BUILDINGENERGY BOSTON

Monitoring Energy Performance & IAQ: Multifamily Energy Star vs. PHIUS+

August 13, 2020 · 1:00pm

Presenters:

Katrin Klingenberg (PHIUS), Connor Jansen (Slipstream), & Lisa White (PHIUS)

PHIUS

www.phius.org

PHIUS+ CERTIFICATION - PASSIVE/ZERO ENERGY READY MULTIFAMILY BUILDIINGS

AGENDA

- PHIUS Mission & Vision
- Background on Verification and Certification
- Affordable Housing Trend
- PHIUS+ Case Studies

VISION AND MISSION STATEMENT

EXECUTIVE DIRECTOR & CO-FOUDER: KATRIN KLINGENBERG, M. ARCH, DIPL. ING., RA (GERMANY), CPHC®

The PHIUS mission

is to address the climate crisis through passive/zero energy ready buildings that can both mitigate and adapt to climate change. As a society overall we must get to 100% renewable energy. PHIUS+ is a design strategy that focuses on conservation first. It represents the best way to cost optimize buildings on the path to zero.

The PHIUS vision

is “to make high-performance passive building commonplace”.

MAJOR ACTIVITIES

PROGRAMS, PRODUCTS & SERVICES

PHIUS develops and promotes Passive/Zero Energy Ready & Source Zero Building Standards, practices, and certifications for buildings, professionals and products:

Project Certification Programs:

PHIUS®+ certified passive/zero energy ready
PHIUS+ source zero certified

Product Certification Programs:

Windows
Wall assemblies
Ventilation systems

Professional Certificate Programs:

Certified passive house consultant (CPHC®)
Certified builder (PHIUS Certified Builder)
Certified onsite verifier (PHIUS+ Certified Rater/Verifier)

Research & Development Program:

Materials/systems verification standards development
Monitoring – proof of concept
Details and mechanical systems catalogue

Products:

WUFI Passive (Sales agent for NA)
Conference proceedings
E–books and other publications

Calculation based on ISO 10077-2, EN 673, EN 410

Product name: **ALPEN 725 High Performance Casement**

Center-of-glass properties: Alpen HPP 725-7H No Grids

ASHRAE/IECC /DOE North American Climate Zone	South-facing	North, East, West - facing	Whole-window installed U-value W/m2K	BTU/hr.ft2.F	Ucog-Value SHGC	W/m2K	BTU/hr.ft2.F
8			1.02	0.18	0.558	0.703	0.124
7			1.00	0.18	0.558	0.678	0.119
6			1.00	0.18	0.558	0.684	0.120
5			1.00	0.18	0.558	0.686	0.121
4			1.01	0.18	0.558	0.692	0.122
Marine North			1.01	0.18	0.558	0.695	0.122
Marine South			1.02	0.18	0.558	0.702	0.124
3			1.01	0.18	0.558	0.698	0.123
2 West			1.03	0.18	0.558	0.716	0.126
2 East			1.03	0.18	0.558	0.716	0.126

ALPEN 725 High Performance / Allmetal 250P SST	FRAME Frame height mm	in	U-frame W/m2K	BTU/hr.ft2.F	Psi-spacer Ψ W/mK	BTU/hr.ft.F	Psi-opaque W/mK
Head	73	2.86	1.15	0.20	0.054	0.031	0.143
Sill	73	2.86	1.16	0.20	0.054	0.031	BTU/hr.ft.F
left jamb	73	2.86	1.16	0.20	0.054	0.031	0.083
right jamb	73	2.86	1.16	0.20	0.054	0.031	Grade B

Valid through October 2018

WHAT DOES PHIUS DO?

ORGANIZATIONAL HISTORY

PHIUS MILESTONES:

2003 Katrin Klingenberg built the first passive house in North America

2006 The 1st North American Passive House Conference was held in MN

2007 PHIUS was founded, became a non profit in 2009

2008 PHIUS created the design professional credential, CPHC ®

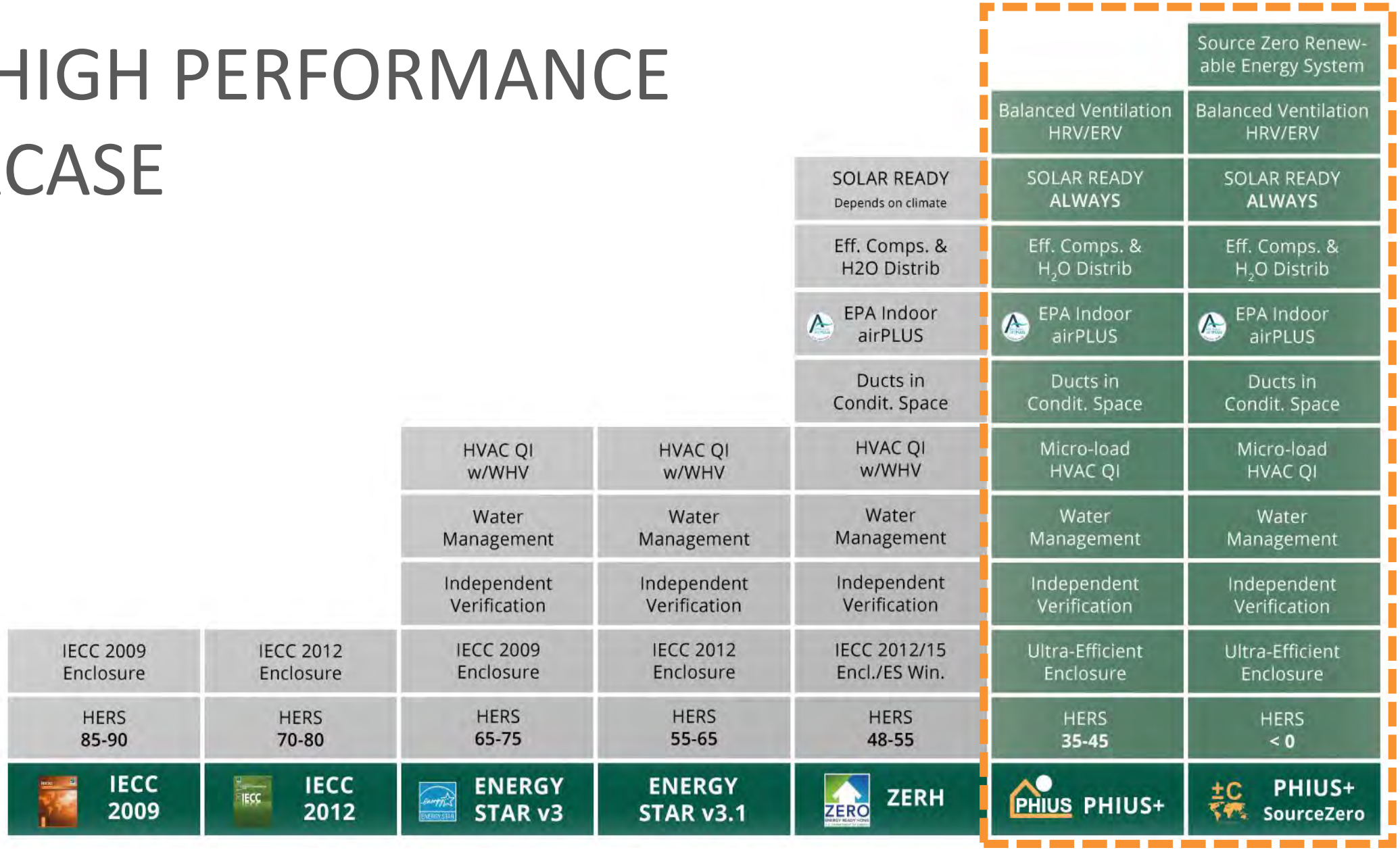
2011 PHIUS partnered with RESNET to create a brand new third-party QA/QC project certification, customized for passive & zero energy.

2012 PHIUS integrated Department of Energy's Zero Energy Ready Home requirements and EPA indoor airPLUS and launched the PHIUS+ Building certification program.

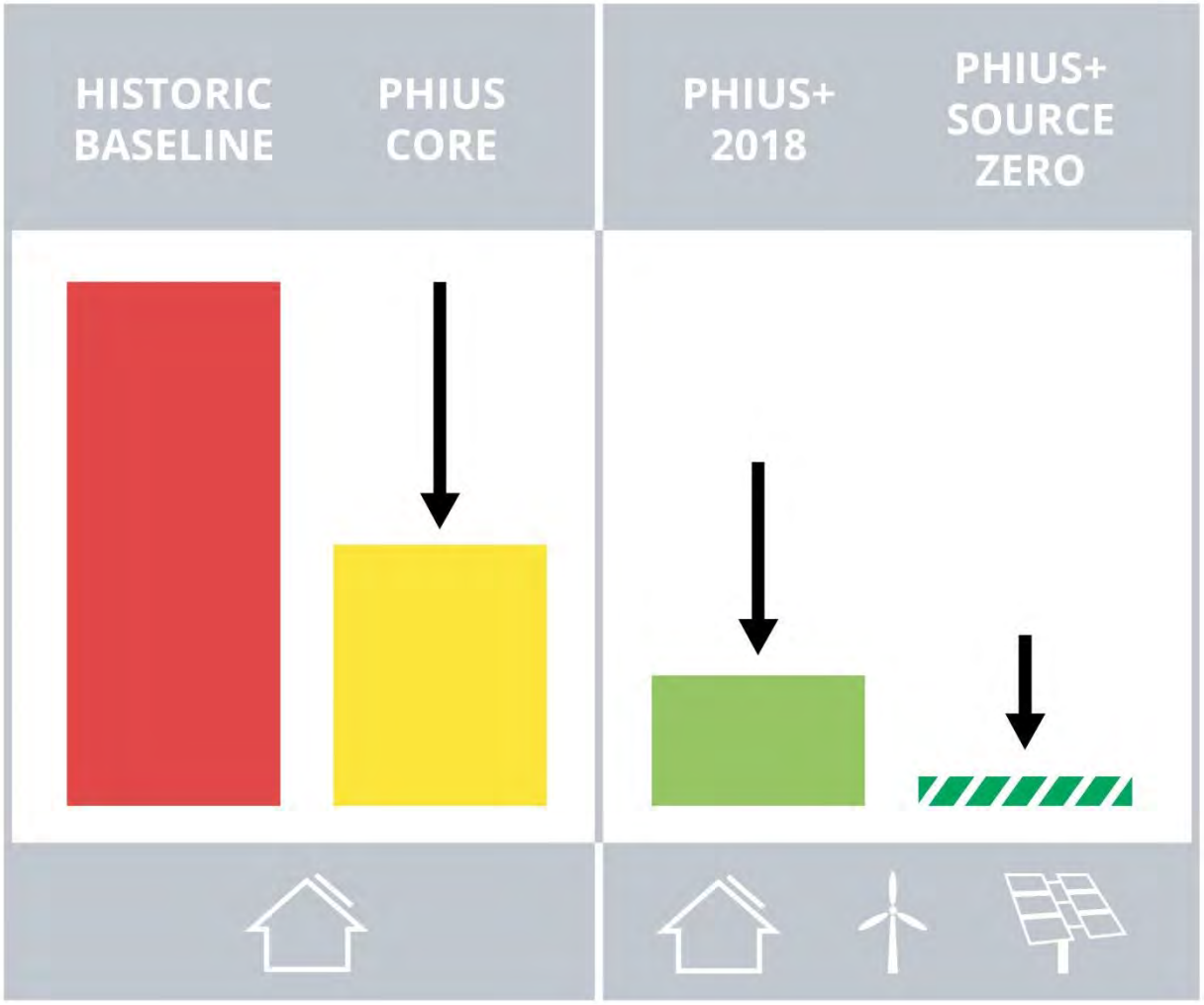
2015 PHIUS released the PHIUS+ 2015 building standard, the first climate-specific passive building standard in the world. PHIUS+ was developed in partnership with Building Science Corporation under a U.S. Department of Energy Grant

2018 PHIUS released PHIUS+ 2018 building standard updates on the path to ZERO

DOE HIGH PERFORMANCE STAIRCASE

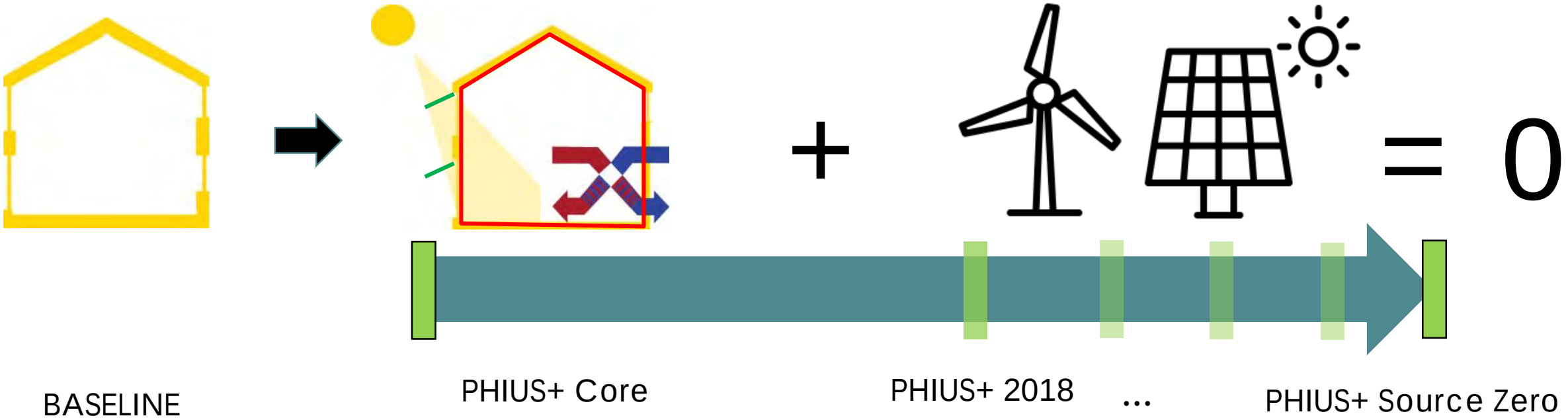


NET SOURCE ENERGY



NET SOURCE ENERGY GOALS

PHIUS+ Core: Targeting the sweet spot for on-site conservation
PHIUS+ 2018: Reduced target, on the "fair share" glide-path to zero by 2030.
PHIUS+ Source Zero: Targeting annual net zero operational energy

