Degree Hour Ratio

A Low-Tech Test for Thermal Resilience

Al Mitchell

Committee

- Dr. Mohammad Heidarinejad
- Dr. Brent Stephens
- Dr. Jamshid Mohammadi
- Dr. Ankit Srivastava
- Dr. Ralph Muehleisen
- Dr. Ji-Hyun Kim






Summary

- Research Objective 1: Develop and test a methodology for standardized modeling of the thermal resilience of residential buildings.
  - Develop free, user-friendly tool
  - Demonstrate tool on a parametric study of single family homes
  - Evaluate resilience metrics
  - Envelope drives winter resilience, summer needs backup or dynamic passive strategies
- Research Objective 2: Measure the interior and exterior conditions of single-family homes in Chicagoland during a cold weekend with no heating.
  - Compare measured data to modeled data for the same homes
  - Calibrate models and improve modeling process
  - Develop a DIY measurement test

Summary

Objective 1

Scale: Single Residence
Method: Simulation
Stakeholders:
-Design Professionals
-Home Owners

Objective 2

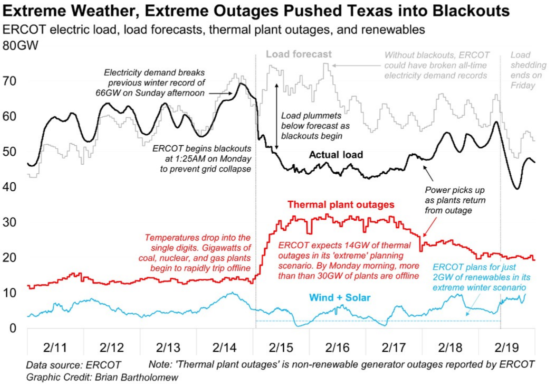
Scale: Single Residence
Method: Measurement
Stakeholders:
-Design Professionals
-Home Owners

Objective 3

Scale: City Wide
Method: Simulation
Stakeholders:
-Policy Makers
-Code Developers

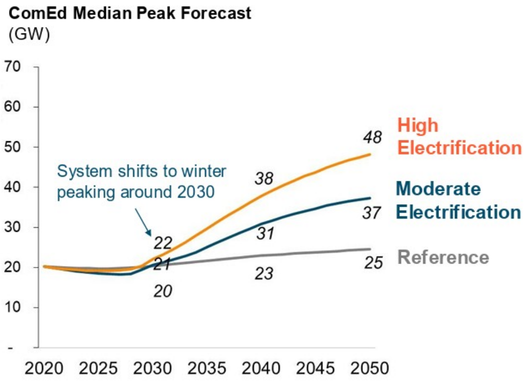
Grid Background

- Electrification of building heating systems is a good method for decarbonization
- Changes the grid profile, moves peaks to winter in cold climates
- Can overload grid distribution capacity
- Peak demands on grid are most carbon intensive



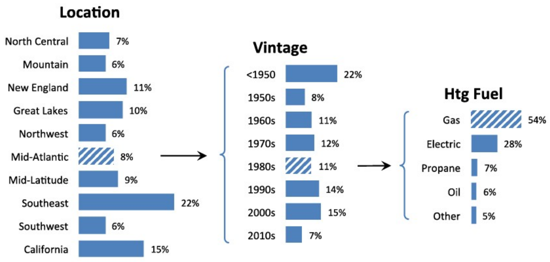
Grid Background

- Grid capacity needs to double
- In Chicago area, peak is expected to shift to winter around 2030
- Even at moderate electrification, the peak demand on the grid is expected to double



Building Stock Background

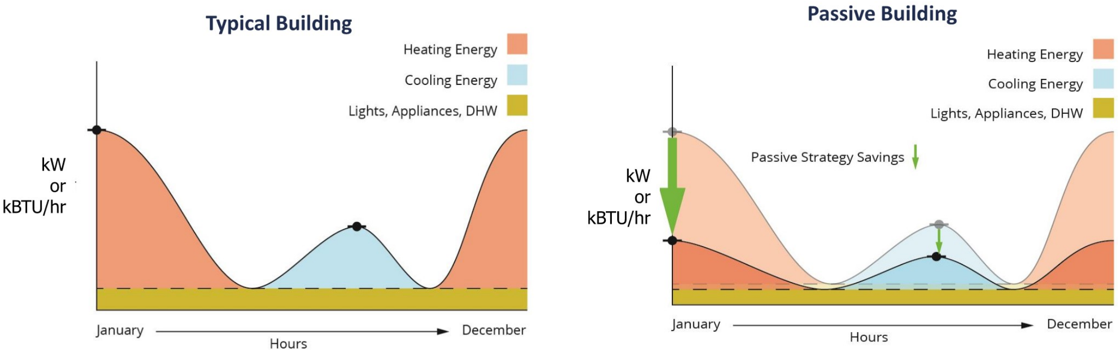
- 53% of US residential building stock was built before 1980
- Only 28% of homes are currently heated with electricity
- Retrofit before electrification becomes critical in reducing and managing peak loads on grid



Chicago Building Stock Background

- 2,664,000 residents as of 2023
- 1,254,009 residential units across the city
- Average year built: 1932
- Median year built: 1926
- 75% built before 1955

Passive Buildings



Annual Energy = kWh/yr (or kBTU/yr) → area under the curve
Peak Power = kW (or kBTU/hr) → point at top of curve

Resilience Definition

- Definition from literature:
  - "A building's ability to remain at and/or to recover to a habitable state after a disruptive event (such as power outage) where mechanical equipment is not providing heating, cooling or ventilation."

Key Point

This definition does not allow for mixed mode operation, which may be needed in climates with hot, humid summers. Some mechanical ventilation may also be needed in airtight buildings.

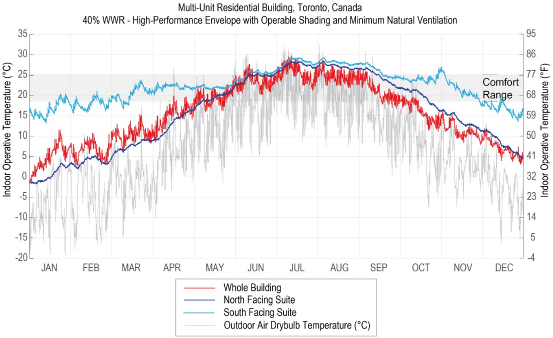
- Amended definition:
  - A building's ability to remain at and/or to recover to a habitable state after a disruptive event (such as power outage) where mechanical equipment is not providing heating, cooling or ventilation, **although some critical loads may be met with local renewable generation and battery backup.**

Resilience Metrics

Metric	Use Case	Required Data
SET Hours	Winter or Summer	Temp, radiant temp, RH, air speed, clo, met
Heat Index	Summer	Temp, RH
Hours < 2℃	Winter	Temp
Mora Deadly Day	Summer	Temp, RH
WBGT	Summer	Temp, radiant temp, RH
Humidex	Summer	Temp, RH

