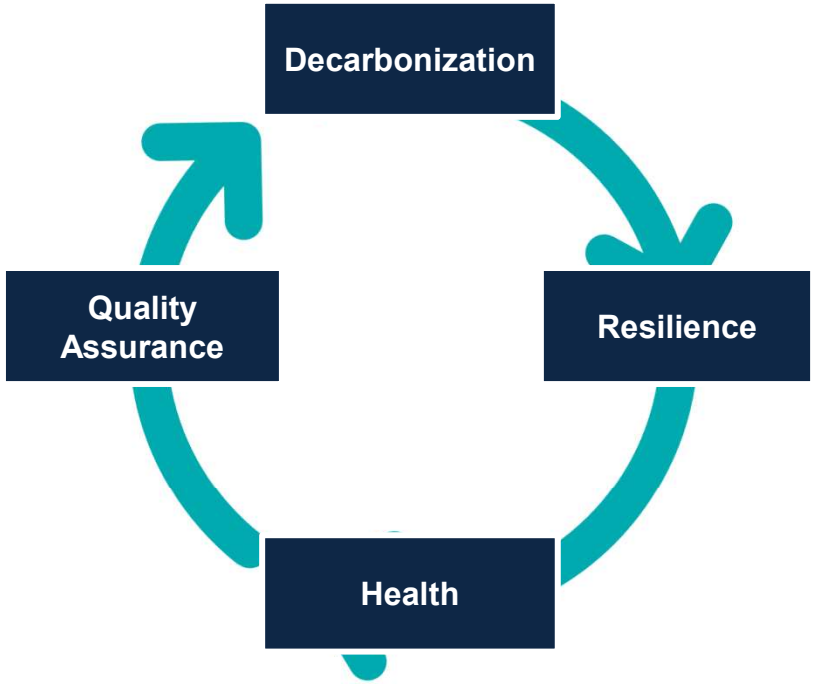
Update on Phius' Retrofit Standard

Graham S. Wright, Al Mitchell

Overview

- About the Standard
- Performance Calculation Examples



Vision

Every building supports the health of **people** and the **planet**.

Vision

Every building supports the health of:

People

&

Planet

Vision

Every building supports the health of:

People

&

Planet

- Climate / GHG / CO_2 / Carbon

Vision

Every building supports the health of:

People

&

Planet

- Climate / GHG / CO_2 / Carbon

Let's focus on just this crisis for now.

Vision

Every building supports the health of:

People

&

Planet

- Climate / GHG / CO_2 / Carbon

I recently learned that waste heat will boil the oceans in about 400 years.

Sabine Hossenfelder · 390K views · 3 weeks ago

Sabine Hossenfelder

Climate Action

Every building supports the health of:

People

&

Planet

- Climate / GHG / CO_2 / Carbon ➡ Decarbonization

Vision Again

Every building supports the health of:

People

&

Planet

- Climate / GHG / CO_2 / Carbon ➡ Decarbonization

Absolute Zero - no emissions ever happen in the supply chain or building life.*

No resort to carbon offsets

Vision

Every building supports the health of:

People

- Shelter (it's what buildings do for people)

&

- Health per se

Planet

- Climate / GHG / CO_2 / Carbon ➡ Decarbonization

From Vision to Action – Things to do

for existing buildings

Every building supports the health of:

People

- Shelter ➡ Robust, Resilient – Weatherization & Fortification versus site hazards
- Health ➡ Removing-unhealthy-stuff-ification

Planet

- Climate / GHG / CO_2 / Carbon ➡ Decarbonization

A way to describe the concept quickly

Resilience (or weatherization)

+

Health

+

Decarbonization

Measures such as:

Resilience | Air sealing, insulation, seismic, PV, batteries…

+

Health | Radon, Carbon monoxide, mold…

+

Decarbonization | Electrification, community solar, low-carbon choices…

+ Quality Assurance Process

To ensure the requirements are met and that benefits persist.

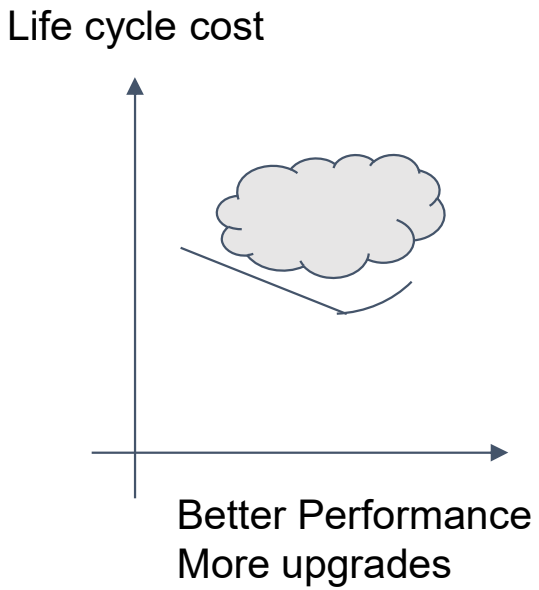
Circling back to Decarbonization

- Absolute Zero can’t yet be done so, then what? Meaning what now?
- What about operational vs. embodied carbon?

Decarbonization

An Idea

- Design as if there's a cost of carbon
- Minimize total cost, total life cycle cost



Decarbonization

An Idea

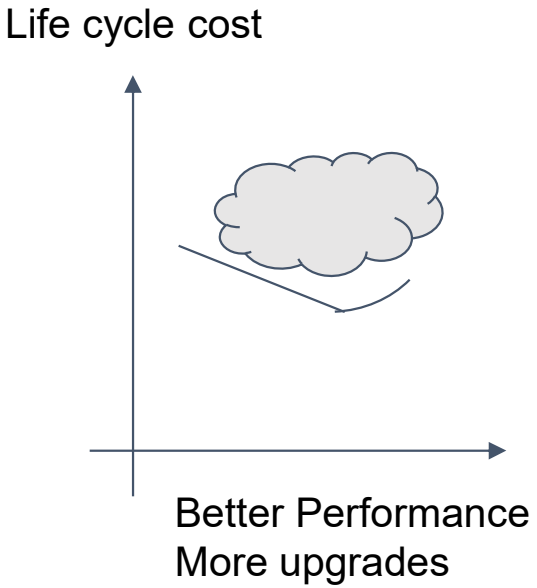
- Design as if there's a cost of carbon
- Minimize total cost, total life cycle cost

Dear Funder,

If there were a carbon tax, I could justify doing <this much> to decarbonize my building; would you like to fund any of that in the name of ESG or the like?

Regards,

Owner



Decarbonization

Cost Metric = Sum of these annualized costs:

- Direct energy cost. E.g. site kWh * $/kWh = $
- Direct building retrofit measures cost (material & labor) including building-level electrification cost. E.g. ft3 of stuff * $/ft3 = $
- Cost of carbon -- upfront/embodied. CO2e kg * $/kg = $
- Cost of carbon – operating. CO2e kg * $/kg = $
- Energy system transition cost. E.g. new solar + storage. $/MW * MW = $

Names

Begin thinking about which you'd prefer, will poll in a bit…

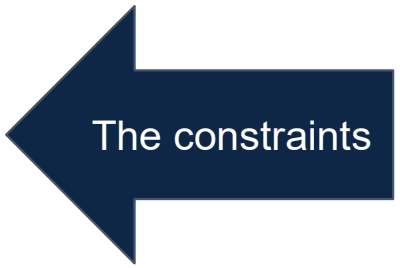
- **ADORB** cost - **A**nnualized **D**ecarbonization **O**f **R**etrofitted **B**uildings cost
- **FCALC** cost - **F**ull **C**ost **A**ccounted **L**ife **C**ycle cost

Retrofit Planning Framed as an Optimization

Every building supports the health of:

People

- Shelter → Robust, Resilient – Weatherization & Fortification.
- Health → Removing-unhealthy-stuff-ification.



Planet

- Climate / GHG / CO_2 / Carbon → Decarbonization
- **Minimize ADORB / FCALC cost**

More Practical Approach for Now

Every building supports the health of:

People

- Shelter → Robust, Resilient - Weatherization & Fortification.
- Health → Removing-unhealthy-stuff-ification.

Planet

- Climate / GHG / CO2 / Carbon → Decarbonization.
- ~~Minimize~~ **ADORB / FCALC cost ≤ Baseline**

+ Additional decarbonization effort – op & embodied

Requirements

More requirements

ADORB / FCALC

More about some of these later

Default pattern for time-of-use electricity rates

Carbon price $250 per ton

Lifetime 70 years

Transition Cost $2.82 per W

Database of upgrade costs

Long run marginal emissions rates for electricity

Embodied carbon calc
Level 1 approx
Level 2 approx

Discount rate 2% for direct costs, else 0

One Question Poll:

ADORB or FCALC?

Next Up: **Resilience**

Takes on Resilience

It's always fair to ask: resilient to what?

Building / campus / block scale

- Resilience from the grid
- Outage conditions

Mainly this kind for now

Thermal & electrical

Utility scale

- Resilience for the grid
- Normal operation

Resilience Performance Protocol

- Simulate seven-day outages, in extreme weather.
- Whole building remains habitable, not just a protected zone.
- On-site PV and batteries provide limited power.
- Assume full design occupancy for residential.
- Reduced ventilation rate 5 cfm/person.

Resilience Performance Protocol & Criteria

- Simulate seven-day outages, in extreme weather.
- Whole building remains habitable, not just a protected zone.
- On-site PV and batteries provide limited power.
- Assume full design occupancy for residential.
- Reduced ventilation rate 5 cfm/person.

Winter Resilience Criteria

- Zero hours below 35°F
- Limited degree-hours

  ≤ 216 SET-hours*, base 54°F

  (*similar to LEED pilot credit)

Resilience Performance Protocol & Criteria

- Same as Winter
- Simulate seven-day outages, in extreme weather.
- Whole building remains habitable, not just a protected zone.
- On-site PV and batteries provide limited power.
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Summer Resilience Criteria

- Zero hours of Heat Index in Danger
- Limited hours of Heat Index in Extreme Caution

Health and Hazards

EPA

1. Asbestos
2. Belowground contaminants (except radon)
3. Building products/material emissions
4. Carbon monoxide and other combustion appliance emissions (nitrogen oxides, VOCs and particulates)
5. Environmental tobacco smoke
6. Garage air pollutants (CO, benzene and other VOCs)
7. Lead
8. Moisture (mold and other biologicals)
9. Pests
10. Polychlorinated biphenyls
11. Radon
12. Wood smoke and other solid fuel emissions
13. Heating, ventilating and air conditioning (HVAC) equipment
14. Combustion safety, vented combustion appliances
15. Combustion safety, unvented combustion appliances
16. Source or local exhaust ventilation
17. Whole-dwelling ventilation for distributed contaminant sources
18. Home safety
19. Protecting IAQ during construction
20. Jobsite safety

FEMA, IBHS

SEISMIC

FLOOD, TSUNAMI

HAIL

WIND

ICE DAMS, SNOW LOAD

WILDFIRE

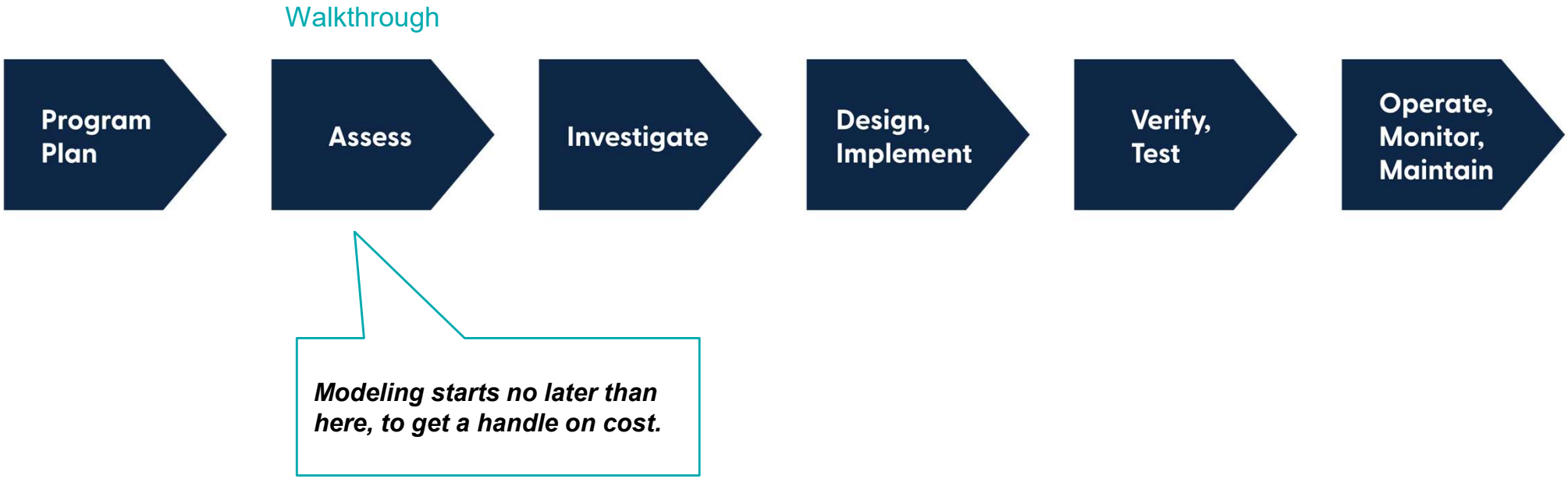
Break for questions

Next Up: **Quality Assurance**

+ Quality Assurance Process

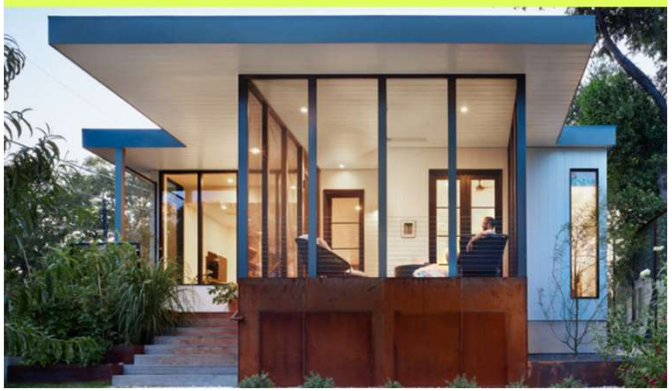
RETROFIT or REPLACE?
Which buildings first?

