Connecticut X2001 Measure Life Study

Final Results

June 19, 2023

Introduction

Study Objectives and Approach

- Objectives
  - Identify the highest priority EULs to address
  - Update EUL and RUL values for key measures for TRM
- Approach
  - Conduct one study of participants from multiple (9+) years rather than multiple studies of single-PY cohort
  - Use Web survey. Limited to measures easily-identified by participants, that would tend to have memorable failure dates
  - Provides more efficient, quick turn-around, and cost-effective approach for EULs than usual single year approach

Effective Useful Life (EUL) – the median number of years between installation of a piece of equipment and its failure or removal

Remaining Useful Life (RUL) – the difference between the current age of operating equipment and its expected age at failure or removal

Key Recommendations
Effective Useful Life (EUL)

1. Update the EUL values in the Program Savings Document (PSD) for the measure types with adequate precision levels.

   a. Updates to residential measures were made in 2023 PSD

2. Conduct additional research on residential natural gas furnaces and insulation to develop EUL estimates with better precision that can be used to update the PSD in the future.

Measure	Estimated EUL (years)	2021 PSD Value	Recommendation
Air Source Heat Pump	20	18	**Update PSD to 20 years**
Ductless Heat Pump	17	18	**Update PSD to 17 years**
Heat Pump Water Heater	15	13	**Update PSD to 15 years**
Central Air Conditioner	25	18	**Update PSD to 25 years**
Gas Furnace	28	20	Continue using PSD value of 20 years
Insulation	38	25	Continue using PSD value of 25 years
Commercial HVAC	n/a	15	Continue using PSD value of 15 years

Key Recommendations
Remaining Useful Life (RUL)

3. Where practical, programs should document the age of the replaced equipment at a site-specific level and use researched RUL values.

4. Where the age of the existing equipment cannot be determined, programs should use the recommended values in this study.

5. For natural gas furnaces and other measures without an RUL specified in the PSD, continue to use the industry standard practice of 1/3 of the EUL.
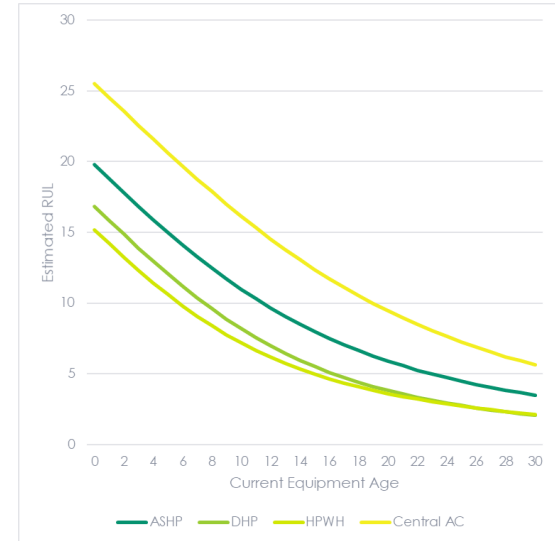
	Recommended EUL	Recommended RUL if Unknown Age
Air Source Heat Pump	20	6
Ductless Heat Pump	17	5
Heat Pump Water Heater	15	5
Central Air Conditioner	25	7
Gas Furnace	20	7*
Insulation	25	N/A

*Denotes 1/3 of Existing PSD EUL

Key Recommendations
EUL Study Methodology

6. Consider conducting future EUL research similar to this for measures that meet the criteria of high levels of participation, large contributions to Connecticut's energy efficiency portfolio, and are able to be easily observed and self-reported by participants.

7. Conduct future research on the measures included in this study, as new cohorts of participants can be added to this data to bolster these results.

8. Consider using the combination of respondent-provided photographs and follow-up interviews for other evaluations and studies where additional verification may be desired but site visits are too costly.

Key Recommendations
EUL Study Methodology, cont'd

9. Consider a mixed mode approach, using both mailed and emailed invitations, for commercial recruitment. Mailed invitations may result in a lower response rate than emailed invitations but are recommended because the person with the email address or the business may no longer be at the address where the equipment was installed.

