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Valuing Energy Efficiency for Energy Resilience

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Valuation of Energy Efficiency for Energy Resilience

A collaborative **PNNL, NREL, and LBNL** project guided by a **technical advisory group** and **US DOE Building Energy Codes Program**

Purpose
- Expand energy efficiency cost effectiveness assessment to include resilience considerations
  - develop a **standardized** methodology to **quantitatively** assess how building efficiency impacts energy resilience
  - calculate **metrics** to support the quantification of impact

Focus
- Extreme heat and cold events **coincident with a power outage**

Application for investment decision making
- **Benefit cost ratio** annualized cost effectiveness calculation
- Metrics included as part of a **decision matrix**

Project Team and Technical Advisory Group

Project Team and DOE Advisors

Pacific Northwest National Laboratory

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Technical Advisory Group

- Fred Malik, Insurance Institute for Business & Home Safety (IBHS)
- Rick Jones, Hartford Steam Boiler
- JiQiu (JQ) Yuan, National Institute of Building Sciences (NIBS)
- Ryan Colker, International Code Council (ICC) / Alliance for National and Community Resilience (ANCR)
- Sheila Hayter, ASHRAE / NREL
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- Steve Cauffman, Cybersecurity & Infrastructure Security Agency (CISA)
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- Jesse Rozelle , Federal Emergency Management Agency (FEMA)
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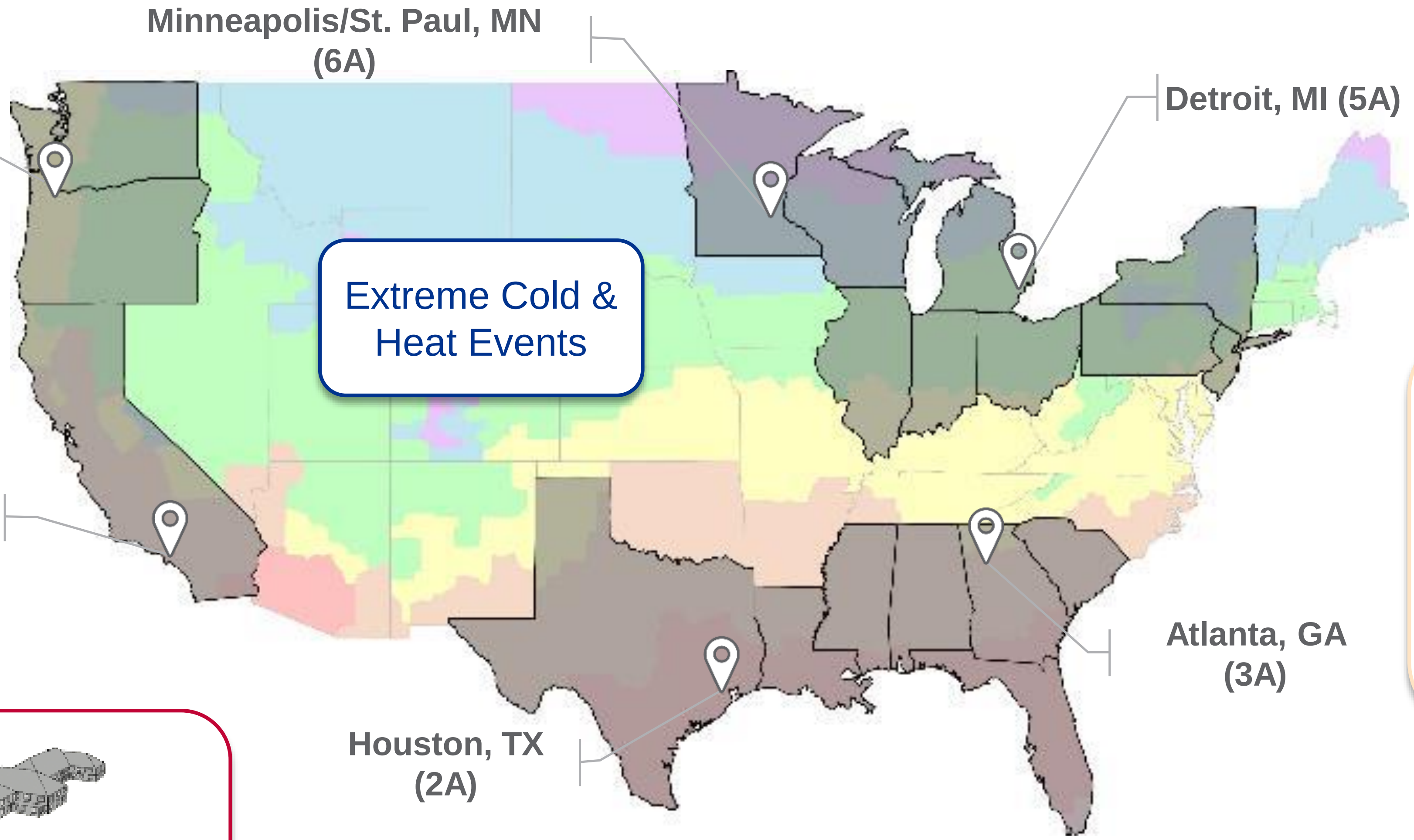
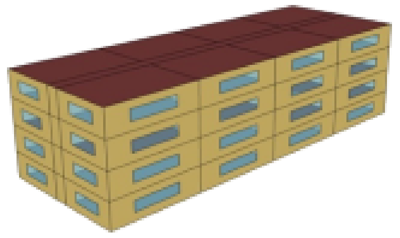
- Rodney Sobin, National Association of State Energy Officials (NASEO)
- Jenn Kallay, Synapse Energy Economics
- Kristie Ebi, University of Washington
- Colby Tucker, U.S. EPA