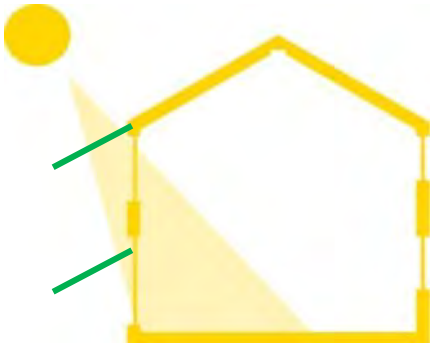


PASSIVE BUILDING PRINCIPLES

Thermal Control

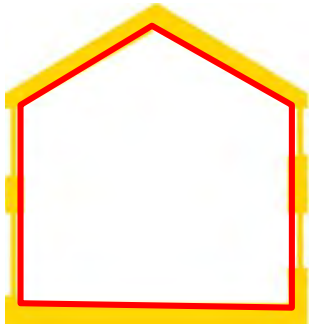
CONTINUOUS INSULATION

Radiation Control



OPTIMIZED WINDOWS & SOLAR GAINS

Air Control



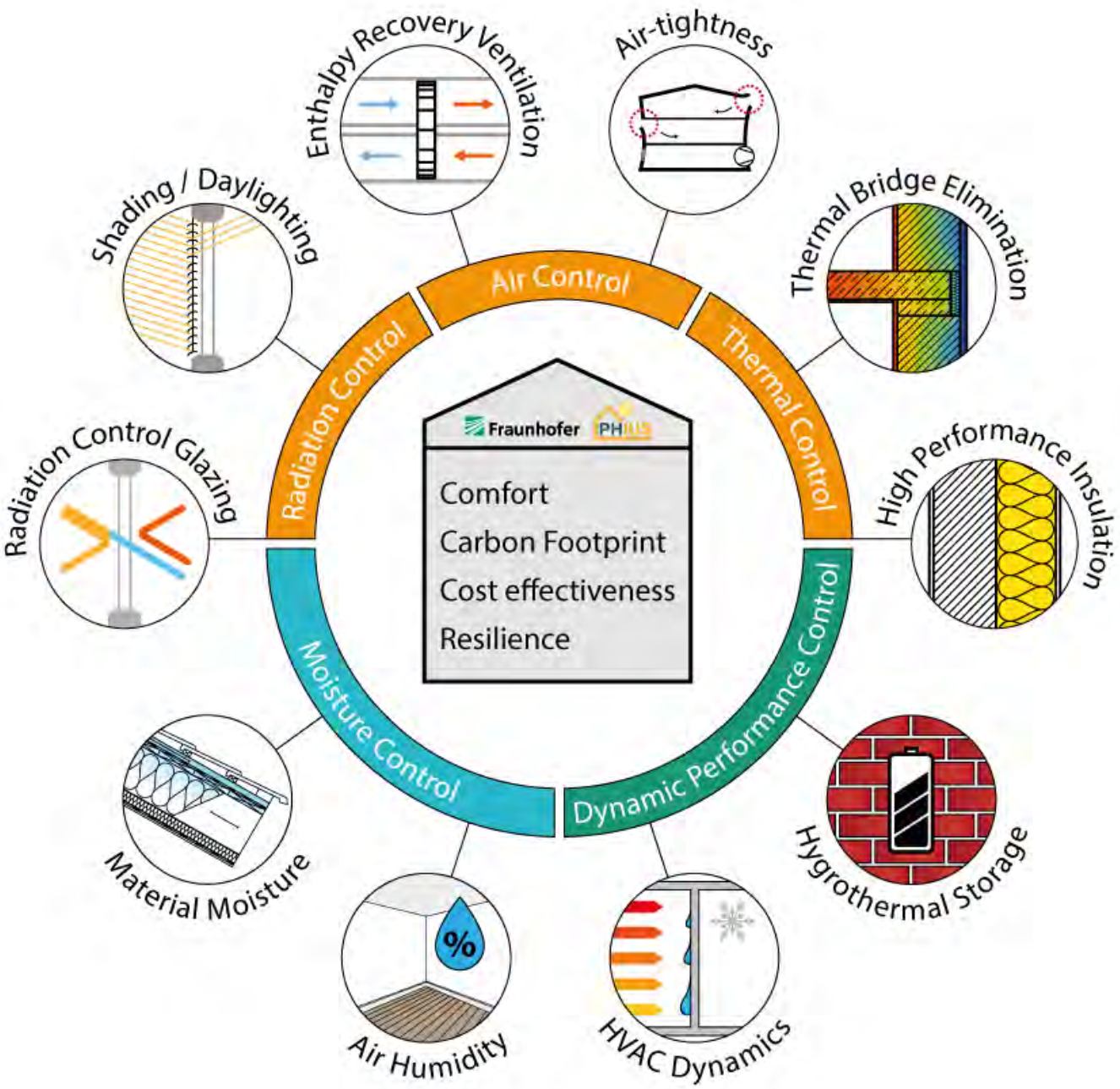
AIR-TIGHT CONSTRUCTION

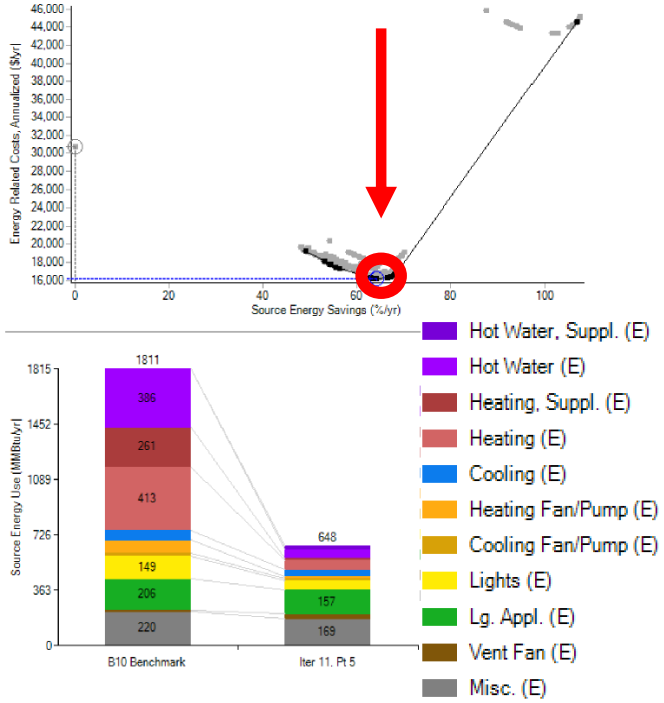
BALANCED VENTILATION WITH HEAT RECOVERY

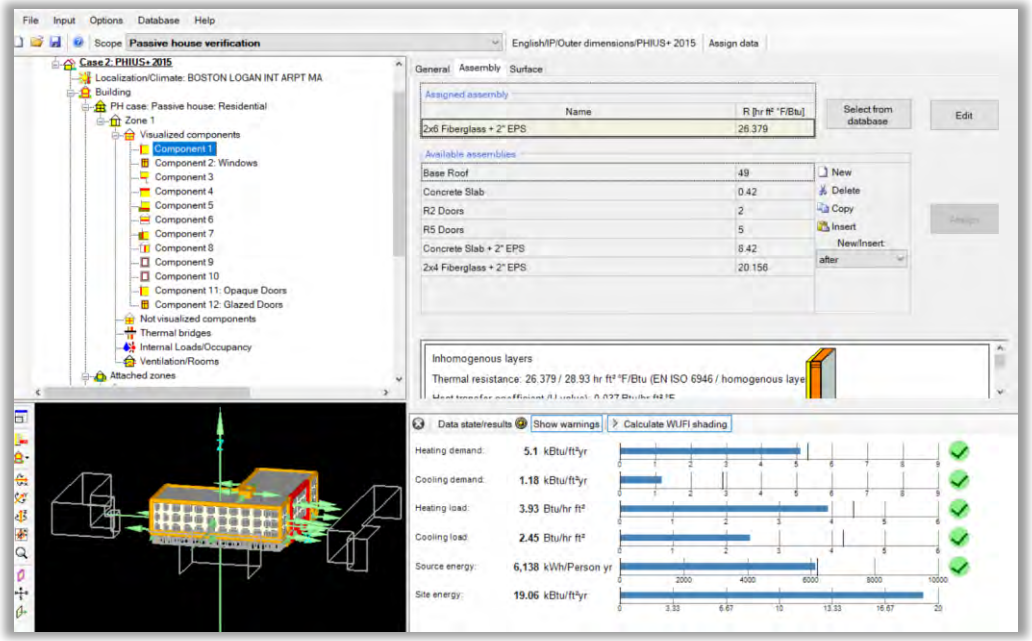
Systems

EFFICIENT APPLIANCES/ MINIMIZED MECHANICAL SYSTEMS

BUILDING SCIENCE PRINCIPLES



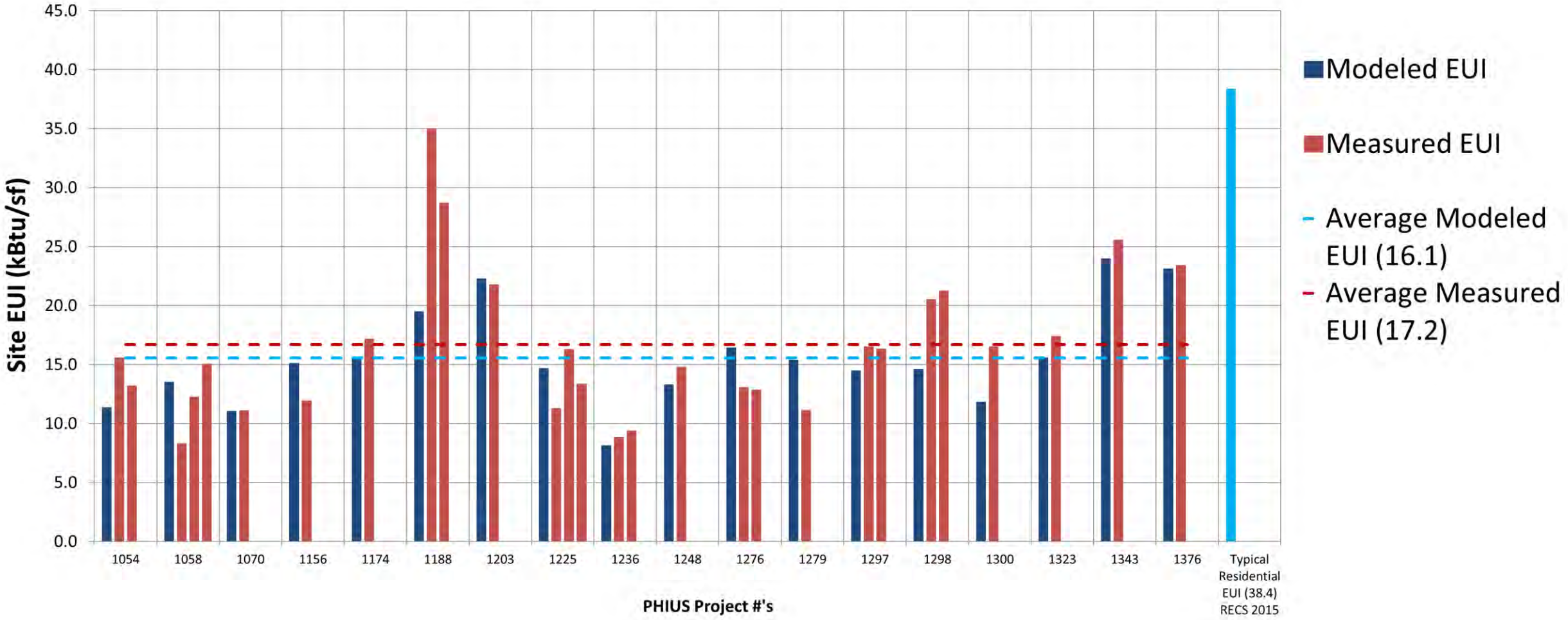




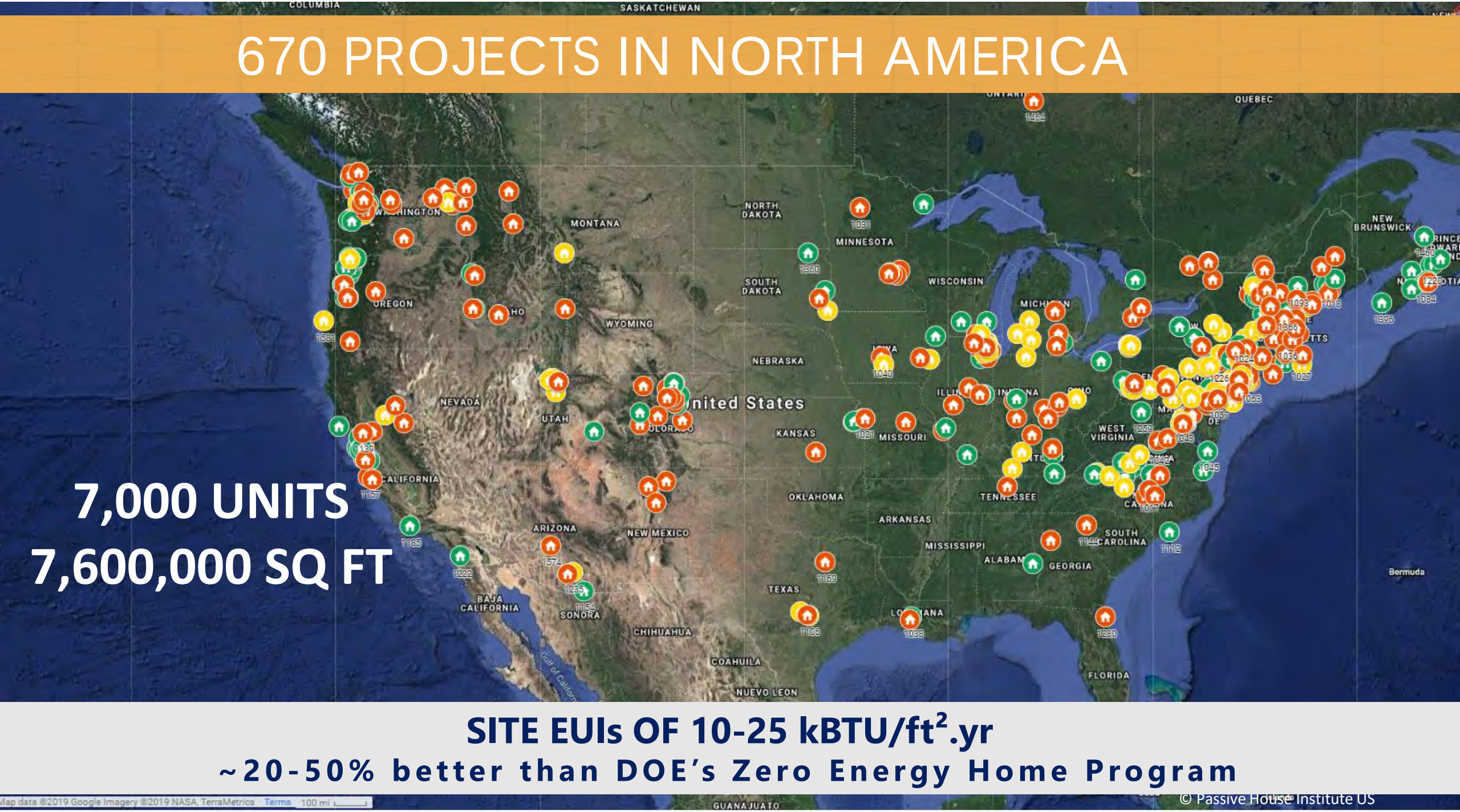
NEAR TERM/FUTURE GOALS:

- MAKE PHIUS+ AVAILABLE IN A CODE ADOPTABLE FORMAT
- CONTINUE TO DEVELOP/IMPROVE AFFORDABLE, EASY TO USE DESIGN, VERIFICATION, QUALITY ASSURANCE TOOLS AND PROTOCOLS FOR NET-ZERO, RESILIENT, GRID-FRIENDLY BUILDINGS FOR MOST ACCURATE RESULTS (+-5%)
- DEVELOP MONITORING BASED COMMISSIONING PROTOCOLS
- MASS ADOPTION IN THE BUILDING SECTOR (RES, COMM, RETROFIT)