+ Quality Assurance Process



Concepts for Requirements

1. A quality assurance process covers all phases of the retrofit.
2. The existing building is assessed as to suitability for retrofit, energy performance, and risks to indoor air quality and from site hazards.
3. **Resilience to grid outages summer and winter - buildings remain habitable and critical electrical loads are covered.**
4. **Fix any existing deficiencies that pose risks to indoor air quality.**
5. Life cycle calculations are done using a full-cost accounting metric called ADORB / FCALC that includes a cost of carbon.
6. Direct emissions cease soon.
7. Project cost data and post-retrofit measured energy performance are reported.



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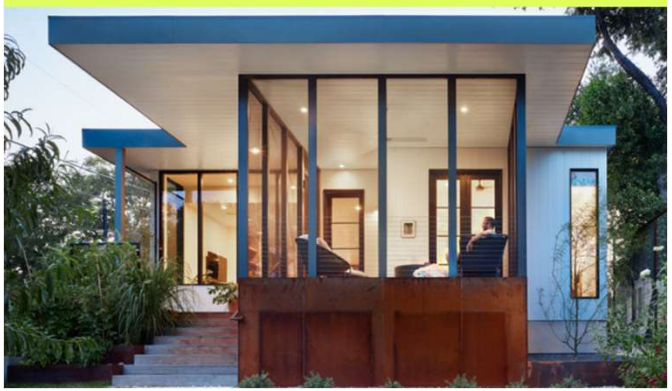

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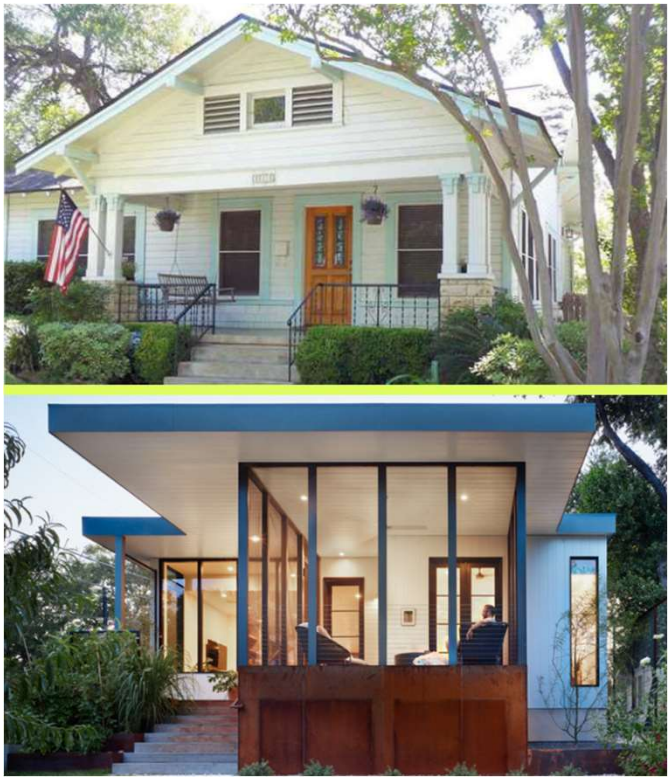


Outline of the Standard

Foreword

1. Purpose
2. Scope
3. Definitions
4. Process
5. Mitigate Existing Deficiencies
6. Performance Requirements
7. Monitoring, M&V Requirements

Additions are within scope, if smaller than the existing building

Including just the normative appendices

A - ADORB Calculation method

T-0 Program Plan Outline

T-1 CFR/OPR Outline

T-2 Commissioning Plan Outline

T-6 Commissioning Report Outline

T-7 Ongoing Commissioning Plan Outline

T-8 Ongoing Commissioning Report Outline

Openness, for Scalability

100+ million buildings

The Standard Document

Name: Phius/TBD EB1-2023

- Written in code-mandatory language.
- All calculation protocol spelled out, for requirements on modeled performance.

Roles:

- Owner
- Authority
- Commissioning Provider
- Verification & Testing Providers

The Certification Program

Name: Phius REVIVE Pilot (for now)

- Our certification to the standard.
- Maintain open-source calculation engine.

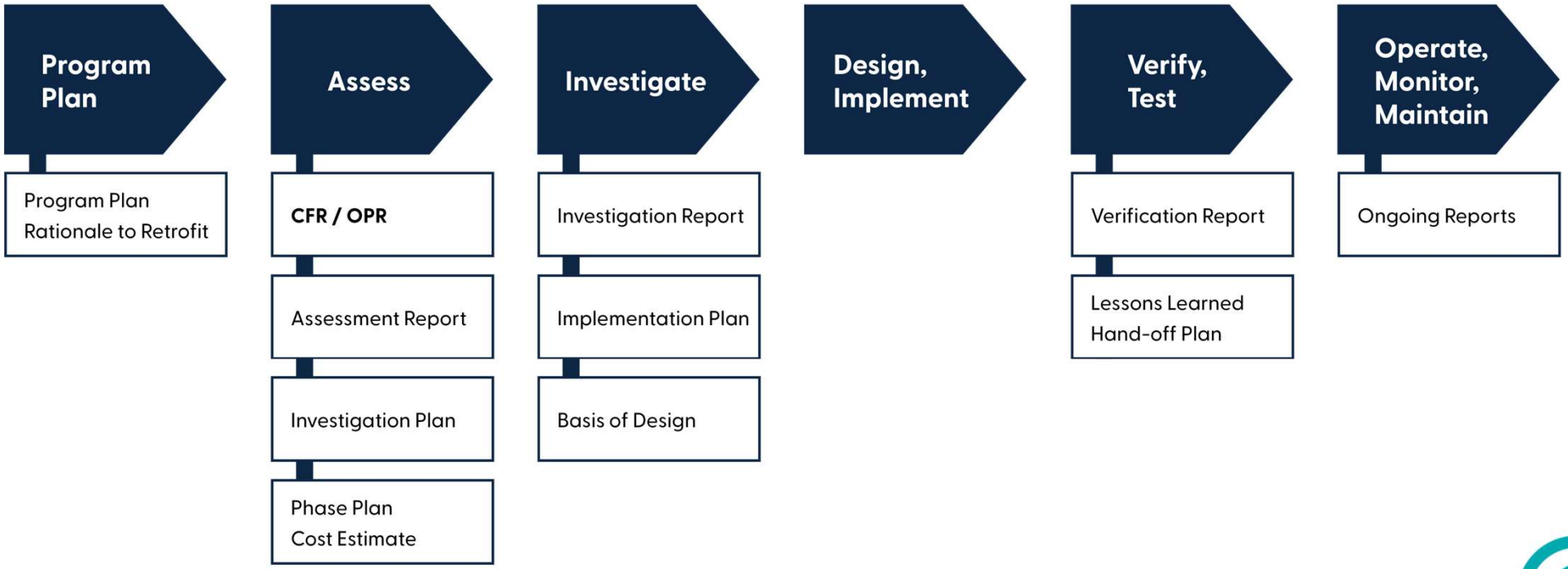
Corresponding Roles for our certification to the standard:

- Owner
- Phius
- CPHC®
- Phius Raters & Verifiers

4 | Quality Assurance Process

Compliance is documented

Per ASHRAE Guideline 0.2 commissioning process



Use of Commissioning for Certification / Enforcement

ASHRAE Cx standards are written for the benefit of the Owner, to fulfill Owner's Project Requirements (OPR).

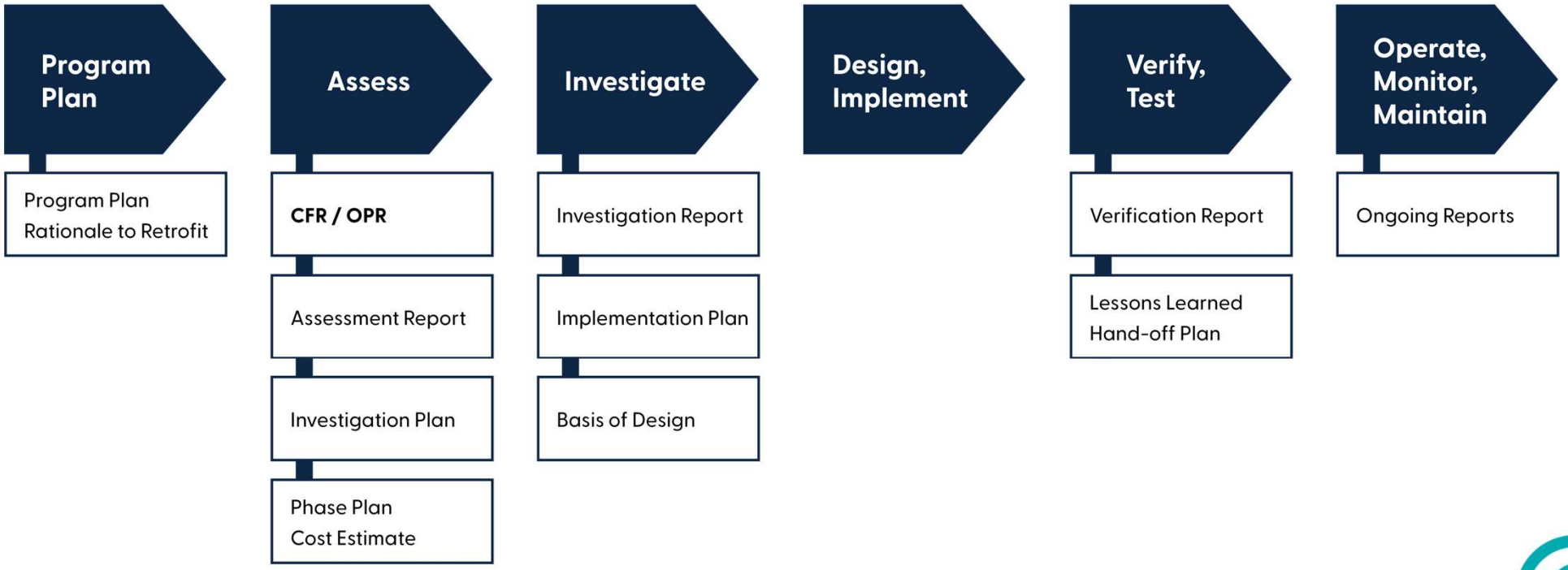
Adaptations for use in Certification / Enforcement:

- Most of the requirements in the CFR / OPR are those of this standard.
- Documentation deliverables go to both Owner and Authority.
- Gates for Acceptance & decision-to-proceed require concurrence of Owner and Authority.

4 | Quality Assurance Process

Compliance is documented

Zoning | Permit | C.O. | BPS



Owner Input

A la carte electives listed in the standard.

- These are additional improvements beyond the required minimums.
- If the owner opts for any of these, they are subject to the QA process.

Other, such as:

- Regulatory, i.e., correct this code violation X.
- Functional requirements, especially in the case of additions
  - e.g., Kitchen needs cooktop but not an oven, need an ADA door here…
- Preferred vendors

Questions so far?

