Research Findings: Effective Useful Life (EUL) of Insulation Products

Presented to the Michigan EWR Collaborative

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July 16, 2024

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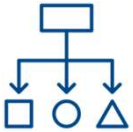
Today's Agenda

Insulation EUL Research Findings

EUL Background & Recommendations Summary

TRM Benchmarking & Literature Review



Methodology Overview

Results and Recommendations

EUL Background & Recommendations Summary

EUL *Is*…

- By its common definition:
  *The **median** number of years that a population of measures is installed and generating savings*
- Slightly different definition for EM&V:

$$EUL = \frac{Lifetime\ Savings}{First\ Year\ Savings}$$

- **Used to calculate** population-wide **typical lifetime savings** for energy-efficiency measures
- Often a negotiated value based on statutory requirements and rarely validated with actual lifetime data

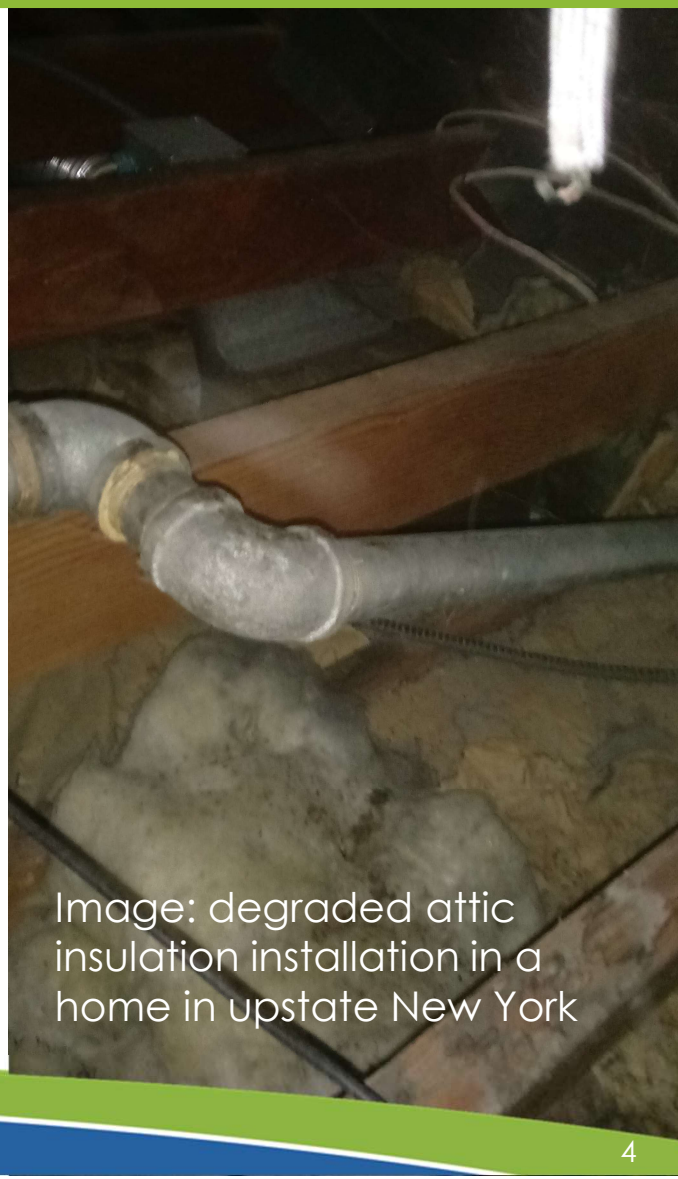


Image: degraded attic insulation installation in a home in upstate New York

EUL *Is Not*…

- A tool for **predicting the age** when a particular piece of equipment will fail
- The age at which all installed equipment for a particular measure is expected to have failed
- Comprehensive enough to manage all edge cases

Image: 1901 "Centennial Light" Livermore, CA

Effective Useful Life Overview

Effective useful life (EUL) is used to determine the savings a measure can achieve over its service life. EUL includes both **technical life** and **persistence**.[a]

Technical life is an estimate of how long a measure can operate based on engineering specifications and standard operating procedures. It may be affected—positively or negatively—by climate, maintenance, and installation conditions.

