



REVIVE Pilot

Good for your buildings
Good for the planet
Quality-assured results

Graham S. Wright
Al Mitchell

Program Vision

1. Retrofitted buildings do not cause greenhouse gas emissions in operation, directly or indirectly.
2. Energy performance is upgraded such that the building can function on locally-generated renewable energy, and remains habitable during utility outages.
3. The emissions associated with the retrofit work itself are “low”, ideally zero and without using any offsets.
4. Existing deficiencies are fixed, including risks to indoor air quality and vulnerabilities to site hazards.
5. A quality assurance process verifies results. Data is captured on cost and performance.



Key requirements

0. A commissioning / QA process covers all steps, from planning through operations, and through all construction phases.
 1. Direct emissions cease soon (preferably in the 1st phase)
 2. In both summer and winter grid outage situations, the building remains habitable and critical loads are covered by on-site renewable generation / storage.
 3. Fix any deficiencies that pose risks to indoor air quality.
 4. The life-cycle cost of the retrofit plan must be lower than continuing with the building as is, when cost of carbon is included.
 5. Project cost data and energy performance are reported at some level of granularity.



Resilience test summary

Scenario: 7-day outage, at “extreme” weather conditions, summer and winter. Rooftop PV with battery can operate an ERV, a super efficient fridge, and an evap cooler. Exterior shading and window night-flush are available in the summer. People bundle up to 1 clo during the winter outage.

Winter criteria: No pipe freezing (zero hours < 35 F / 2C), No more than 216 SET-hours (degree hours below 54 F adjusted for clothing)

Summer criteria: Zero hours of Heat Index in Danger zone.



The retrofit packages will vary

The envelope upgrade is mainly driven by the resilience criteria. These might call for retrofit packages anywhere on this spectrum or in between:

0. IAQ/Fortification work only

1. Add equipment swap-outs (HPs, LED, duct sealing & insul.)
2. Add “DOE envelope”: lo-e storm windows, attic, +R6.5 wall
3. IECC 2021 envelope + H/ERV
4. Plius envelope + H/ERV (current program)

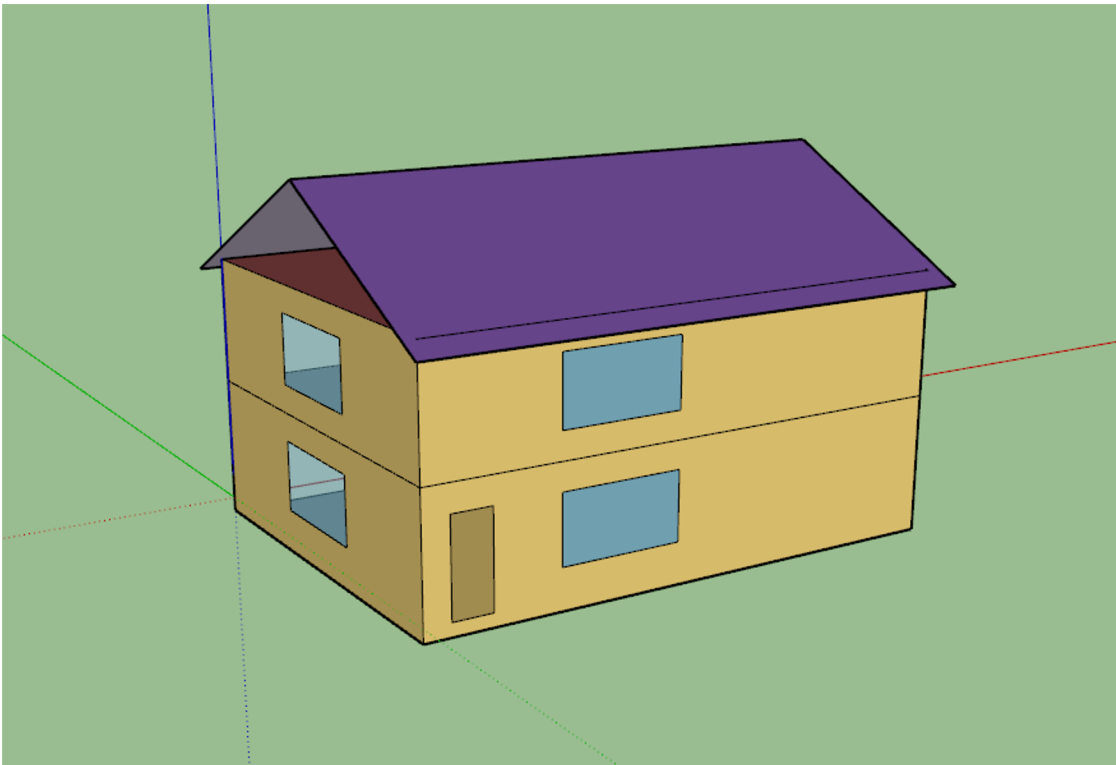
Plius will undertake simulations to find combinations of upgrades that meet the Resilience criteria. There is no additional fee for this work.

The QA process must accommodate this variation





Test building



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

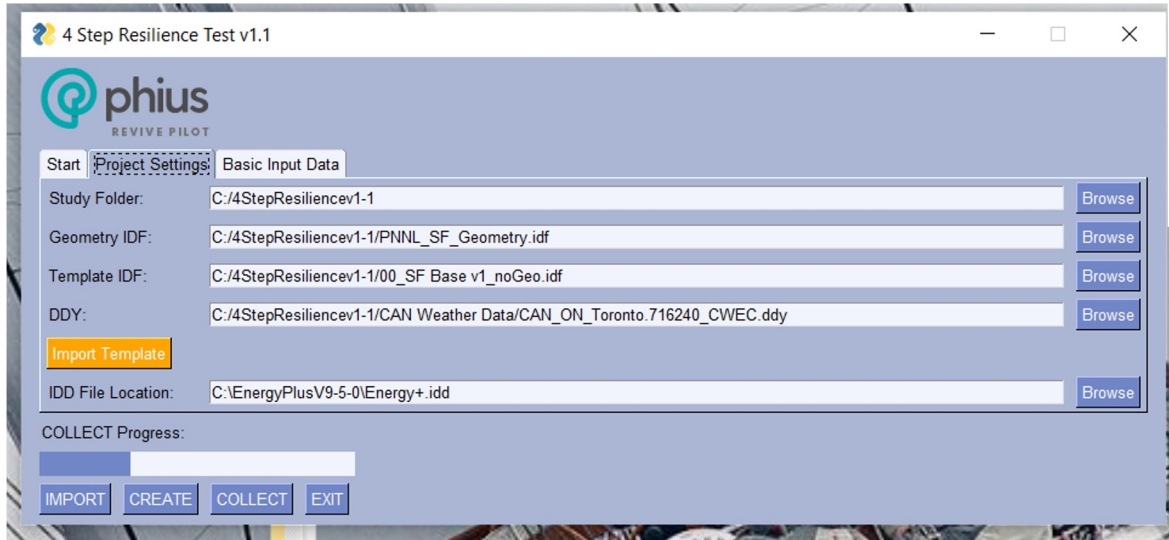
Retrofit Packages:

- 0 - Baseline, typical existing condition
- 1 - Equipment & appliances, electrification
- 1 - but better ERV
- 2 - add DOE "Market ready envelope"
- 2 - but better ERV
- 3 - IECC 2021
- 4 - Phius 2021 excl. subslab insul.
- 4 - Phius 2021 incl. subslab insul.