Next Up: **Actual Requirements**

5 Mitigate Existing Deficiencies
6 Performance Requirements
7 Monitoring, M&V Requirements

5 | Mitigate Existing Deficiencies

5.1 Indoor Air Quality and Moisture Risk Mitigation

5.2 Hazard Mitigation

5 | Mitigate Existing Deficiencies

5.1 Indoor Air Quality and Moisture Risk Mitigation

- All Minimum Actions in the EPA Energy Savings Plus Health Guidelines.
    - Any EPA Expanded Actions elected by the Owner.
- New additions comply with Energy Star Residential New Construction.
- Phius Certification Guidebook Appendix B.

5.2 Hazard Mitigation

5 | Mitigate Existing Deficiencies

5.1 Indoor Air Quality and Moisture Risk Mitigation

Most of the hazard mitigation is elective.

5.2 Hazard Mitigation minimum actions (as applicable)

- **Seismic** performance grade B- or higher (a la FEMA P-50).
- Electrical / mechanical protected from **flood** per FEMA or IBHS.
- **Hail** – Roof mounted PV meets IBHS FORTIFIED™ Hail Supplement.
- **Structural/Wind** – No unreinforced dry-stack foundations. FORTIFIED Roof .
- Mitigate any **ice dams**.
- **Wildfire** – Berkeley defensible space and home hardening checklist.

6 | Performance Requirements

6.1 Simulation General Requirements

6.2 Winter Resilience

Main driver of envelope upgrades

6.3 Summer Resilience

6.4 Life Cycle Cost and Impact Control

6.4.1 ADORB / FCALC Cost Limit

6.4.2 Additional Decarbonization Effort

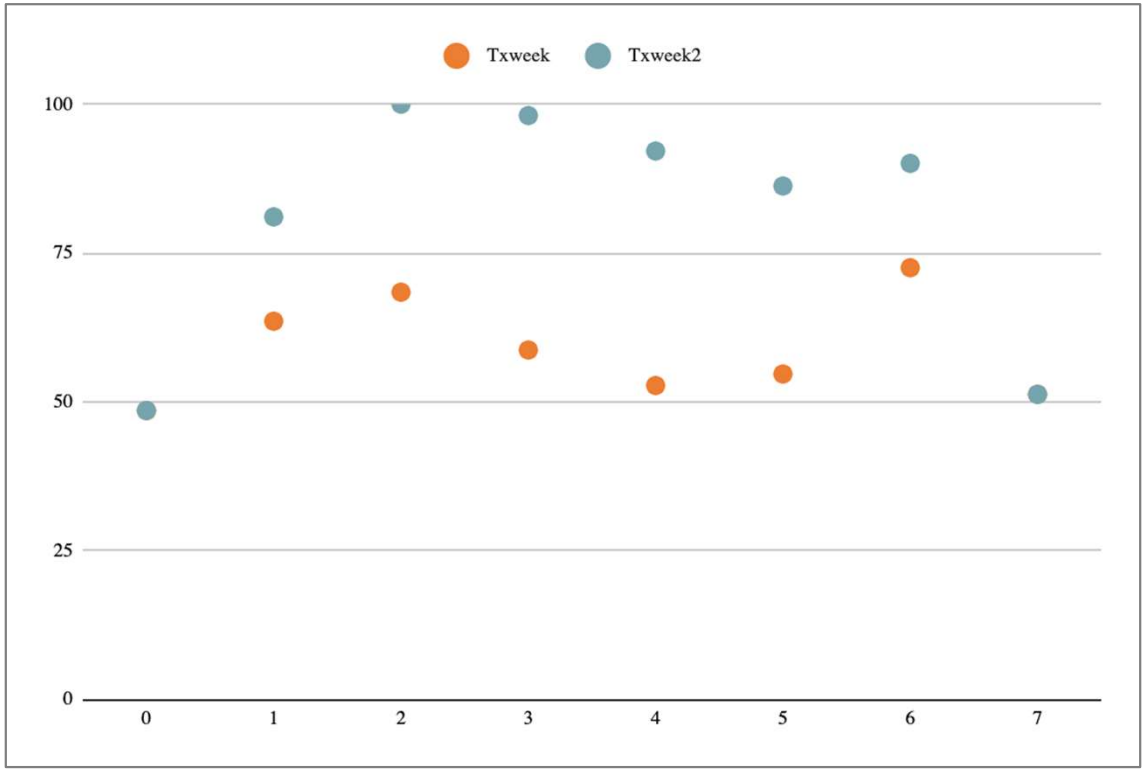
6.1 | Stress Weather for Resilience Tests

Take extreme week from TMY STAT file.

Morph to hit ASHRAE 50-year return temperature extremes

Dry bulb & wet bulb

20-year?



6.3 | Summer Resilience

- Zero hours of Heat Index in Danger
- Limited hours of Heat Index in Extreme Caution

Probably requires at least two simulation passes, to try different operation modes, e.g.

- Passive – window shades, window night flush, evaporative cooling
- Add or substitute active daytime PV-powered mechanical cooling

7 | Monitoring Requirements

Minimum requirements

- Track energy use in Energy Star Portfolio Manager
- Report to authority

7.1 Indoor Environment Monitoring Electives

7.2 Energy End-Use Monitoring Elective

7.3 Water Quality Monitoring Elective

7.4 Waste/Materials Tracking Elective

6.4 | ADORB / FCALC

Direct cost categories, for planning & reporting

Performance related

- Envelope
  - Air leakage / sealing / tightness
  - Ceilings, Roofs
  - Walls
  - Foundation, Floors
- HVAC
  - Mechanical ventilation
  - Space Conditioning
- Hot Water (DHW, SHW)
- Major appliances
- Lighting
- PV / Battery / Generation
- Other performance-related

Not performance related

- Indoor air quality related
- Hazard mitigation related
- Other in-scope
- Other out-of-scope
- Incentives
- Tax credits

ADORB / FCALC

Carbon accounting concepts

The boundary in space encompasses the whole world supply chain.

The boundary in time:

- Extends into the future through the life of the building.
- Does **not** extend indefinitely into the past, i.e., to carbon sequestration done by trees decades ago.
  - We are not counting the emissions from making the original building decades ago…
  - Nor the original emissions from steel that we are recycling…

ADORB / FCALC

Embodied carbon: Level 1 embodied carbon calculation

Economic input-output based

- Cost of materials and labor, including soft costs
- Country of origin for materials

ADORB / FCALC

Embodied carbon: Level 1 embodied carbon calculation

Economic input-output based

- Cost of materials and labor, including soft costs
- Country of origin for materials

Country	US Trading Rank	GDP [USD MM]	CO_2 [MT]	EF [kg/$]
USA	-	20,936,600.00	4,900.0	0.234
China	1	14,722,730.70	9,500.0	0.645
Canada	3	1,643,407.98	565.2	0.344
Germany	5	3,806,060.14	696.1	0.183
India	10	2,622,983.73	2,300.0	0.877
France	15	2,603,004.40	303.5	0.117

ADORB / FCALC

Embodied carbon: Level 1 embodied carbon calculation

For a $1,000 Import from Canada:

$1,000 × 0.344 kg/$ = **344 kg** CO_2e

344 kg × $0.25/kg

= $86 embodied carbon cost

6% consulting fees on a $1,000,000 project:

$60,000 × 0.234 × 0.25 = **$3,510**

Country	US Trading Rank	GDP [USD MM]	CO_2 [MT]	EF [kg/$]
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ADORB / FCALC

Embodied carbon: Level 2 embodied carbon calc

A **correction** to Level 1 rather than a replacement of it.

Credits for carbon reductions available from 3 kinds of measures:

- Material choices
- Business practices
- Personal choices
  - Apply in the years worked on the project, adjusted based on % of income from project.

Reductions are relative to measure-specific baselines.

ADORB / FCALC

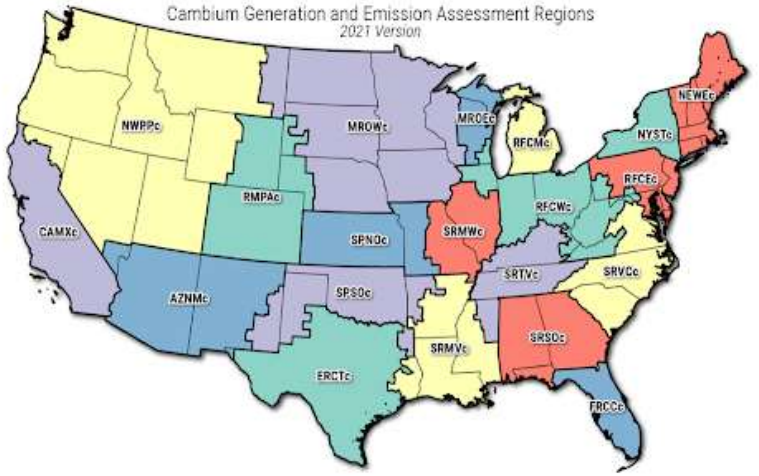
Operational carbon - emission rates for electricity used

Time resolution - hourly (or annual)

Spatial resolution - GEA regions (similar to Egrid)

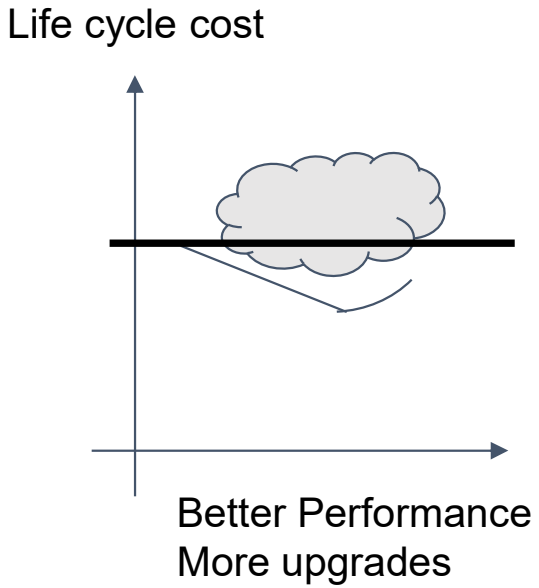
Protocol - NREL Cambium Levelized LRMER with

- Emission - CO_2e
- Emission stage - Combined
- Start year - 2023
- Evaluation period - 70 years
- Discount rate (real) - 0
- Scenario - 95% decarb by 2050
- Global Warming Potentials - 100-year (AR5)
- Location - End-use



6.4.1 | Life Cycle Cost Limit

- The ADORB / FCALC cost of the proposed retrofit is to be no greater than that of a baseline case, in which the building is operated and maintained as-is.



6.4.2 | Additional Decarbonization Effort

Operational — Do one of the following:

a. Electrify in the 1st implementation phase and use onsite and offsite renewables per Phius Zero (see Appendix A of Certification Guidebook.)
b. From the 1st implementation phase onward, subscribe to community solar at 100% of predicted post-retrofit energy use.

** Elective - community scale storage or full-on microgrid.*

Embodied — Do at least one Level 2 embodied carbon measure.

Additional decarbonization effort

The ADORB cost limit may motivate this well enough on its own.

Operational — Do one of the following:

a. ~~Electrify in the 1st implementation phase and use onsite and offsite renewables per Phius Zero (see Appendix A of Certification Guidebook.)~~

b. ~~From the 1st implementation phase onward,~~ By the final phase, subscribe to community solar at 100% of predicted post-retrofit energy use.

~~ Elective~~ - community scale storage or full-on microgrid.*

Embodied — Do at least one Level 2 embodied carbon measure.

Summary

1 | Purpose

1.1

To establish:

Requirements for retrofit improvement work on existing buildings.

Criteria for the selection of buildings for retrofit (as opposed to razing or replacement with new buildings.)

1 | Purpose

1.2

The purposes of the improvements are to:

Eliminate direct and indirect greenhouse gas emissions, in normal operation.

Provide resilience to winter and summer power outages.

Fix defects of concern to the US EPA, that pose risks to indoor air quality.

Where appropriate, fortify the building against certain site hazards of concern to US FEMA.

Meet specific owner's project requirements closely related to the above.

1 | Purpose

1.3

There are also process requirements:

For commissioning / quality assurance.

To calculate the climate impact of the retrofit work itself and make efforts to reduce it.

To collect data on project costs, post-retrofit performance, and lessons learned.