Existing Modeling Studies

- Existing modeling studies focus on MURBs or commercial buildings
- Some utilize outage periods, while others are looking at thermal autonomy
- Multiple metrics are proposed in various studies, limits unclear
- Weather data is either typical or shifted future projection

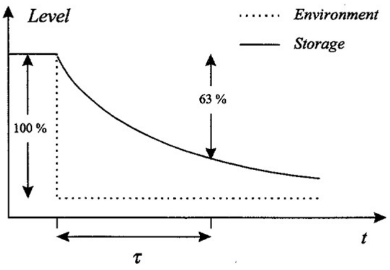


Co-Heating

- Current, state of the art validation of building envelope performance
- Requires house to be vacant for a period of around 1 week
- Requires calibrated heaters and measurement equipment
- Done in conjunction with blower door or tracer gas test
- Does not account for real internal heat gains that would be present during an outage
- Ideally has steady state outdoor conditions

Time Constant

- Calculated decay time of building
- Tests for thermal inertia
- Requires house to be vacant
- Does not account for real internal heat gains that would be present during an outage
- Ideally has steady state outdoor conditions



The time constant, τ, is the time to fulfil 63 % of a step change.

Problem Statement

- Climate change is causing increasing intensity and frequency of heat waves and cold snaps
- Extreme weather correlates with grid instability
- Electrification of heating systems amplifies this concern
- Buildings should "Protect the health and safety of occupants"

Knowledge Gaps

- No user friendly, accessible to practitioners tool exists to simulate thermal resilience in residential buildings during outages
- Many passive survivability metrics are considered, limited consensus as to which to use
- Decarbonization efforts are focused on energy and emissions savings on a mass scale, not necessarily individual buildings
- Limited monitored data of interior conditions during a cold event with no space conditioning.

Research Objectives

- Research Objective 1: Development of a Standardized Residential Thermal Resilience Modeling Tool
  - Focus: Development of methodology for testing thermal resilience
- Research Objective 2: Measured Validation of Resilience Modeling
  - Focus: Validate methodology from objective 1
- Research Objective 3 Evaluating Thermal Resilience as a Retrofit Metric
  - Focus: Testing thermal resilience at a city scale

Research Objective 1 Goals

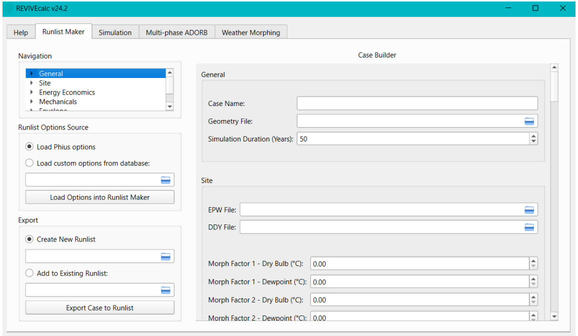
- Research Objective 1: Develop and test a methodology for standardized modeling of the thermal resilience of residential buildings.
  - Explore existing methods for thermal resilience modeling using building performance simulation
  - Evaluate thermal comfort and survival metrics, understand the required data, assumptions, use in outcomes, and recognition by building occupants
  - Standardize a residential modeling method for single family and smaller multifamily buildings
    - Develop a repeatable tool that is simple to use, and make it accessible to the general public
  - Test package upgrades for single family homes in various representative climate zones
  - Evaluate summer metrics for stringency and application

Objective 1 Methods

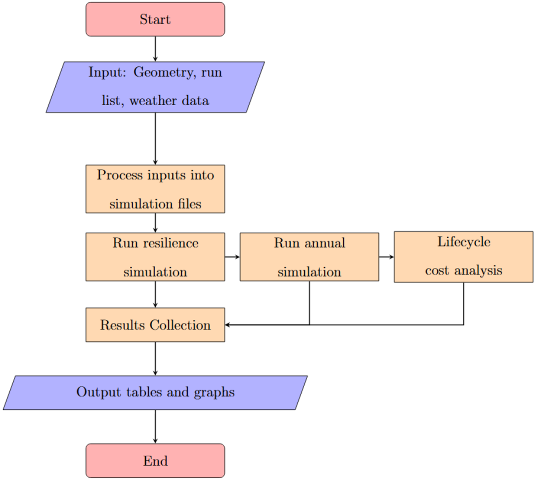
- Building performance modeling requires significant effort to perform accurately, scripting can streamline the process
- Develop scripts to take a pre-existing building energy model, and inject objects to simulate a power outage
  - This was performed using EnergyPlus, an object oriented, text file input based modeling tool
  - Schedules were created to define the dates that the outage occurs, aligned with the extreme week from the weather data statistics file (STAT) **Schedule:Compact**
  - Control system programs were implemented to control outage (turn off internal gains other than occupants, and mechanical systems) and passive responses (operable windows) **EnergyManagementSystem:Program**
- Additional code was written to read results files and summarize the metrics into a summarized output table

Objective 1 Methods

- Rolled scripts into GUI tool
- Supports parametric processing through a batch file / run list that describes each building input
- Builds out resilience model, annual normal operation model, and life cycle cost analysis
- Collects results files into a table to quickly compare retrofit packages, costs, and generate graphs

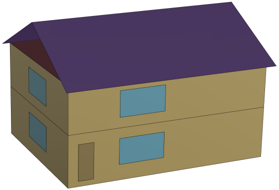


Objective 1 Methods



Objective 1 Methods

- Tested tool by performing a parametric study on a single family home
- Using house based on the PNNL single family prototype
  - 197 m^2
  - 3 Bed, 2 Bath
  - 13 % window to wall ratio
- Tampa, FL
- El Paso, TX
- Nashville, TN
- Albuquerque, NM
- Chicago, IL
- Vancouver, BC