Project Scope



Multi-Family

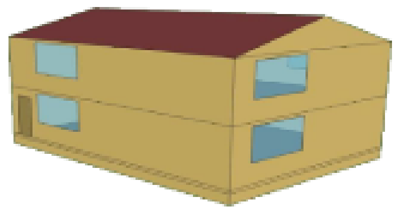


New & Existing

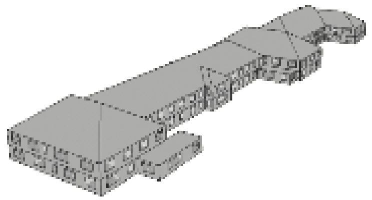
Baseline Condition
Historic Code/Existing Stock

Current Code
ASHRAE 90.1-2019 & IECC-R 2021

Beyond Code
Informed by 2021 Passive House



Single-Family



Assisted Living Facility

Counterfactual Case Study

2021 Texas Winter Storm and Extreme Heat Event

Metrics & Valuation

Thermal Resilience: Standard Effective Temperature, Heat Index
Mortality: Gasparrini Relative Rate Model
Investment: Benefit Cost Ratio (BCR),

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Key metrics applied in study

Metrics are calculated for base case and improved conditions

Thermal resilience metrics indicating occupant exposure	
Standard Effective Temperature (SET)	Indoor conditions measurement that considers of temperature and relative humidity
SET Degree Hours	Cumulative hourly SET degrees that fall outside of a specified threshold (54°F and 86°)
Days of Safety	The time elapsed over a 7-day period when the SET Degree Hours does not exceed a value of 216.
Occupant damage metrics	
Excess deaths	Deaths attributed to the extreme event
Economic metrics (for annualized net present value calculation)	
Measure investment costs	First costs for installation of measure package
Measure annual energy cost savings	Evaluated based on a typical weather year
Societal value of emissions reduction	Associated with annual energy use savings
Losses associated with excess deaths	Based on $10 million per excess death
Losses associated with property damage	Based on FEMA national risk data base values
Benefit cost ratio	Based on annual coincident risk of extreme temperature events and above economic values

Resilience Analysis Workflow

Hazard Risk Analysis

- Historical extreme temperature event identification and selection
- Extreme temperature-power outage annual risk

Hazard risk identification →

Exposure Analysis

- Baseline and two efficiency packages
- Existing and new building energy simulation analysis

Indoor condition effect on habitability →

Damage Analysis

- Historical property damage data
- Epidemiological fragility models
- Relationship to extreme temperatures

Property damage and excess mortality →

Mitigation Valuation

- Valuation of loss
- Mitigation costs
- Annualized impacts
- Net present value analysis

Return on investment

Hazard Risk Analysis

What is the coincident probability of extreme temperature events coinciding with a power outage?