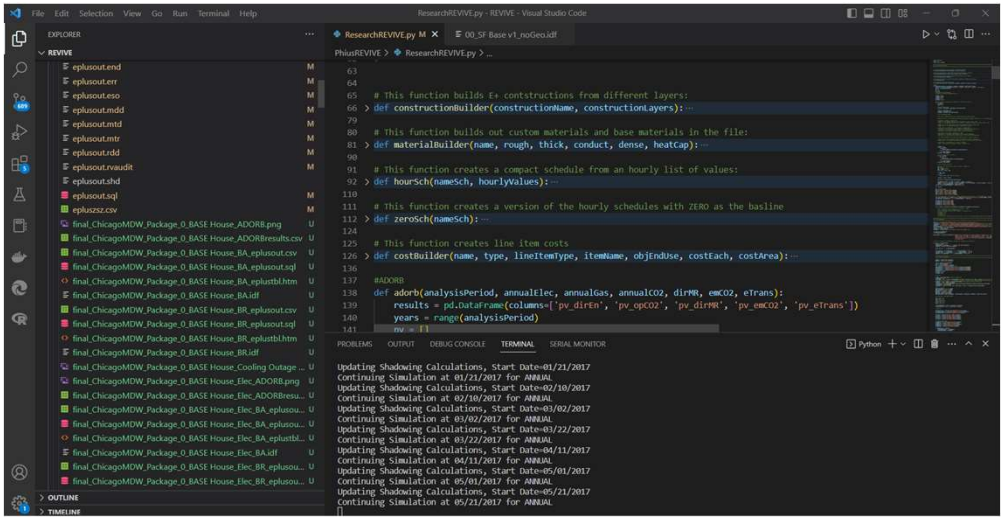
Let’s take a break for more questions.

Next Up: **Some sample calculations by AI**

Modeling Overview

Developing a new tool to support these analyses:

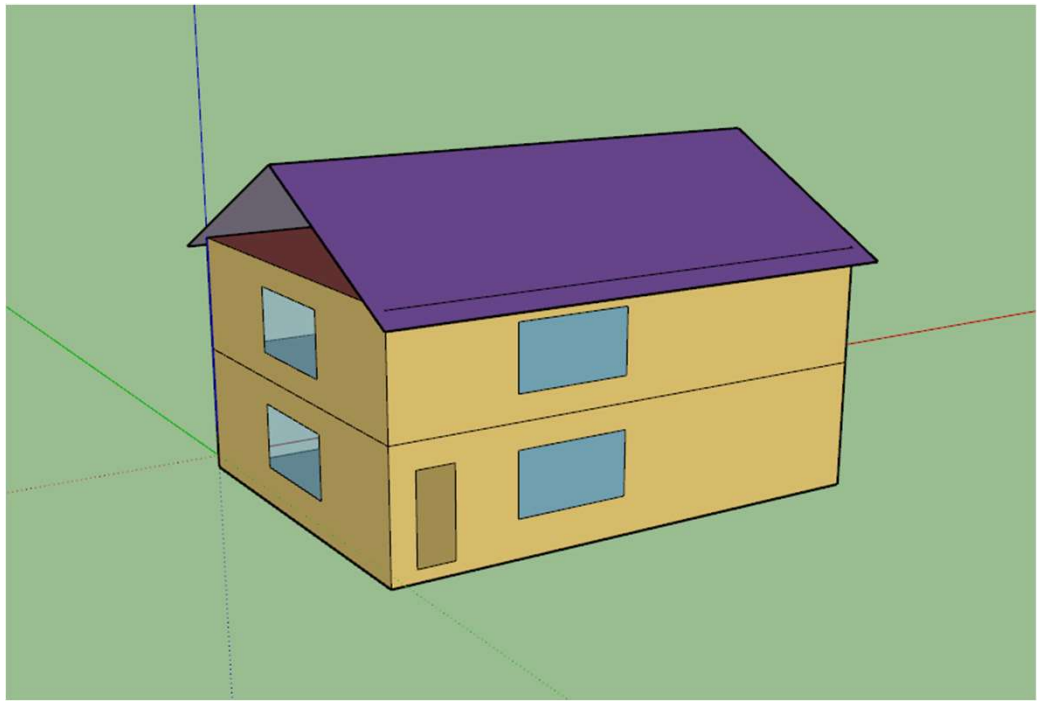
- Hourly resilience simulation
- Hourly annual normal operation Simulation
- ADORB LCCA
- Future GUI Interface



Test House

US DOE Prototypical Single Family House:

- 2 Stories
- 3 beds (4 occ)
- 2,128 sqft (198 sqm)
- 13.5% WWR
- slab on grade



Packages and Summer Modes

Retrofit Packages:

0. Baseline House
1. Electrification
2. DOE ‘Market Ready Envelope’
3. IECC 2021

3b. IECC 2021 @ 0.06cfm50

4. Phius CORE Prescriptive

Summer Modes:

NV - natural vent., temp control

SNV - scheduled nat. vent., temp ctrl.

SNV+Shd - add exterior blinds

HP - heat pump

HP+Shd - heat pump + ext. blinds

EC - evaporative cooler (B zones)

EC+Shd - evap cooler + ext. blinds

Chicago Cases Input Summary

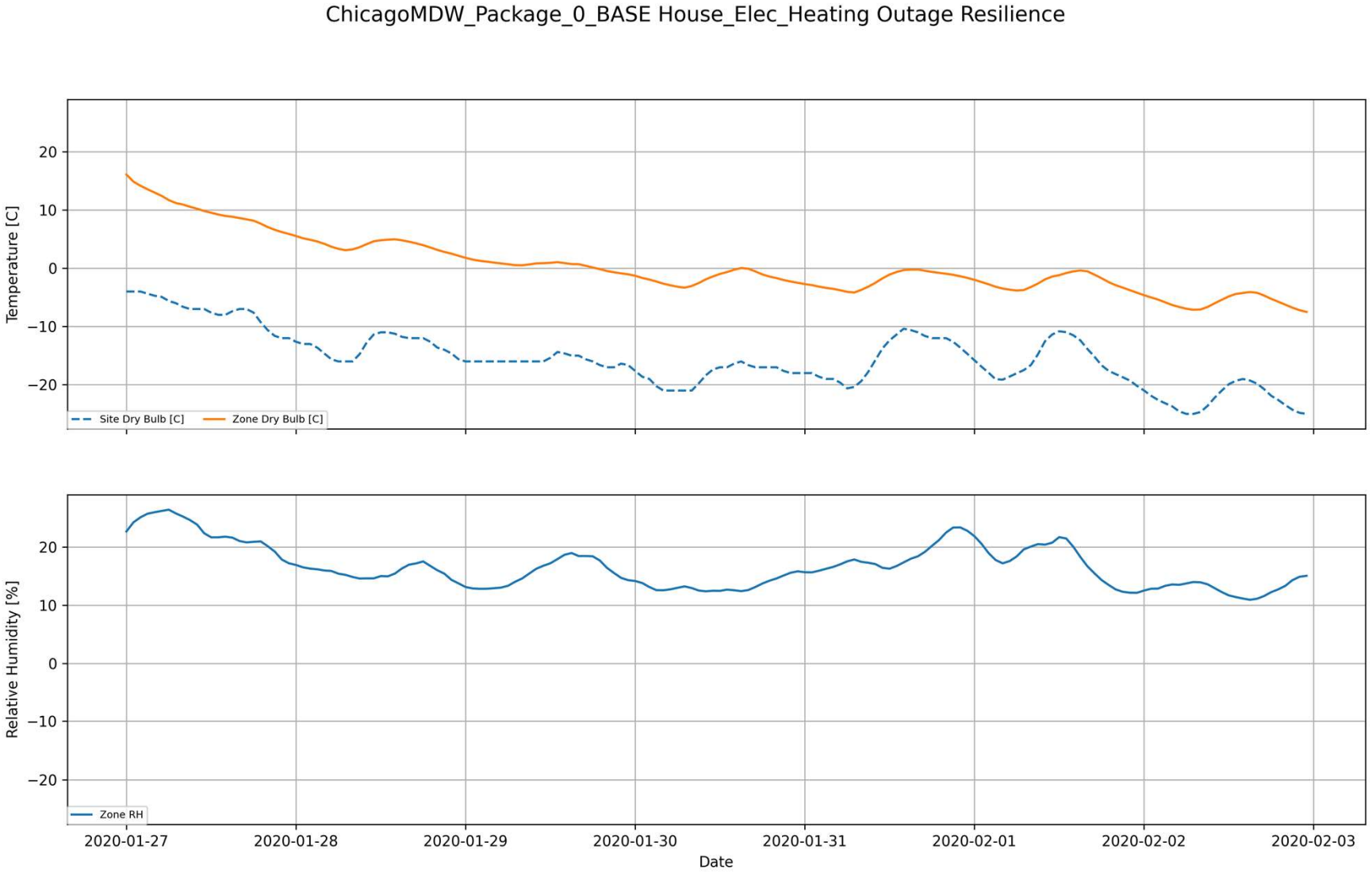
Package	Grid Region	Water Heater Fuel	Space Conditioning System	Flow Coefficient [SI]	Window U-Factor	Ext. Wall Type	Roof Type	Natural Ventilation Type
Pkg 0_Base House_NG	RFCWc	NaturalGas	GasFurnaceDXAC	0.14849	0.47	Exterior Wall	Exterior Roof	NatVent
Pkg 2_DOE Ready Envelope_NG	RFCWc	NaturalGas	GasFurnaceDXAC	0.09292	0.36	Exterior Wall +1.625in EPS	Exterior Roof R-60	SchNatVent
Pkg 3_IECC 2021_NG	RFCWc	NaturalGas	GasFurnaceDXAC	0.09292	0.3	Exterior Wall +2in EPS	Exterior Roof R-60	SchNatVent
Pkg 3B_IECC 2021 @ 0.06CFM50_NG	RFCWc	NaturalGas	GasFurnaceDXAC	0.00695	0.3	Exterior Wall +2in EPS	Exterior Roof R-60	SchNatVent
Pkg 4_Phius Prescriptive_NG	RFCWc	NaturalGas	GasFurnaceDXAC	0.00695	0.15	Exterior Wall +6in EPS	Exterior Roof R-75	SchNatVent
Pkg 0_Base House_E	RFCWc	Electricity	PTHP	0.14849	0.47	Exterior Wall	Exterior Roof	NatVent
Pkg 2_DOE Ready Envelope_E	RFCWc	Electricity	PTHP	0.09292	0.36	Exterior Wall +1.625in EPS	Exterior Roof R-60	SchNatVent
Pkg 3_IECC 2021_E	RFCWc	Electricity	PTHP	0.09292	0.3	Exterior Wall +2in EPS	Exterior Roof R-60	SchNatVent
Pkg 3B_IECC 2021 @ 0.06CFM50_E	RFCWc	Electricity	PTHP	0.00695	0.3	Exterior Wall +2in EPS	Exterior Roof R-60	SchNatVent
Pkg 4_Phius Prescriptive_E	RFCWc	Electricity	PTHP	0.00695	0.15	Exterior Wall +6in EPS	Exterior Roof R-75	SchNatVent