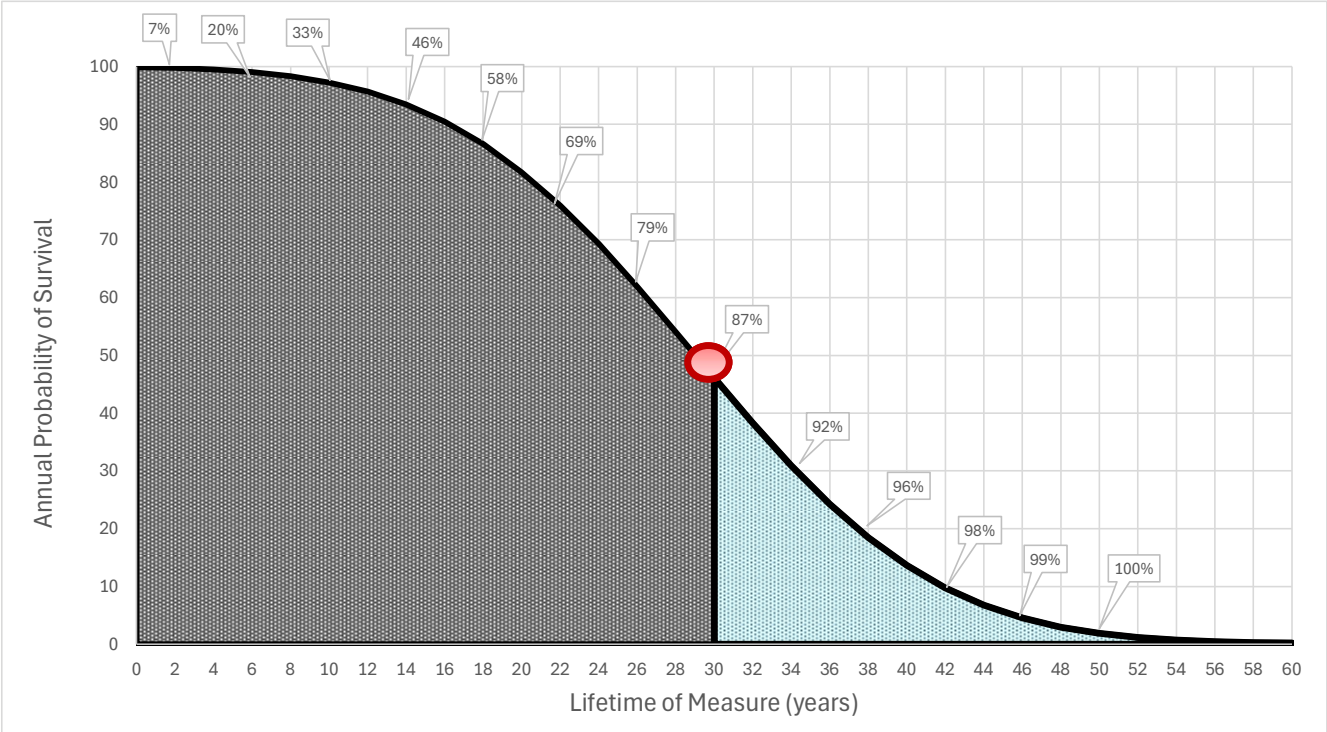
Persistence is the change in savings over the functional life of a measure. This includes two types of changes:

- ***Savings persistence*** refers to factors that affect savings during the measure's use, such as changes in operating hours, processes, maintenance, or performance degradation
- ***Measure persistence*** involves factors that affect the measure's continued use, such as early retirement, retrofits, remodeling, or property turnover

[a] This was paraphrased from the ACEEE paper, "Energy Efficiency Over Time: Measuring and Valuing Lifetime Energy Savings in Policy and Planning."

Example: Annual Savings 30-Year EUL

- The darker shaded area represents cumulative savings after 30 years
- **87% of lifetime savings are realized in 30 years**: As time progresses, the uncertainty of annual savings increases but the future savings estimates represent a diminishing portion of total lifetime savings



EUL Example: Boilers (LBNL Survey)

Table 2. Results for Lifetime Weibull Parameters and Statistics

Sets of Data	Weibull Parameters			Statistics	
	Scale (α)	Shape (β)	Delay (θ)	Mean	Median
Pre 2000 Survey Data	30.0	2.14	1.0	27.6	26.3
Post 2000 Survey Data	29.1	1.84	1.0	26.8	24.8
Post 2005 Survey Data	28.5	2.06	1.0	26.3	24.9
Total Stock only	25.4	3.19	1.0	25.6	25.4
Stock by Age Bin Only	24.6	1.45	1.0	28.6	24.6
All Data	**28.5**	**2.39**	**1.0**	**26.3**	**25.5**