93% Modeled vs Actual Performance Data



670 PROJECTS IN NORTH AMERICA



7,000 UNITS

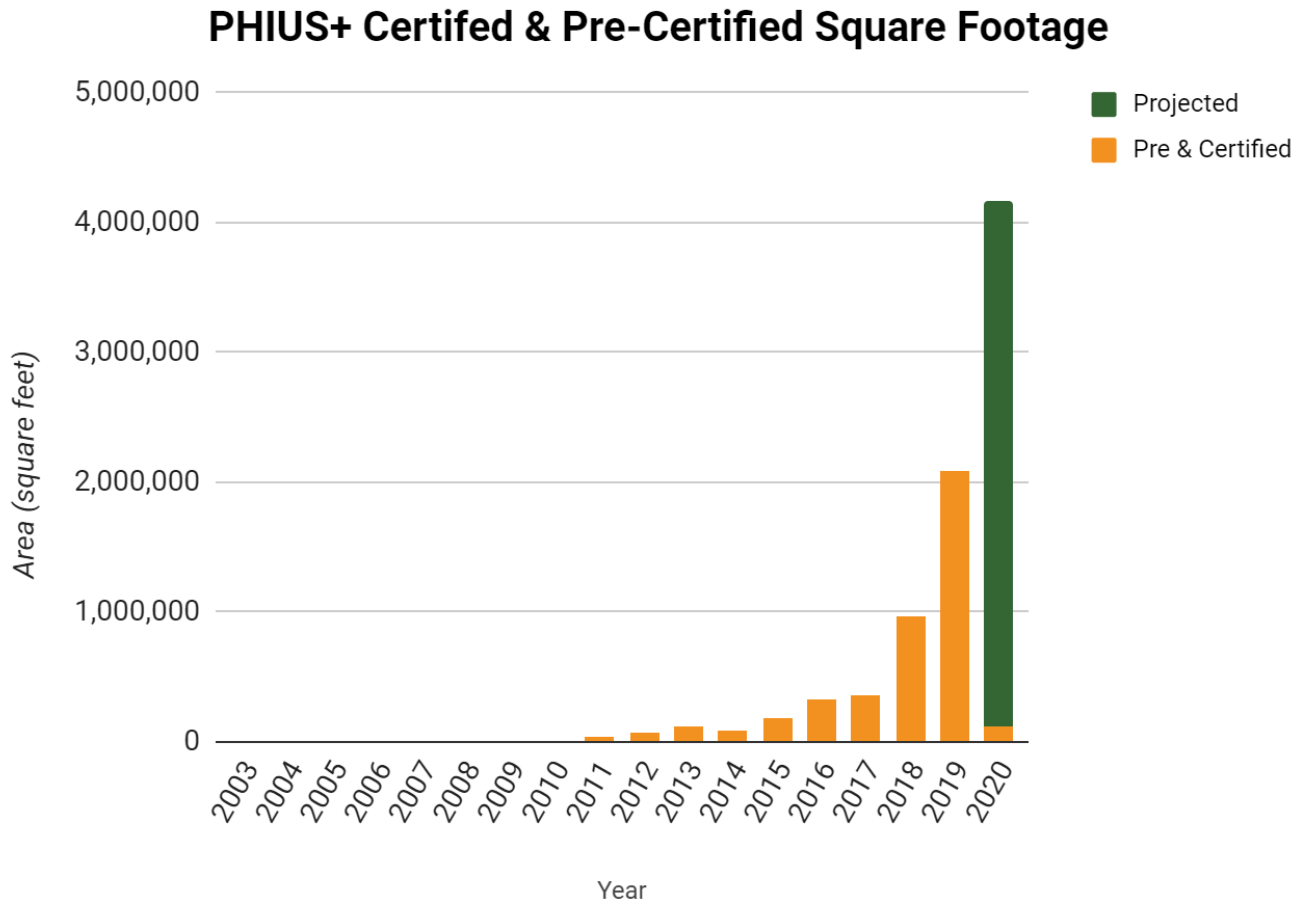
7,600,000 SQ FT

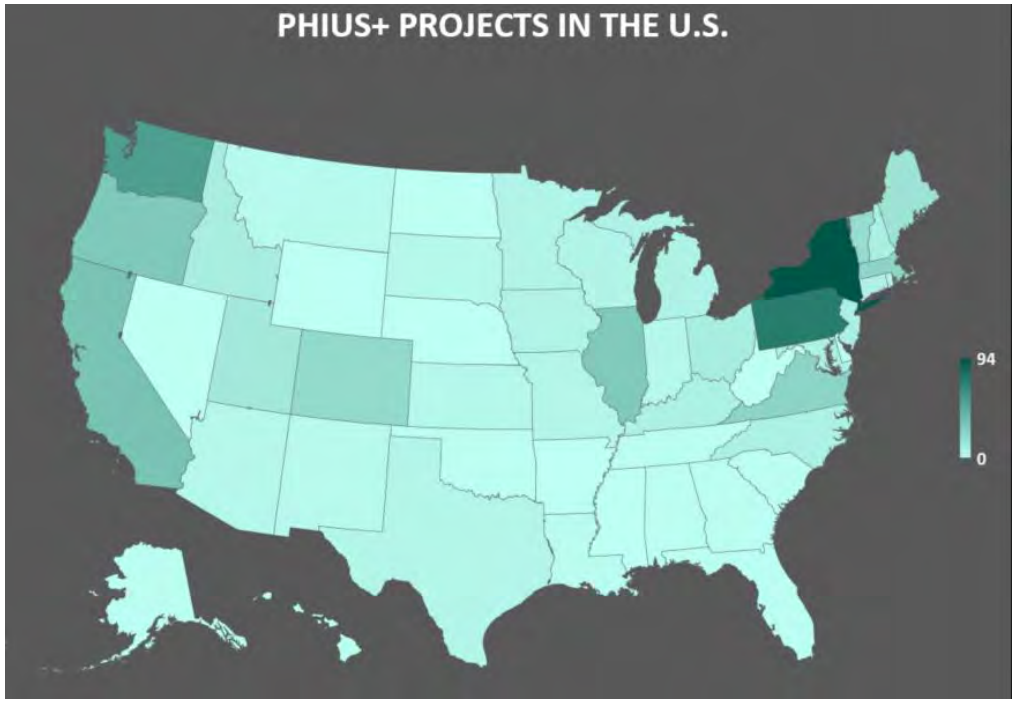
SITE EUIs OF 10-25 kBTU/ft^2.yr

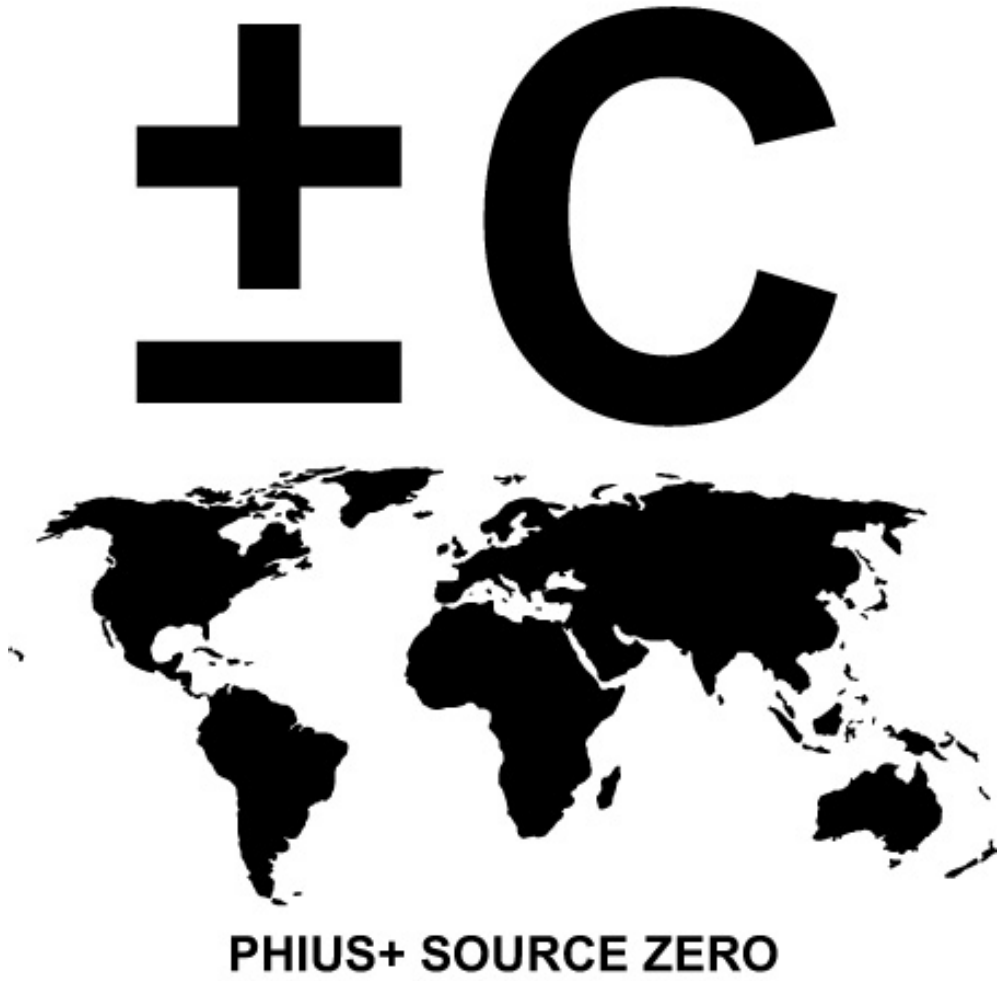
~20-50% better than DOE's Zero Energy Home Program

PHIUS+ PROJECT CERTIFICATION

By the numbers



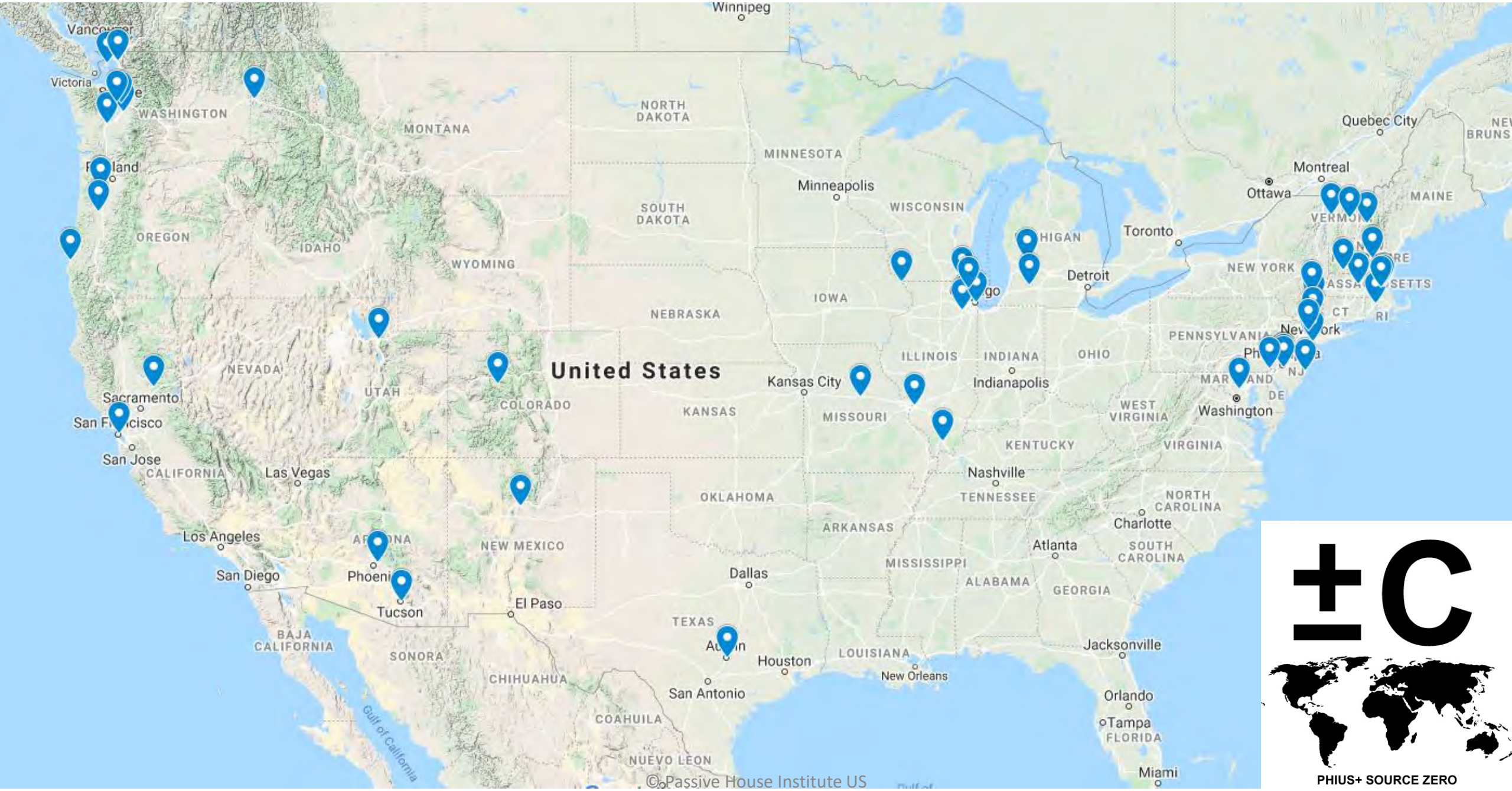




PHIUS+ SOURCE ZERO

19 CERTIFIED
18 PRE-CERTIFIED
23 SUBMITTED

60 TOTAL



±C

PHIUS+ SOURCE ZERO

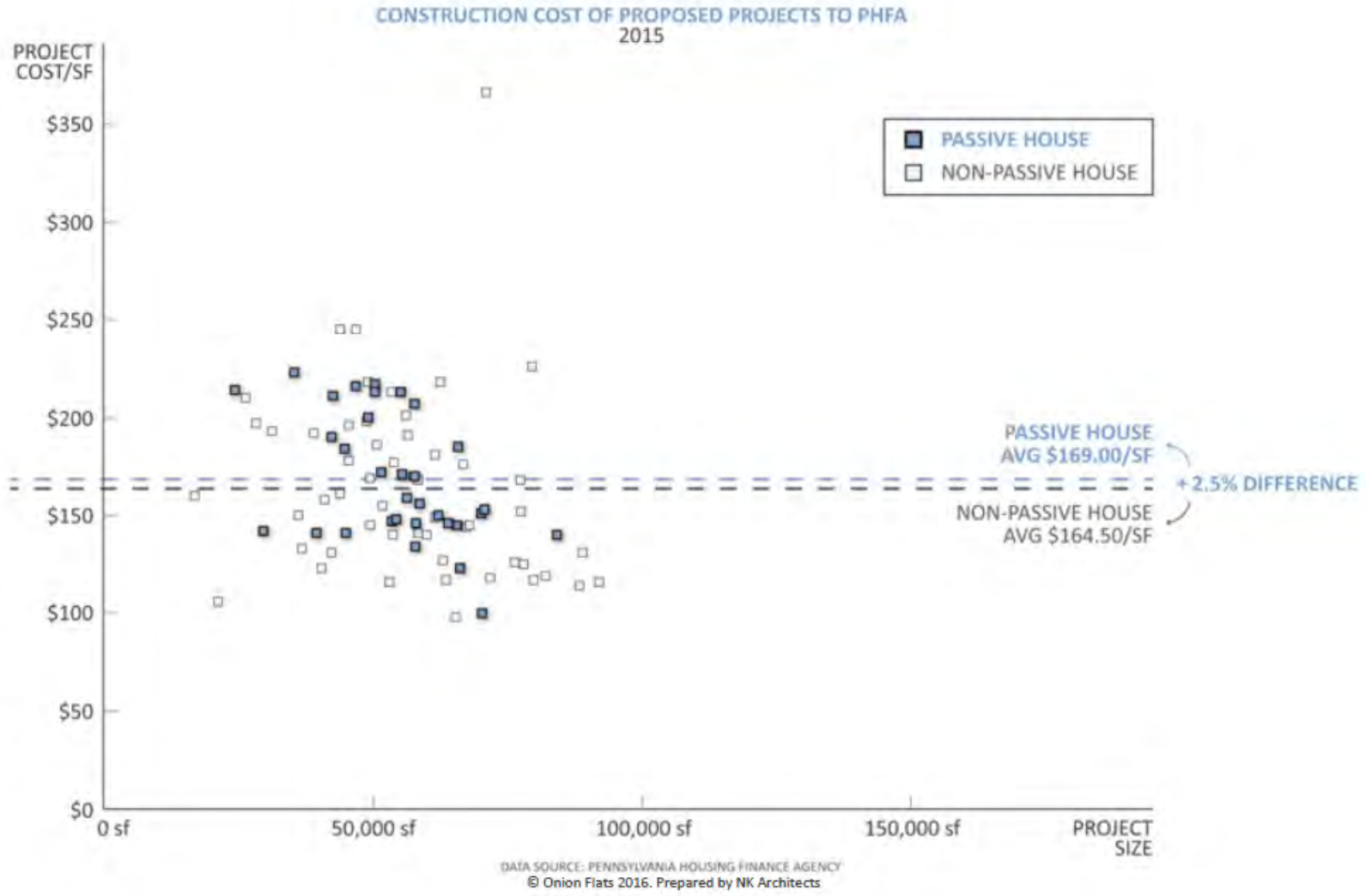
Affordable Housing Successes

Low Income Housing Tax Credit (LITHC) Applications: Housing agencies are awarding additional points in the LITHC application for affordable housing projects built to passive building standards.

Affordable Housing Successes (PHFA)

2015

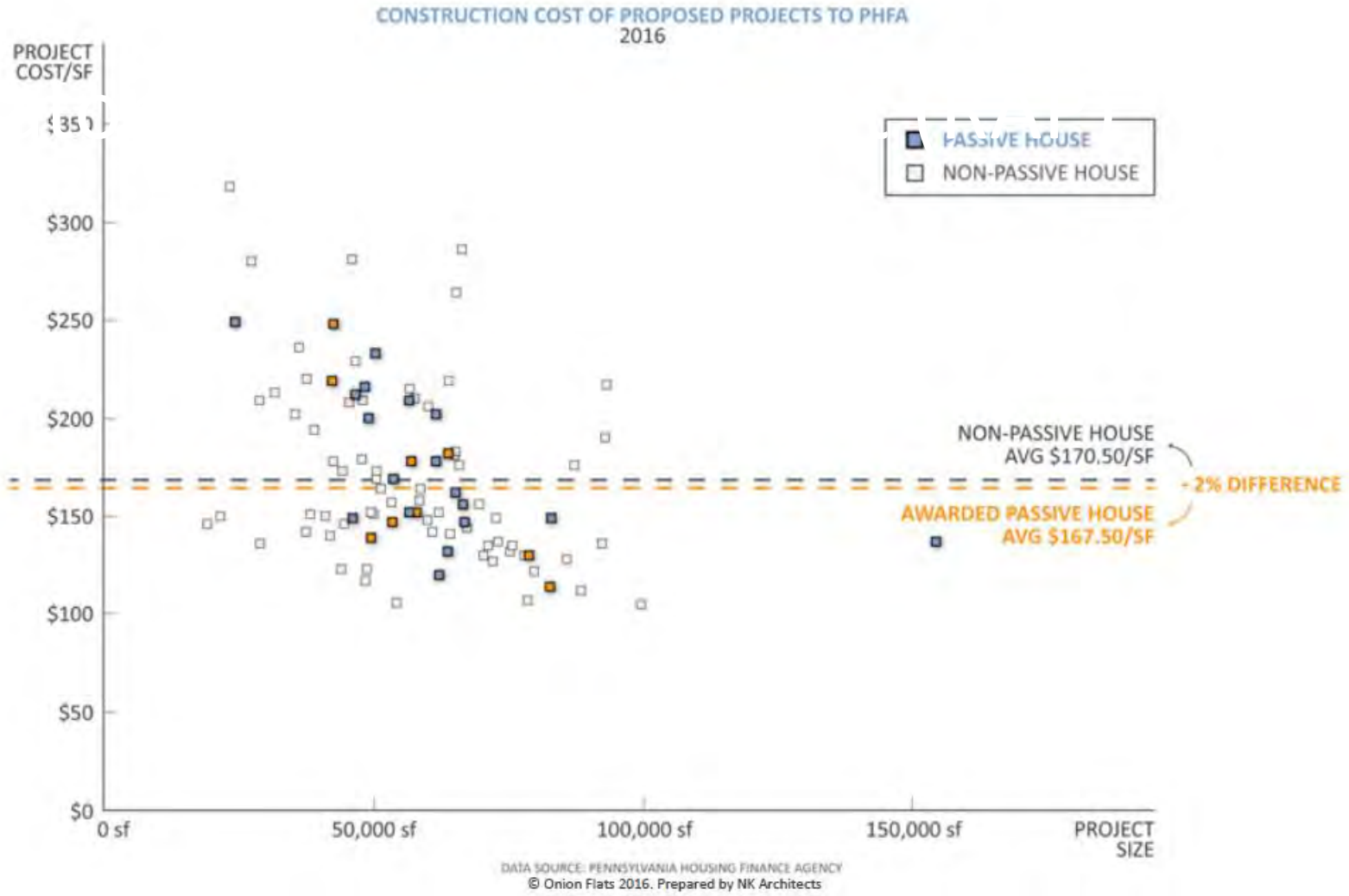
+ 2.5% on PH



Affordable Housing Successes (PHFA)