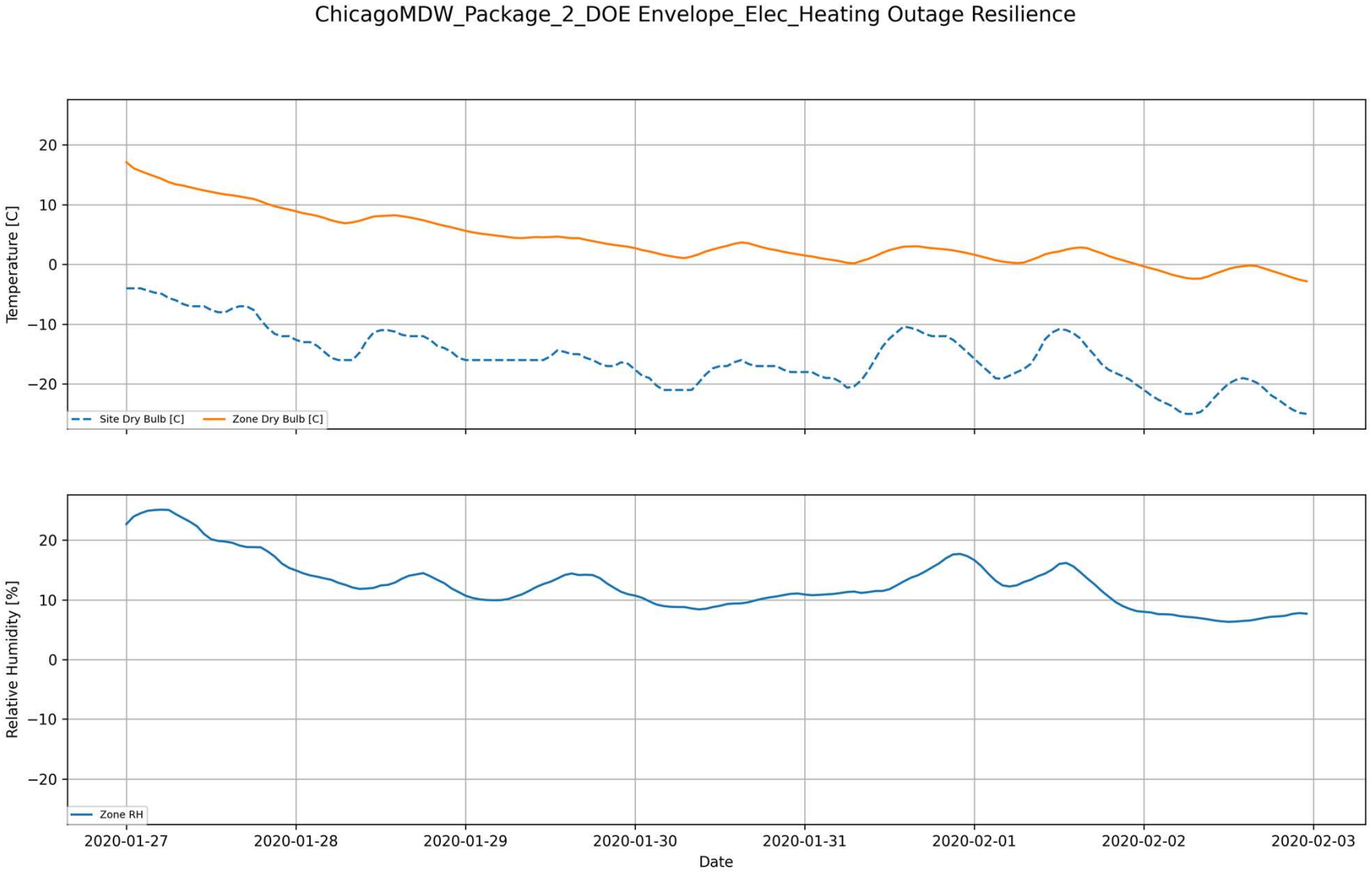
Chicago Cases Output Summary

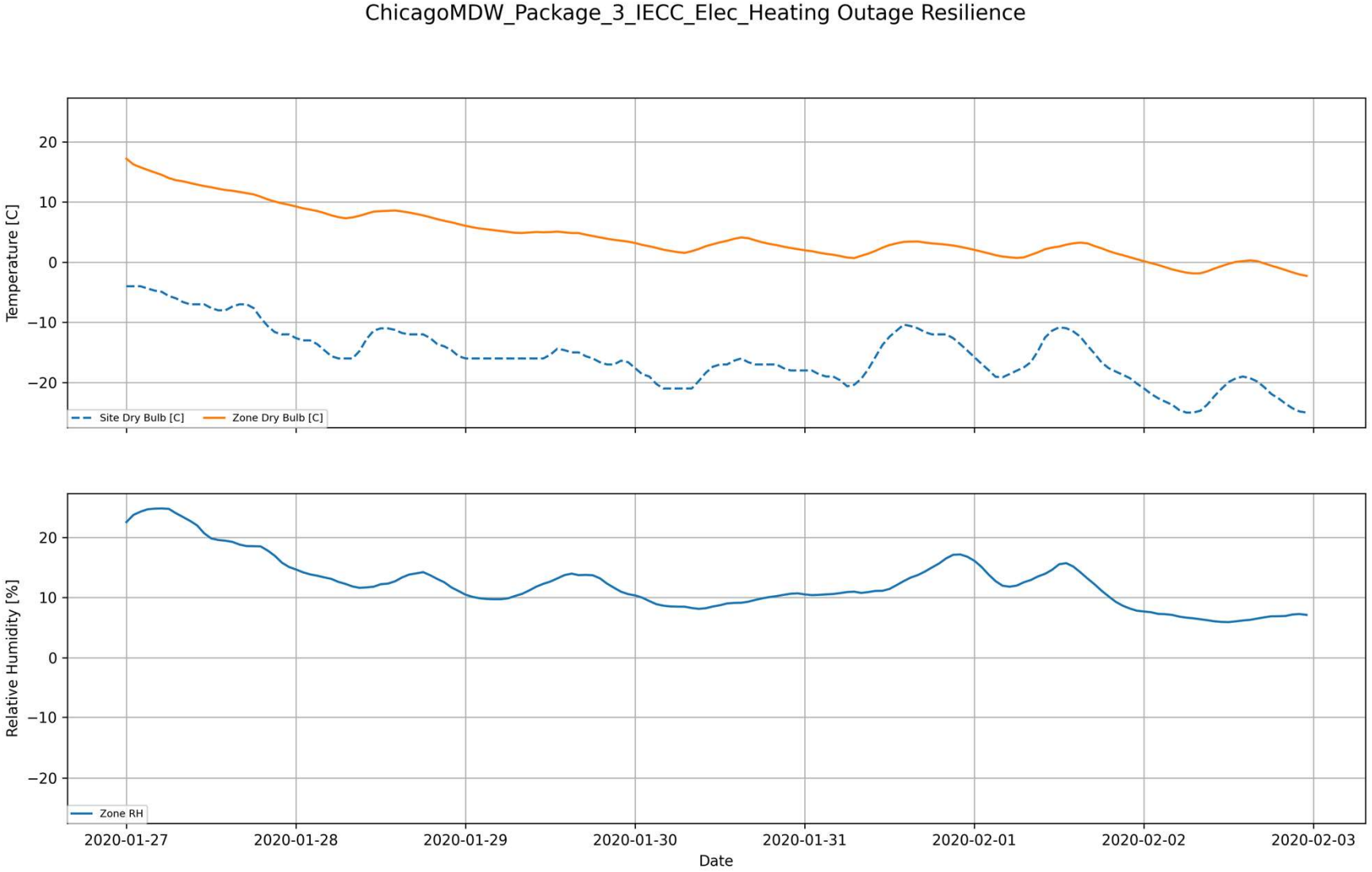
Package	SET < 54°F [hr]	Hours < 35°F [hr]	Caution [hr]	Extreme Caution [hr]	Danger [hr]	Extreme Danger [hr]	EUI [kBtu / sf yr]	Peak Electric Demand [W]	Heating Battery Size [kWh]	Cooling Battery Size [kWh]	Total ADORB Cost [$]
Pkg 0_Base House_E	1019	119	66	58	0	0	38.7	20420	7.1	4.8	$200,889.44
Pkg 2_DOE Ready Envelope_E	556	53	60	65	0	0	27.8	13543	7.1	4.8	$169,735.37
Pkg 3_IECC 2021_E	504	41	62	63	0	0	26.9	13045	7.1	4.8	$165,994.31
Pkg 0_Base House_NG	1020	119	66	58	0	0	52.1	4488	7.1	4.8	$149,247.36
Pkg 2_DOE Ready Envelope_NG	557	53	60	65	0	0	35.5	3727	7.1	4.8	$144,998.14
Pkg 3_IECC 2021_NG	505	41	62	63	0	0	34.0	3645	7.1	4.8	$143,281.25
Pkg 4_Phius Prescriptive_NG	0	0	54	57	0	0	17.3	2359	7.1	4.8	$126,063.41
Pkg 3B_IECC 2021 @ 0.06CFM50_E	60	0	56	56	0	0	18.7	6863	7.1	4.8	$125,091.65
Pkg 3B_IECC 2021 @ 0.06CFM50_NG	61	0	56	56	0	0	22.3	2789	7.1	4.8	$124,416.52
Pkg 4_Phius Prescriptive_E	0	0	54	57	0	0	15.3	4889	7.1	4.8	$119,252.07