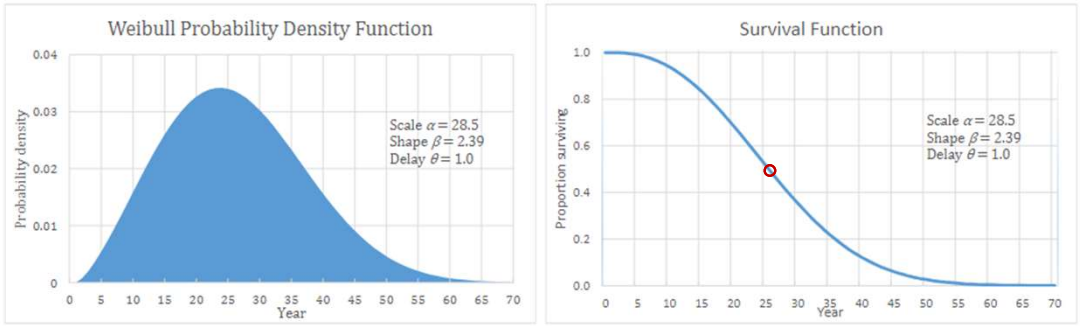


Figure 5 Weibull Lifetime Distribution and Survival Function for Residential Gas Boilers

Source: Franco, Victor, Youness Bennani, Jing Ke, Edward Cubero, and Alex Lekov. August 2018. "Estimating Residential Appliance Lifetime for Energy Efficient Policy Analysis." https://escholarship.org/uc/item/7z222821

- The calculated EUL is based on a **survival curve function**, developed with collected data
- LBNL researchers developed a boiler EUL based on survey data.
- The **mean is higher than the median** for this measure, indicating that a small population of equipment survives for much longer than the EUL.

MEMD EUL Values and Recommended Update

Measure	2024 MEMD EUL Values	Possible EUL Source	Recommended Measure Life (years)
Roof Insulation	**N/A:** Res and MF **30**[a]**:** Commercial	NY TRM	**35**
Ceiling insulation [b]	**20:** Res and MF **30:** Commercial	GDS 2007 Report NY TRM	
Infiltration Reduction [b]	**13**[c]**:** Res and MF	Don't know 11 (DEER, others) or 15 (MA)	
Wall insulation	**25:** Res, MF, and Commercial	MA TRM	
Kneewall Insulation	**20:** Res and MF	Minnesota or Rhode Island TRM	
Rim Joist Insulation	**25:** Res and MF	**TRMs**: MA, VT, WI, NY, CT, ME	
Floor Insulation	**25:** Res and MF		
Basement Wall Insulation	**25:** Res and MF		
Crawlspace Wall Insulation	**25:** Res and MF		
Floor Insulation	**25:** Res and MF		
Belly Insulation (Manufactured Homes)	**25:** Res and MF		

[a] This only applies to roof Insulation between R-11 and R-24. All other measure specifications (such as "Roof Insulation R10 to R18") have 30-year EUL.

[b] The 2023 MEMD update retired the infiltration reduction and attic insulation measure, which was replaced by the tiered ceiling insulation measure (RS 2.2). This effectively de-coupled infiltration savings that would be associated with added insulation (for example, spray foam rim joists can result in significant air leak reduction).

[c] The recommended EUL of 35 years for infiltration reduction is appropriate for projects receiving comprehensive air sealing and insulation. Air sealing measures like weatherstripping or caulking around doors or windows may have different EUL.