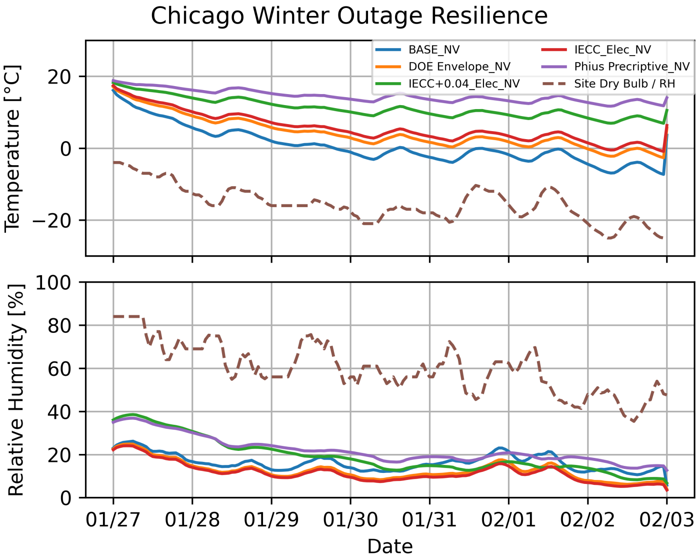


- Great Falls, MT
- International Falls, MN

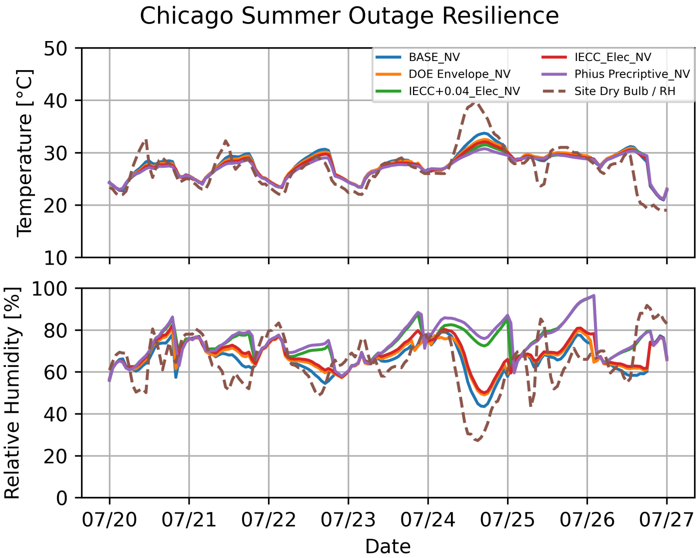
Objective 1 Methods

Package	Description	Ceiling	Wall	Window	Infiltration [m^3/hr @ 50 Pa	Mechanical Ventilation	Refrigerator [kWh/yr]
BASE	Baseline existing house, leaky, limited infiltration	Exterior Roof	Exterior Wall	U-2.83, g=0.4	1.69	Exhaust	360
Base Elec	Baseline with electric heat pump	Exterior Roof	Exterior Wall	U-2.83, g=0.4	1.69	Exhaust	360
DOE Envelope	Electrified baseline with added insulation, airsealing	IECC 2021	Exterior Wall + 1.625in EPS	U-2.27, g=varies	0.85	Exhaust	289
IECC-Elec	IECC 2021 with electric heat pump	IECC 2021	IECC 202	IECC 2021	0.53	Balanced ERV	289
IECC-0-04-Elec	IECC 2021 with electric heat pump and Phius airsealing	IECC 2021	IECC 2021	IECC 2021	0.068	Balanced ERV	289
Phius Prescriptive	Phius 2021 CORE Prescriptive	Phius Prescriptive	Phius Prescriptive	Phius Prescriptive	0.068	Balanced ERV	289

RO1 Results: Chicago TMY Heating Outage



RO1 Results: Chicago TMY Cooling Outage



Objective 1 Results

Run Name	SET Hours <12.2℃	Hours <2℃ [hr]	Total Deadly Days	Caution (>26.7, <32.2℃) [hr]	Extreme Caution (>32.2, <39.4℃) [hr]	Danger (>39.4, <51.7℃) [hr]	Extreme Danger (>51.7℃) [hr]	EUI [kWh/m2 yr]
Tampa, Florida								
BASE_NV	0.0	0.0	7.0	52.8	80.8	11.8	0.0	61.4
DOE Envelope NV	0.0	0.0	5.0	61.0	83.0	0.0	0.0	46.4
IECC_NV	0.0	0.0	6.0	57.3	84.5	2.5	0.0	48.9
IECC+0.4_NV	0.0	0.0	6.0	55.8	64.0	24.8	0.0	46.3
Phius Prescriptive NV	0.0	0.0	5.0	57.5	83.0	3.3	0.0	43.3

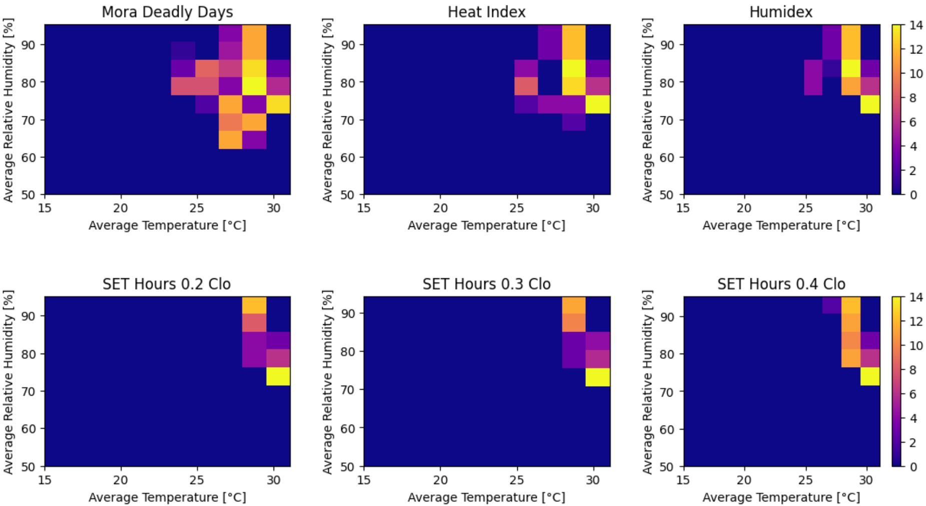
Objective 1 Results

Run Name	SET Hours <12.2℃	Hours <2℃ [hr]	Total Deadly Days	Caution (>26.7, <32.2℃) [hr]	Extreme Caution (>32.2, <39.4℃) [hr]	Danger (>39.4, <51.7℃) [hr]	Extreme Danger (>51.7℃) [hr]	EUI [kWh/m2 yr]
International Falls, Minnesota								
BASE_NV	1619.0	159.3	0.0	39.0	0.0	0.0	0.0	291.5
DOE Envelope_NV	1041.3	122.8	0.0	36.0	0.0	0.0	0.0	157.7
IECC_NV	777.5	103.3	0.0	33.0	0.0	0.0	0.0	141.7
IECC+0.4_NV	60.0	0.0	0.0	34.3	0.0	0.0	0.0	81.2
Phius Prescriptive NV	0.0	0.0	0.0	34.0	0.0	0.0	0.0	54.6