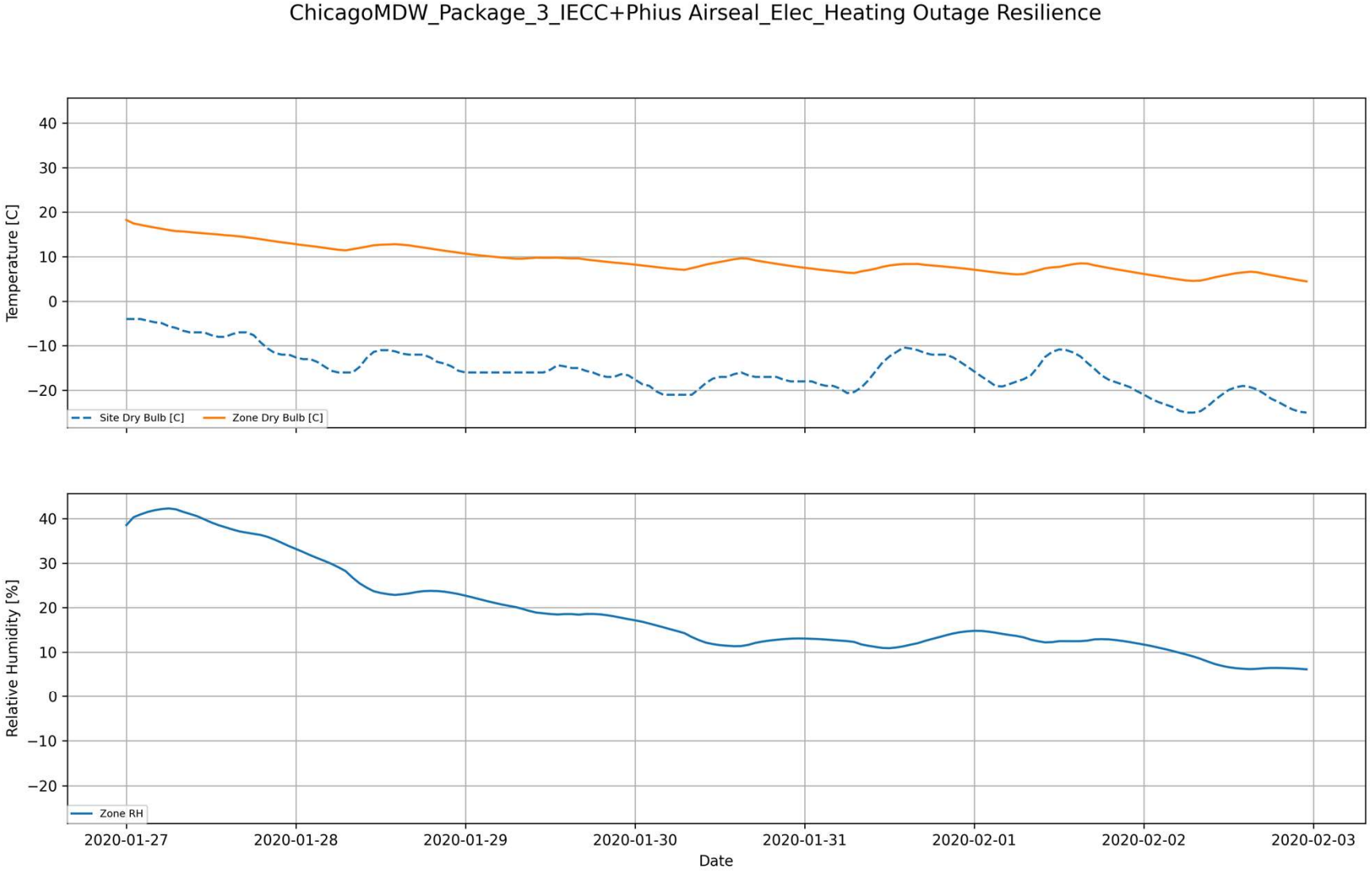
NYC Cases Output Summary

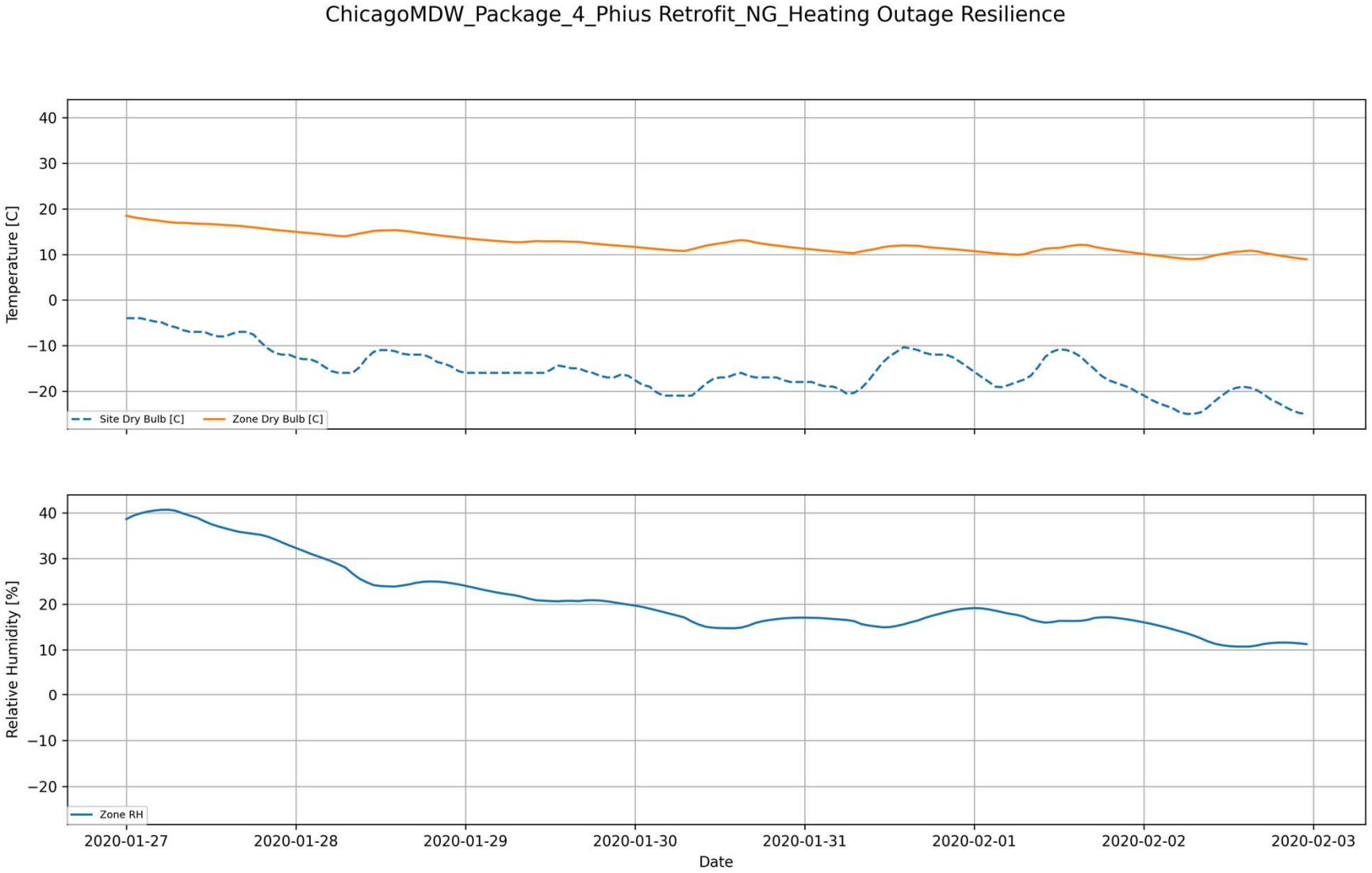
Package	SET < 54°F [hr]	Hours < 35°F [hr]	Caution [hr]	Extreme Caution [hr]	Danger [hr]	Extreme Danger [hr]	EUI [kBtu / sf yr]	Peak Electric Demand [W]	Heating Battery Size [kWh]	Cooling Battery Size [kWh]	Total ADORB Cost [$]
NYC_JFK_Package_0_BASE House_Elec	350	10	71	10	0	0	31.8	13758	6.8	4.7	$145,801.47
NYC_JFK_Package_2_DOE Envelope_Elec	105	0	73	0	0	0	23.5	9175	6.8	4.7	$129,568.76
NYC_JFK_Package_3_IECC_Elec	78	0	71	0	0	0	22.8	8814	6.8	4.7	$124,119.79
NYC_JFK_Package_0_BASE House	350	10	71	10	0	0	48.0	3013	6.8	4.7	$121,312.64
NYC_JFK_Package_2_DOE Envelope_NG	105	0	73	0	0	0	33.8	2535	6.8	4.7	$121,228.07
NYC_JFK_Package_3_IECC_NG	78	0	71	0	0	0	32.5	2486	6.8	4.7	$117,014.21
NYC_JFK_Package_4_Phius Retrofit_NG	0	0	0	0	0	0	18.6	2020	6.8	4.7	$108,753.66
NYC_JFK_Package_3_IECC+Phius Airseal_NG	0	0	0	0	0	0	22.8	2217	6.8	4.7	$102,554.65
NYC_JFK_Package_4_Phius Retrofit_Elec	0	0	0	0	0	0	14.5	4037	6.8	4.7	$99,849.41
NYC_JFK_Package_3_IECC+Phius Airseal_Elec	0	0	0	0	0	0	16.9	5280	6.8	4.7	$97,444.34

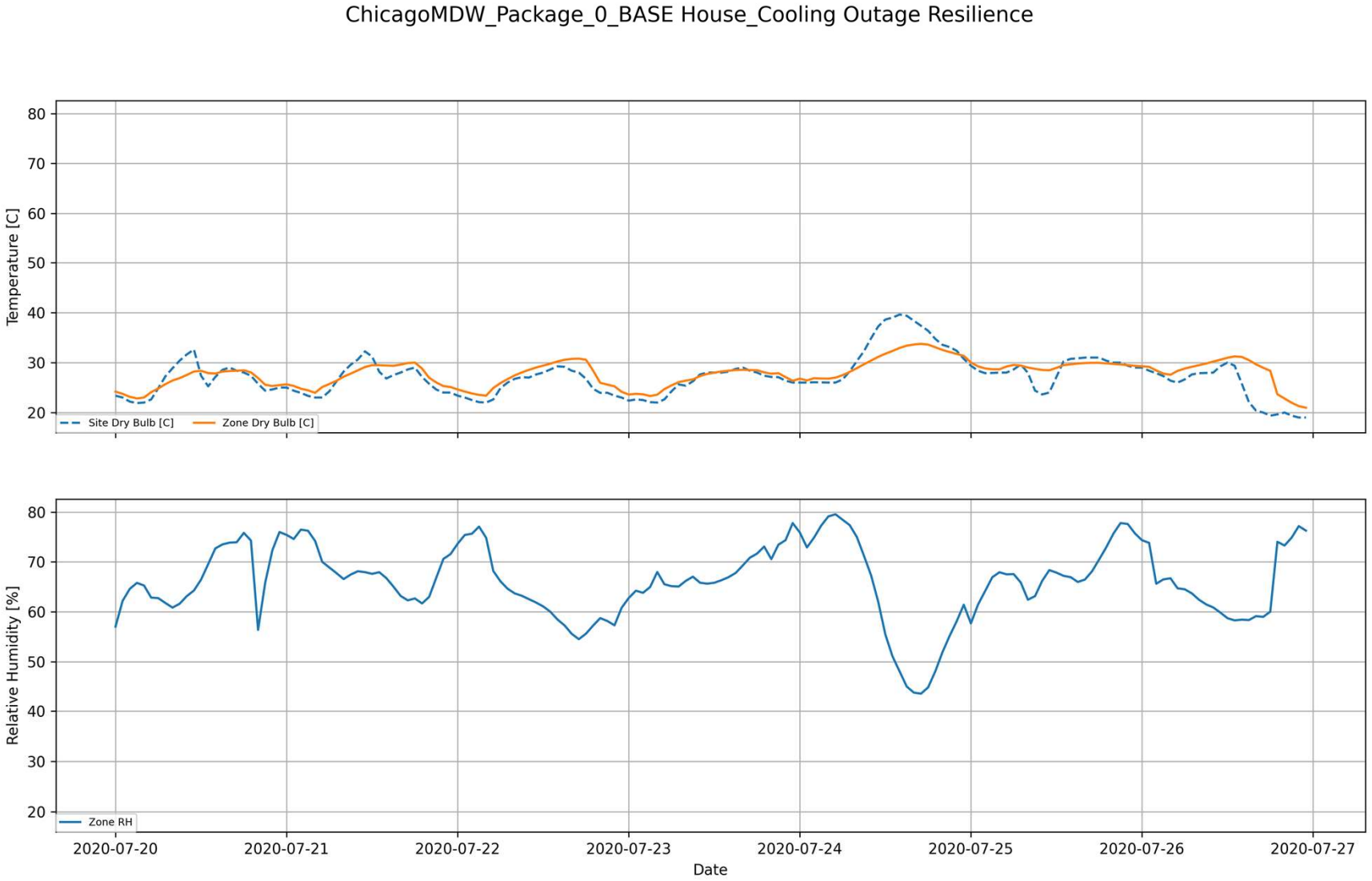

ChicagoMDW_Package_0_BASE House_Elec_Heating Outage Resilience
Temperature [C]
20
10
0
−10
−20
Site Dry Bulb [C]
Zone Dry Bulb [C]
Relative Humidity [%]
20
10
0
−10
−20
Zone RH
2020-01-27
2020-01-28
2020-01-29
2020-01-30
2020-01-31
2020-02-01
2020-02-02
2020-02-03
Date

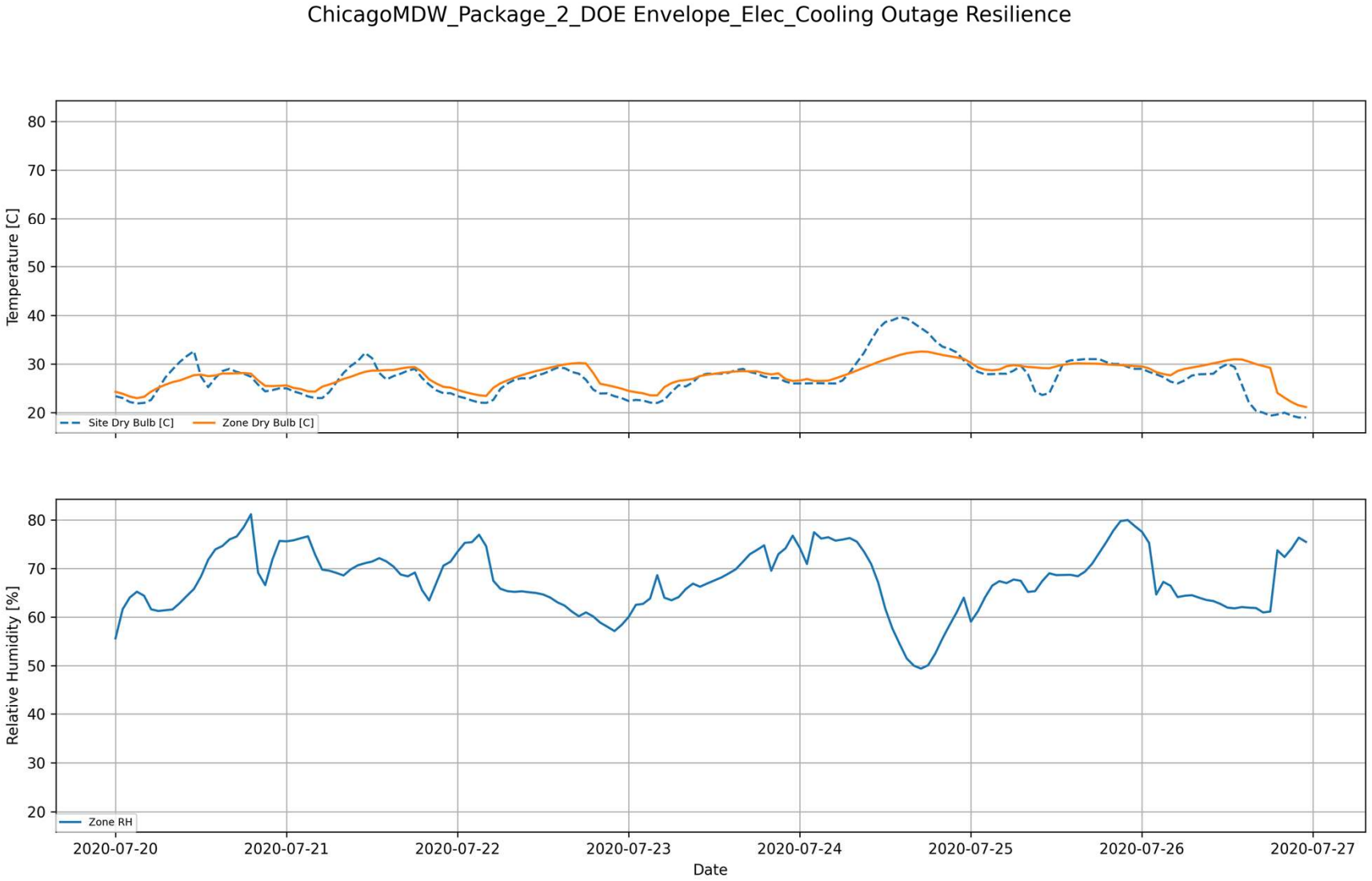

ChicagoMDW_Package_2_DOE Envelope_Elec_Heating Outage Resilience
Temperature [C]
20
10
0
−10
−20
Site Dry Bulb [C]
Zone Dry Bulb [C]
Relative Humidity [%]
20
10
0
−10
−20
Zone RH
2020-01-27
2020-01-28
2020-01-29
2020-01-30
2020-01-31
2020-02-01
2020-02-02
2020-02-03
Date