Methodology

Measure Selection

- Based on:
  - PSD review
  - Program tracking data
  - Feedback from utility staff
- Priority-setting criteria:
  - Utility Data:
    - Number of units installed across years
    - Availability of contact information
  - Availability, rigor, and age of past EUL research
  - Future trends of measures in programs
  - Recent and anticipated changes in technology
  - Limitations of self-reported data collection

Selected Measures

1. Air Source Heat Pump (ASHP)
2. Ductless Heat Pump (DHP)
3. Heat Pump Water Heater (HPWH)
4. Central Air Conditioner (CAC)
5. Natural Gas Furnace
6. Insulation

Residential Measures Selected had Many Installations

Number of Installed Units by Equipment Type by Year

Program (installation) Year	Air Source Heat Pump	Ductless Heat Pump	Central AC	Furnace (Natural Gas)	Heat Pump Water Heater	Insulation[a]
2011	547	431	2,655	15	93	1,146
2012	325	482	2,008	249	175	1,225
2013	264	575	2,081	642	378	1,511
2014	343	2,735	2,404	1,252	1,205	2,253
2015	337	1,332	1,704	1,905	1,015	2,281
2016	115	823	1,023	2,188	1,404	1,769
2017	182	4,768	1,600	3,222	1,657	1,600
2018	146	6,197	1,532	5,185	4,203	948
2019	88	7,810	1,350	7,069	4,666	1,346
Total	2,347	25,153	16,357	21,727	14,796	14,079
Operating Years[b]	7.2	3.9	6.5	3.7	3.8	6.0

a: Number of homes installing attic/wall insulation
b: Weighted average years of operation, computed as differences between 2021 and installation year.
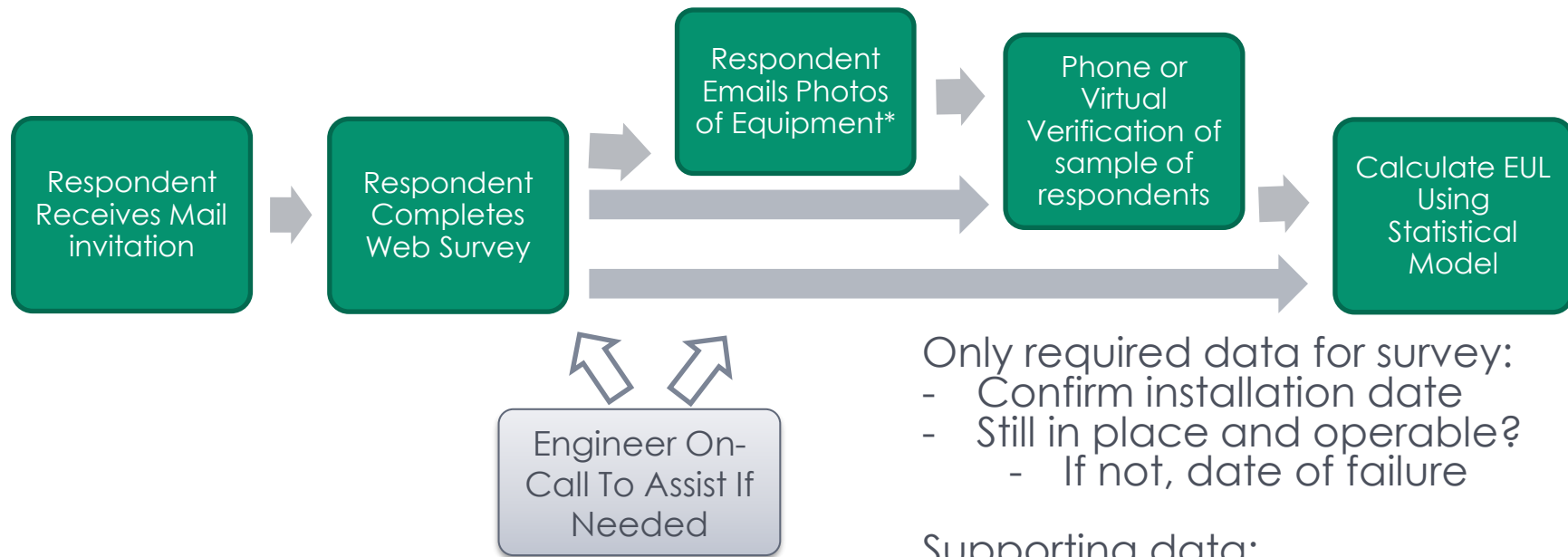
Commercial Measure Selection – More Limited

- **Commercial HVAC** is defined as high efficiency unitary equipment, including both air conditioning equipment and heat pumps.