Benchmarking & Literature Review

Benchmarking

In 8 peer TRMs, **EUL** values ranged from **20 to 30 years**

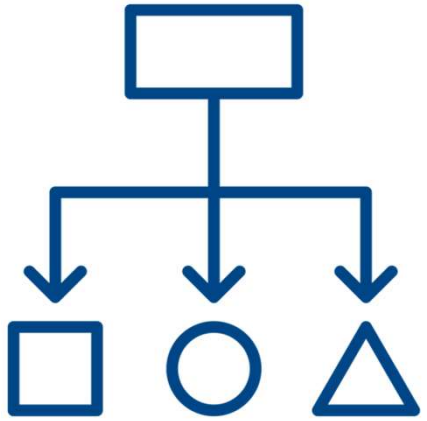
- The most-cited study, a GDS Associates measure life report from 2007, is primarily based on consensus measure life values from program documentation rather than independent research
- Some jurisdictions, such as California, have a statutory limit on the maximum EUL for measures

TRM Document	EUL	EUL Citation in TRM	Year
2021 CT PSD	25	X2001 Study Estimate [a]	2021
Efficiency Vermont TRM	25	None	N/A
Wisconsin TRM	25	None	N/A
New York TRM (v11)	25 Res; 30 C&I	GDS Associates 2007 Measure Life Report [b]	2022
Massachusetts TRM 2022-2024 Plan	25		2022
Rhode Island TRM PY2020	20		2020
Efficiency Maine (v2022.3)	25		2023
Illinois TRM	30 50 (concrete forms) [c]	CPUC [d]	2024

[a] https://energizect.com/sites/default/files/documents/X2001BFINALReport_051523.pdf
[b] https://energizect.com/sites/default/files/documents/Measure%20Life%20Report%202007.pdf
[c] A footnote in the Illinois TRM (v12) specifies: "While manufacturers claim the lifetime of the foam exceeds 100 years, due to likely degradation and or changes to the building shell over that timeframe, the TAC proposed a measure life of 50 years."
[d] https://www.calmac.org/publications/CPUC_Group_A_2023_Res_Insulation_EUL_Study_Final_Report_CALMAC.pdf

Literature Review: Recent EUL Derivation Studies

Objective	Methodology	Findings
CPUC: Residential Insulation Measure Effective Useful Life Study Final Report (2023)		
Revise CA DEER EUL values for residential wall and ceiling insulation measures	• On-site inspections of insulation installed in 2006 and 2007 • Secondary research of degradation studies and human factors • Survival analysis using both non-parametric estimators • Weibull distribution models	DEER EUL values were previously capped at 20 years. This study recommended a **conservative update to 30 years for both wall and ceiling insulation**.
CPUC: EMV Group A, Deliverable 16 EUL Research - Residential Insulation (2021)		
Determine whether to use existing insulation remaining useful life or full EUL for new insulation, and whether to have separate EUL values for different insulation types	• Survey previous program participants and contractors • Conduct a literature review	The **median EUL was 32 years**, with the age of replaced insulation at between 30.5 and 33 years. Augmented insulation does not require removal at end of EUL. There was some evidence that foam insulation could have a higher EUL.
Final Evaluation Report: Connecticut Measure Life/EUL Update Study – Residential & Commercial (2021)		
Study multiple measure EULs and recommend updates if the results meet precision targets	Parametric survival analysis approach: • Survey homes and businesses that had participated in utility programs between 2001 and 2019	The **median EUL** estimate for insulation was **38 years**, but limited sample sizes resulted in low relative precision and the study recommended keeping the current 25-year EUL.



Methodology Overview

Aggregating EUL Factors

EUL of home
(Technical Life)

−

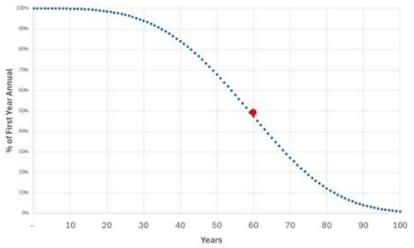
Probability of insulation damage
(Measure Persistence)

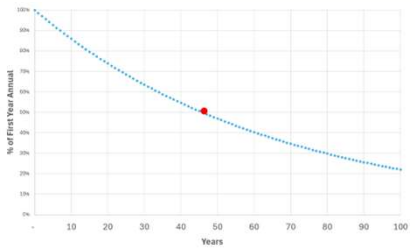
−

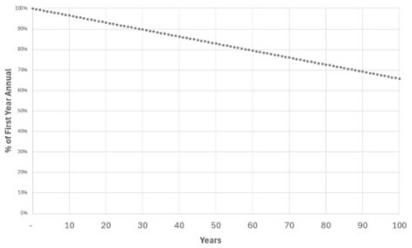
Insulation annual degradation
(Savings Persistence)

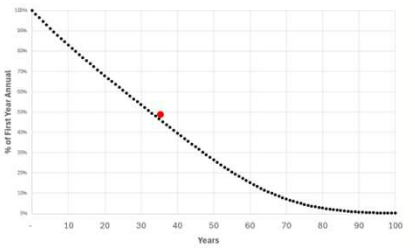
=

EUL curve
(Mortality Function)









Methodology – Why This Approach?