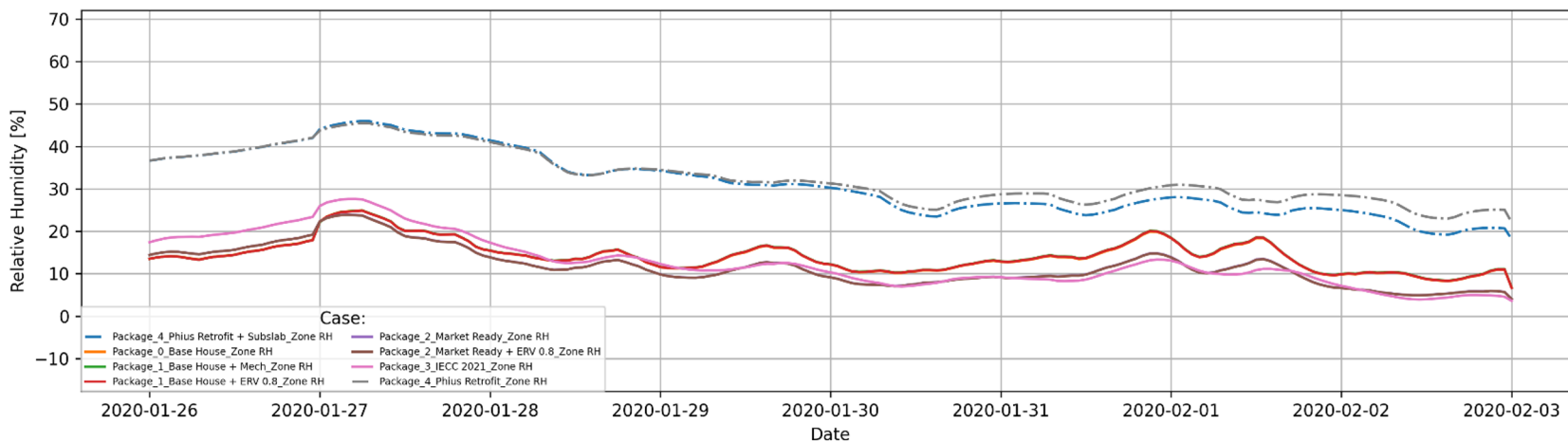
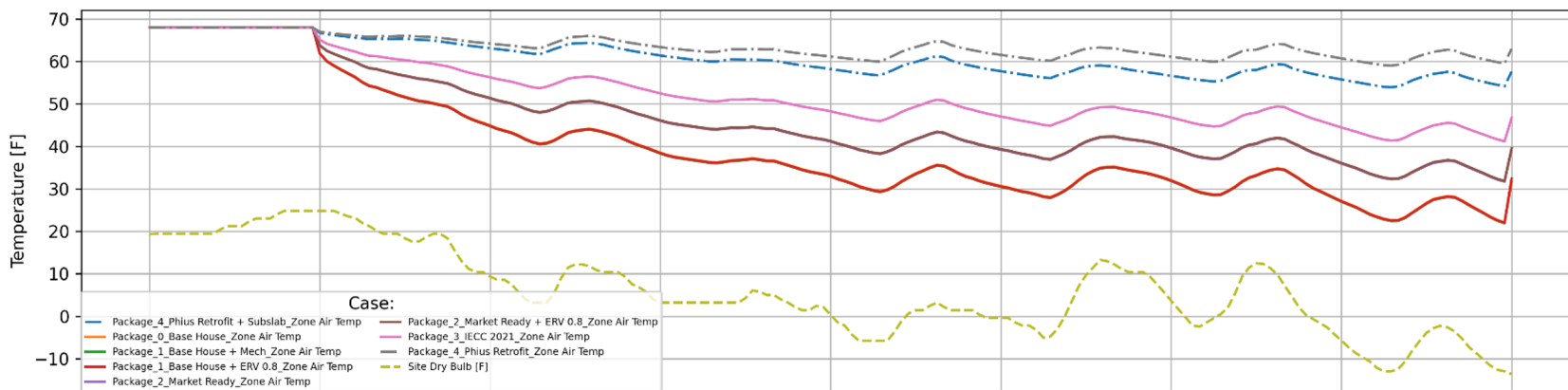
Summer modes