Objective 1 Results

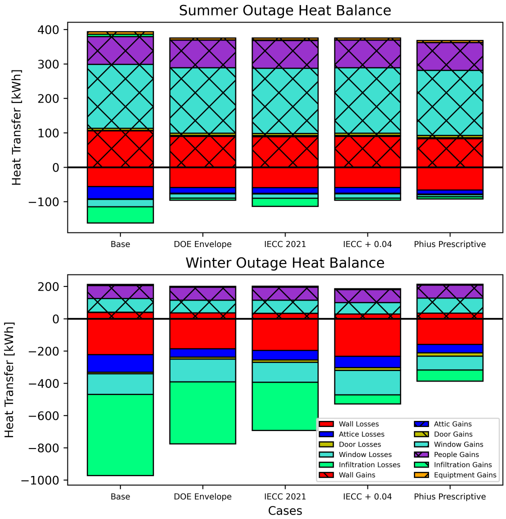
Run Name	SET Hours <12.2℃	Hours <2℃ [hr]	Total Deadly Days	Caution (>26.7, <32.2℃) [hr]	Extreme Caution (>32.2, <39.4℃) [hr]	Danger (>39.4, <51.7℃) [hr]	Extreme Danger (>51.7℃) [hr]	EUI [kWh/m2 yr]
Chicago, Illinois								
BASE_NV	998.0	118.1	2.0	66.5	57.0	0.0	0.0	162.7
DOE Envelope_NV	540.3	48.6	2.0	67.0	56.5	0.0	0.0	88.6
IECC_NV	370.8	21.0	2.0	71.8	50.3	0.0	0.0	80.5
IECC+0.4_NV	2.7	0.0	3.0	54.0	59.8	7.0	0.0	54.6
Phius Prescriptive NV	0.0	0.0	3.0	59.3	61.0	0.0	0.0	44.5

Objective 1 Results

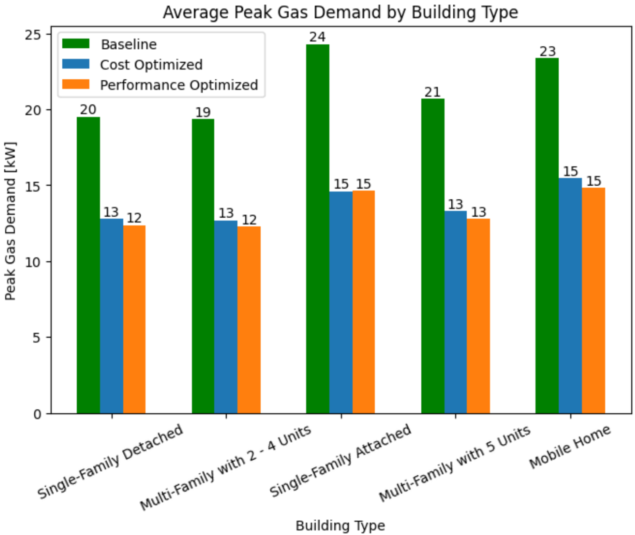


Objective 1 Results

- Heat balances calculated for Chicago, IL
- Winter balance is driven by thermal envelope, predominantly infiltration
- Summer balance less driven by thermal envelope, those more losses present in leaky base case
- Internal gains are fairly constant, winter solar gains were equivalent to internal gains
  - Internal gains constitute occupants and refrigerator



Load Reduction Potential



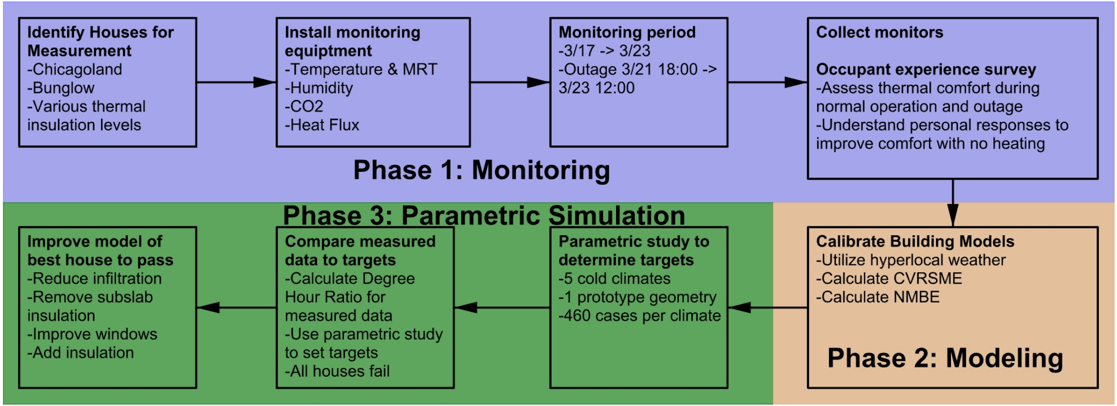
Research Objective 2 Goals

- Research Objective 2: Measure the interior and exterior conditions of single-family homes in Chicagoland during a cold weekend with no heating.
  - Test and validate modeling methods using monitoring of real single family houses
  - Calibrate building performance modeling assumptions and ensure accuracy
  - Develop a physical testing method for buildings with occupants present, while minimizing risk
  - Compare measured thermal resilience performance of buildings with different building envelope specifications, but similar size

Objective 2 Methods

- Monitored 3 Chicago Bungalows of different orientation and envelope performance
- Monitored normal operation from 3/17 - 3/21, then outage period from 3/21 18:00 - 3/23 approx 12:00
- Starting temperature 22°C, end temperature 10°C
- Occupants can utilize appliances, lighting, ventilation - no mechanical heating
- Occupants were asked to track major appliance uses and activities

Objective 2 Flowchart



Test House Data

- House A
- Circa 1918
- Frame, cedar shakes,lightly insulated, leaky
- Vinyl replacement windows
- Oriented long ways N-S

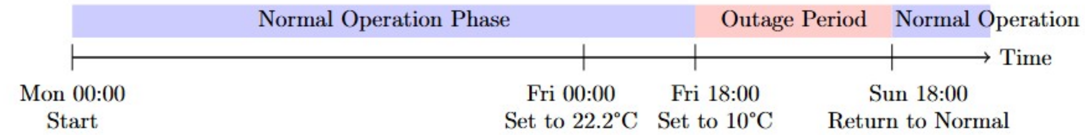
- House R
- Circa 1922
- Frame, stucco, moderate insulation, leaky
- Wood double glazed windows
- Oriented long ways E-W

- House T
- Circa 1915
- Frame, wood siding, retrofitted, well insulated
- Double glazed vinyl wood triple pane
- Oriented long ways E-W

Monitoring Setup

- Real time temperature and humidity monitoring using Temp Stick
- More detailed monitoring using HOBO Logger with radiant temperature monitoring
- Each home was modeled and calibrated to the measured data
- Parametric simulation was used to determine measurement performance targets