Annual Probability Risk	Houston (2A)	Atlanta (3A)	Los Angeles (3B)	Portland (4C)	Detroit (5A)	Minn./St. Paul (6A)
Extreme heat event with outage	75%	10%	34%	10%	17%	15%
Extreme cold event with outage	3%	4%	15%	8%	8%	3%

Relatively high coincident probability values may alert states and local governments of the importance of energy efficiency for energy resilience considerations for their region.

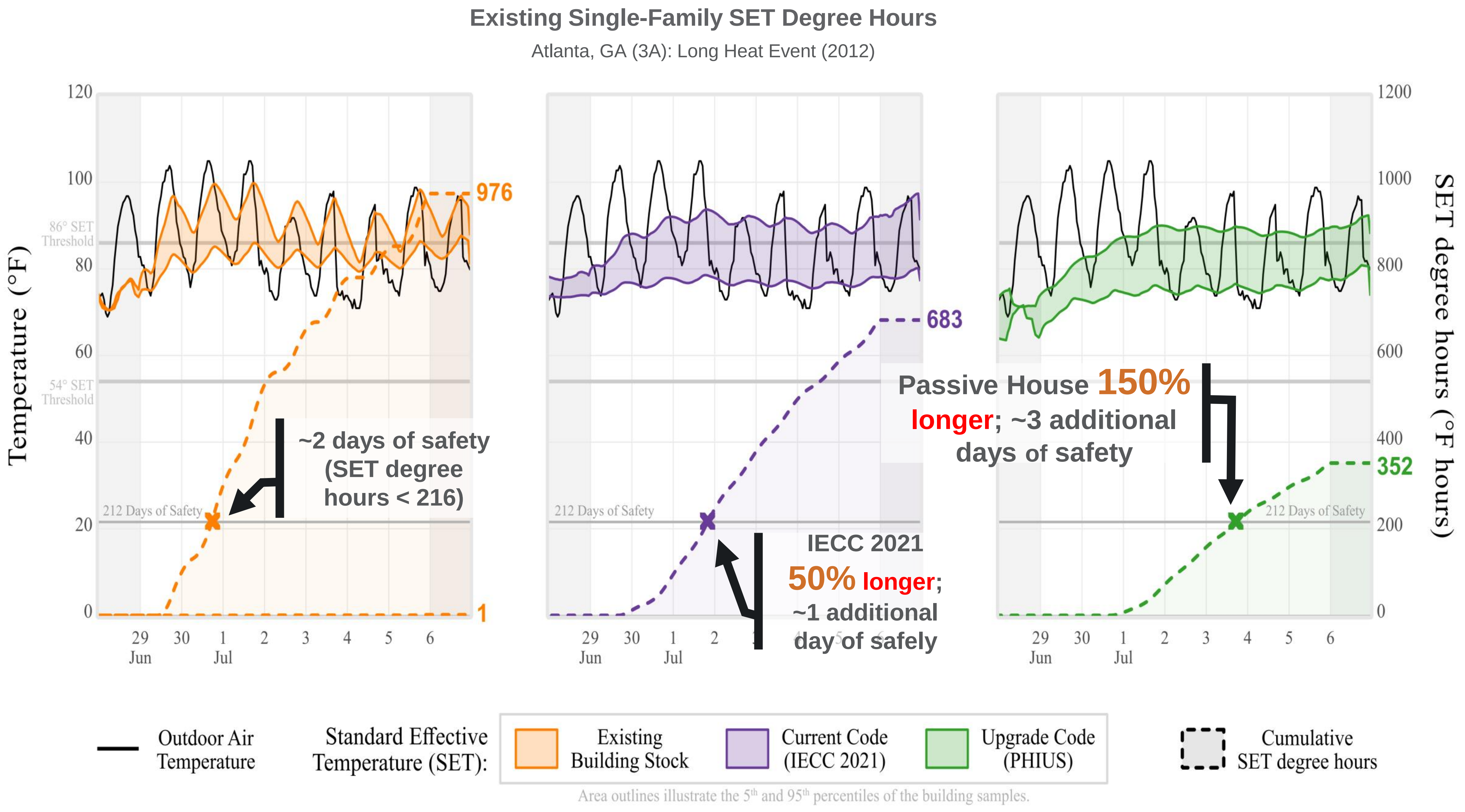
Note: Power outage data extracted from the DOE Office of Cybersecurity, Energy Security and Emergency Response Electrical Emergency Incident and Disturbance data collected on form OE-417. **Due to lack of data resolution, the assessment assumed reported outages affect the entire state and service is restored to all customers at the time indicated on the form. Due to this assumption, the coincident risk values may be overstated for large states.**