- 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

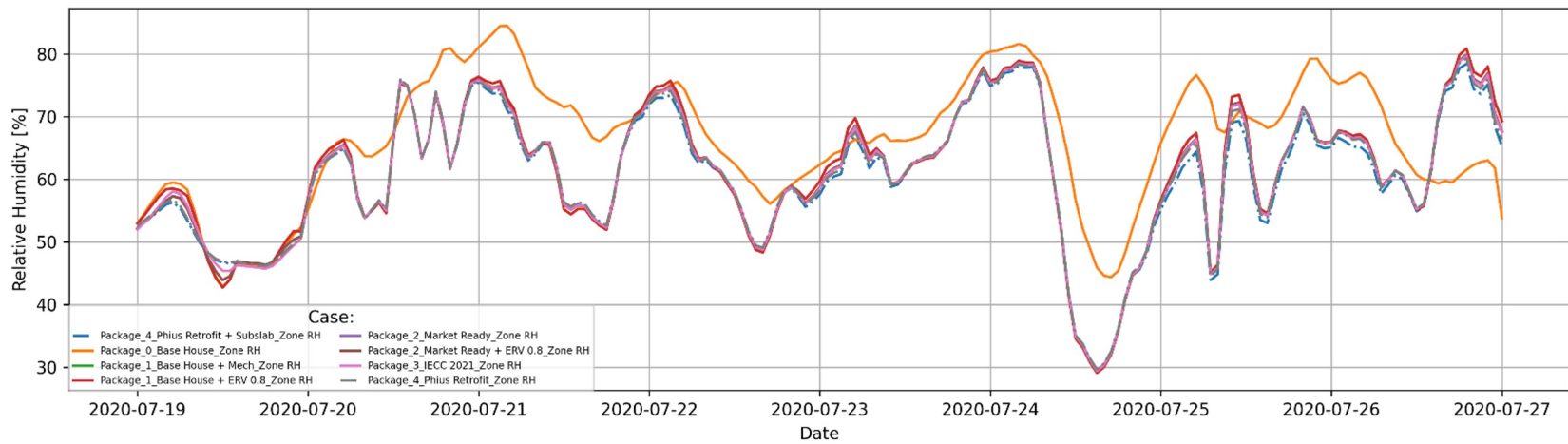
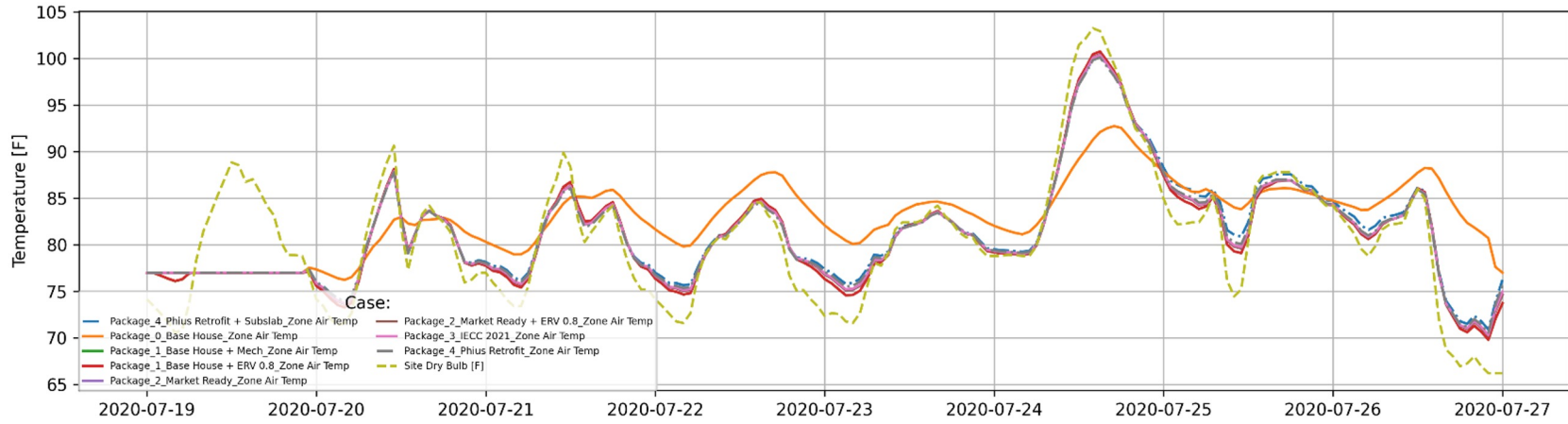
Tool Development



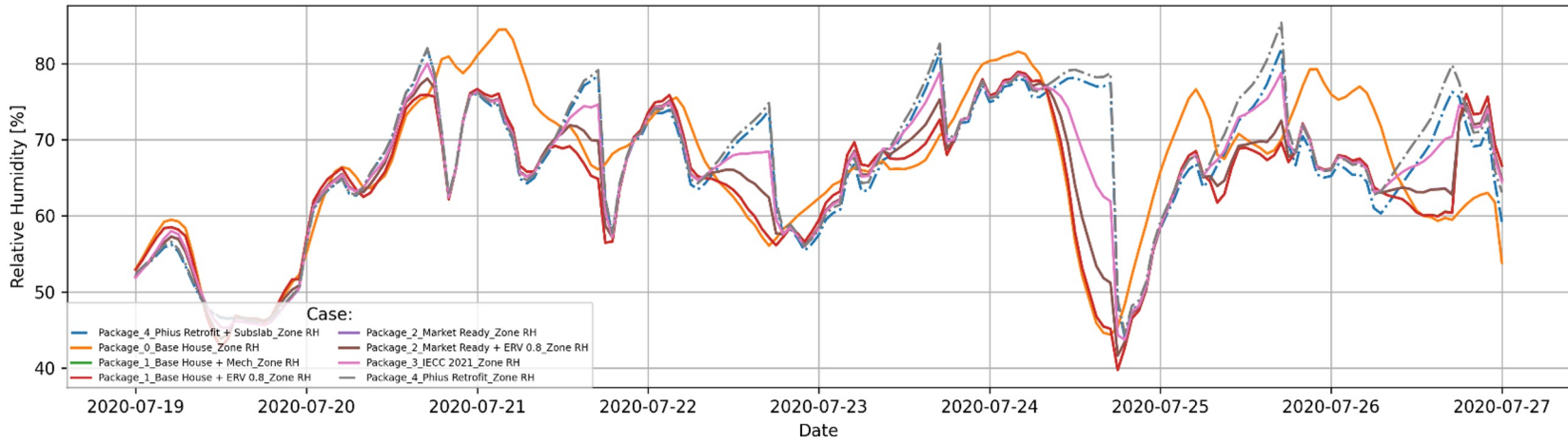
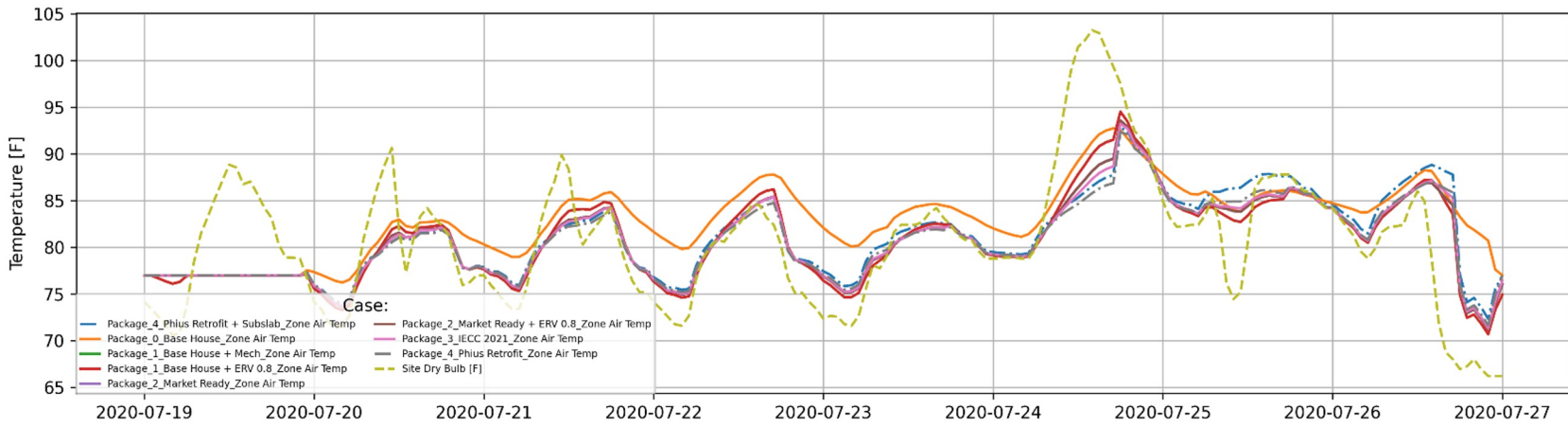
CHICAGO_NV_Heating Outage Resilience