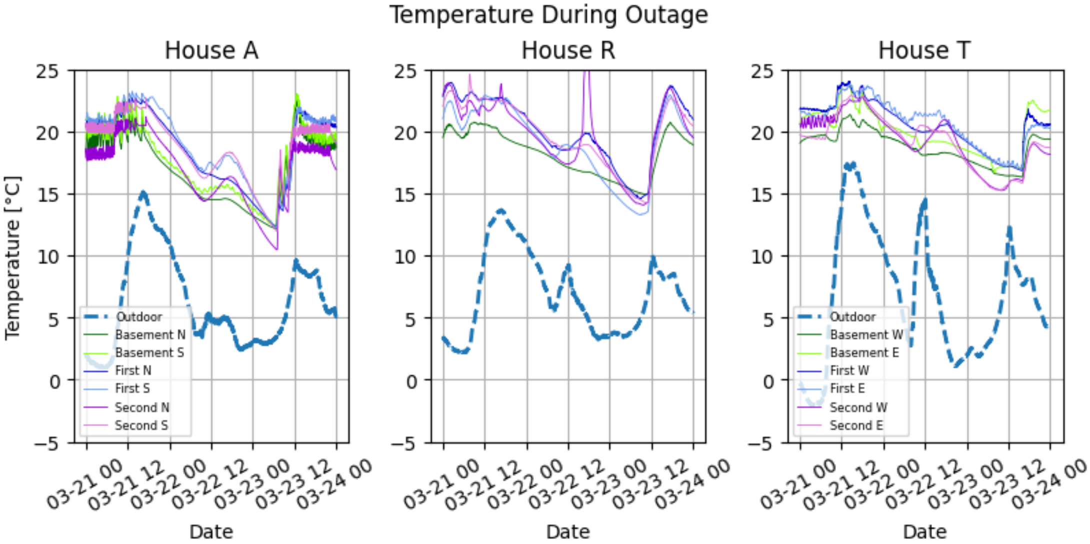
Monitoring Timeline



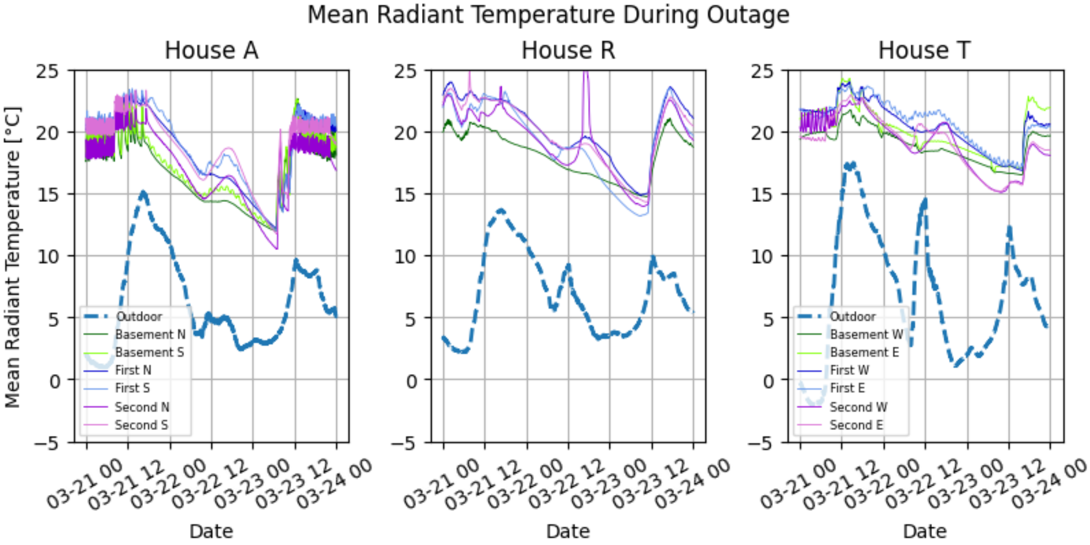
Additional Notes:

- If space temp drops below 10°C, experiment ends early for that home.
- Week after: Equipment collected and occupant survey conducted.

Objective 2 Results



Objective 2 Results



Estimating AER

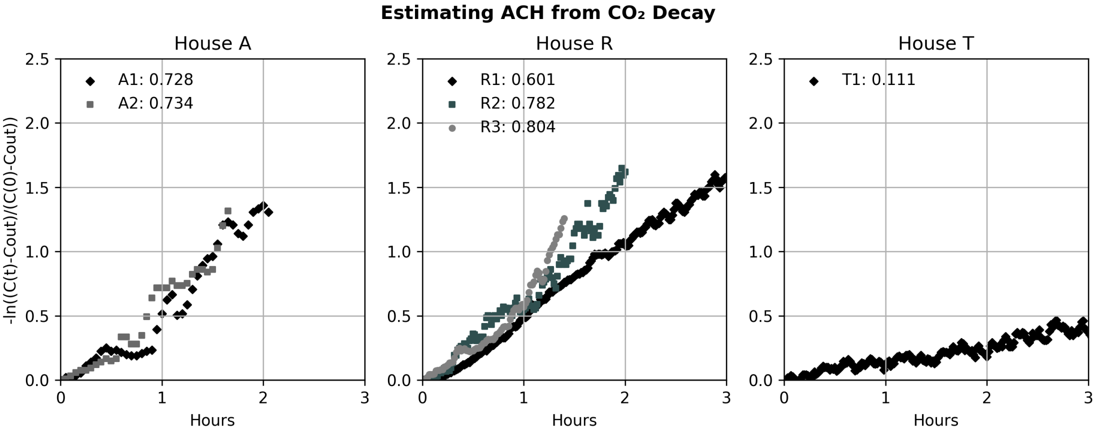
Using the CO_2 concentrations for indoor and outdoor air, the air change rate per hour in homes can be calculated. The mass balance equation can be written as:

$$-\ln\left(\frac{C(t) - C_{\text{bg}}}{C_0 - C_{\text{bg}}}\right) = \lambda t \tag{1}$$

$$t = \frac{\text{seconds since start}}{3600} \tag{2}$$

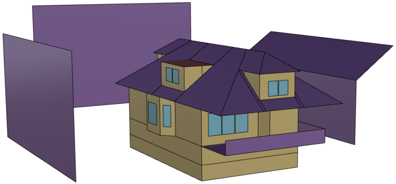
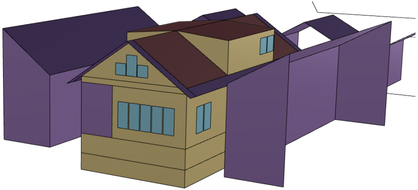
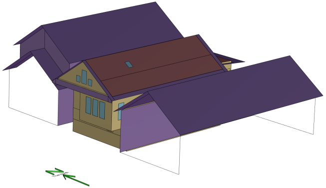
The slope of the plot of the natural log versus time in hours provides the AER for the monitored homes. In Equation 1, $C_{\text{in,bg}}$ is equal to $C_{\text{out}} + \frac{E}{\lambda V}$, where E is the emission rate and V is the volume, which represents the steady-state indoor background concentration influenced by both outdoor air and continuous indoor sources. Subtracting $C_{\text{in,bg}}$ instead of C_{out} accounts for possible low-level indoor emissions and avoids calibration discrepancies between indoor and outdoor monitors. This method enhances the accuracy of AER estimation.