2016

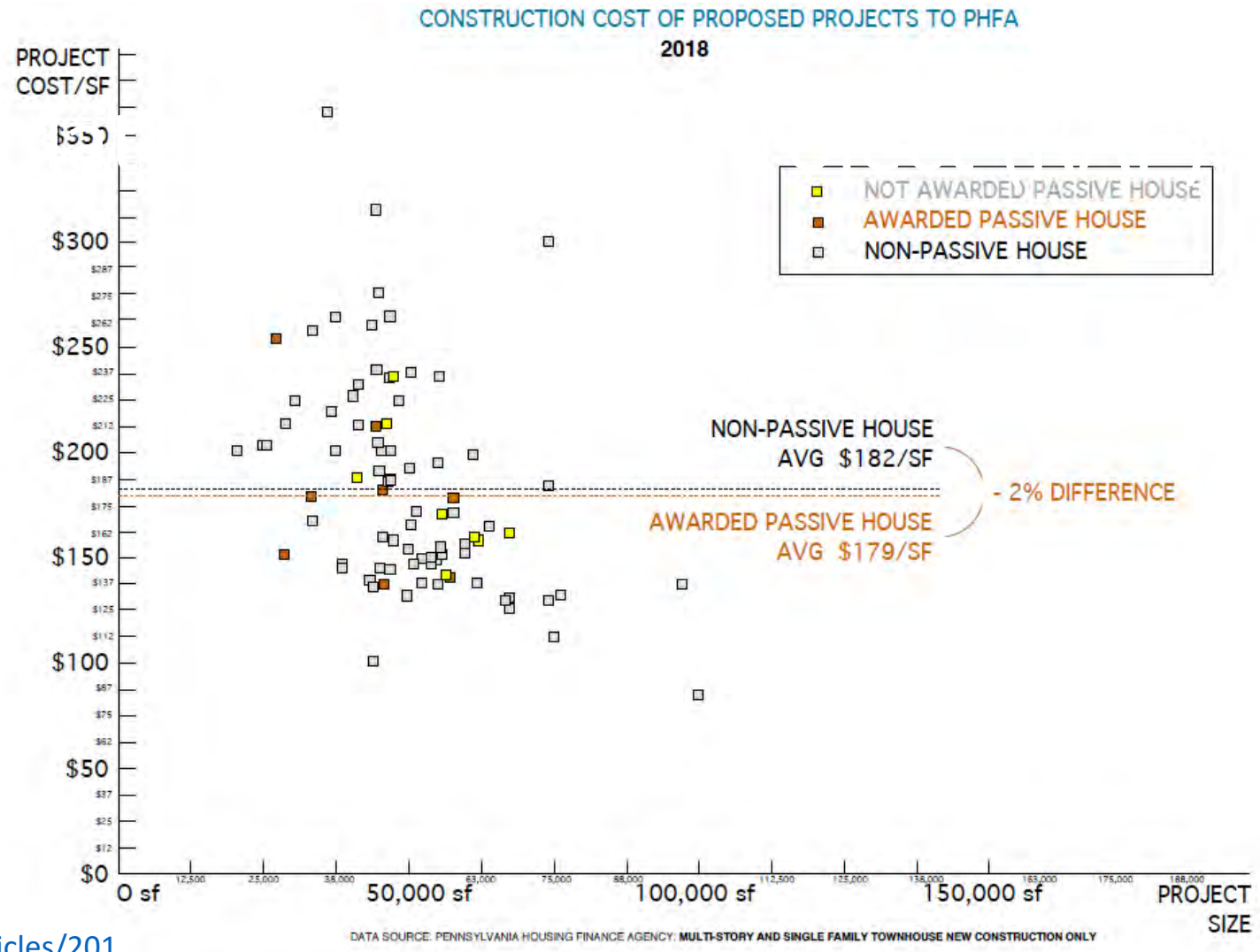
- 2%!



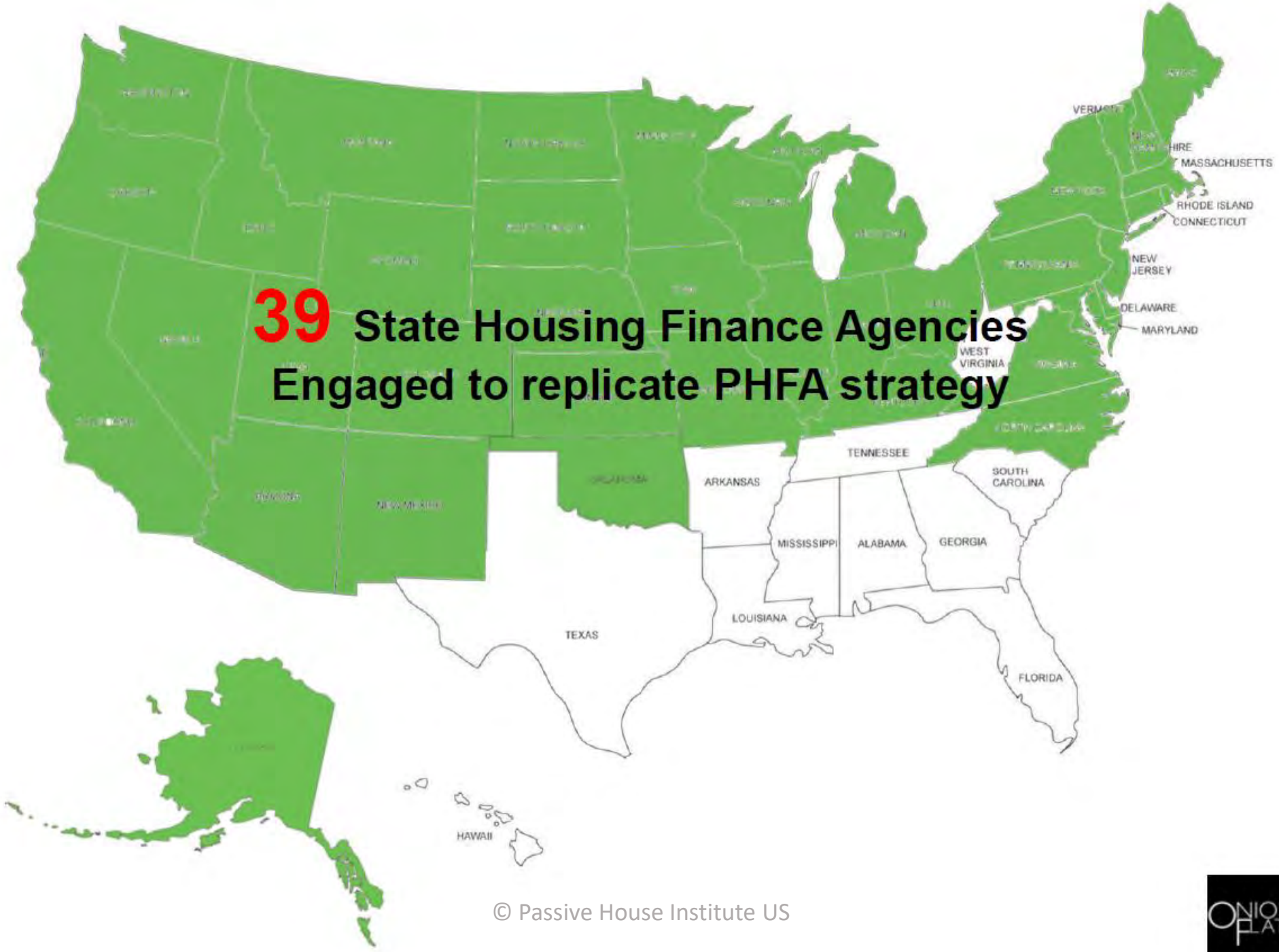
Affordable Housing Successes (PHFA)

2018

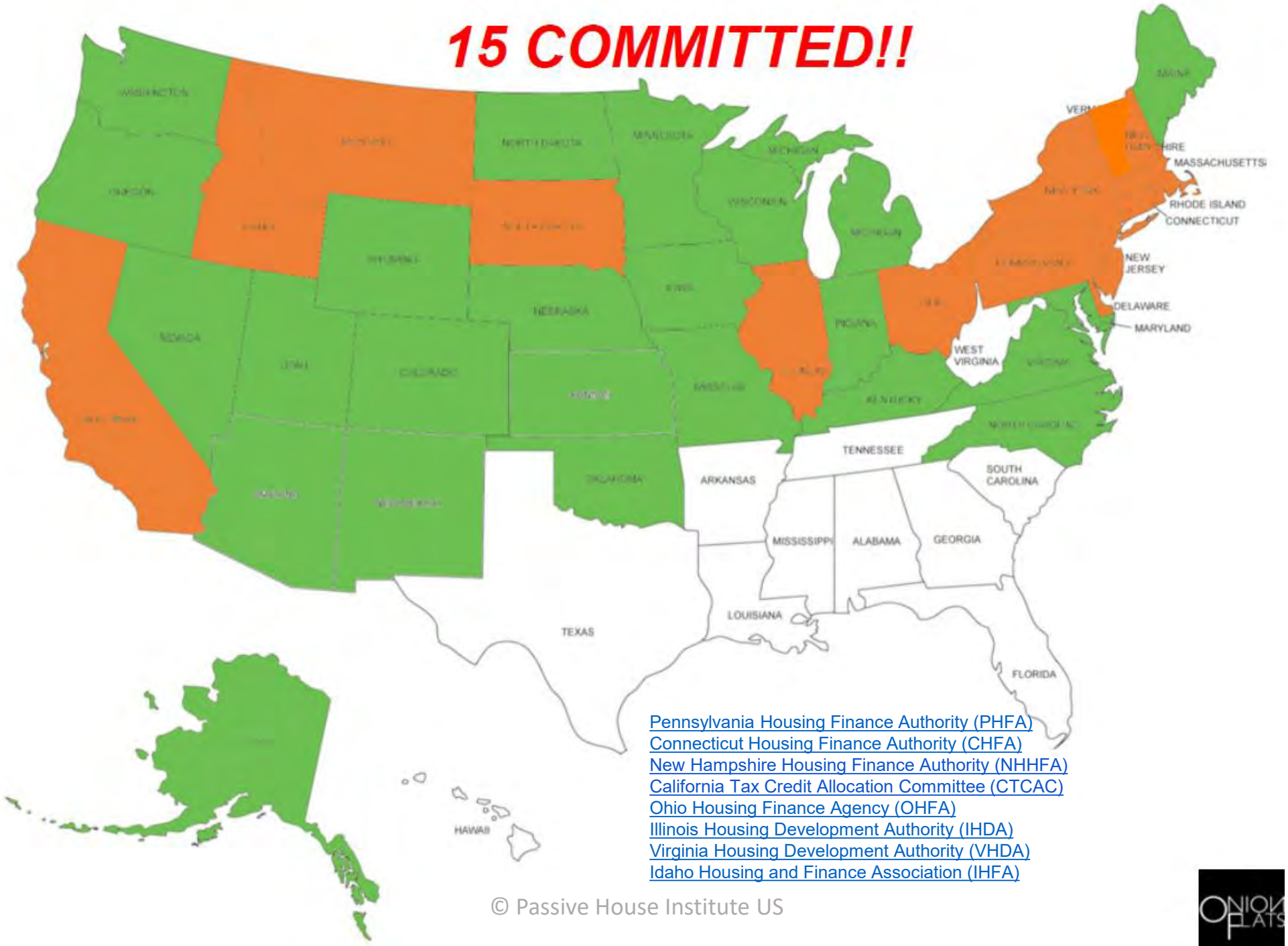
- 2%!



https://passivehouseaccelerator.com/articles/2019-new-gravity-housing-conference-july-1st-2nd



15 COMMITTED!!

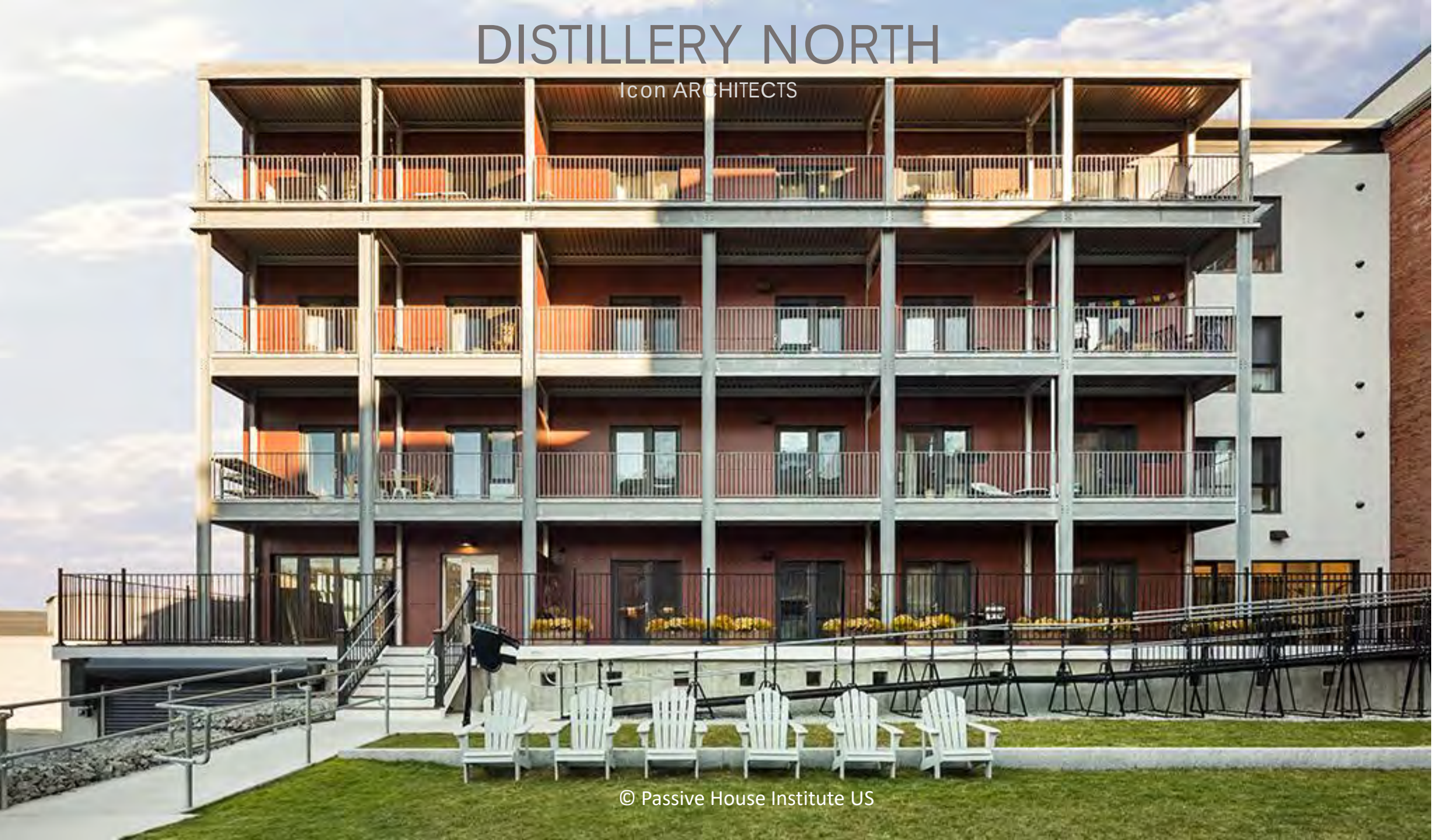


[Pennsylvania Housing Finance Authority (PHFA)]
[Connecticut Housing Finance Authority (CHFA)]
[New Hampshire Housing Finance Authority (NHHFA)]
[California Tax Credit Allocation Committee (CTCAC)]
[Ohio Housing Finance Agency (OHFA)]
[Illinois Housing Development Authority (IHDA)]
[Virginia Housing Development Authority (VHDA)]
[Idaho Housing and Finance Association (IHFA)]

ONION FLATS: THE BATTERY IN PHILADELPHIA

DISTILLERY NORTH

Icon ARCHITECTS



HOOK & LADDER

PHOTO: STARTRIBUNE.COM

ORCHARDS AT ORENCO PHASE II – PORTLAND, OR

58 units | 47,000 ft^2

PARK AVENUE GREEN
South Bronx, NYC
154 Units
153,000 ft^2

PAX FUTURA
Seattle, WA

PHOTO: **SLOAN RICHIE**

45 UNITS

AFFORDABLE/MARKET RATE, 274 UNITS
KANSAS CITY, MO

CHOM Village Center, Brewer, ME

47 UNITS – AFFORDABLE – BREWER, ME

425 GRAND CONCOURSE, BRONX, NY

289 UNITS
~300,000 SF

RESIDENTIAL
DAYCARE
OFFICES

TIERRA LINDA

LANDON BOONE BAKER ARCHITECTS

FIRST MULTI-FAMILY IN THE CITY OF CHICAGO

Project Overview

Two new, 6-unit properties developed by LUCHA

Designed by Landon Bone Baker Architects

Built by Linn-Mathes and verified by Eco Achievers

Both part of ComEd Affordable Housing New Construction Program

Same layout, same orientation, same location in Chicago, IL

Constructed to two different energy efficiency standards

ENERGY STAR Homes Certification v3.1

Passive House Institute US (PHIUS+ 2015)

ComEd Funded Study - How do they compare?