- While the program tracking data identified the specific equipment (i.e., air conditioning equipment versus heat pumps) for most records, many records were inconclusive and only included a model number or a generic description like "New 5 ton RTU."

Number of Installed Commercial HVAC Units by Equipment Type by Year

Program (installation) Year	Number of Units	Program (installation) Year	Number of Units
2000	141	2011	197
2001	59	2012	169
2002	31	2013	134
2003	85	2014	485
2004	507	2015	488
2005	145	2016	416
2006	189	2017	647
2007	186	2018	418
2008	170	2019	466
2009	172	Total	5,253
2010	148		

Data Collection Overview

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┌──────────────┐      ┌──────────────┐                    ┌──────────────┐      ┌──────────────┐      ┌──────────────┐
│  Respondent  │  →   │  Respondent  │         →          │  Respondent  │  →   │  Phone or    │  →   │ Calculate EUL│
│ Receives Mail│      │  Completes   │                    │ Emails Photos│      │  Virtual     │      │    Using     │
│  invitation  │      │  Web Survey  │                    │ of Equipment*│      │Verification of│     │  Statistical │
└──────────────┘      └──────────────┘                    └──────────────┘      │ sample of    │      │    Model     │
                                            →                                   │ respondents  │  →   └──────────────┘
                                                                                └──────────────┘
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Engineer On-Call To Assist If Needed

Only required data for survey:
- Confirm installation date
- Still in place and operable?
  - If not, date of failure

Supporting data:
- Move-in date

* Photos were optional and not essential to EUL analysis.
(Not asked for commercial HVAC.)

Used Efficient EUL Project Design

- **Single PY multiple studies**: Many EUL studies are conducted using ONE program year of installations.
    - Must wait a few years for **failures**
    - Then wait more years for more failures.
    - Multiple studies, long elapsed time to gain EUL estimate
- **Multiple PYs in one study**: This study leverages program data
    - Uses many (9+) years of participants immediately.
    - Early installations provide source of failures **now**; no need for a second follow-up study.
    - Proven methodology in other jurisdictions (but not for Utility measures)
        - Utility program data provides installation date and equipment type - key pieces of data that need validation in non-utility applications
- Results are less costly and FASTER than panel approach that tracks equipment over multiple years
- Conducted follow-up, since event recall needed

Survey Fielding

- Residential: Two waves
  - Wave 1: ASHP, DHP, HPWH (5/21)
  - Wave 2: CAC, NG Furnaces, Insulation (7/21)
- Commercial: Two waves (2022-23)
  - Wave 1 to premises with only 1 HVAC unit (n=661)
  - Wave 2 to all unique premises with email addresses (n=515)
  - Overall sent to 910 unique facilities out of 1,621

Both
  - Mailed letter invitation with a follow up reminder postcard
  - Incentive of $25 Dunkin' gift card

Completed Residential Surveys

- Total of 2,846 responses
  - Some respondents answered for multiple measures
- Overall response rate of 11%
  - Response rate does not include 252 responses from heat pump survey

Survey Completes and Response Rates for EUL Survey

Measure Type	2011	2012	2013	2014	2015	2016	2017*	2018*	2019*	Total
				Survey Completes						
Air Source Heat Pump	69	50	47	42	46	16	0	6	4	280
Ductless Heat Pump	75	78	96	62	60	62	2	105	63	603
Heat Pump Water Heater	26	45	80	42	3	58	21	14	37	326
Central Air Conditioner	77	89	92	90	82	80	79	50	49	688
Natural Gas Furnace	3	28	85	78	76	73	68	48	51	510
Insulation	71	72	72	72	72	72	72	49	48	600
Measure Type	2011	2012	2013	2014	2015	2016	2017*	2018*	2019*	Total
				Response Rate						
Air Source Heat Pump	15%	18%	21%	21%	16%	16%	--	--	--	18%
Ductless Heat Pump	19%	19%	21%	8%	8%	8%	--	--	--	17%
Heat Pump Water Heater	30%	28%	24%	19%	9%	13%	--	--	--	25%
Central Air Conditioner	9%	11%	12%	12%	10%	10%	10%	9%	9%	10%
Natural Gas Furnace	33%	22%	20%	10%	10%	9%	8%	8%	10%	11%
Insulation	9%	9%	8%	8%	8%	8%	8%	8%	8%	8%