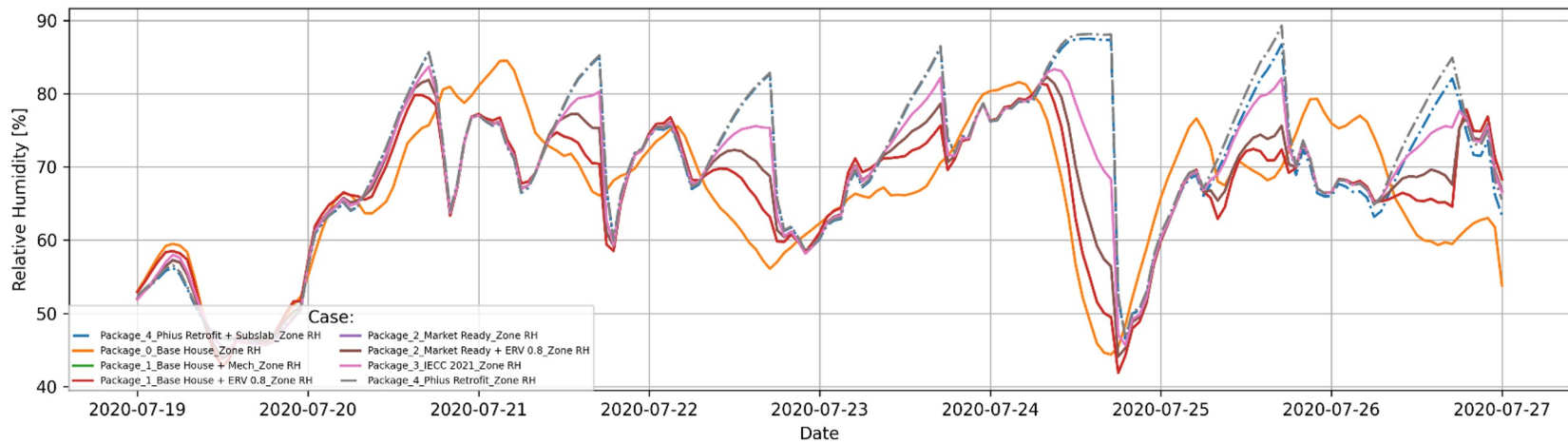
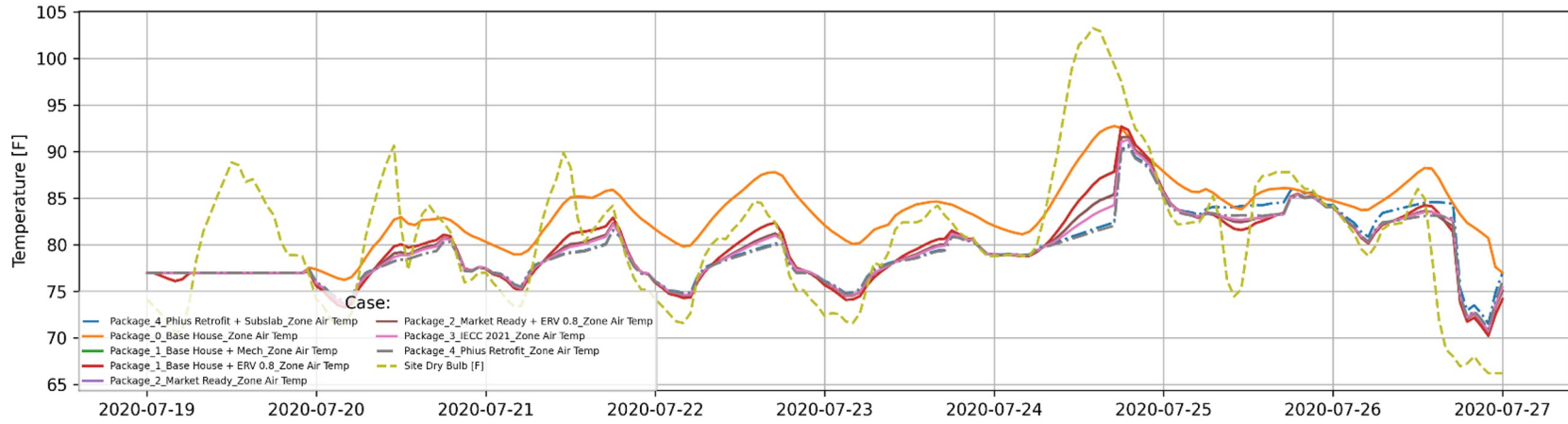
CHICAGO_NV_Cooling Outage Resilience