Exposure Analysis

Three thermal resilience metrics reported in the study include:

- SET
- SET degree hours
- Days of safety

What is the fluctuation in indoor comfort conditions extreme temperature events? How does it affect habitability?



Example Exposure Results

Performance for median existing single-family building (ResStock Analysis)

Location (Climate Zone)	Event	Existing Stock Median	Current Code IECC 2022 Median	Beyond Code PHIUS 2021 Median
Houston, TX (2A)	Cold	749	222	-
	Heat	600	141	-
Atlanta, GA (3A)	Cold	2,558	1,610	200
	Heat	438	59	-
Los Angeles, CA (3B)	Cold	87	-	-
	Heat	100	-	-
Portland, OR (4C)	Cold	2,963	1,849	237
	Heat	371	319	-
Detroit, MI (5A)	Cold	4,248	3,020	1,778
	Heat	223	53	0.3
Minneapolis/ St. Paul, MN (6A)	Cold	5,397	3,699	2,190
	Heat	215	66	5

* SET Degree Hours are cumulative SET hourly values > 86 F for extreme heat and < 54 F during extreme cold. The values in the table are based on a 7-day period. The threshold for habitability is 216, which is in accordance with the USGBC LEED resilience credit.

Damage Analysis

How do the study estimates compare to published data?

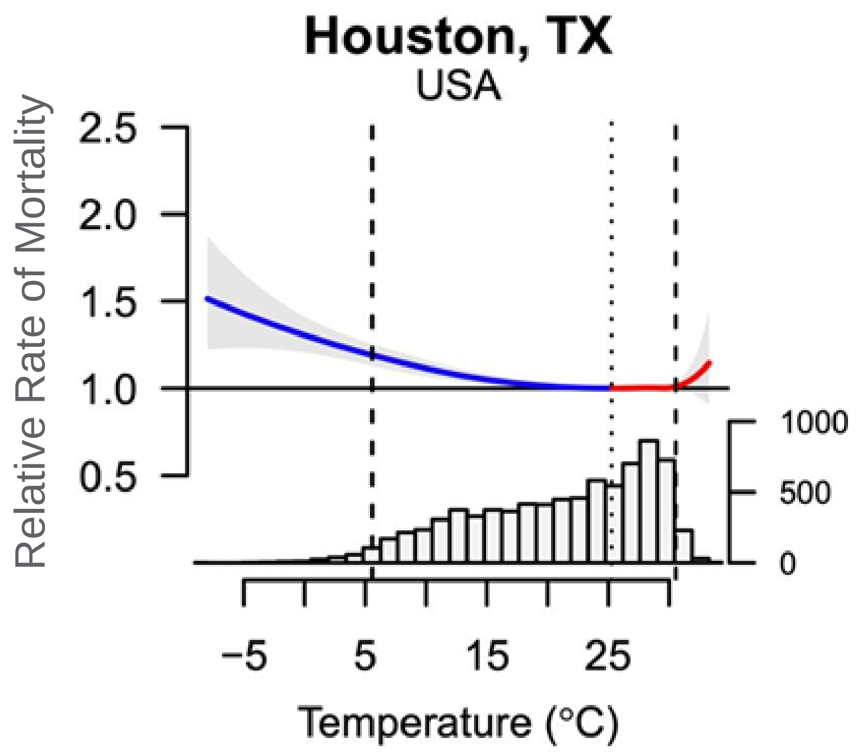
2021 Texas Winter Storm Event Case Study

	Texas	Harris County	Harris County
	Published	Published Prorated	Study Estimate
Excess mortality	755	249	202

Notes: The published value for excess mortality for Texas is 755 per Aldhous P, and Z Hirji. 2022. "Texas Is Still Not Recognizing the Full Death Toll of Last Year's Devastating Winter Storm." Buzzfeednews.com. Accessed June 1, 2022. The event occurred from February 13 to February 24, 2021. The study excess mortality analysis is for the entire event period over the 12 days.