- Michigan-specific and relevant data available
- Persistence survey data not possible – especially participants > EUL
- DOE Rulemaking and TSDs (Technical Support Documents) use Weibull survival curves
- TRM values and literature review suggests no insulation EUL values supported by rigorous research, typically:
  - Manufacturer data
  - Delphi panel
  - Persistence study (e.g. post-install surveys years later)

Technical Life – Data Sources & Assumptions

- A **primary driver of technical life** for a building material is based on the **lifespan for the building itself**[1].
- Assumed home construction, damage, and renovation represents insulation
- Per U.S. Census data, 44% of the nation's housing stock was built before 1970 Therefore, it is reasonable to assume **existing home median life is greater than 55 years**

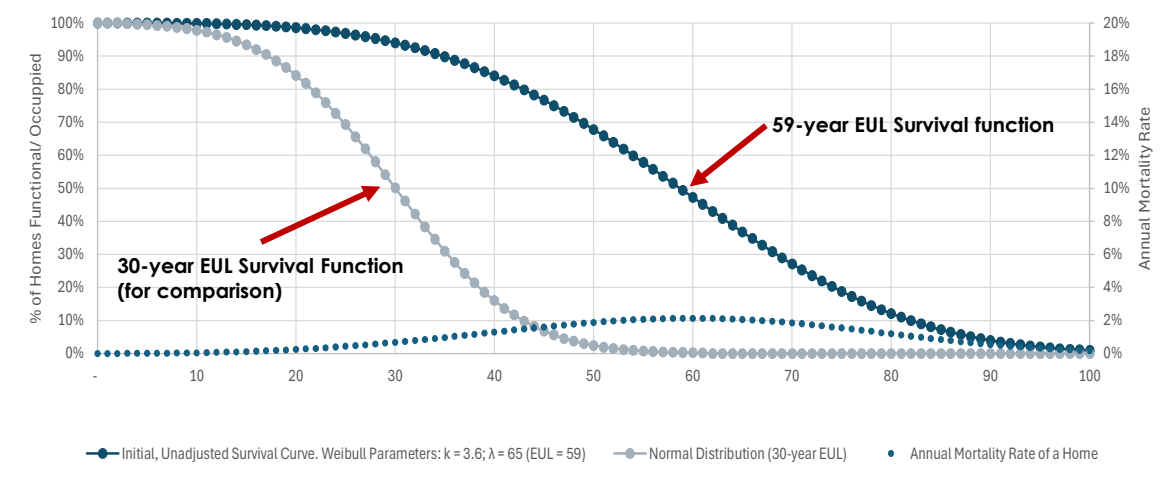
Decade	Number of Homes Required for Population (2.52 people/home)	Number of New Homes Constructed	Estimate of Number of New Homes Required this Decade	% of New Homes Built	% of New Homes Needed
1960-1969	3,104,442	322,006	417,416	10.4%	13.4%
1970-1979	3,521,858	372,231	153,569	10.6%	4.4%
1980-1989	3,675,428	212,870	13,182	5.8%	0.4%
1990-1999	3,688,610	379,729	255,217	10.3%	6.9%
2000-2009	3,943,827	314,676	-21,748	8.0%	-0.6%
2010-2019	3,922,079	278,869	76,862	7.1%	2.0%
Average	3,642,707	313,397	149,083	**8.7%**	**4.4%**

[1] International Association of Certified Home Inspector's (InterNACHI) Standard Estimated Life Expectancy https://www.nachi.org/life-expectancy.htm

Technical Life – Results

To develop the 1st of 3 components, U.S. Census data was used to determine home construction and demolition patterns in Michigan since 1970 and population patterns since 1910.

Michigan Housing Stock Survival Curve Basis: 59-year EUL (Weibull parameters: k = 3.6, λ =65)



Per the analysis, the **median technical life** of a home in Michigan was set at **60 years**.