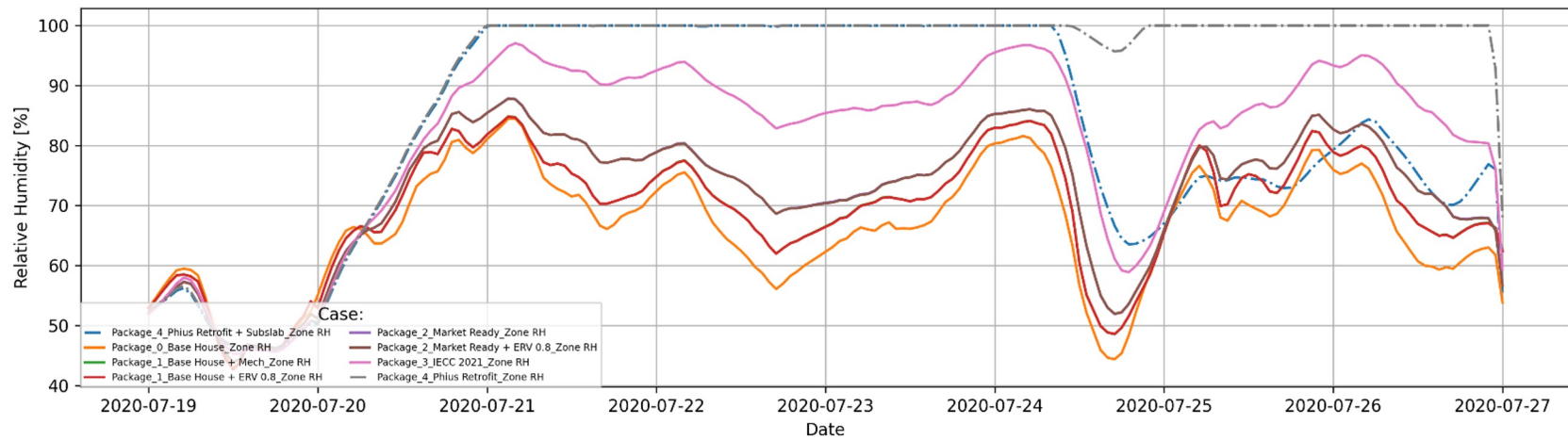
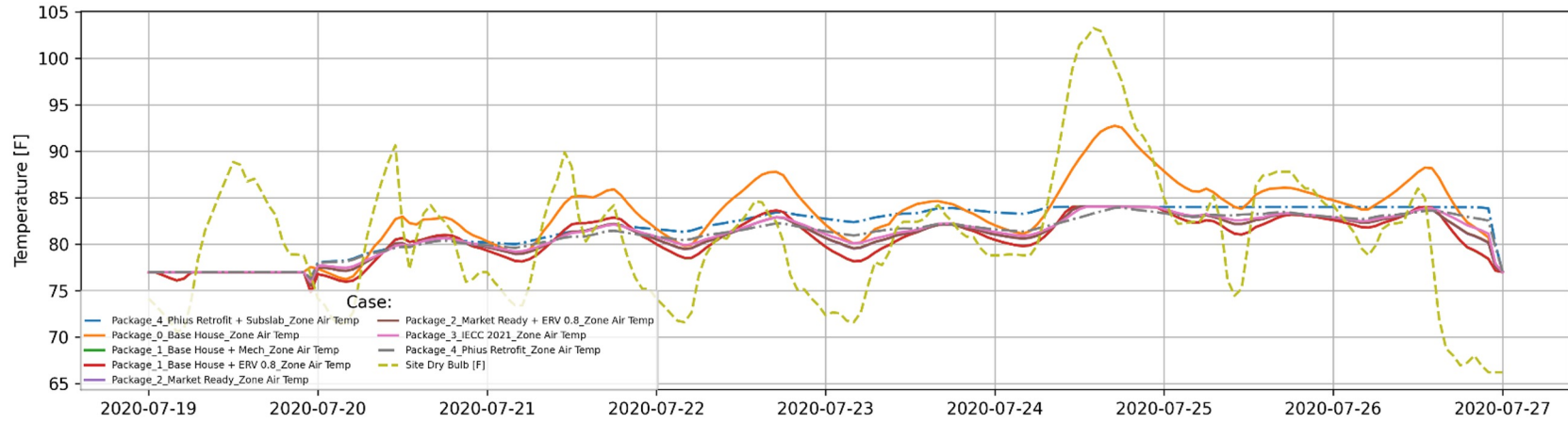
CHICAGO_SNV_Cooling Outage Resilience



CHICAGO_SNV+Shd_Cooling Outage Resilience



CHICAGO_HP+Shd_Cooling Outage Resilience





Single Point Metrics

Heating Set Hours (12.2°C)	Package_0 Base House	Package_1 Base House + Mech	Package_1 Base House + ERV 0.8	Package_2 Market Ready	Package_2 Market Ready + ERV 0.8	Package_3 IECC 2021	Package_4 Phius Retrofit	Package_4 Phius Retrofit + Subslab
MIAMI, FL	0	0	0	0	0	0	0	0
EL PASO, TX	0	0	0	0	0	0	0	0
SEATTLE, WA	0	0	0	0	0	0	0	0
DENVER, CO	7	8	8	0	0	0	0	0
CHICAGO, IL	817	831	824	315	307	24	0	0
INTL FALLS, MN	1313	1326	1320	646	637	138	0	0



Single Point Metrics

Freezing hours (T<2°C)	Package_0 Base House	Package_1 Base House + Mech	Package_1 Base House + ERV 0.8	Package_2 Market Ready	Package_2 Market Ready + ERV 0.8	Package_3 IECC 2021	Package_4 Phius Retrofit	Package_4 Phius Retrofit + Subslab
MIAMI, FL	0	0	0	0	0	0	0	0
EL PASO, TX	0	0	0	0	0	0	0	0
SEATTLE, WA	0	0	0	0	0	0	0	0
DENVER, CO	0	0	0	0	0	0	0	0
CHICAGO, IL	92	96	94	14	13	0	0	0
INTL FALLS, MN	151	151	151	71	67	0	0	0



Single Point Metrics

Natural Ventilation - Extreme Caution	Package_0 Base House	Package_1 Base House + Mech	Package_1 Base House + ERV 0.8	Package_2 Market Ready	Package_2 Market Ready + ERV 0.8	Package_3 IECC 2021	Package_4 Phius Retrofit	Package_4 Phius Retrofit + Subslab
MIAMI, FL	119	97	97	98	99	99	104	115
EL PASO, TX	36	8	8	6	6	12	6	12
SEATTLE, WA	0	0	0	0	0	0	0	0
DENVER, CO	0	3	3	2	2	2	1	2
CHICAGO, IL	89	31	31	33	33	33	34	37
INTL FALLS, MN	18	0	0	0	0	0	0	0



Single Point Metrics

Natural Ventilation -Caution	Package_0 Base House	Package_1 Base House + Mech	Package_1 Base House + ERV 0.8	Package_2 Market Ready	Package_2 Market Ready + ERV 0.8	Package_3 IECC 2021	Package_4 Phius Retrofit	Package_4 Phius Retrofit + Subslab
MIAMI, FL	13	57	57	61	61	68	95	104
EL PASO, TX	115	89	89	91	92	88	92	88
SEATTLE, WA	28	13	13	13	13	13	13	15
DENVER, CO	101	53	53	54	54	54	54	54
CHICAGO, IL	70	80	80	80	80	80	80	77
INTL FALLS, MN	78	44	44	44	44	44	42	42