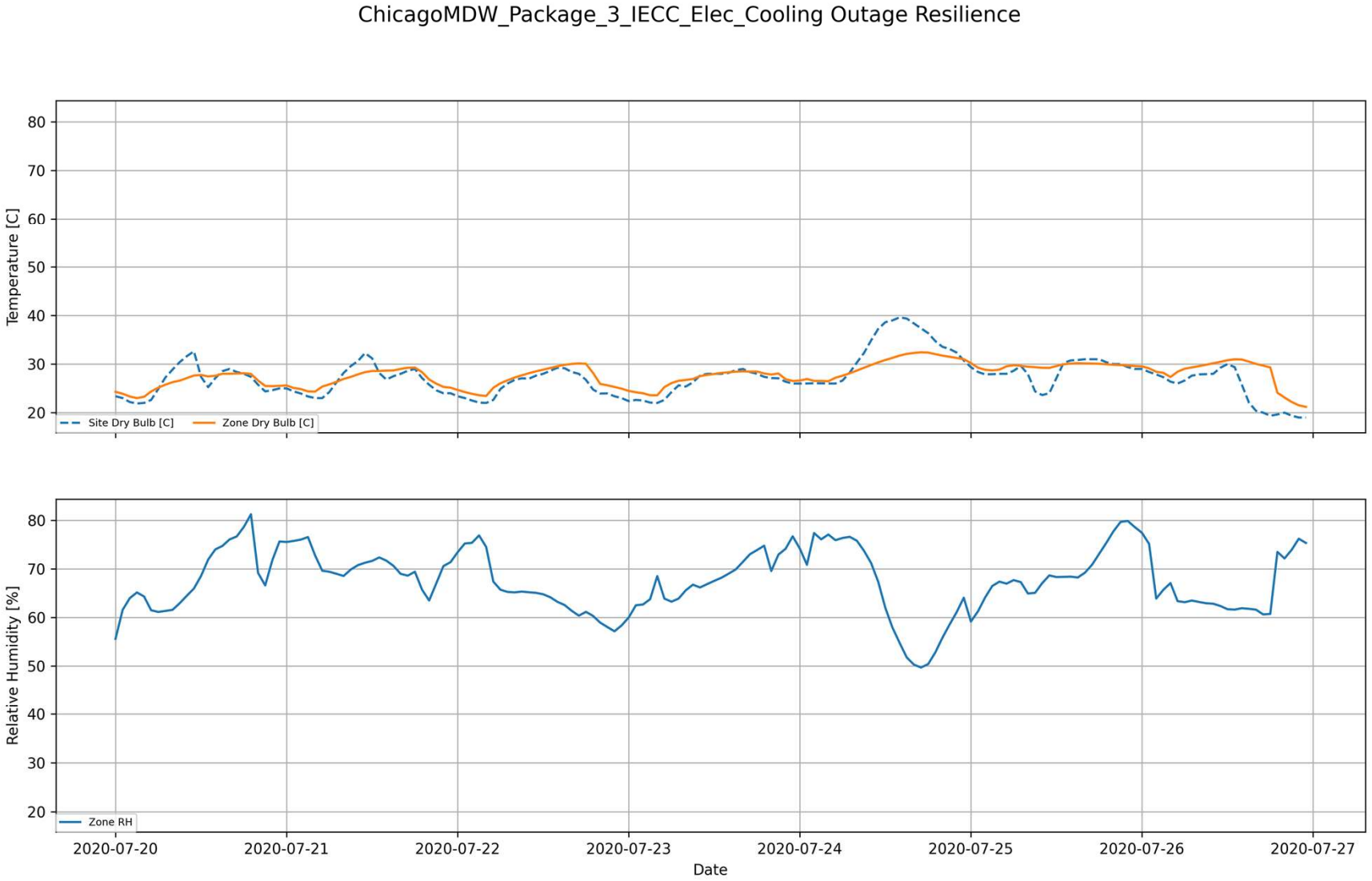

ChicagoMDW_Package_3_IECC_Elec_Heating Outage Resilience
Temperature [C]
20
10
0
−10
−20
Site Dry Bulb [C]
Zone Dry Bulb [C]
Relative Humidity [%]
20
10
0
−10
−20
Zone RH
2020-01-27
2020-01-28
2020-01-29
2020-01-30
2020-01-31
2020-02-01
2020-02-02
2020-02-03
Date

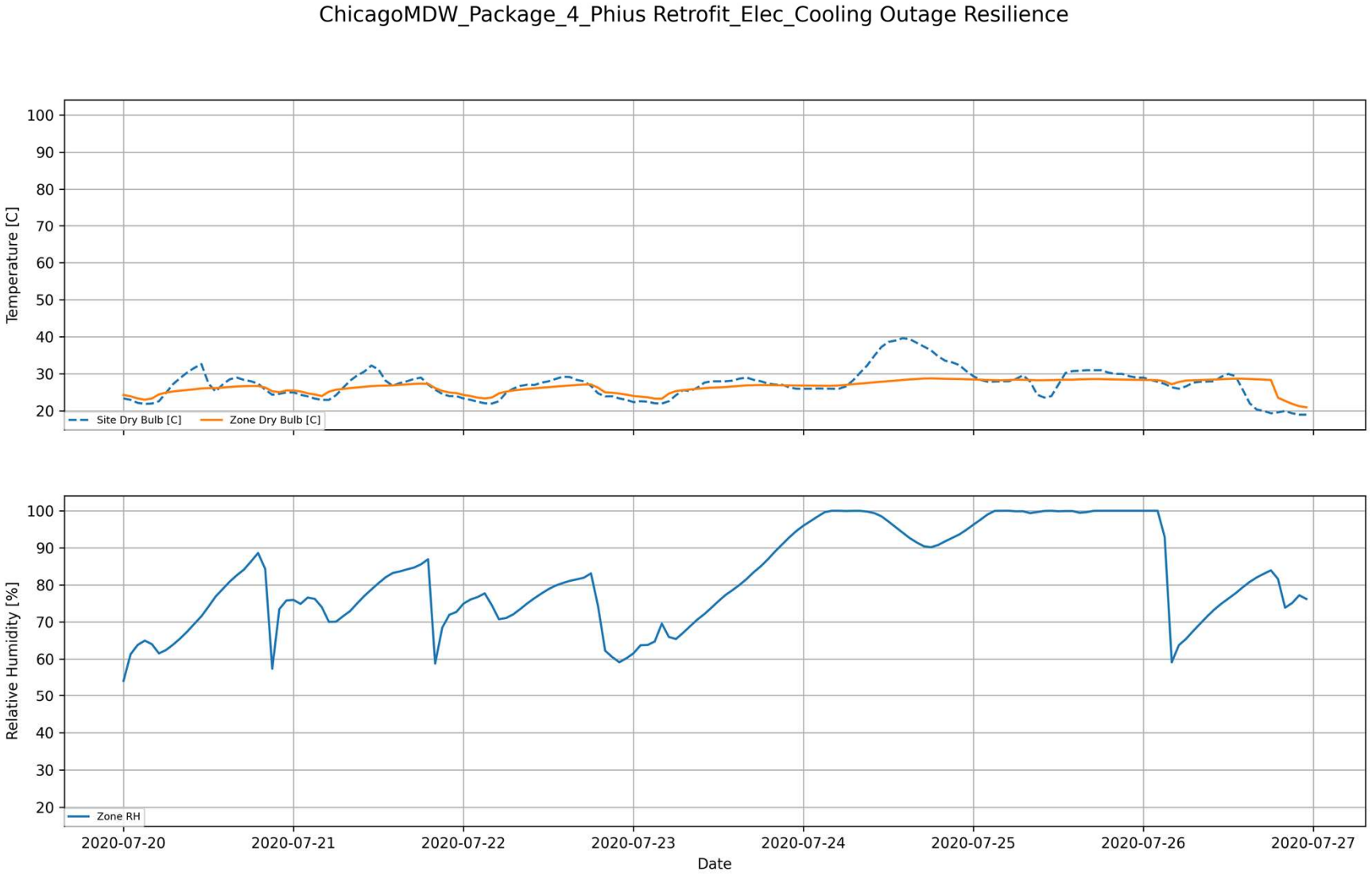

ChicagoMDW_Package_3_IECC+Phius Airseal_Elec_Heating Outage Resilience
Temperature [C]
40
30
20
10
0
−10
−20
Site Dry Bulb [C]
Zone Dry Bulb [C]
Relative Humidity [%]
40
30
20
10
0
−10
−20
Zone RH
2020-01-27
2020-01-28
2020-01-29
2020-01-30
2020-01-31
2020-02-01
2020-02-02
2020-02-03
Date

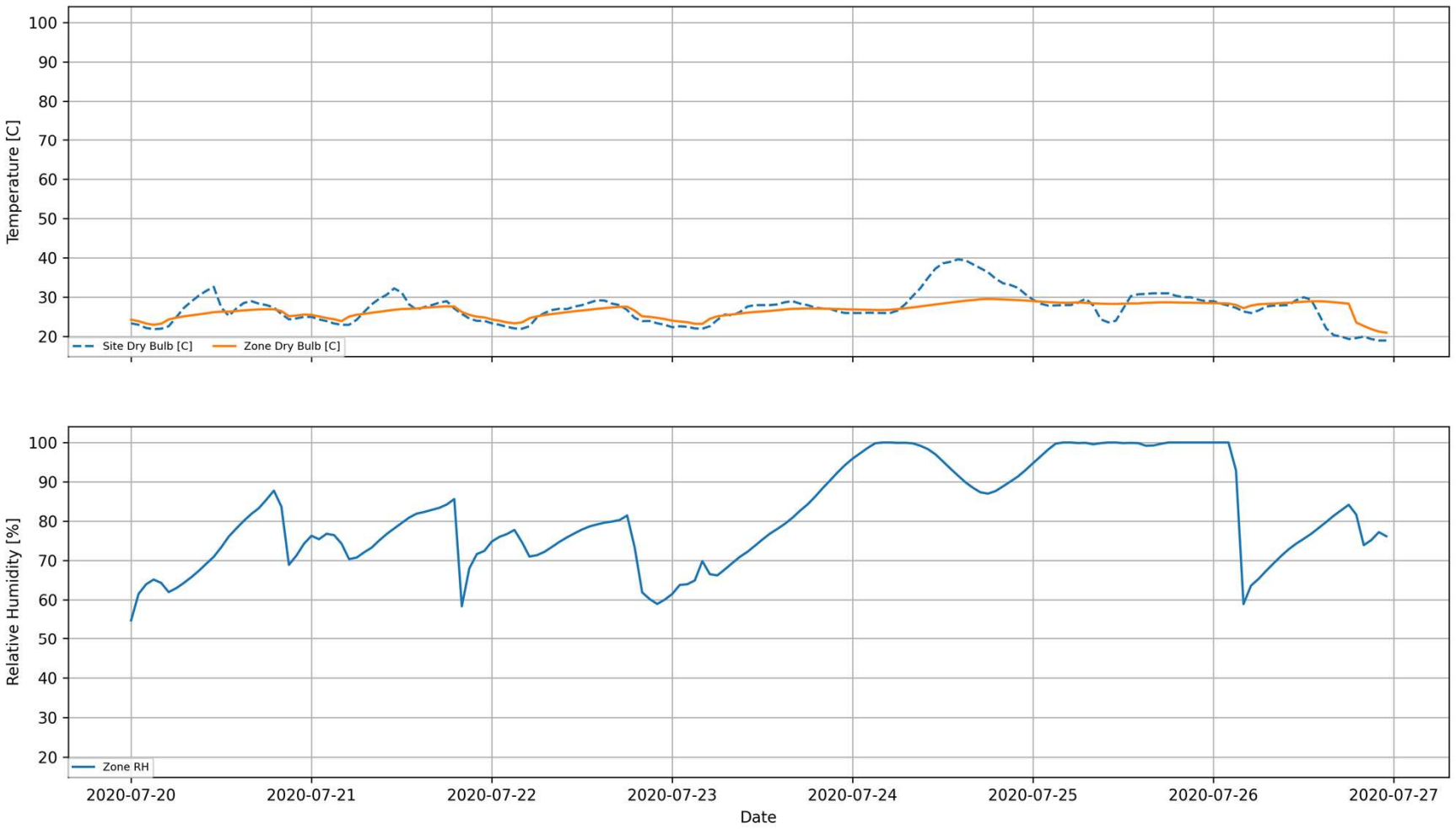

ChicagoMDW_Package_4_Phius Retrofit_NG_Heating Outage Resilience
Temperature [C]
40
30
20
10
0
−10
−20
Site Dry Bulb [C]
Zone Dry Bulb [C]
Relative Humidity [%]
40
30
20
10
0
−10
−20
Zone RH
2020-01-27
2020-01-28
2020-01-29
2020-01-30
2020-01-31
2020-02-01
2020-02-02
2020-02-03
Date


ChicagoMDW_Package_0_BASE House_Cooling Outage Resilience
Temperature [C]
80
70
60
50
40
30
20
Site Dry Bulb [C]
Zone Dry Bulb [C]
Relative Humidity [%]
80
70
60
50
40
30
20
Zone RH
2020-07-20
2020-07-21
2020-07-22
2020-07-23
2020-07-24
2020-07-25
2020-07-26
2020-07-27
Date