How does extreme heat and cold impact mortality rate?

Relative rate of death curves as a function of **outdoor temperature** published by Gasparrini available for over 130 U.S. cities

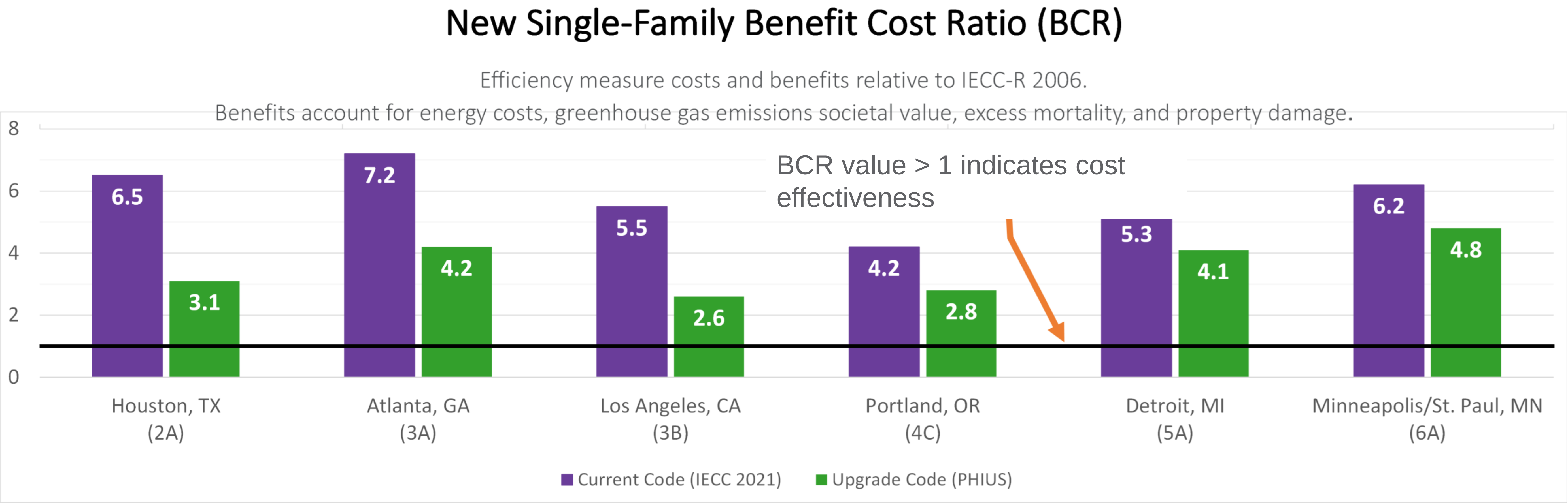


Mean Daily Outdoor Air Temperature (C)

Notes: Vertical dashed lines indicate the temperature at 2.5th percentile and 97.5th percentile. The vertical dotted line indicates the temperature at which the relative rate of death is one or the temperature at which deaths are not attributed to severe temperatures

Example Benefit Cost Ratio Results

What is the return on building efficiency investment with **annual energy cost saving, societal value of reduced CO2e emissions, and annualized excess deaths?**



Methodology Robustness Assessment

Category	Component	Robustness
1. Hazard Risk Identification	Develop weather data files representative of extreme temperature events	
	Develop coincident probability risk factors to annualize event losses and benefits	
2. Exposure Analysis	Assess relative impact of efficiency measures on habitability	
	Determine indoor habitability conditions exceeding thresholds	
3. Vulnerability Assessment	Evaluate occupant exposure effect on mortality, health, and well-being	
	Evaluate property exposure effect on active building state and systems	FUTURE
4. Mitigation Valuation	Quantify the monetary value of resilience	
	Inform resilience planning efforts	