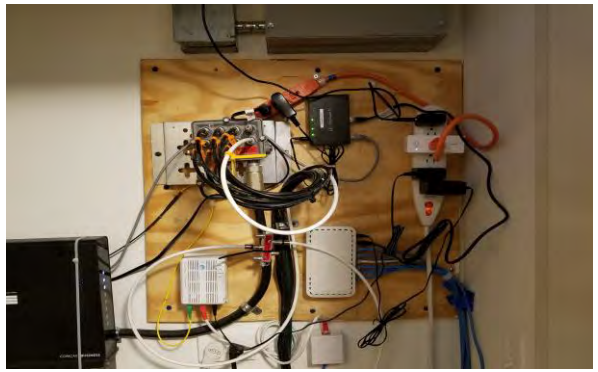
Energy performance

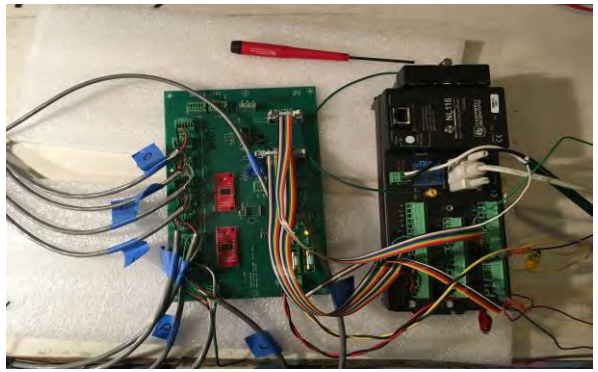
Construction and operating costs

Indoor air quality (IAQ)

Photos Curtesy of LUCHA

Intensively monitored for energy and IAQ





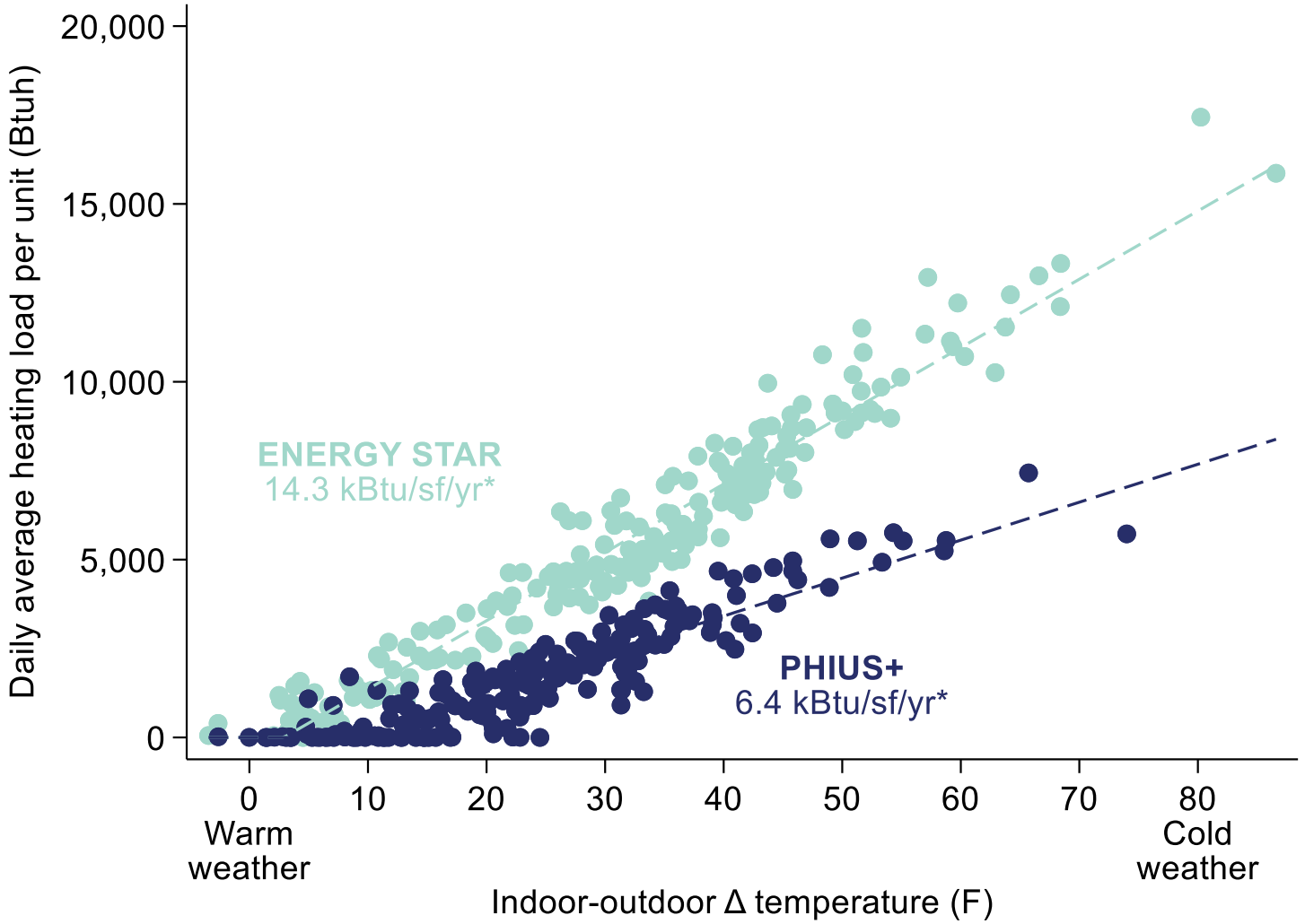
Site Location and Floor Plan

Comparison of key property features

Feature	ENERGY STAR property	PHIUS+ property
Measured air leakage	1.90 (ACH50)	0.49 (ACH50)
Ceiling insulation	R-50	R-60
Wall insulation	R-14.5 assembly	R-29.4 assembly (EIFS)
Windows	Double-pane (U-value 0.29)	Triple-pane (U-value 0.17)
Heating	Two-stage gas furnace (AFUE 96)	Variable-speed ducted heat pump (HSPF 9.5, SEER 17.6)
Cooling	SEER 16 central A/C	
Ventilation	Continuous bath exhaust (40 CFM, 110 CFM boost)	Energy recovery ventilator (90-110 cfm)
Domestic hot water	Power-vented, 40-gal. gas water heater	
Cooking	Gas range w/ vented exhaust	Gas range w/ unvented exhaust (but ERV exhaust pickup in kitchen)
Laundry	Vented dryer w/ booster fan	Unvented compact dryer
Construction cost	$178/ft^2	$214/ft^2

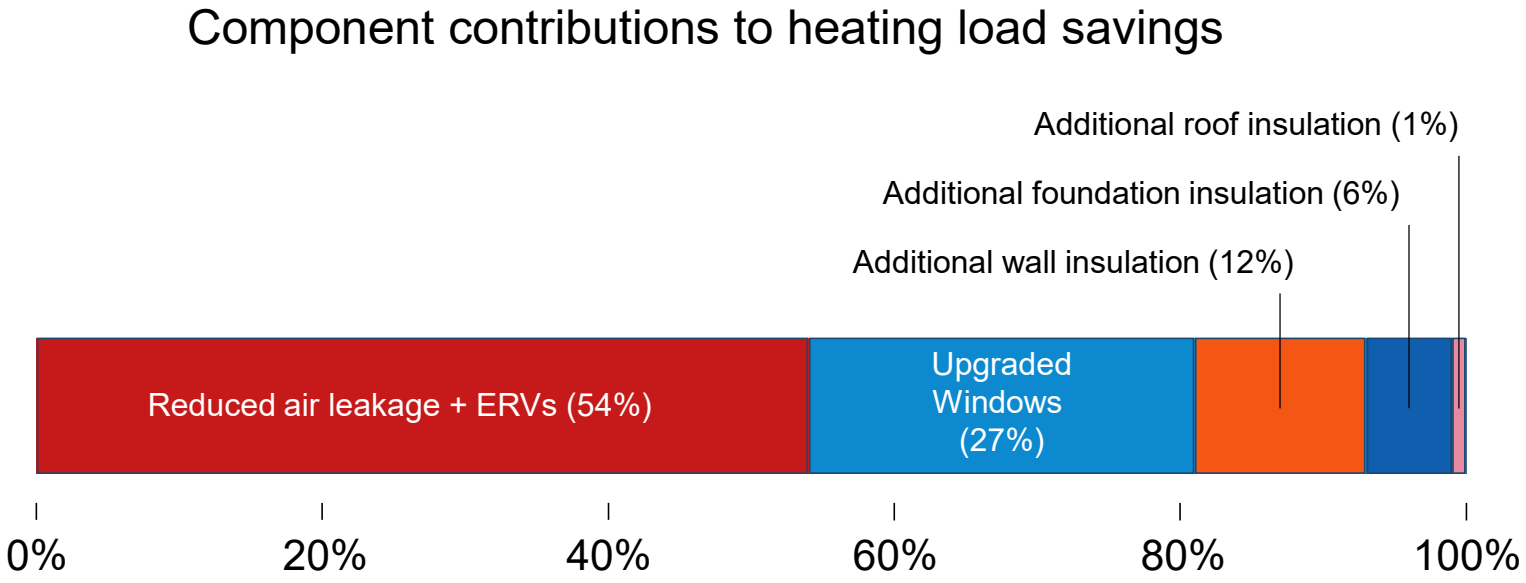
The seasonal heating requirement for the PHIUS+ property appears to be about half that of ENERGY STAR property

- At the building level, the PHIUS+ property needs to be supplied with 42% as much heat seasonally as the ENERGY STAR property.
- The analysis is based on daily measured heat output for all heating systems in each building as a function of daily indoor-outdoor temperature difference. The relationship at the building level is reasonably linear for both properties.
- Cooling load analysis is still in development but appears to be about 14% less in the PHIUS+ property



The majority of the heating savings comes from air sealing and ERVs

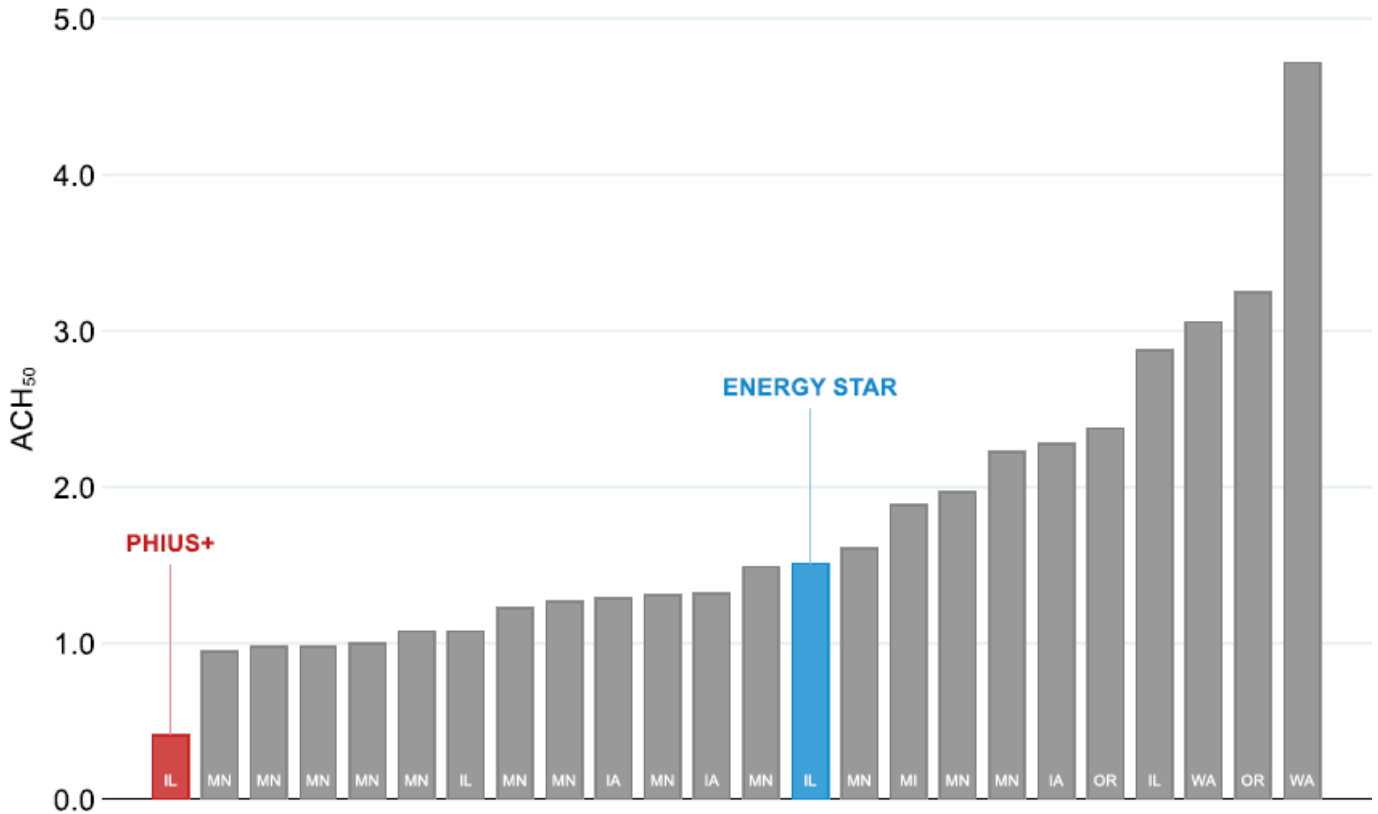
- The ERV and air leakage reduction are synergistic measures.
- Windows did show a significant improvement in performance compared to the wall insulation improvement.
- The roof and foundation insulation proved to have the least heating load impact
- A similar study on cooling load savings is in progress



Comparing Air Leakage

- PHIUS property is far below the average air leakage
- 4 times lower than the Energy Star property
- Larger sample of low-rise multifamily properties that were tested for air leakage as part of a recent DOE code compliance study.

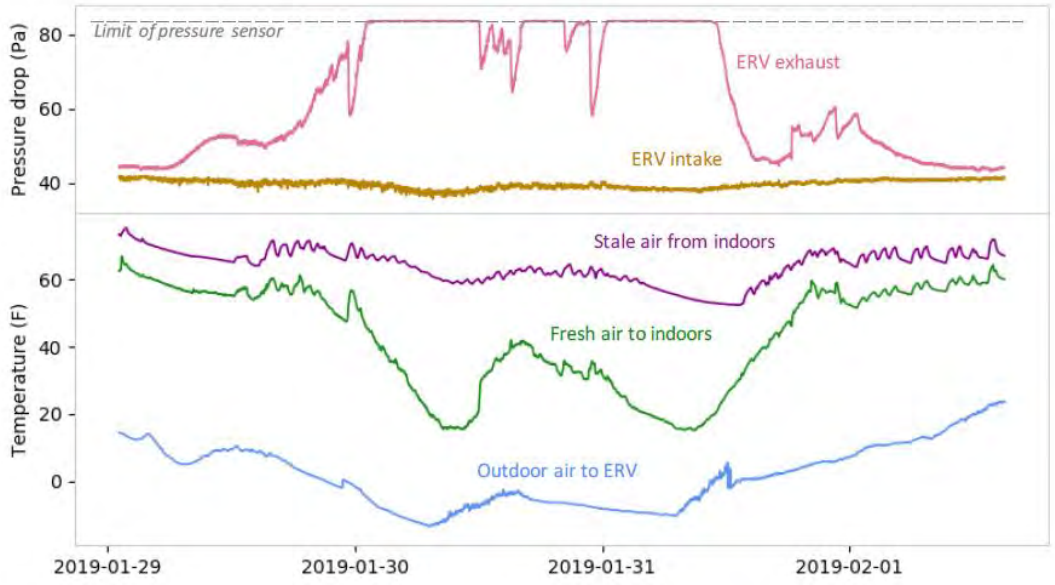
U.S. DOE Low-rise Multi-family Air Sealing Comparison

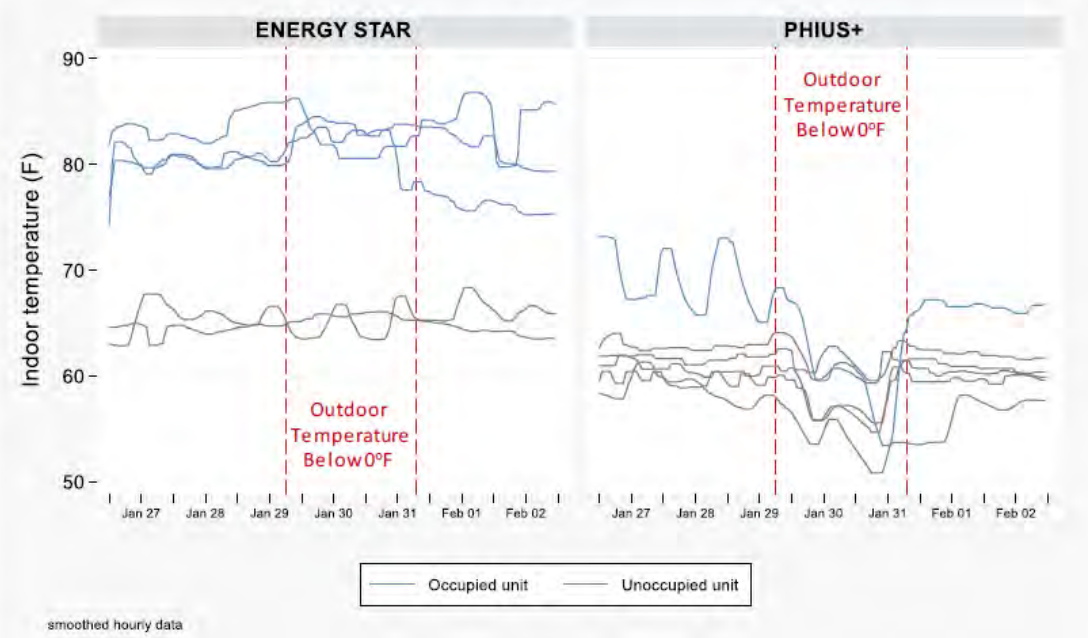


ERV Freeze Up

- During the 2019 Polar Vortex the ERV froze up for two days
- No electric back up heater was specified, retrofit opportunity in progress
- Caused a dip of indoor temperatures below 60F
- Several units were unoccupied at the time
- Interesting that Energy Star indoor air temperatures set above 80F