*Includes survey completes from concurrent heat pump study (R2027)

Completed Commercial HVAC Surveys

- Total of 42 responses
- Overall response rate of 4.6%
- Higher response rate for email invitations

Survey Completes and Response Rates for Commercial HVAC Survey

	Sample	Completes	Response Rate
Mail	661	12	1.8%
Email	515	30	5.8%
Total	910	42	4.6%

Equipment Verification (Residential Only)

- Web survey approach has lower fielding costs than in-person site visits but risk of respondent error

- Verified responses in two ways:
  - Photographs of installed equipment
  - Follow-up verification interviews

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Results

Residential Survival Functions

Industry standard estimation method needs only "event" (still operating vs. failure) and years
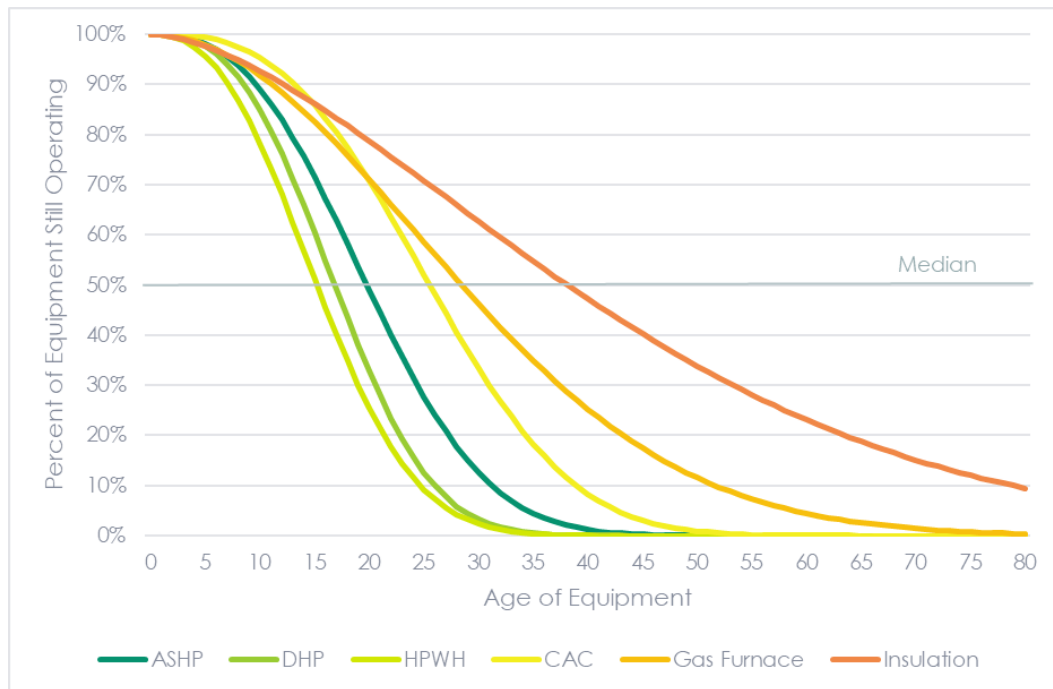
- Survival function shows the share of equipment still operating in each year
- Measure's EUL is the age at which each curve intersects the 50% value of the y-axis (i.e., the **median**)

Residential EUL Estimates, Confidence Intervals, and Recommendations

Installed Measure	Study EUL Estimate	Relative Precision (90% CI)	Lower Bound (90% CI)	Upper Bound (90% CI)	Existing 2021 PSD Value	Recommended Value
Air Source Heat Pump	19.8	30%	13.8	25.7	18	20
Ductless Heat Pump	16.8	20%	13.5	20.1	18	17
Heat Pump Water Heater	15.2	20%	12.1	18.3	13	15
Central Air Conditioner	25.5	39%	15.5	35.6	18	25
Gas Furnace	28.4	87%	3.7	53.1	20	20
Insulation	38.1	89%	4.2	72.0	25	25