Single Point Metrics

Scheduled Natural Ventilation - Extreme Caution	Package_0 Base House	Package_1 Base House + Mech	Package_1 Base House + ERV 0.8	Package_2 Market Ready	Package_2 Market Ready + ERV 0.8	Package_3 IECC 2021	Package_4 Phius Retrofit	Package_4 Phius Retrofit + Subslab
MIAMI, FL	119	87.5	87.5	87.83	88	72.5	76	79.83
EL PASO, TX	36.17	1.33	1.33	0	0	24.83	10.33	26.17
SEATTLE, WA	0	0	0	0	0	0	0	0
DENVER, CO	0	3	3	2.33	2.33	2.33	1.33	2
CHICAGO, IL	89.17	40.17	40.17	40.83	41	48.83	48.33	51.17
INTL FALLS, MN	18.17	0	0	0	0	2	2	0.83

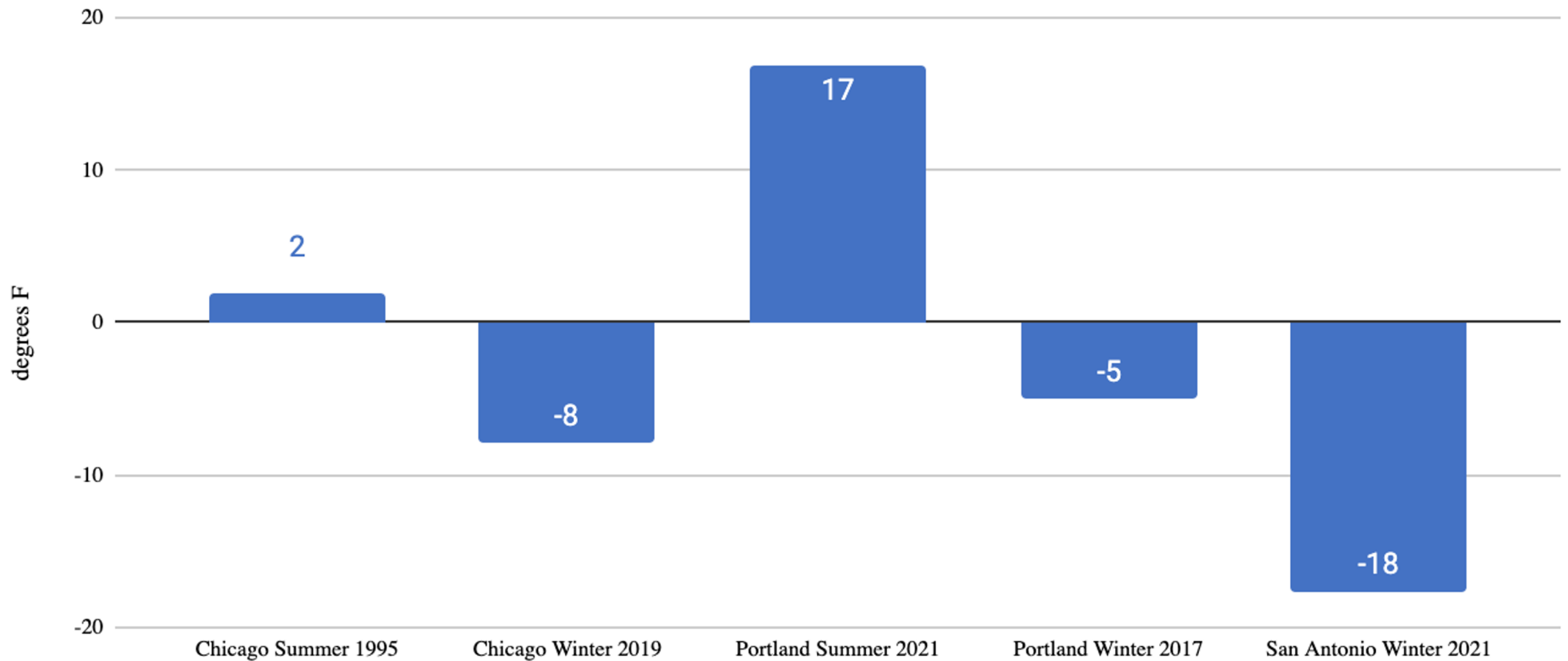


Single Point Metrics

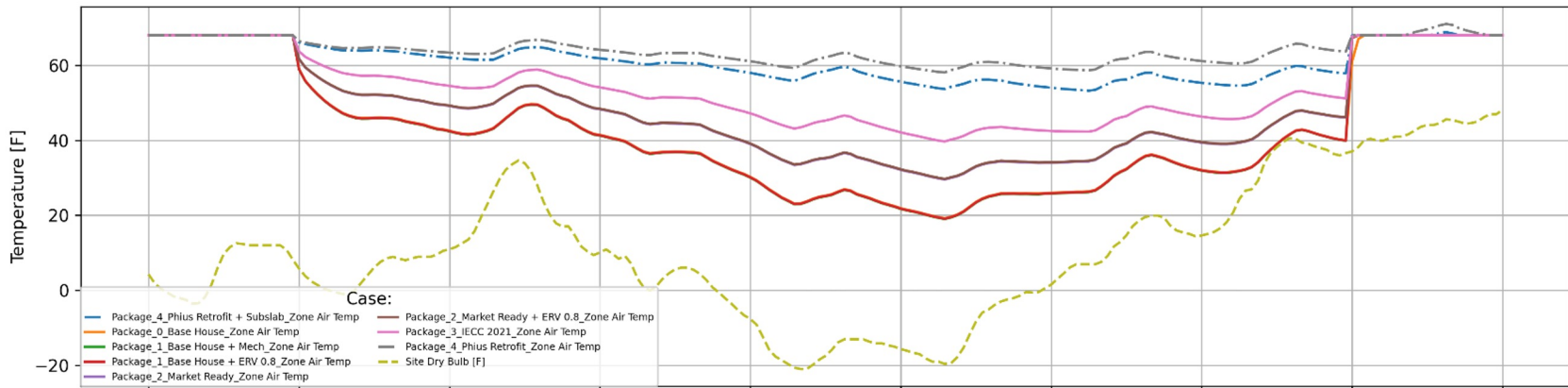
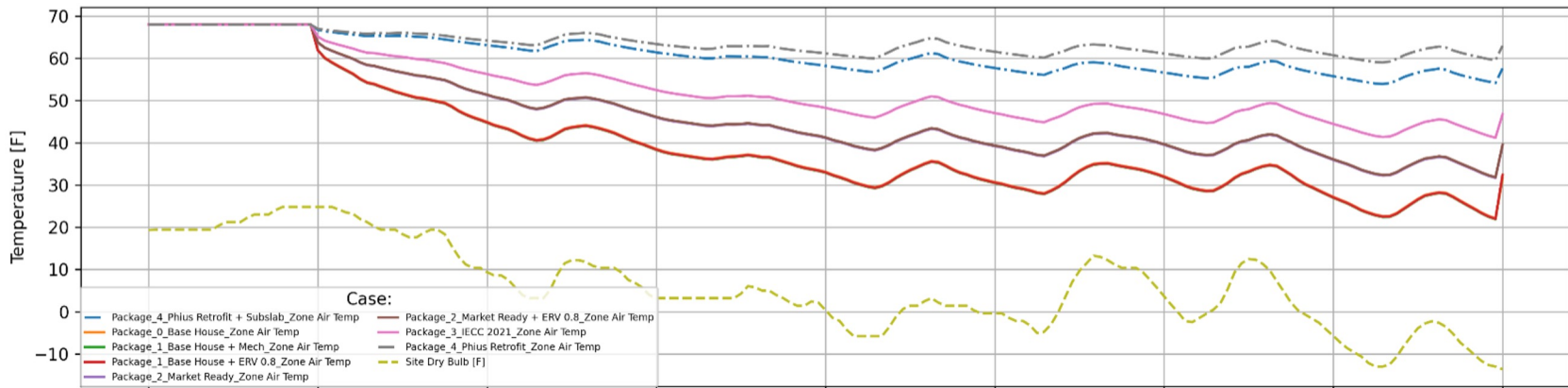
Scheduled Natural Ventilation -Caution	Package_0 Base House	Package_1 Base House + Mech	Package_1 Base House + ERV 0.8	Package_2 Market Ready	Package_2 Market Ready + ERV 0.8	Package_3 IECC 2021	Package_4 Phius Retrofit	Package_4 Phius Retrofit + Subslab
MIAMI, FL	13.33	63.17	63.17	68.17	68.67	75.17	103.83	106.5
EL PASO, TX	114.5	97	97.17	98.67	98.67	76.83	90	75.67
SEATTLE, WA	28	7.5	7.33	4.67	4.67	5	4.83	8.33
DENVER, CO	100.67	53	53	53.67	53.67	53.83	53.83	54.33
CHICAGO, IL	69.83	76	76	75.67	75.5	67.67	69.67	60.83
INTL FALLS, MN	78	34.83	34.83	33.83	33.83	32.5	32.67	31.83

Resilience stress weather conundrum

Extremes, temp. diff. historical minus typical (TMY STAT)



CHICAGO_NV_Heating Outage Resilience



“Embodied Carbon”

everyone’s jumping in on this

The radical ideal