Objective 2 Results



Objective 2 Methods



Calibration Methods

Equations 3 and 4 summarize the coefficient of the variation of the root mean square error (CVRMSE) and Normalized Mean Bias Error (NMBE) as the calibration metrics. CVRMSE was used to check the shape of the hourly temperature data, and NMBE was used to check the total degree hours during the outage period. Satisfactory hourly calibration thresholds were 30% and 10%, respectively.

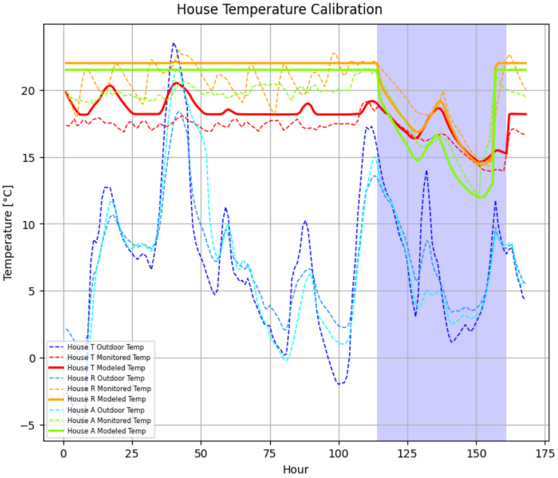
$$CVRMSE = 100 * \frac{1}{\overline{y}}[\sum \frac{(y_i - \hat{y}_i)^2}{(n-p)}]^{\frac{1}{2}} \tag{3}$$

$$NMBE = 100 * \frac{\sum (y_i - \hat{y}_i)}{(n-p) \times \overline{y}} \tag{4}$$

where y_i is the observed value, $\hat{y}_i$ is the predicted value, $\bar{y}$ is the mean of observed values, n is the number of observations, and p is 1 here.

Objective 2 Results

- Modeling data calibrated well to measured
- House T CVRSME: 7.3% & NMBE of -4.0%
- House R CVRSME: 7.3% & NMBE of 2.8%
- House A CVRSME: 9.0% & NMBE of 5.4%
- Demonstrates that modeling and measurement can be linked



Objective 2 Results

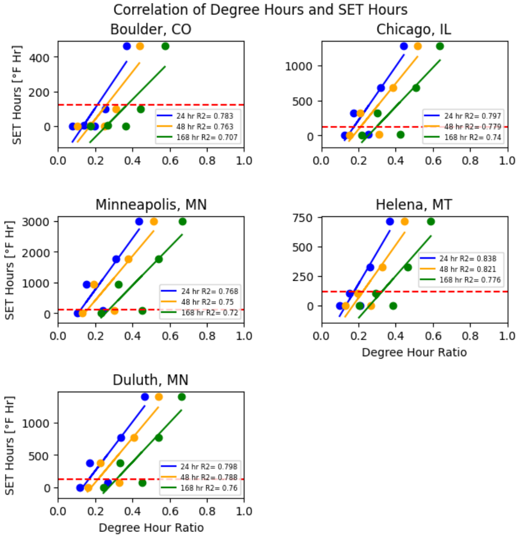
- Low cost, low tech measurement test has been developed
- Perform on 24 hour cold weekends
- Monitor hourly indoor and outdoor conditions
- Can be done with thermostat and phone weather data, inexpensive weather station, or data loggers

$$Degree\ Hour\ Ratio = \frac{\sum_0^{hr}(T_{set} - T_{int})}{\sum_0^{hr}(T_{set} - T_{out})} \quad (5)$$

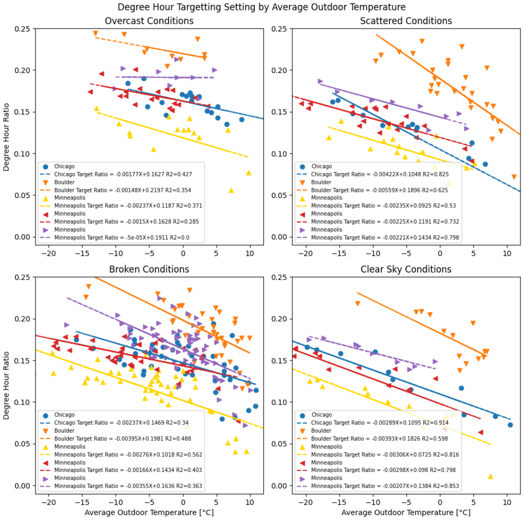
Where:

- T_{set} = Starting temperature
- T_{int} = Indoor Temperature
- T_{out} = Outdoor Temperature