Recommendations have been incorporated into 2023 PSD

Remaining Useful Life Curves
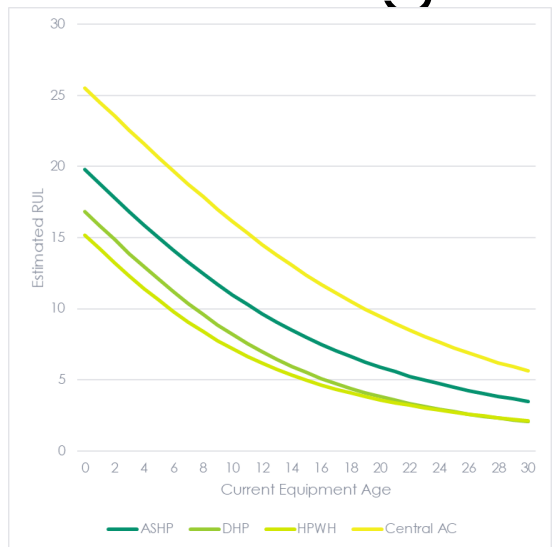
- Survival functions lead directly to estimated RULs for each equipment type
- RUL is an estimate of the remaining life of already-installed equipment
  - Accounts for the fact that the equipment has already installed up to a specific point

Estimated RULs by Length of Time Already Installed

Installed Measure	Length of Time Measure Has Been Installed				
	5 Years	10 Years	15 Years	20 Years	25 Years
Air Source Heat Pump	15	11	8	6	4
Ductless Heat Pump	12	8	6	4	3
Heat Pump Water Heater	11	7	5	4	3
Central Air Conditioner	21	16	12	9	7

Recommended RULs

Estimated RULs by Length of Time Already Installed

Installed Measure	Length of Time Measure Has Been Installed				
	5 Years	10 Years	15 Years	20 Years	25 Years
Air Source Heat Pump	15	11	8	6	4
Ductless Heat Pump	12	8	6	4	3
Heat Pump Water Heater	11	7	5	4	3
Central Air Conditioner	21	16	12	9	7

Recommended RUL if Equipment Age is Unknown

	Recommended EUL	Recommended RUL if Unknown Age
Air Source Heat Pump	20	6
Ductless Heat Pump	17	5
Heat Pump Water Heater	15	5
Central Air Conditioner	25	7
Gas Furnace	20	7*

*Denotes 1/3 of Existing PSD EUL

Commercial HVAC Survival Functions

- All 42 systems were in place and operational at time of survey
  - No failed systems

Estimated Survival Function of Commercial HVAC Equipment with a 15-Year EUL
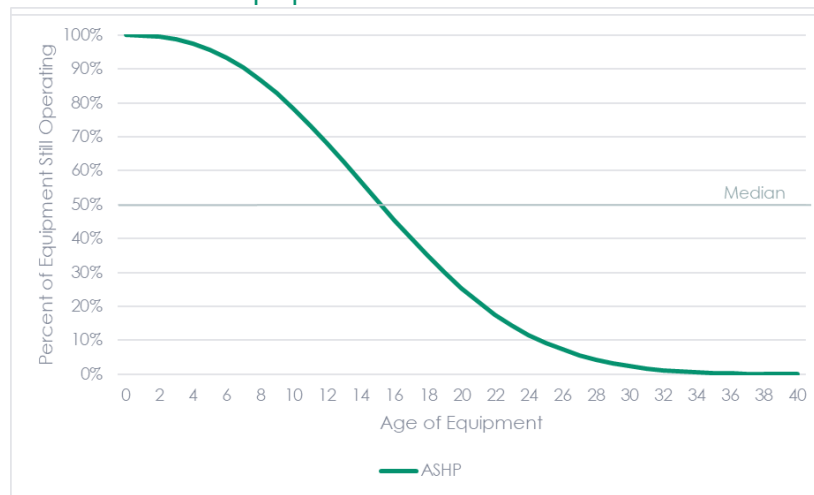
Commercial HVAC Survival Functions

- Applying this survival function to the respondents in the study results in an expected number of failures of **2.1** out of 42, assuming a 15-year EUL

- Cannot determine if lack of failures was due to sampling error from a small sample size with no observations beyond nine years or if the 15-year EUL assumption is too low.

- Overall, while the analysis of the survey results is inconclusive, the Evaluation Team did not see sufficient quantitative evidence that the current 15-year EUL used in the PSD should be updated at this time

Expected Number of Failures in Survey Data Given an EUL of 15 Years