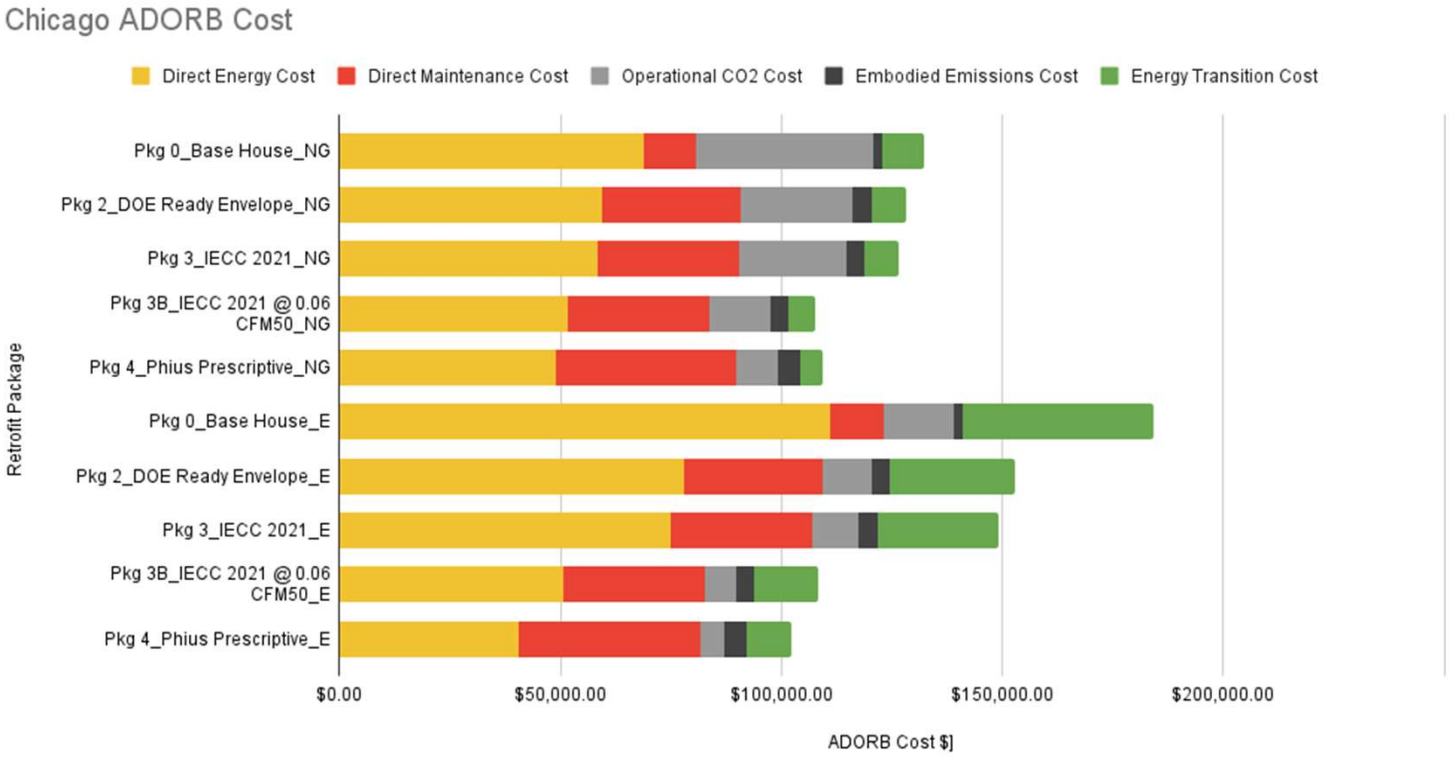

ChicagoMDW_Package_2_DOE Envelope_Elec_Cooling Outage Resilience
Temperature [C]
Site Dry Bulb [C]
Zone Dry Bulb [C]
Relative Humidity [%]
Zone RH
2020-07-20
2020-07-21
2020-07-22
2020-07-23
2020-07-24
2020-07-25
2020-07-26
2020-07-27
Date


ChicagoMDW_Package_3_IECC_Elec_Cooling Outage Resilience
Temperature [C]
Site Dry Bulb [C]
Zone Dry Bulb [C]
Relative Humidity [%]
Zone RH
2020-07-20
2020-07-21
2020-07-22
2020-07-23
2020-07-24
2020-07-25
2020-07-26
2020-07-27
Date

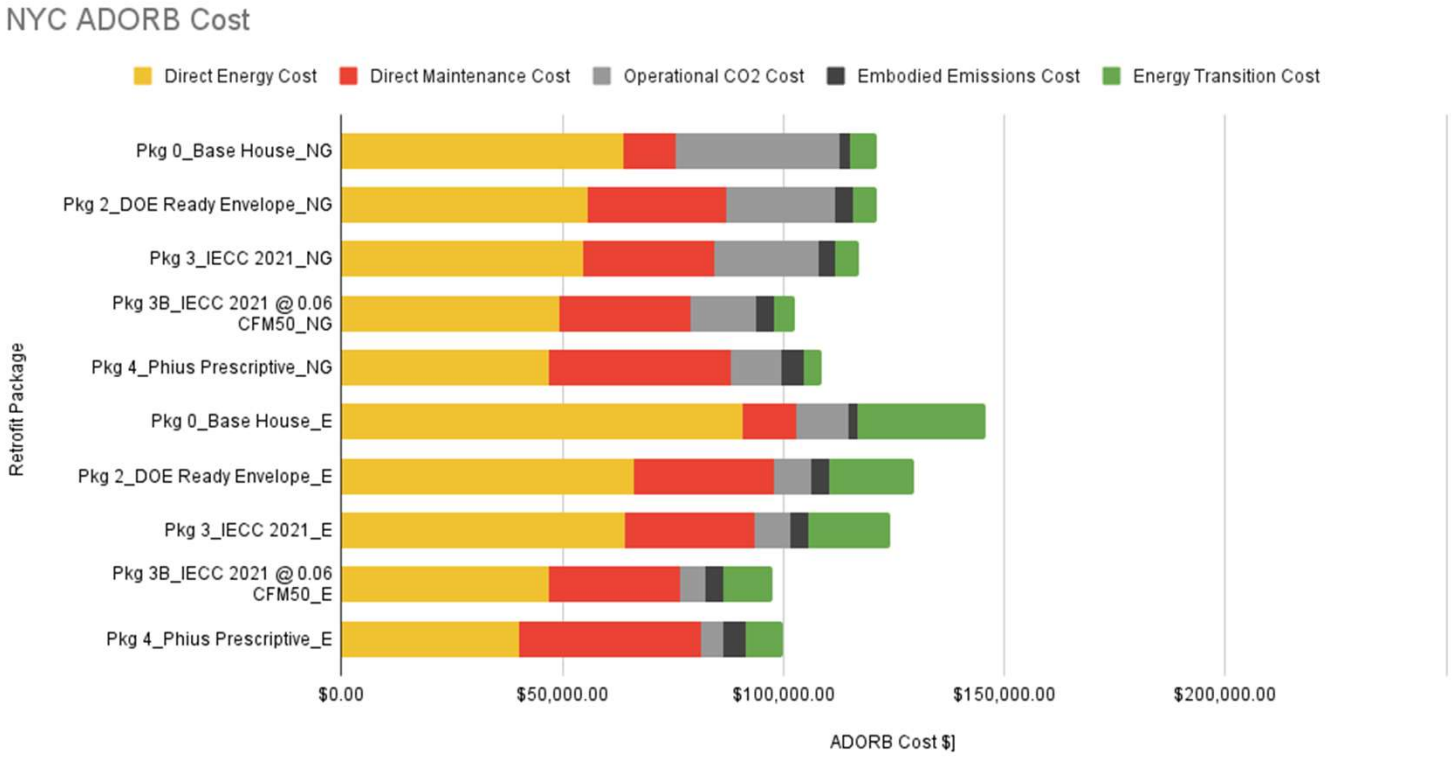

ChicagoMDW_Package_4_Phius Retrofit_Elec_Cooling Outage Resilience
Temperature [C]
Site Dry Bulb [C]
Zone Dry Bulb [C]
Relative Humidity [%]
Zone RH
2020-07-20
2020-07-21
2020-07-22
2020-07-23
2020-07-24
2020-07-25
2020-07-26
2020-07-27
Date


ChicagoMDW_Package_3_IECC+Phius Airseal_NG_Cooling Outage Resilience
Temperature [C]
Site Dry Bulb [C]
Zone Dry Bulb [C]
Relative Humidity [%]
Zone RH
2020-07-20
2020-07-21
2020-07-22
2020-07-23
2020-07-24
2020-07-25
2020-07-26
2020-07-27
Date

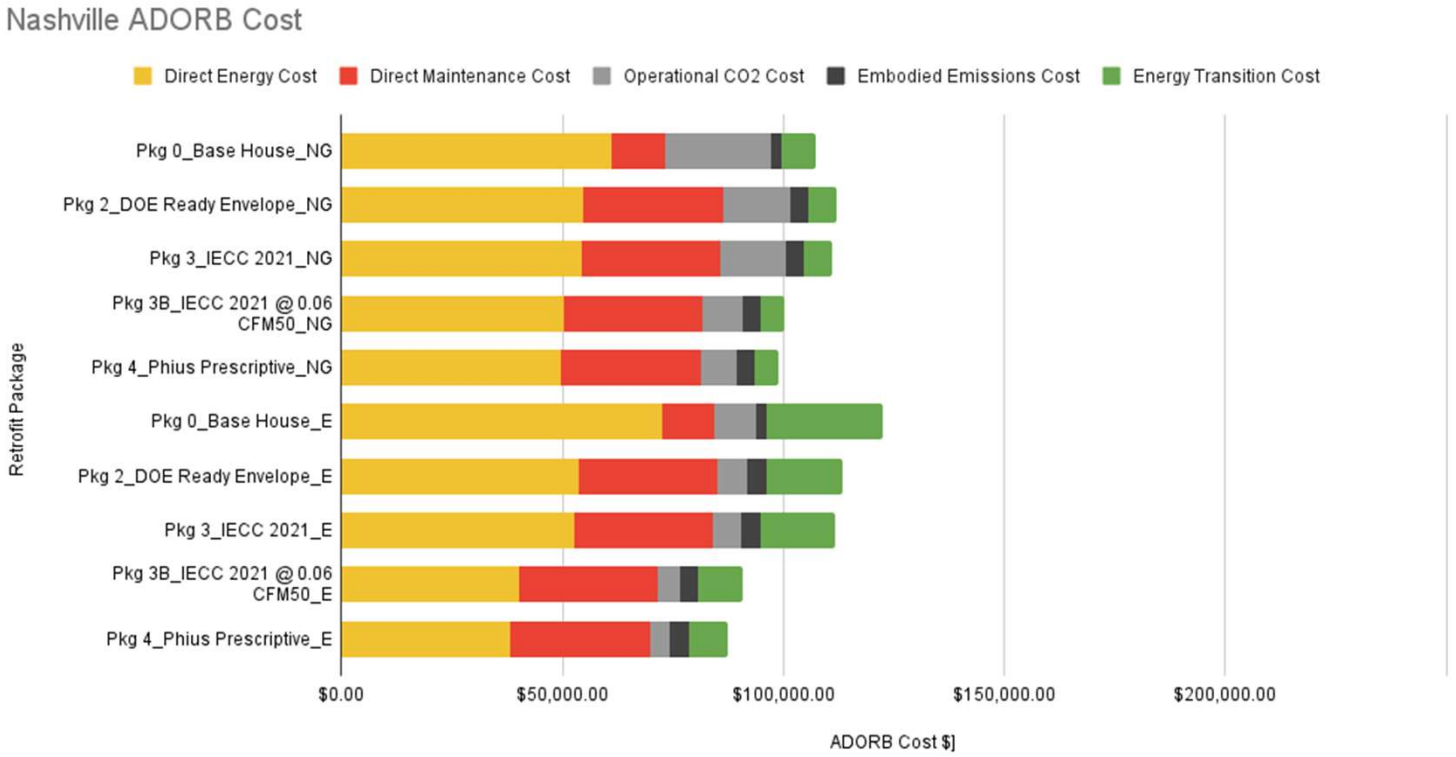
ADORB Results



ADORB Results



ADORB Results



Evolution / Improvement Opportunities

- How tight is the bind, between enough for resilience and too much life cycle cost? Stringency adjustment (discount rate on carbon?)
- Stress weather for resilience – tie to future climate models a la Sandia MEWS.
- Human exposure models other than Heat Index.
- Adding parametric / parallel coordinate / optimization wrapped around the single-case calculation engine.
- Add calculation methods for new resilience measures.
- Derivation of more prescriptive guidance from parametric results.
- More localism – microgrids, local spare parts and servicepeople.
- Turn some electives into mandatory.

Within a few weeks, we expect:

- Publication and a call for public comment
- A call for participation in our open-source software development

Thank you!

Call for Abstracts NOW OPEN!

Link to submit presentation proposals for PhiusCon 2023 will be sent via email tomorrow

Conference Registration Coming Soon!

- Early bird registration will be opening in the next several weeks
- Follow our social media channels for the latest updates!