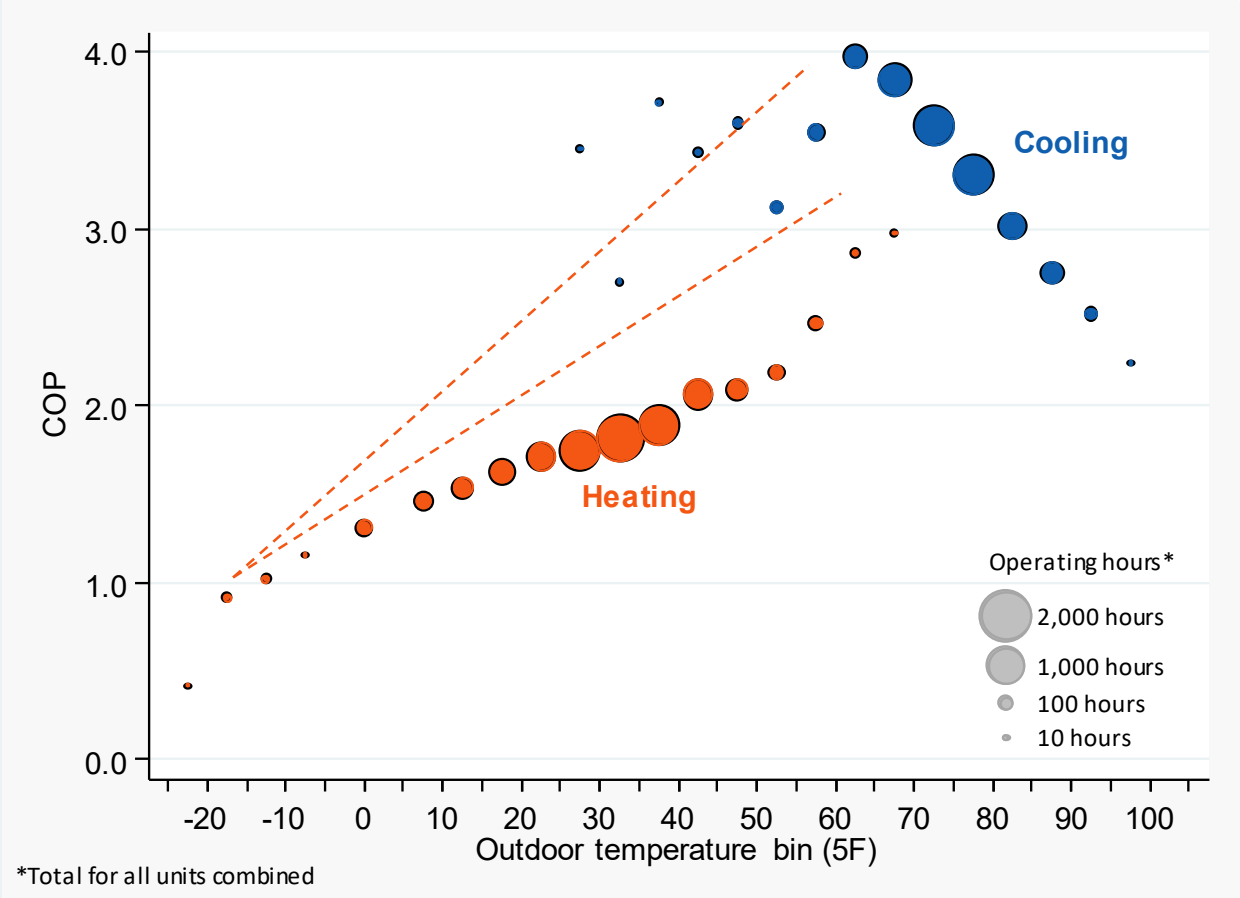
Polar Vortex Performance of ERV





Heat pumps under performing

- These are cold climate heat pumps rated at HSPF of 9.5 (COP 3.7@47f) that are operating at a combined seasonal COP of 1.69
- Based on the other testing we'd expect seasonal COPs closer 2.0-2.5
- Cooling performance was better yet still did not meet expectations



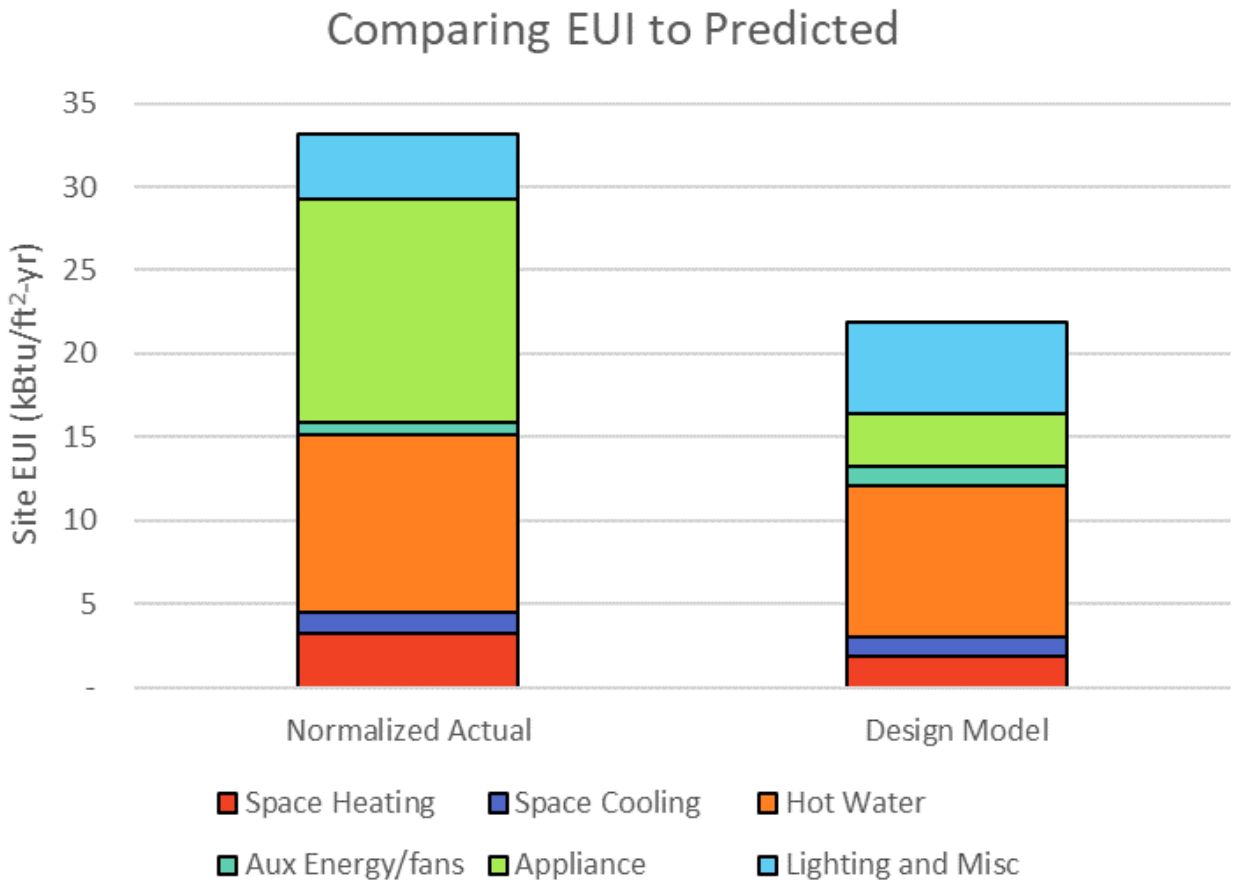
36% energy savings

- PHIUS property had a 36% reduction in overall energy usage compared to Energy Star
- The Energy Star property has an EUI of 52.5 kBtu/ft^2-yr compared to the PHIUS property with an EUI of 33.7. (Was normalized energy usage from lights, water heating, and appliances)
- Clothes drier was a significant energy user as well as the lighting and miscellaneous

Annual Energy Use (Per Unit)	ENERGY STAR	PHIUS+
Natural gas (therms)		
Space heating[a]	347	--
Gas clothes dryer[b]	44	--
Gas water heater[c]	249	
Gas range/oven[d]	30	
Total	670	279
Electricity (kWh)		
Space heating[a]	324	2,219
Space cooling[a]	1,196	821
Space-conditioning standby[a]	60	331
Mechanical ventilation[e]	55	361
Clothes dryer[b]	142	933
Gas water heater (power-vented) [c]	109	
Gas range/oven + range hood[d]	46	
Lighting & other[f]	2,339	
Total	4,271	7,159
Total (kBtu)		
Natural Gas + Electricity (kBtu/ft^2)	52.5	33.7
Difference	-18.8	
% Difference	-36%	

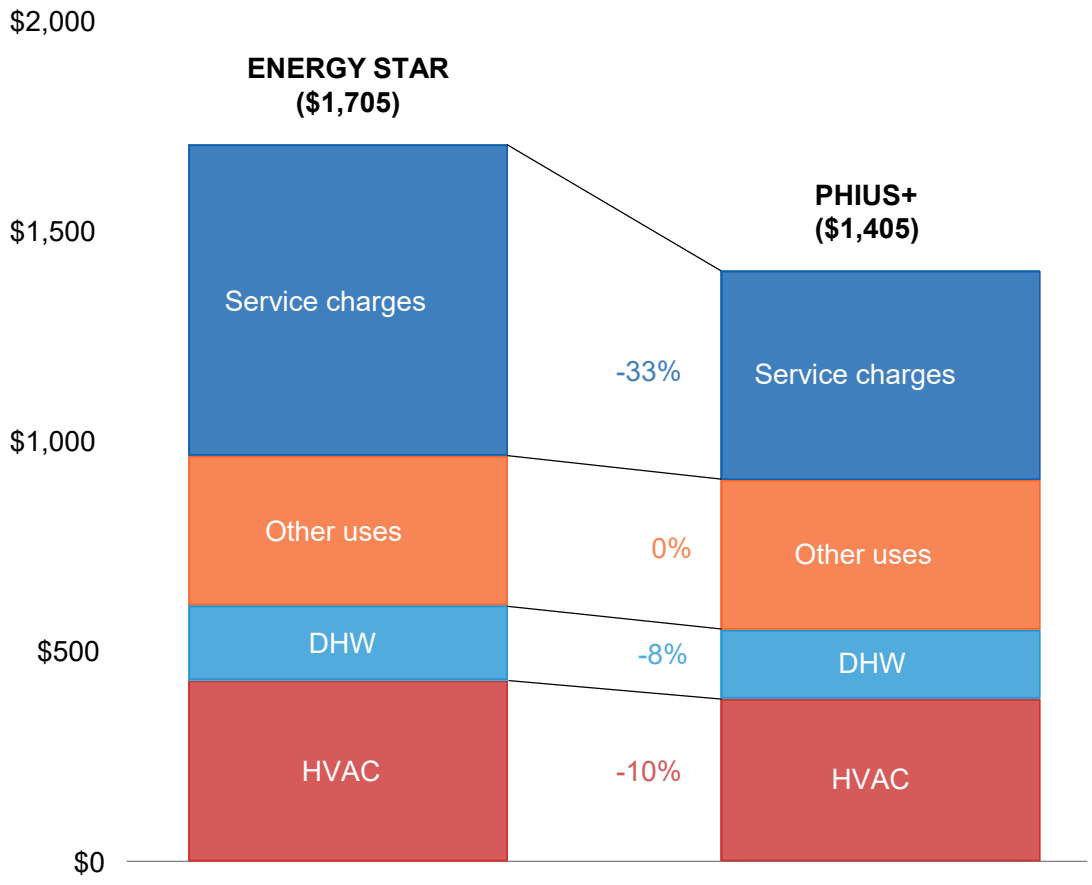
Actual vs Predicted

- The normalized energy results across the 6 PHIUS units showed an EUI of 33.7 compared to the WUFI design model of 23.1
- The main differences were across heating, miscellaneous loads and appliances
- We also developed an ASHRAE 90.1 Appendix G energy model which had an EUI of 24.6



Energy costs were lower for reasons you wouldn't expect

- Energy costs were only 18% less between normalized units while Energy savings in kBtu's was double that at 36%
- Energy cost savings come mostly from the difference in gas fuel prices between buildings
- These savings values would be highly dependent on what utilities served the homes



		ENERGY STAR	PHIUS+
Monthly service charge			
	Natural gas	$44.67	$22.62
	Electricity	$17.02	$18.82
Energy charge			
Natural gas (per therm)		66.0¢	61.1¢
Electricity (per kWh)	Summer[a]	11.9¢	9.9¢
	Non-summer	12.4¢	10.4¢
	Blended avg.	12.2¢	10.2¢

Cutting the gas connection pays off

- Energy costs savings can increase from 18% over Energy Star with gas heat to upwards of 30% without gas demand charges
- Important to utilize heat pump water heaters as electric resistance would increase overall utility costs
- Significant emissions savings can also be found in switching to heatpump water heaters nearly doubling the CO2 reduction

All-Electric Utility Cost Comparison

Scenario	Air-source heat pump	Water heater	Range/oven	Total energy cost[a]	
				$/unit/yr	Relative to ENERGY STAR property
Actual	Current	Gas	Gas	$1,401	-18%
1	Current	Conventional Electric	Conventional Electric	$1,491	-12%
2	Current	Heat pump[b]	Induction	$1,248	-27%
3	High-efficiency[c]	Heat pump[b]	Induction	$1,179	-31%

All-Electric Carbon Emission Comparison

Scenario (see Table 10)	Annual $CO2_e$ emissions[a] (metric tons per unit per year)			
	Using average emissions factor for electricity[b]		Using marginal emissions factor for electricity[c]	
	MT/unit/yr	Relative to ENERGY STAR[d]	MT/unit/yr	Relative to ENERGY STAR[d]
Actual	5.75	-33%	6.90	-26%
1	4.95	-43%	6.93	-26%
2	3.99	-54%	5.59	-40%
3	2.69	-69%	3.77	-60%

Adaptation of the RESET standard for Tierra Linda

- Based on how tight the PHIUS building was constructed and the limited research on how natural air leakage contributes to providing adequate ventilation looked to RESET to test acceptability
- RESET is a monitoring-based standard for commercial spaces and provides useful benchmarks for residential
- RESET calls for no more than 10% “fail” days relative to these thresholds

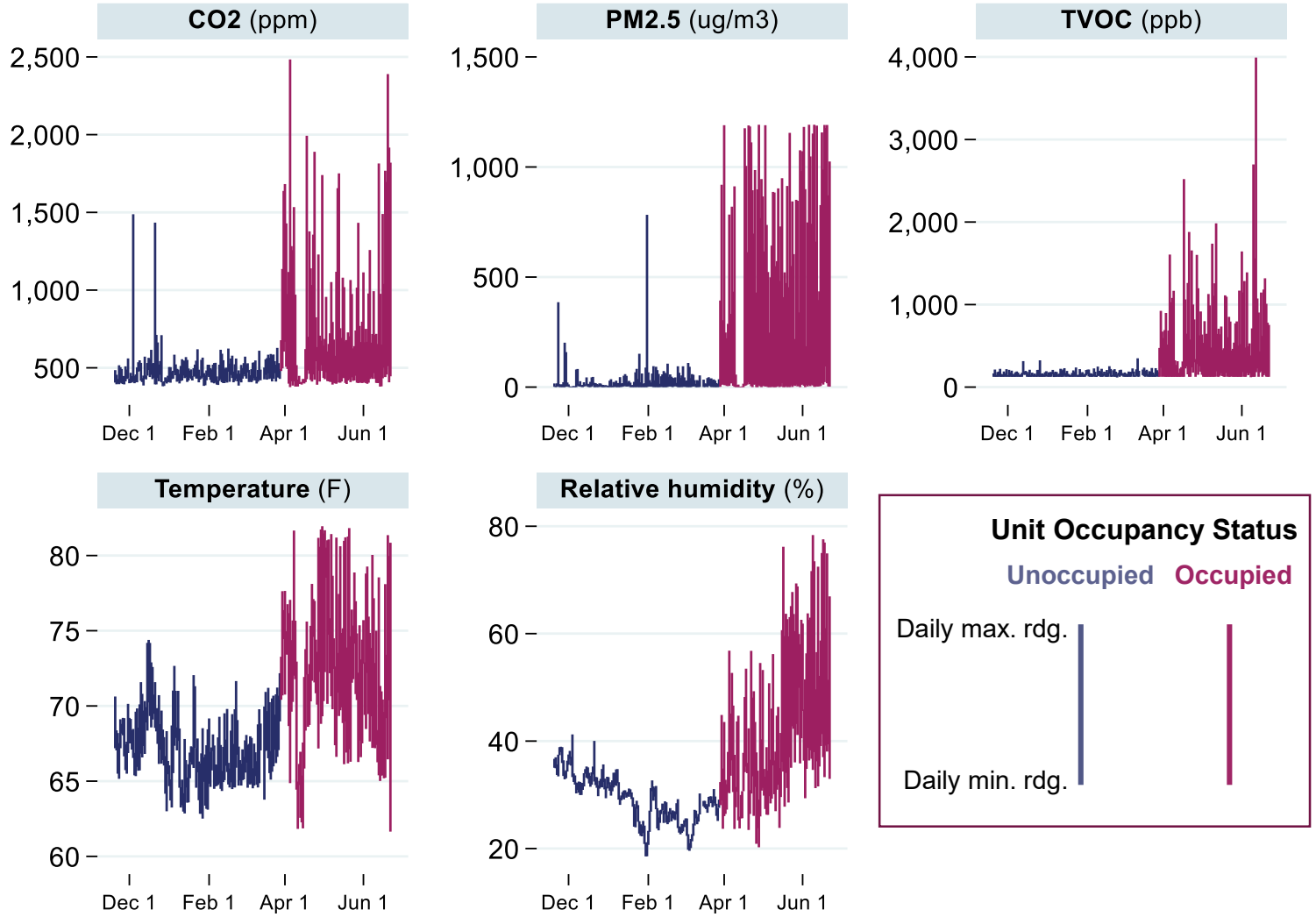
PM2.5 Particulate Matter	**TVOC** Total Volatile Organic Compounds	**CO2** Carbon Dioxide
Acceptable < 35 µg/m3	Acceptable < 500 µg/m3	Acceptable < 1,000 ppm
High Performance < 12 µg/m3	High Performance < 400 µg/m3	High Performance < 600 ppm