Example Decision Matrix

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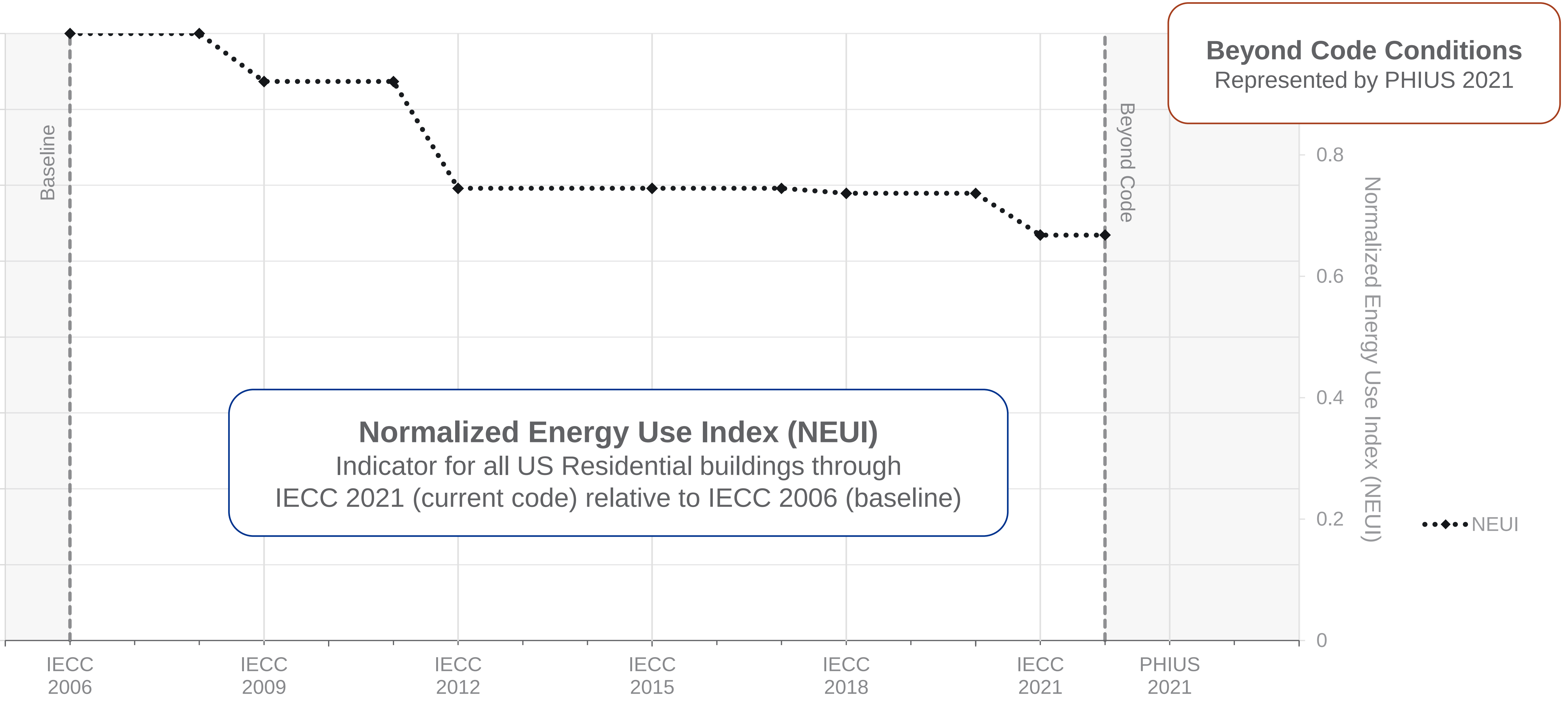
How can resilience metrics be used to inform investment decision-making?

