by the contractors. For the 10 heat pump HVAC nameplate pictures we received from contractors, we estimated the installation date of the removed heat pump technologies by comparing nameplate manufacturing date with the contractor reported installation date. We then compared the verified installation date against the date of removal to estimate the age of heat pump HVACs at replacement. The age-at-replacement analysis of heat pump HVAC yielded a median age of 21.72 years and an average age of 20.03 years. This is consistent with the 23 year EUL estimated through our primarily analysis.

1.3 Key findings and recommendations

The key findings and recommendations from the residential EUL evaluation study are as follows.

Finding 1. Increases to the EUL values for heat pump HVAC, heat pump water heaters, and gas storage water heaters should be considered based on the results of this study.

As presented in

Table 1-3, this study developed EUL estimates of five residential HVAC and DHW technologies. For the heat pump HVAC and heat pump water heaters (nascent heat pump technologies), the EUL values estimated by this study are 23 years and 38 years, respectively, which are above the CPUC's 20-year EUL limit. [2] Similarly, for the established gas furnace and gas storage water heaters, the EUL values estimated by this study are well above the 20-year EUL cap. For gas tankless water heaters, the EUL value estimated by this study is exactly 20 years.

The CPUC has a 20-year cap on EUL of all energy efficiency measures [2]; however, per the criteria set forth by Decision 09-05-037[3], the 20-year EUL cap can be extended to 30 years if "substantiated by supporting measure empirical data and subjected to review by Energy Division". The evaluated EUL values for heat pump HVAC, gas furnaces, and gas storage water heaters in this study are backed by empirical data, affirming their eligibility for a 30-year cap extension. However, for heat pump water heaters, such an extension is not eligible due to limited data availability. We cannot confidently extrapolate

[2] CPUC. cpuc.ca.gov D0111066 Energy Efficiency Policy Manual (ca.gov)

[3] Decision 09-05-037. May 21, 2009. Application of Southern California Edison Company (U338E) for Approval of its 2009-2011 Energy Efficiency Program Plans and Associated Public Goods Charge (PGC) and Procurement Funding Requests.

longevity beyond 20 years for this technology. Therefore, heat pump water heaters should still be subjected to the 20-year cap.

Table 1-3. EUL results

Residential technology	Existing EUL (years)[4]	Estimated EUL (years)	Proposed EUL (years)
Nascent heat pump technologies			
Heat pump HVAC (ductless & central)	15	23	23
Heat pump water heater	10	38	20[1]
Established gas technologies			
Gas furnace (central & wall)	20	36	30[2]
Gas storage water heater	11	25	25
Gas tankless water heater	20	20	20

[1] Based on the available regional survival data, we can confidently project an EUL up to 20 years. However, we cannot confidently project an EUL longer than 20 years due to significant extrapolation of the available data.
[2] EUL extension to a maximum of 30 years is allowed per Decision 09-05-037.

Recommendation: Update the EUL values for the heat pump technologies, gas furnaces, and gas storage water heaters.

We recommend updating the EUL values for the following EUL Identifications (IDs) in the Database for Database for Energy Efficient Resources (DEER):

- 'HV-ResHP' with an EUL value of 23 years for heat pump HVAC
- 'WtrHt-HtPmp' with an EUL value of 20 years for heat pump water heaters
- 'HV-EffFurn' with an EUL value of 30 years for gas furnaces
- 'WtrHt-Res-Gas' with an EUL value of 25 years for gas storage water heaters.

Based on the comprehensive analysis conducted and supported by empirical data, we recommend extending the 20-year EUL cap for heat pump HVAC, gas furnaces, and gas storage water heaters to a 30-year EUL limit. The empirical evidence gathered indicates a strong case for the longevity of these technologies, justifying their eligibility for such an extension. However, for heat pump water heaters, due to limited data availability and the inability to confidently extrapolate longevity beyond 20 years, we recommend maintaining the 20-year cap. These recommendations align with the criteria set forth by Decision 09-05-037 and aim to ensure accurate and effective management of energy efficiency measures.

Finding 2. Heat pump technologies have a high retention rate.

[4] California Electronic Technical Reference Manual (terms). caetrm.com, 2023. https://www.caetrm.com/login/?next=/

Based on the in-place and operable data gathered for the sampled heat pump HVACs with age groups ranging from 1 to 20 years, we estimated that 93% of the heat pump HVACs that we observed were still working in 2023. In other words, the retention rate of heat pump HVACs stands at 93%. This high retention rate across different age groups suggests that the heat pumps HVACs are expected to last longer than the current EUL of 15 years.

Similarly, we gathered in-place and operable data for heat pump water heaters that were 1 to 12 years old and found that 95.1% of the observed units were still in place and working in 2023. While we did not have data for units older than 12 years old, based on this high retention rate of 12 years or newer heat pump water heaters, we can conclude that heat pump water heaters are expected to last longer than the current EUL of 10 years.

Recommendation: DNV has no specific recommendation for this finding.