https://www.reset.build/standard#std__download

Unit occupants have a large effect on IAQ parameters

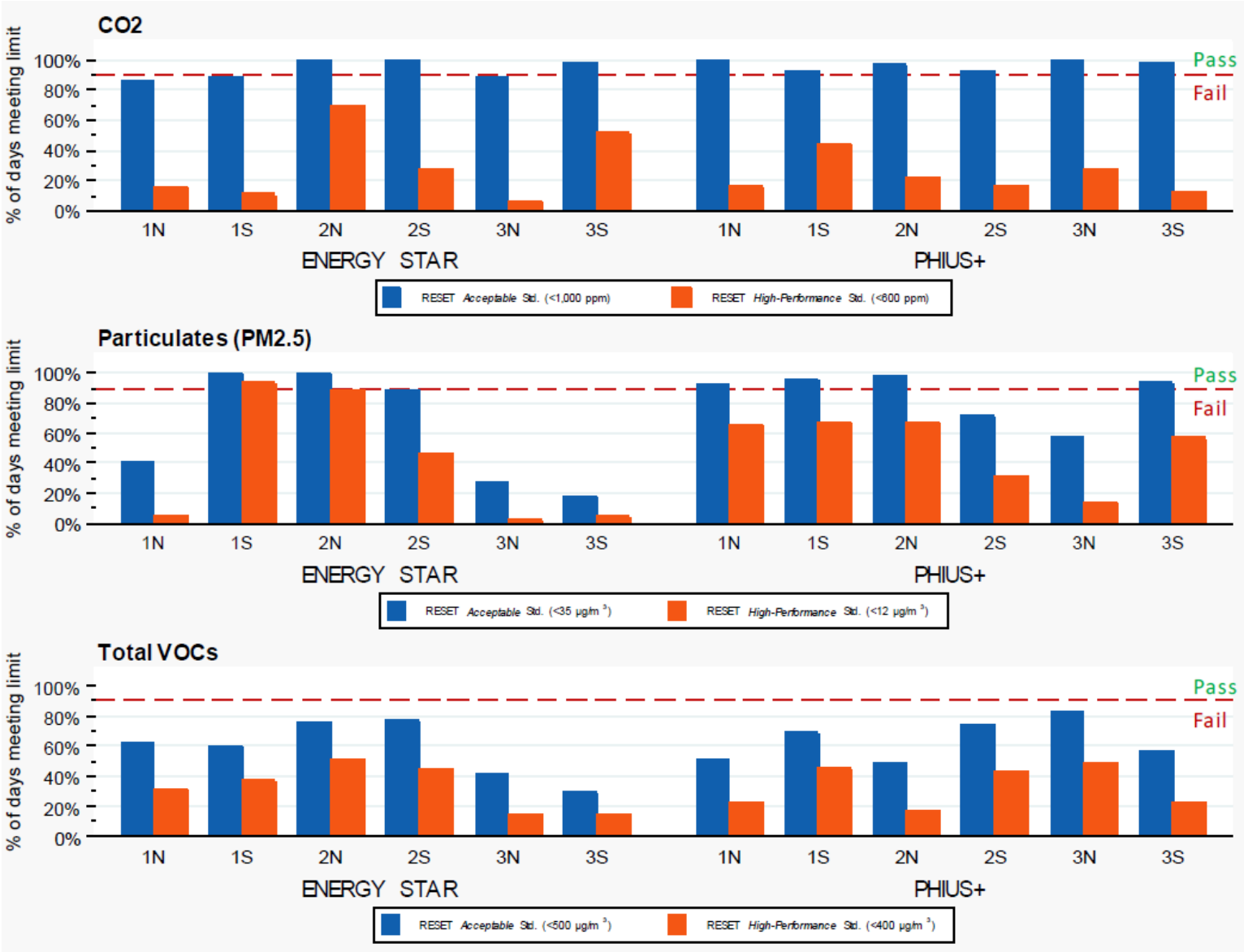
- As the example at right shows, unit occupancy has a large impact on the daily range of IAQ parameters such as particulates (PM2.5) and total volatile organic compounds (TVOCs). This indicates that these pollutants are mainly occupant-generated and not inherently sourced in the building itself.

Single Unit Before and After Move In



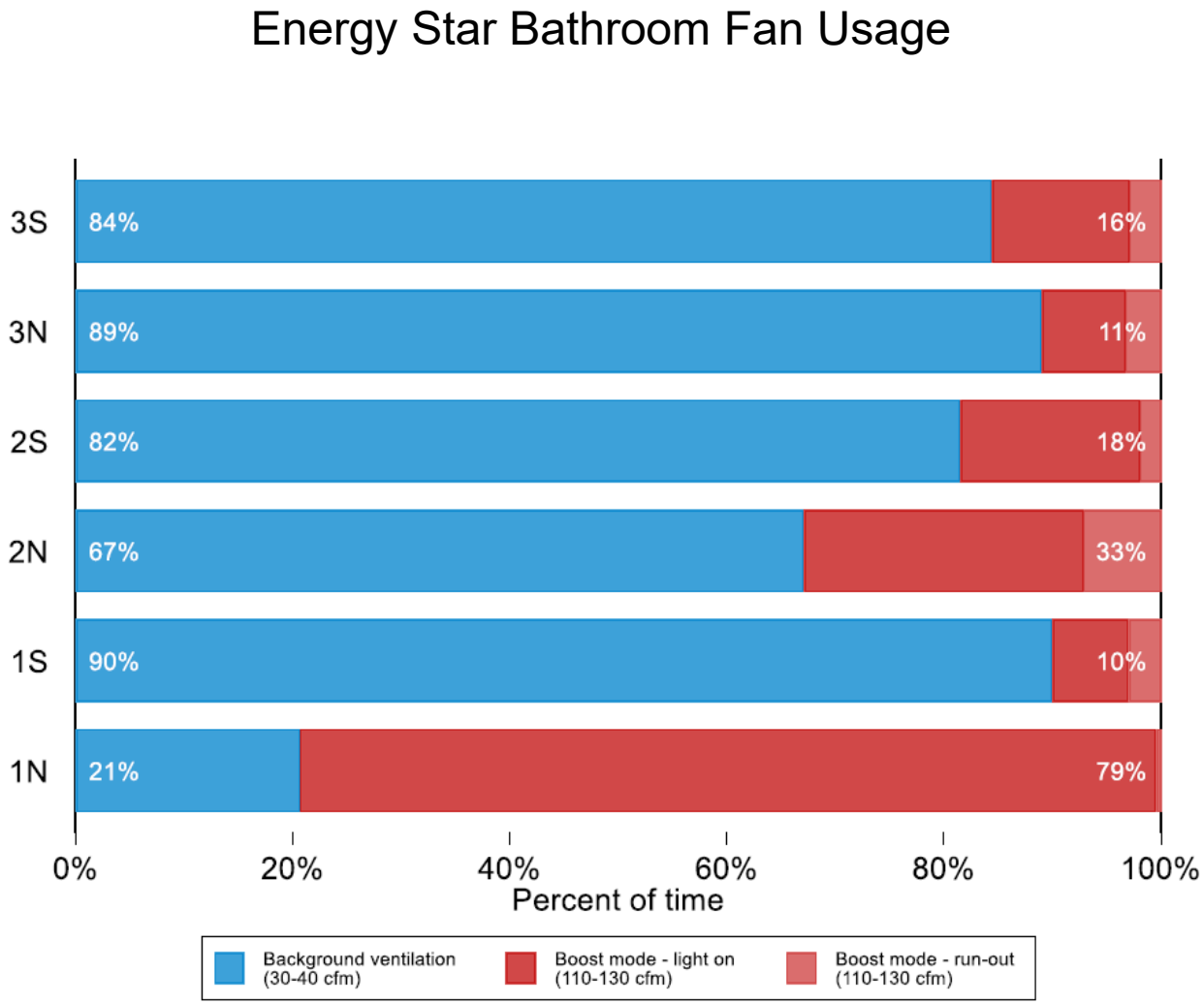
Most units pass the Acceptable threshold for CO2 and PM2.5 but none meet TVOC requirements

- No statistical difference in indoor air quality between the two properties
- The PHIUS+ property gets about 50% more air exchange than the Energy Star property on annual average
- Relative humidity levels across winter months were significantly better in the PHIUS property ranging between 30%-40% than the Energy Star property consistently below 30%.
- Summer humidity was well controlled in both properties between 50%-60%



The importance of continuous exhaust

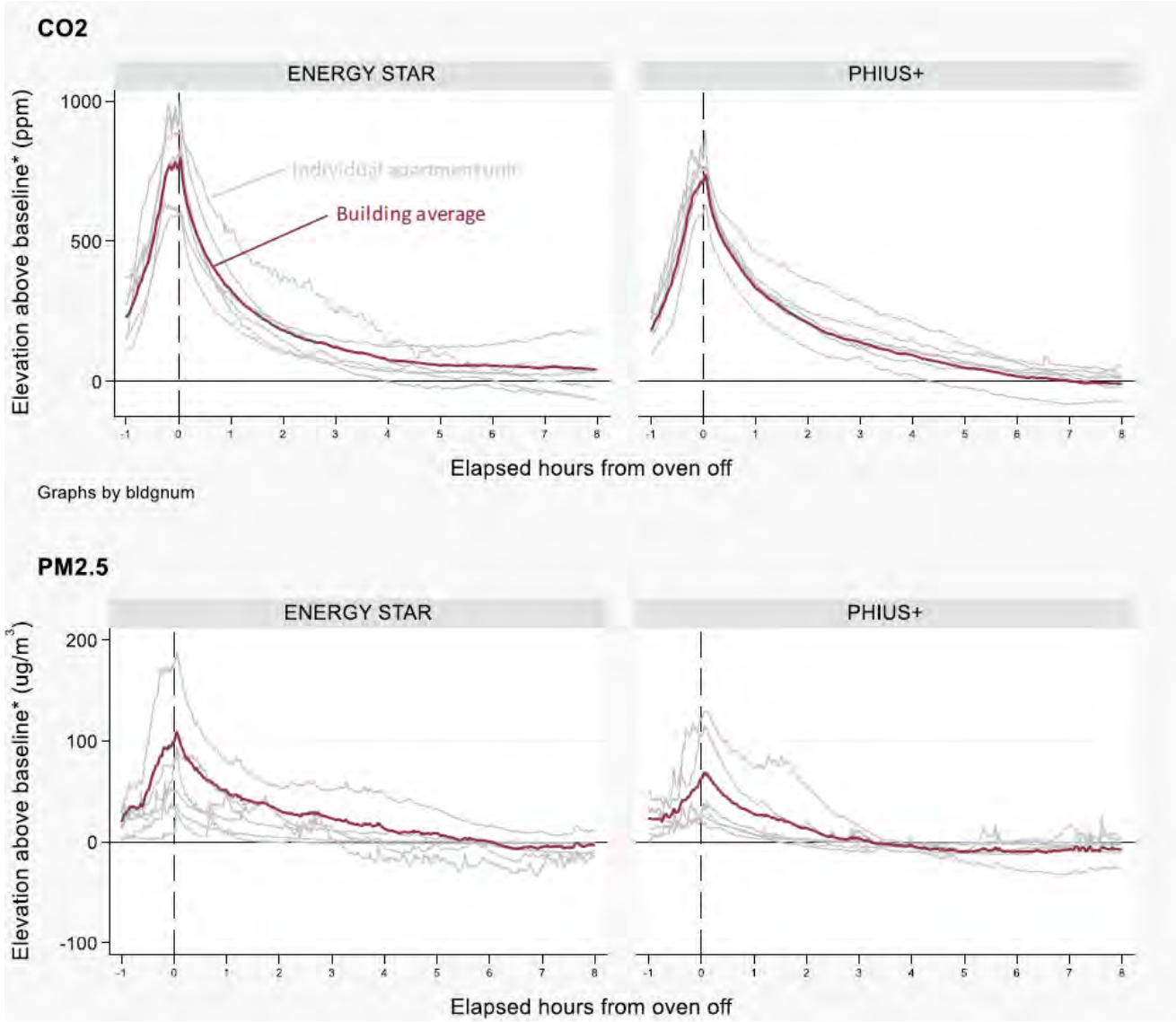
- Average unit ventilation rate for the Energy Star property was approximately 60CFM
- Boosted operation of the fans to 110 CFM was controlled by light switch
- One unit consistently had bathroom lights on
- Other instances ranged between 10%-33% of hours
- If exhaust was only controlled by light switch operation ventilation would be drastically reduced



Oven usage can cause lasting CO2 and PM2.5 spikes

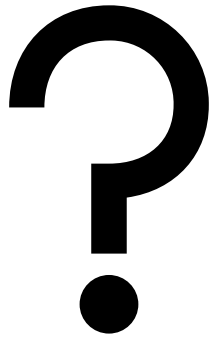
- Over 800 oven use events were recorded
- Energy Star property has a manual range hood used about 40% of days
- PHIUS has an exhaust pickup within 8’ of the oven as part of the ERV
- Combustion of natural gas by the oven itself produces a large plume of CO2 and PM2.5
- The decay of this plume over time following the oven event provides a useful metric sometimes taking over 4 hours to balance below baseline levels

Oven Usage CO2 and PM2.5



PHIUS+ CERTIFICATION

Design → Construction & Commissioning → Occupancy



IMPORTANCE OF MONITORING

- PHIUS+ Certification is based on design, need to verify actual performance
- Quantify real energy/$$ savings
  - Shape incentives from local jurisdictions & rating systems
- Troubleshoot issues
- Adjust energy modeling protocol to improve predicted values

WHO'S RESPONSIBLE?

- This role is critical and often overlooked.
- ***Someone*** must be held accountable for verifying the performance of the building and rectifying any issues
- Design-Build firms have been more successful in the past due to responsibility carried by the same party throughout the process.

PHIUS Monitoring Protocol

FULL REPORT: https://www.phius.org/Tools-Resources/PDF/PHIUS%20Monitoring%20Protocol%20v0.3.pdf

GETTING STARTED: *WHAT'S THE QUESTION?*

1. Does actual energy use match predicted/modeled energy use?
    - If not, why?
    - How steady is the daily electrical load profile?
    - What kind of dashboard would motivate the occupants to save energy?
2. Is thermal comfort being delivered?
3. Is there satisfactory indoor air quality (IAQ)?
4. Is a mechanical system performing as expected?
5. Is an "edgy" moisture design for an assembly staying dry enough?

SELECT EQUIPMENT: *TO ANSWER THE QUESTION*

For Electric, Water, Gas, and Indoor Environment:
PHIUS recommends the Powerwise / Sitesage system

Equipment:

- CTs (current transducers) to measure electricity
- Non-invasive load monitoring (NILM) technologies not as accurate as knowing what you monitor from CT clamps
- Use thermostats that integrate with the monitoring system.
- Wired sensors = more reliable than wireless.

Installation Best Practices:

- Indoor space sensors should be placed 3-6’ above the floor, in a representative thermal zone (not near ceiling).
- Wiring should be done in a place where it can be accessed later for troubleshooting the installation.
- Sensors and meters have an ID #, make sure this is noted during installation.

SELECT EQUIPMENT: *TO ANSWER THE QUESTION*

For Air Quality:

PHIUS recommends the RESET System

- Especially if PM2.5 is a concern.
- RESET is a full air quality standard, setting thresholds/targets/ideal ranges
- RESET provides accreditation for air monitors: https://www.reset.build/monitors

PHIUS MONITORING 'TIERS'

Tiers	0	1	2	3	4	5
Report monthly utility bills, or allow PHIUS access, or Energy Star Portfolio	x	x	x	x	x	x
Monitor electrical mains + plugs		x	x	x	x	-
Monitor indoor temperature			x	x	x	-
Monitor lighting				x	x	-
Monitor major systems (heating, cooling, hot water, ventilation)				x	x	-
Monitor thermostat settings			x	x	x	-
Monitor major appliances, renewables					x	-
Monitor air quality (CO2, VOC, PM2.5, Radon)					x	-
Monitor relative humidity & operative temperatures					x	-
Special situations: moisture in assemblies, site weather, complex mechanicals, etc.						x
Estimated Cost	$0	~$500	~$1000	~ $2000	> $2000	Varies

MONITOR YOUR PROJECT

FREE platforms

1. Energy Star Portfolio Manager
- Input utility data each month
- Benchmark against other similar types

2. WegoHome with Wegowise
- Track, visualize and analyze utility usage
- Benchmark your home against similar buildings
- Measure building upgrade results
- Identify spikes in energy and water usage
- Online login – share with PHIUS

3. Green Button Alliance
- Provides online access to utility bills for 3rd party organizations (PHIUS)
- PHIUS is affiliate of program
- Owner selects PHIUS as acceptable viewer of data

4.Share utility bills w/PHIUS. Get in touch with certification@phius.org to get set up on an automated system.