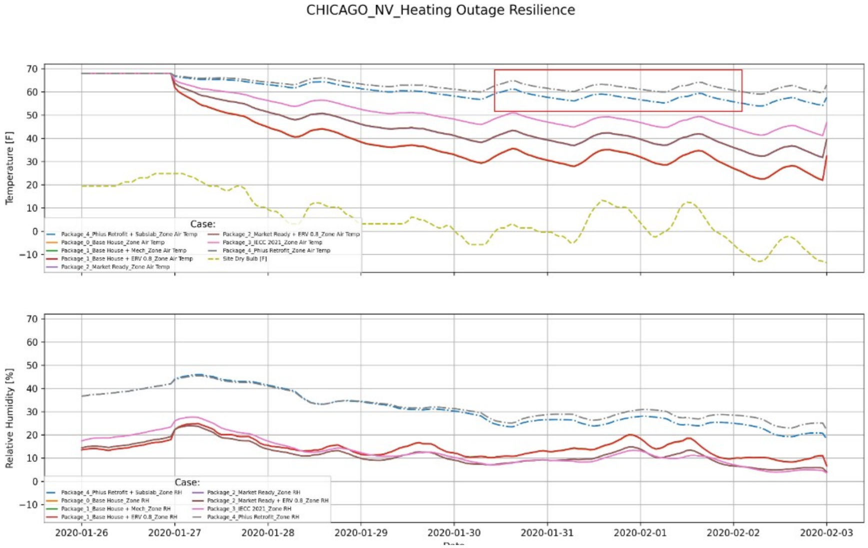
Objective 2 Results



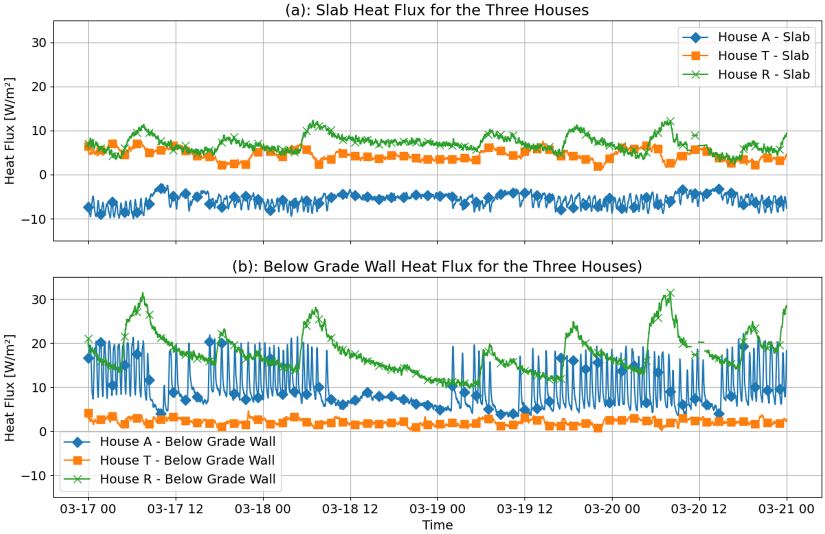
Objective 2 Results



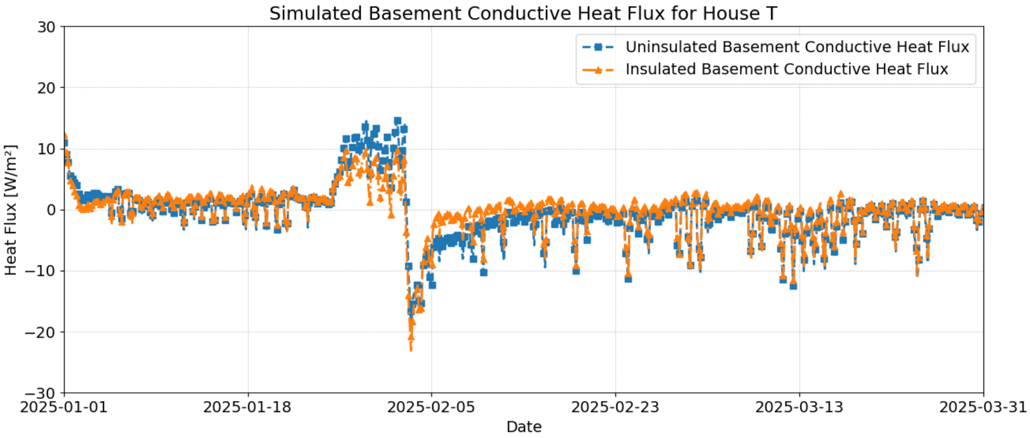
Slab Heat Flux



Slab Heat Flux



Slab Heat Flux



Objective 1 Publication

- Published in the *Journal of Building Performance Simulation*
  - Mitchell, A., Wright, G. S. and Heidarinejad, M. (2025) ‘Thermal resilience in passive buildings: metrics, modeling methods, tool development, and evaluation of passive and mixed mode responses’, Journal of Building Performance Simulation, pp. 1–18. doi: 10.1080/19401493.2025.2496658.
- Contributions
  - Software tool developed available for free download
    - Training videos and user manual PDF provided
  - Evaluated stringency of summer resilience metrics

JOURNAL OF BUILDING PERFORMANCE SIMULATION
https://doi.org/10.1080/19401493.2025.2496658

Taylor & Francis
Taylor & Francis Group

Check for updates

Thermal resilience in passive buildings: metrics, modeling methods, tool development, and evaluation of passive and mixed mode responses

Alexander Mitchell[a,b], Graham S. Wright[b] and Mohammad Heidarinejad[a]

[a]Illinois Institute of Technology, Chicago, Illinois, USA; [b]Phius, Chicago, Illinois, USA

ABSTRACT
Passive building techniques have been employed to create durable, comfortable and energy efficient buildings since the 1970’s. These strategies have been focused on recently for the benefit of thermal resilience as the extreme weather events and electrical grid instability increase while policies encourage electrification. While comfort metrics and medical exposure science can inform metrics and limits, they have not been employed for their rigor to assess thermal resilience. This study synthesizes building performance simulation approaches for resilient buildings. It evaluates building performance, proposes new guidelines for building climate resilience, and compares results with limits identified in existing literature. These simulation approaches have been compiled into an accessible graphical user interface tool that can aid the masses in simulating building floats during an outage, utilized in a parametric analysis. This paper evaluates the effects of building envelope and passive cooling techniques in different climate zones to assess national scale impacts of thermal resilience.

ARTICLE HISTORY
Received 6 March 2024
Accepted 17 April 2025

KEYWORDS
Heat stress; thermal resilience; thermal survivability; passive house; tool development

Introduction

As thermal resilience and passive survivability become a new lens for evaluating the performance of buildings, the establishment of consistent modeling protocol and assessment metrics becomes more important. As the potential for extreme weather events increases (on Climate Change (IPCC) 2023), and the strain on critical energy infrastructure threatens reliability (Levin et al. 2022), localized, building scale resilience and energy storage and generation become more critical.

Recent historic outage events such as the February 2021 cold snap in Austin, Texas (Doss-Gollin et al. 2021; Rostami and Bucking 2024) and the June 2021 heat dome in the Pacific Northwest (White et al. 2023), have occurred during severe weather conditions and have resulted in damage to property, injury and loss of life. These events represent extreme, but not unprecedented weather conditions in these regions, in which the housing stock is not built to be endured. Both events resulted in people sheltering in place in their homes, many of which were not designed or equipped to protect the health or safety of the building occupants for the atypical weather conditions.

In Texas, 4.5 million households were without power during a deep freeze in mid-February 2021 and resulted in the death of 111 people recorded as of March 2021. People were sheltering in place, often multiple families in a household during a global pandemic. Occupants went to extreme means to heat their homes without power, such as running the oven with the door open or burning furniture. The outdoor temperatures in Austin, TX dropped from 0°C on February 12th and 13th, and then to -10°C on the 14th, and -14°C on the 15th. These extreme colds caused a cascade of failure in the energy infrastructure, resulting in the loss of power, which many homes in Texas rely on for heating (Busby et al. 2021).