Median Existing Single-Family Building in Houston

Metric	Value		Assigned Weights	Normalized	
	Current Code IECC 2021	Beyond Code PHIUS		Current Code IECC 2021	Beyond Code PHIUS
BCR	0.63	0.68	30%	0.92	1.00
Levelized First Costs ($/$ft^2$/year)	0.63	0.77	15%	1.00	0.82
Energy Savings (kWh/ft^2/year)	3.1	4.1	15%	0.76	1.00
Lives Saved	62	93	10%	0.66	1.00
SET Degree Hours Reduced	985	1348	30%	0.73	1.00
			Weighted Total	**0.82**	**0.97**

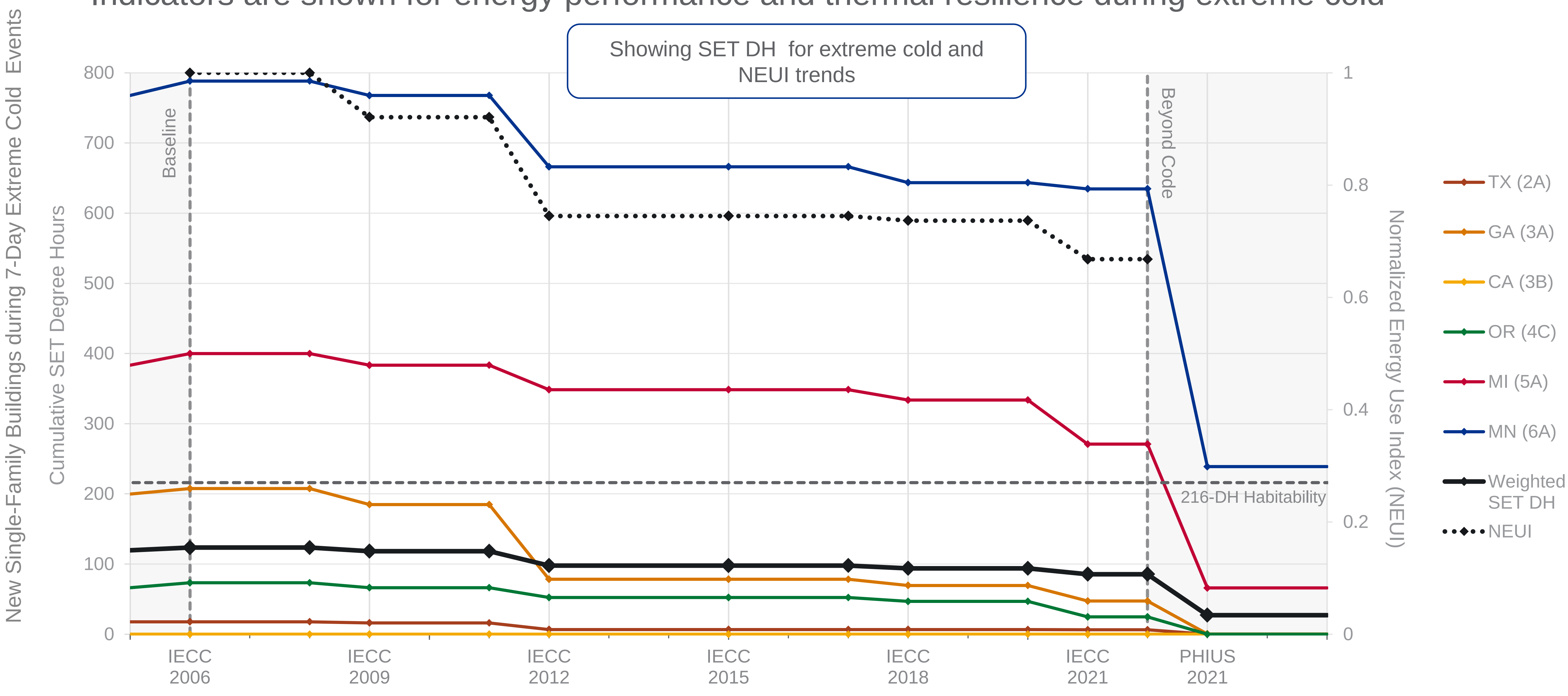
Energy Efficiency Indicator NEUI

- Normalized Energy Use Index is currently used to indicate advances in model energy codes