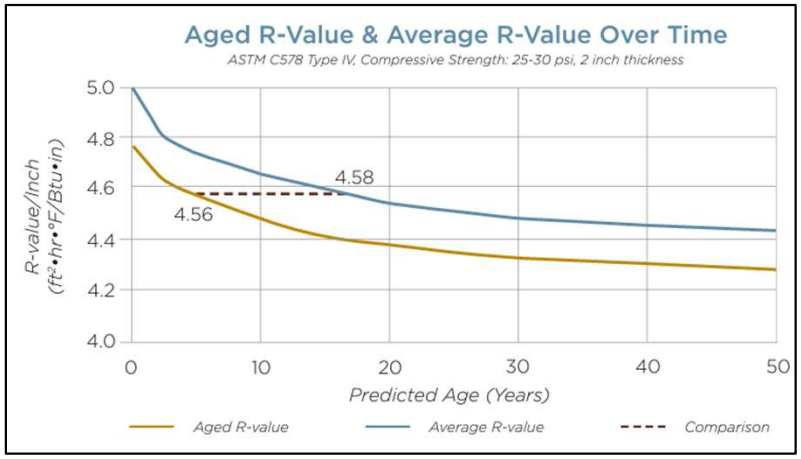
Measure Persistence

- **Insulation persistence is also impacted by** (1) the end of life for a home and (2) repairable **physical damage**
- Used historic homeowner insurance claims in Michigan to estimate rates of physical damage to building insulation
- At a rate of 5 claims per 100 insured homes annually and the factors shown in the table, the **annual probability of insulation measure failure is 1.5%**
- The most conservative assumptions (not realistic) resulting in failure rate of 2.3%, would reduce the EUL from 35 year to ~30 years


Image: an attic in New York with disrupted insulation and rodent traps

Type of Claim/ Damage	Average % of Claims by Type of Damage (2003 to 2020)	Our Assumed % of Claims with Damaged Insulation
Fire, lightning and debris removal	30.1%	25%
Wind and hail	33.0%	25%
Water damage and freezing	22.9%	50%
Theft	2.4%	0%
All other property damage	7.6%	50%
Liability (Bodily injury and property damage)	4.0%	0%
Average Annual Estimate	**31.0%**	**1.5%**

Savings Persistence



Source: EPS Insulation Advancements & Technology Innovations Technical Bulletin
https://www.airfoam.com/EPS-vs-XPS-LTTR-R-Values.pdf

- The first factor in a savings persistence calculation is the **degradation in performance** of the measure over time.
- Some insulation materials show R-value degradation over time:
  - Loose fill cellulose settles over time
  - Closed-cell foam slowly leaks its blowing agent, degrading its R-value
- Worst-Case: R-value rate of ~1% per year.
- Result: Annual Savings Degradation of 0.35%

Insulation Type	% Therms	Subject to Annual Degradation?
Loose Fill Cellulose	57.6%	Yes
Loose Fill Fiberglass	11.6%	No
Fiberglass Batts	11.0%	No
Spray Foam Closed Cell	9.9%	Yes
Spray Foam Open Cell	5.9%	No
Rigid Foam Board	2.2%	No
Other	1.8%	Yes
Savings-Weighted Average % of Insulation Subject to Degradation		**69.2%**

$$\textbf{Heat Loss Reduction } \% = 1 - \frac{R_{base}}{R_{upgrade}}$$

$$\% \textbf{ Savings Reduction} = \frac{\left(1 - \frac{R_{base}}{R_{base} + R_{added}}\right)}{\left(1 - \frac{R_{base}}{R_{base} + R_{added,degraded}}\right)}$$

Results & Recommendations

Overview of Results

The final values result from reasonably conservative assumptions in the analysis:

Other Studies find EUL > 30 years (e.g. 45 years to 267 years for ceiling insulation)
Max EUL of **20-30 years** is typically based on **regional policy**