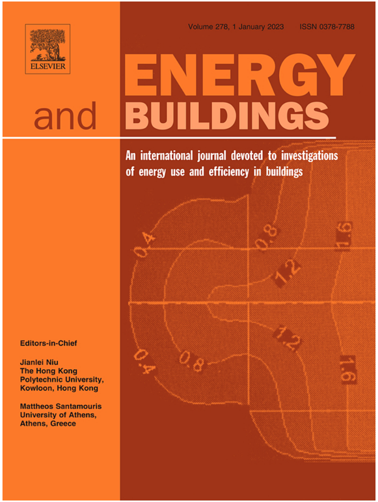
The following summer, a heat wave struck the Pacific Northwest and is at least part cause of nearly 1,000 deaths. This event occurred in an area of the United States where most people live without air conditioning, especially in lower income neighborhoods where many vulnerable people live. While this did not result in a power outage like the case in Texas, people were sheltering in place at home, with themselves and any appliances driven internal gains during the overheating prone event. From June 26th through the 28th, 2021, an extreme heat event occurred, with outdoor temperatures peaking at 45°C, and the evening temperatures not falling below 25°C, making the typical nighttime cooling difficult (Rempel et al. 2022).

These two extreme weather conditions are not unique extreme events as the frequency of these extreme weather events is growing rapidly. Consequently, it is in this context that this study explores the standardization

CONTACT Alexander Mitchell amitche8@hawk.iit.edu

Objective 2 Publication

- Intending to submit to the journal *Energy and Buildings*
- Under Review
- Contributions
  - Validation of modeling for buildings in free float conditions
  - Low tech, low cost resilience measurement test method



Conclusions

- Research Objective 1: Development of a Standardized Residential Thermal Resilience Modeling Tool
  - GUI tool is developed and available for public download from Github
  - Air sealing and insulation has the most significant impact in winter, but can trap too much humidity in summer
  - Dry climates, and large diurnal temperature swings help summer resilience
- Research Objective 2: Measured Validation of Resilience Modeling
  - Modeling calibrates well to measured data, enabling modeling or measurement testing
  - Developed limits for low tech measurement test using parametric model

Limitations & Future Work

- General: Optimize controls of passive dynamic strategies for summer resilience
- General: Improve thermal resilience simulation modeling weather generation
- Research Objective 1: Development of a Standardized Residential Thermal Resilience Modeling Tool
  - Test tool for further building types
  - Further develop optimizer in tool
  - Improve summer resilience response options
- Research Objective 2: Measured Validation of Resilience Modeling
  - Improve parametric study to building more robust target determination for test method
  - Develop user guide for home owners
  - Build into low cost sensor platform

Acknowledgments: Committee

- Dr. Mohammad Heidarinejad
- Dr. Brent Stephens
- Dr. Jamshid Mohammadi
- Dr. Ankit Srivastava
- Dr. Ralph Muehleisen
- Dr. Ji-Hyun Kim






Acknowledgments: Family

Acknowledgments: Phius

Questions?

Thank You!

Objective 1 Results

Run Name	SET Hours <12.2℃	Hours <2℃ [hr]	Total Deadly Days	Caution (>26.7, <32.2℃) [hr]	Extreme Caution (>32.2, <39.4℃) [hr]	Danger (>39.4, <51.7℃) [hr]	Extreme Danger (>51.7℃) [hr]	EUI [kWh/m2 yr]
Great Falls, Montana								
BASE_NV	1297.9	122.5	0.0	21.5	0.0	0.0	0.0	199.7
DOE Envelope_NV	790.9	97.3	0.0	18.3	0.0	0.0	0.0	103.4
IECC_NV	584.9	73.3	0.0	15.0	0.0	0.0	0.0	92.8
IECC+0.4_NV	48.7	0.0	0.0	21.3	0.0	0.0	0.0	57.6
Phius Prescriptive NV	0.0	0.0	0.0	15.3	0.0	0.0	0.0	41.3

Objective 1 Results

Run Name	SET Hours <12.2℃	Hours <2℃ [hr]	Total Deadly Days	Caution (>26.7, <32.2℃) [hr]	Extreme Caution (>32.2, <39.4℃) [hr]	Danger (>39.4, <51.7℃) [hr]	Extreme Danger (>51.7℃) [hr]	EUI [kWh/m2 yr]
Albuquerque, New Mexico								
BASE_NV	0.0	0.0	0.0	90.3	0.0	0.0	0.0	98.7
DOE Envelope_NV	0.0	0.0	0.0	86.0	0.0	0.0	0.0	57.1
IECC_NV	0.0	0.0	0.0	68.8	0.0	0.0	0.0	53.4
IECC+0.4_NV	0.0	0.0	0.0	70.8	0.0	0.0	0.0	41.9
Phius Prescriptive NV	0.0	0.0	0.0	57.0	0.0	0.0	0.0	37.0

Objective 1 Results

Run Name	SET Hours <12.2℃	Hours <2℃ [hr]	Total Deadly Days	Caution (>26.7, <32.2℃) [hr]	Extreme Caution (>32.2, <39.4℃) [hr]	Danger (>39.4, <51.7℃) [hr]	Extreme Danger (>51.7℃) [hr]	EUI [kWh/m2 yr]
Nashville, Tennessee								
BASE_NV	50.0	0.0	3.0	56.5	70.3	0.0	0.0	108.3
DOE Envelope_NV	0.0	0.0	3.0	60.8	68.8	0.0	0.0	64.8
IECC_NV	0.0	0.0	0.0	71.0	49.0	0.0	0.0	59.1
IECC+0.4_NV	0.0	0.0	1.0	57.5	59.0	0.0	0.0	46.0
Phius Prescriptive NV	0.0	0.0	1.0	62.8	53.5	0.0	0.0	41.1

Objective 1 Results

Run Name	SET Hours <12.2℃	Hours <2℃ [hr]	Total Deadly Days	Caution (>26.7, <32.2℃) [hr]	Extreme Caution (>32.2, <39.4℃) [hr]	Danger (>39.4, <51.7℃) [hr]	Extreme Danger (>51.7℃) [hr]	EUI [kWh/m2 yr]
El Paso, Texas								
BASE_NV	0.0	0.0	0.0	73.0	9.3	0.0	0.0	72.5
DOE Envelope_NV	0.0	0.0	0.0	78.0	3.0	0.0	0.0	49.3
IECC_NV	0.0	0.0	0.0	72.5	1.0	0.0	0.0	50.0
IECC+0.4_NV	0.0	0.0	0.0	68.0	3.8	0.0	0.0	44.3
Phius Prescriptive NV	0.0	0.0	0.0	62.0	0.0	0.0	0.0	38.0

Objective 1 Results

Run Name	SET Hours <12.2℃	Hours <2℃ [hr]	Total Deadly Days	Caution (>26.7, <32.2℃) [hr]	Extreme Caution (>32.2, <39.4℃) [hr]	Danger (>39.4, <51.7℃) [hr]	Extreme Danger (>51.7℃) [hr]	EUI [kWh/m2 yr]
Vancouver British Columbia								
BASE_NV	8.4	0.0	0.0	0.0	0.0	0.0	0.0	150.4
DOE Envelope_NV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	66.8
IECC_NV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	58.85
IECC+0.4_NV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	45.5
Phius Prescriptive NV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	38.5

Objective 3 Results