- Absolute Zero – No CO₂/GHG emissions occur anywhere in the building delivery / renovation process, supply chain, or the building operating life, at any time.
 - Offsets / neutrality / net zero does not come into it for the building sector because emissions don’t happen in the first place.
 - The strategy of offsetting is reserved for removing the CO₂ that is already there, or for other sectors such as agriculture.



“Embodied Carbon”

The practical next program requirement

ADORB/FCALC Cost = sum of the following components, each an annual / annualized cost:

- 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 = \$

*INCLUDES LABOR, NOT
JUST MATERIALS.
PERSONAL & BUSINESS
CHOICES COUNT*

As to a criterion, the ADORB cost of the proposed retrofit or replacement should not exceed that of the baseline case, and preferably is actually minimized.

We need to keep score on upfront carbon and [keep asking for more](#), more supply chain decarbonization, forward to Absolute Zero.



Risks and vulnerabilities to mitigate

EPA stuff

ASBESTOS

BELOWGROUND CONTAMINANTS (other than RADON)

BUILDING PRODUCTS/MATERIALS EMISSIONS

CARBON MONOXIDE (CO) AND OTHER COMBUSTION
APPLIANCE EMISSIONS

(NITROGEN OXIDES, VOLATILE ORGANIC COMPOUNDS
[VOCs] AND PARTICULATES)

ENVIRONMENTAL TOBACCO SMOKE (ETS)

GARAGE AIR POLLUTANTS (CO, BENZENE AND OTHER
VOCs)

LEAD

MOISTURE (MOLD AND OTHER BIOLOGICALS)

OZONE

PESTS

FEMA stuff

Earthquake

Flood

High wind

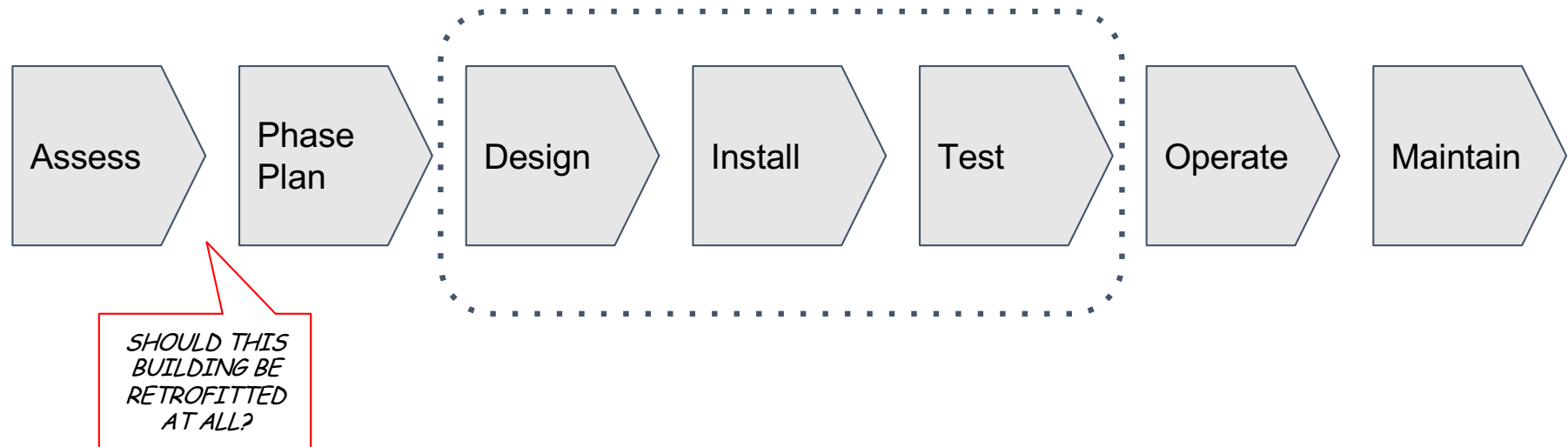
Snow

Hail (on PV)