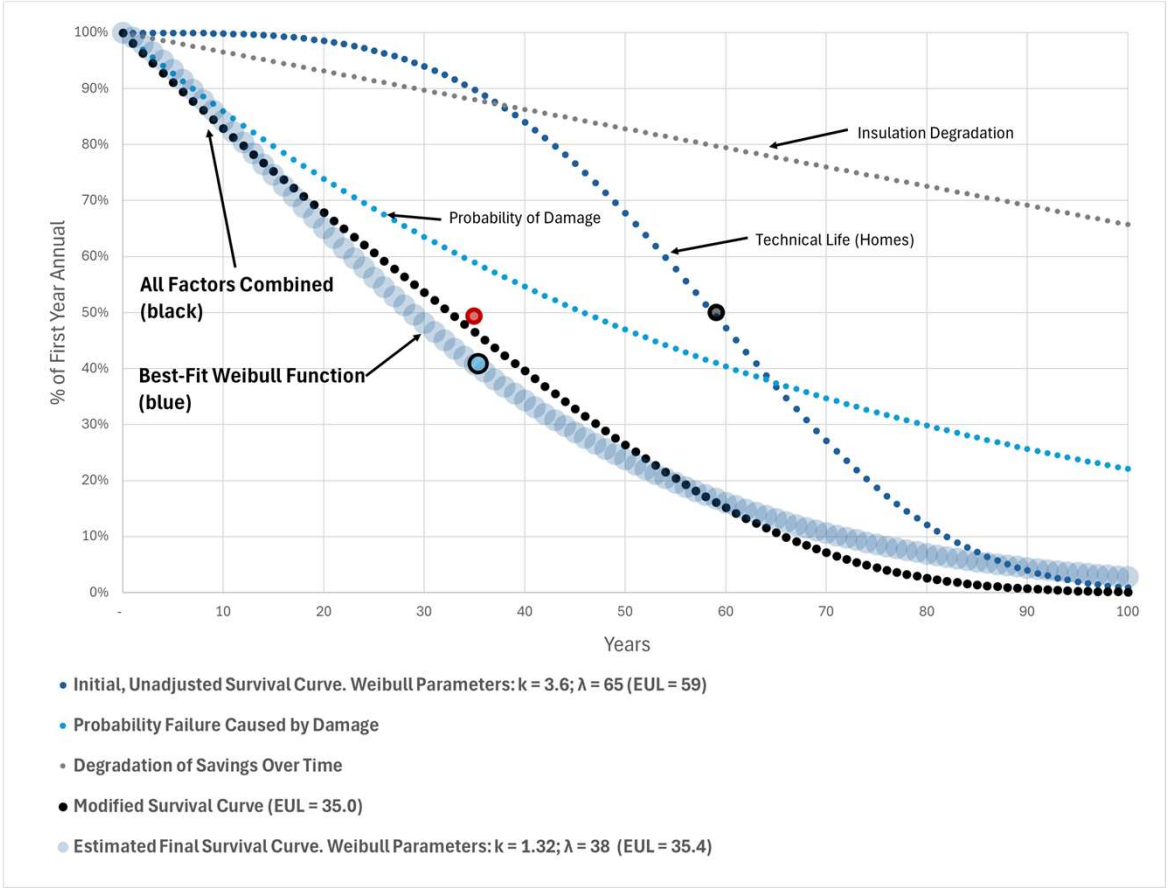
- Used worst-case **R-value degradation of 1% per year** for all relevant insulation types → This may overestimate degradation impacts
- **Limited housing stock mortality to 100 years** → 50% retired at 60 years and 100% at 100 years
  Extending beyond 100 years could increase EUL
- Availability of **Residential data** > Commercial → Commercial building lifetime: Various sources range 50-60 years
- Determined the **probability of damage** based on historical insurance claims → Impact on insulation is estimated based on type of damage
  - Max failure rate: 2.3% per year
  - Value used in analysis: **1.5% per year**

Results

- The final survival curve for insulation is based on a combination of:
  - The technical life survival curve,
  - Degradation factors, and
  - The annual probability of damage.
- The **final recommended EUL** based on this survival curve is

35 years

for all insulation types in both residential and commercial sectors



Recommended EUL Updates

Measure	Residential and/or Multifamily MEMD Measure Life (years)	Commercial and/or Industrial MEMD Measure Life (years)	Recommended Measure Life (years)
Roof Insulation [a]	N/A	30	35
Ceiling insulation [b]	20	30	
Infiltration Reduction [b]	13 [c]	N/A	
Wall insulation	25	25	
Kneewall Insulation	20	N/A	
Rim Joist Insulation	25	N/A	
Floor Insulation	25	N/A	
Basement Wall Insulation	25	N/A	
Crawlspace Wall Insulation	25	N/A	
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[c] This value is being reviewed. It may be modified to less than 35 years and removed from recommended updates.

Questions & Discussion

Thank you!

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