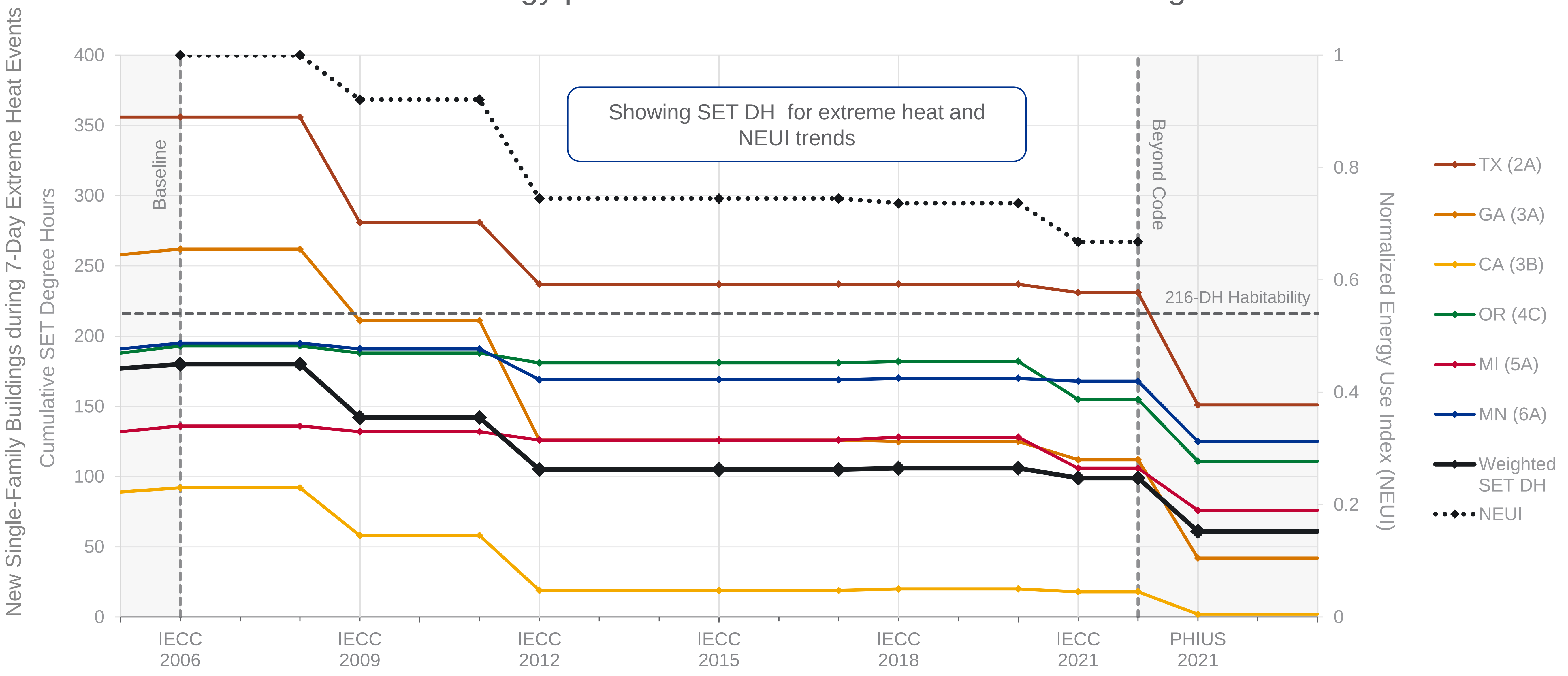
Energy Efficiency and Thermal Resilience Extreme Cold Events

- Indicators are shown for energy performance and thermal resilience during extreme cold



Energy Efficiency and Thermal Resilience Extreme Heat Events

- Indicators are shown for energy performance and thermal resilience during extreme heat



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Key Take-Aways

- Improving envelope efficiency to meet or exceed code requirements extends occupant habitability during extreme temperatures.

- In nearly every situation, improving envelope efficiency saves lives during extreme temperature events.

- Increasing efficiency at the time of construction or major renovation provides a good investment opportunity for addressing resilience.

- SET degree hours and other passive survivability indicators determined from building simulation analysis can be readily applied to indicate resilience benefits associated with passive measures.

Key Take-Aways

- There are application limitations associated with some of the method components, which may lead to an over- or under-estimation of benefits. The team is posting methods on GitHub to engage industry to collaboratively advance methods, including:
  - Determination of coincident probability of power outage – extreme temperature events
  - Application of Gasparrini relative rate of mortality fragility curves
  - Property damage estimates
  - Building performance based on future weather data
  - Other TBD

Questions

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Final report is available at
https://www.energycodes.gov/energy-resilience