Wildfire

Quality process extends earlier and later

The existing conditions need to be investigated, and we want to monitor performance because policy people always ask for such data, among other reasons



QA framework based on ASHRAE Guideline 0.2 - Commissioning Process for Existing Systems and Assemblies

The adaptation of this Guideline for use in a Certification program is that we make considerable input to the CFR, Program Plan, and EBCx Plan - Phius and the Owner come to agreement on these.

The CFR is essentially "meets applicable Phius requirements." Only after such agreement is reached about the scope and documentation workload, is a contract signed and certification fee paid.

Phius acts as the Commissioning Authority (CxA) and the EBCx Team includes a Rater/Verifier.

EBCx Phase	Section	Multiple Facility Program Plan	CFR	EBCx Plan	EBCx Report	Systems Manual	OCx Plan	OCx Report	OCx Training Plan
Multiple Facilities Planning	5	■							
Assessment	6		■	■	■				
Investigation	7		■	■	■				
Implementation	8		■	■	■				
Hand Off	9				■	■	■	■	
On-Going Commissioning	10					■	■	■	■

New or Existing Document
 Updated Document

FIGURE D-1 EBCx documentation matrix.

From Guideline 0.2:

"4.4 A good Cx Process will focus the level of effort and available resources around the key elements and systems that need to be addressed to meet the goals..

4.7 Table 1 and this guideline present the process as occurring in a linear fashion. In reality, the process is often iterative and interactive..

4.8 The complete list of deliverables in Table 1 may not be required or desired due to factors of project size, complexity, etc...Some of the deliverables described may be combined or eliminated in small projects.."



Probably In scope



Probably Out of scope



Probably In scope



Probably Out of scope



Probably In scope

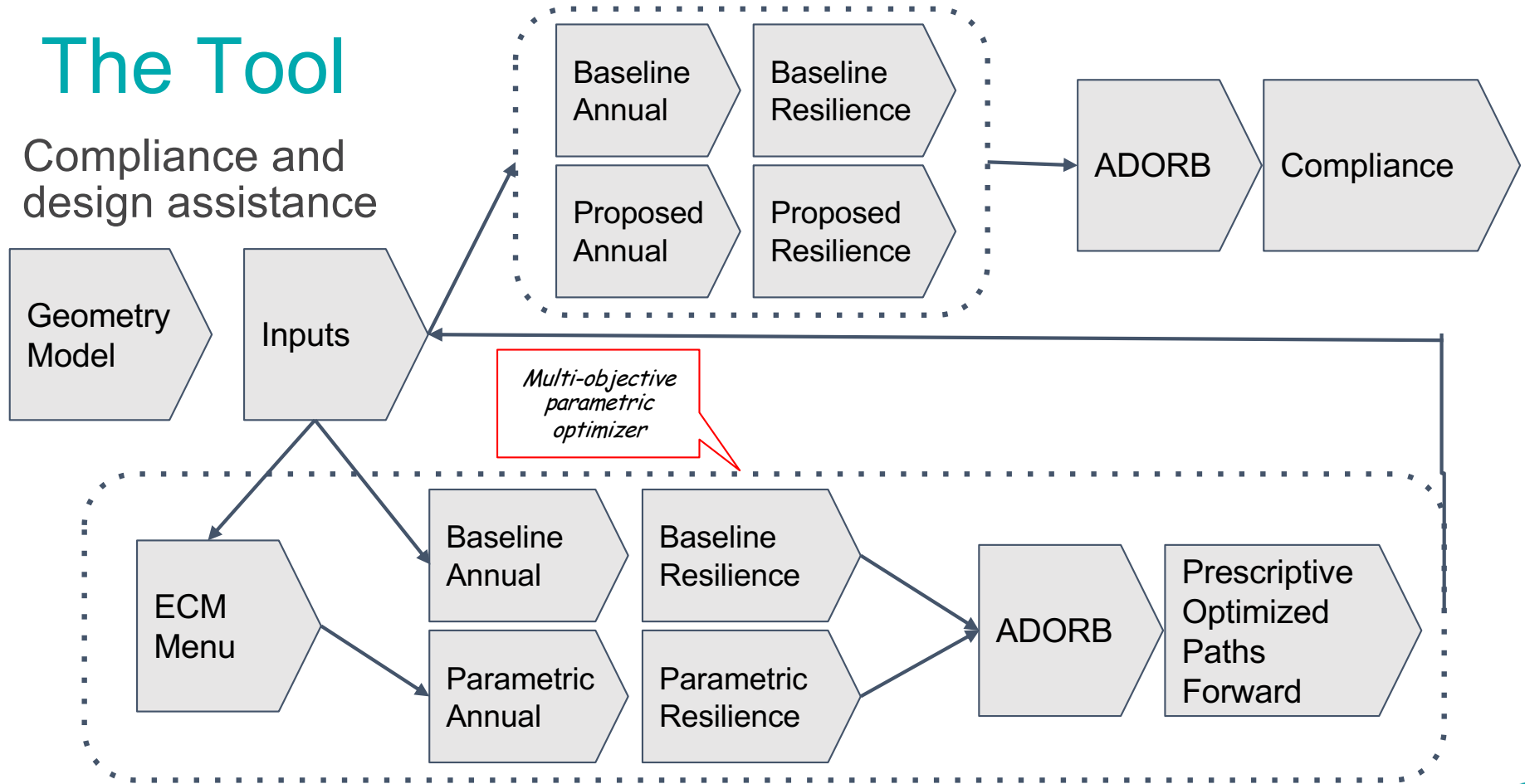


Probably Out of scope



The Tool

Compliance and design assistance



Future Work

- Finish building tool
- Establish embodied carbon database
 - Build out detail cost
- Finish building out certification process and workbook
- Testing!





Questions?

Graham Wright, PhD
Senior Scientist, Phius
gwright@phius.org

AI Mitchell, EIT, CPHC
Technical Staff, Phius
amitchell@phius.org