MONITOR YOUR PROJECT

1. PHIUS+ Project Monitoring Project w/PowerWise
   - 10% discount when PHIUS project
   - ‘Basic’ pre-packaged option already designed

2. PHIUS IAC (Industry Advisory Council) Monitoring Project w/PowerWise
   - Potential funding available for equipment
   - Client pays for design, installation, and maintenance
   - 6 projects assigned, funding available for 30 over time
   - Contact **mknezo@phius.org**

3. WegoData ($1.50/month)
   - Same as WegoHome, but automated

POTENTIAL FACTORS AFFECTING DIFFERENCES BETWEEN MODELED AND MONITORED

- Varying heating setpoint above/below 68°F
- Varying cooling setpoint above/below 77 ° F
- Climatic differences between measured year and ‘typical year’ used for modeling
- Varying number of occupants from modeled assumption (BR+1)
- Occupant behavior (work from home, kids vs adults, lifestyle, habits)
- Equipment tested *efficiency* varying from real performance
- System malfunction

STELLAR APARTMENTS

Eugene, OR

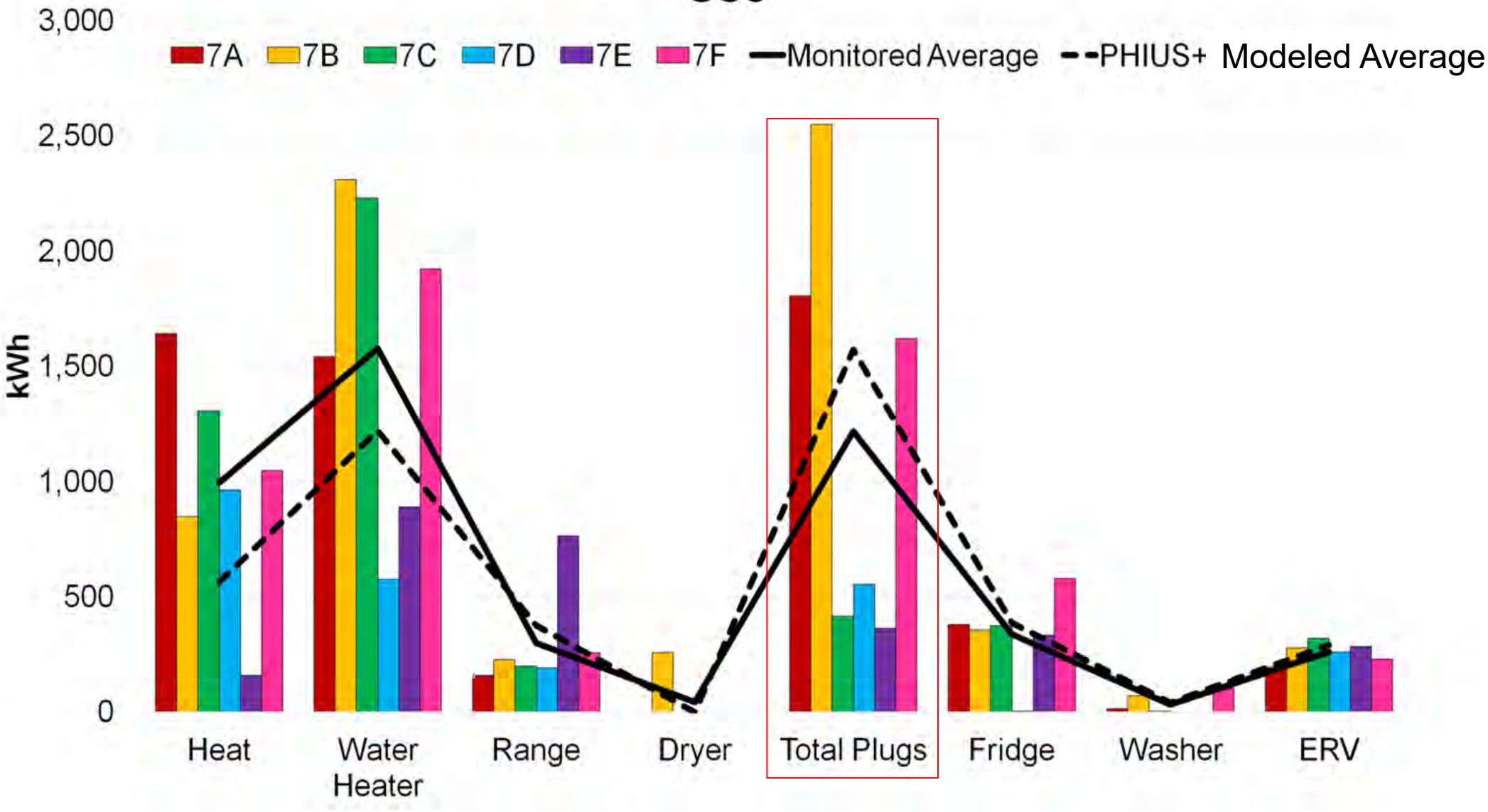
6 units

5,488 ft^2

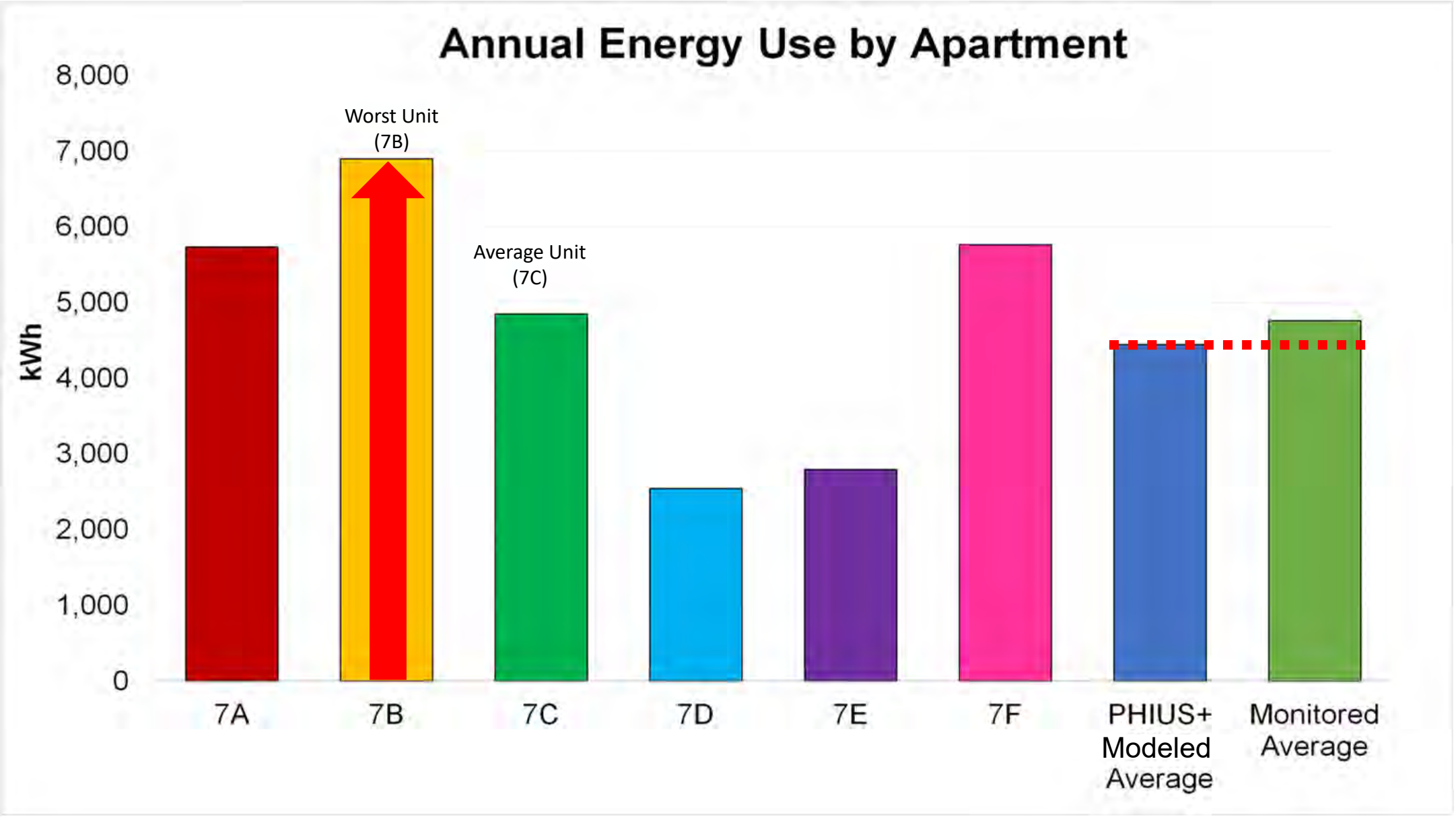
- 8 Meters per unit
- No common spaces
- Electric Heating
- No Cooling
- Heat Pump Water Heaters in outdoor mech closet

STELLAR APARTMENTS

Individual Apartment Energy Use vs Average Energy Use



STELLAR APARTMENTS



BEACH GREEN DUNES – CASE STUDY

FAR ROCKAWAY, QUEENS

BEACH GREEN DUNES

Wegowise Portal

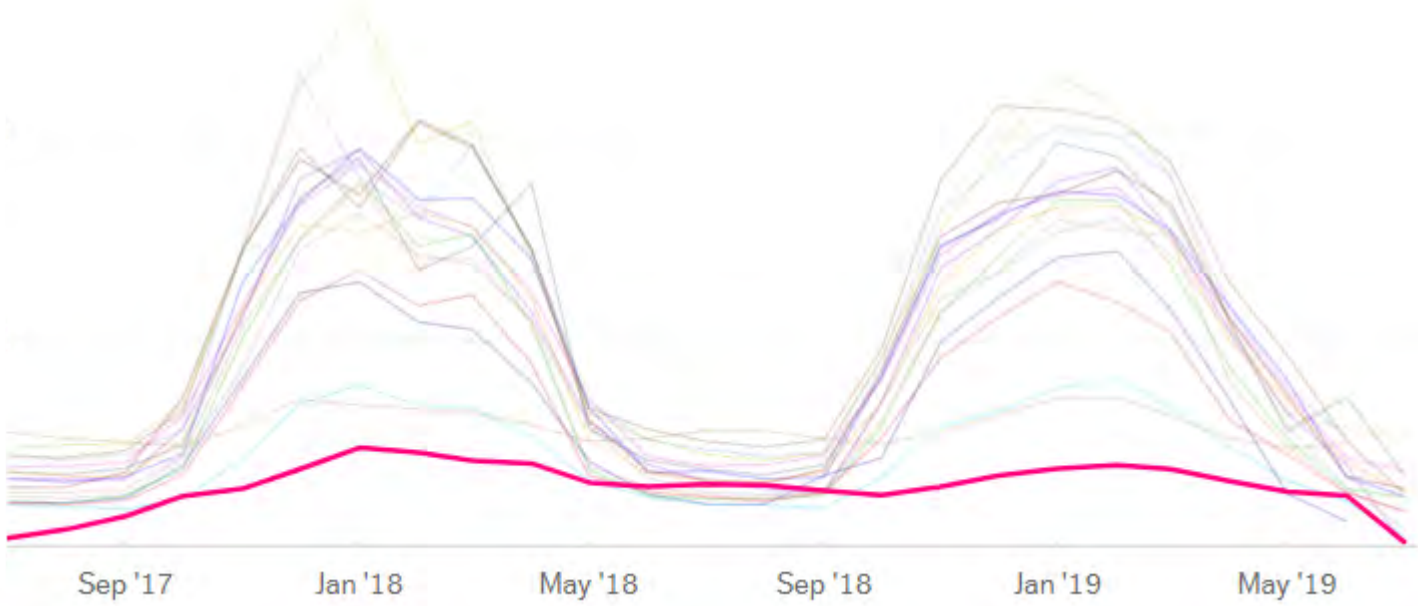
Total energy use in Btu per square foot

Name	Full-Year Sum
43-06 63rd St	91.8k
Flushing Steam Buildin...	85.8k
140-74 34th Avenue	84.8k
138-49 Barclay Avenue	77.6k
95-11 64th Rd	75k
28 Gilchrest Rd	74.2k
141-28 84th Drive	73.7k
Austin St	70.5k
113th St	69.1k
99-22 67th Rd	63k
Kew Gardens	61.7k
140-26 Franklin Avenue	60.5k
9 Chelsea Place	50.9k
193-04 Horace Harding	48.9k
90-11 160th St	41.7k
65-54 Austin St	32.7k
BGN	22.6k

Detailed data per month

You are currently viewing the last 2 years of data only

Zoom out



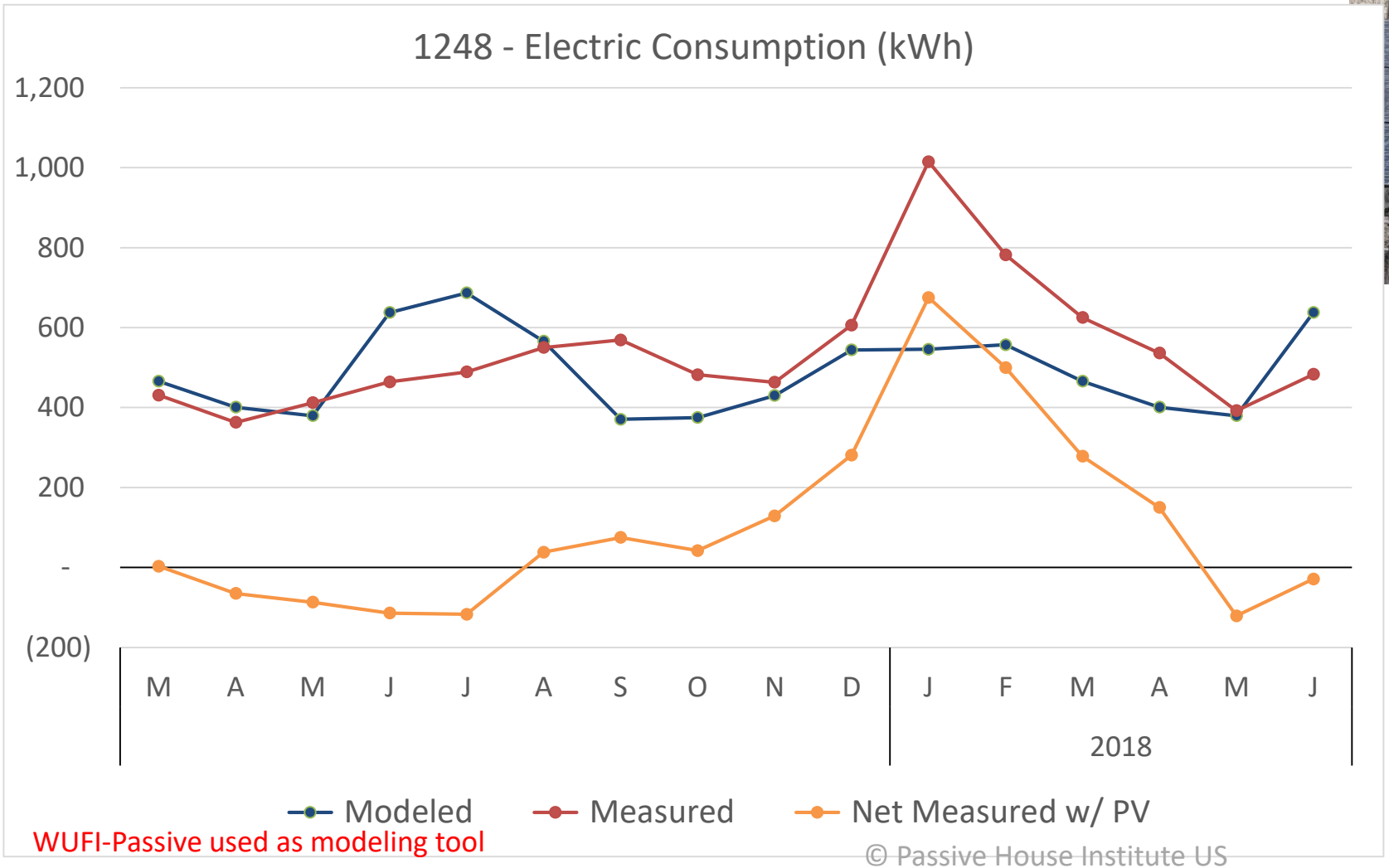
BEACH GREEN DUNES

Name	Full-Year Sum	
140-74 34th Avenue	84.8k*	
138-49 Barclay Avenue	77.6k*	
95-11 64th Rd	75k	
28 Gilchrest Rd	74.2k*	
141-28 84th Drive	73.7k*	
Austin St	70.5k*	
113th St	69.1k*	
99-22 67th Rd	63k*	
Kew Gardens	61.7k*	
140-26 Franklin Avenue	60.5k*	
9 Chelsea Place	50.9k*	
193-04 Horace Harding	48.9k*	
90-11 160th St	41.7k	✓
65-54 Austin St	32.7k	
BGN	22.6k*	✓

Differences
Ventilation & Airtightness

LOUGHRAN RESIDENCE

93% Modeled vs Actual

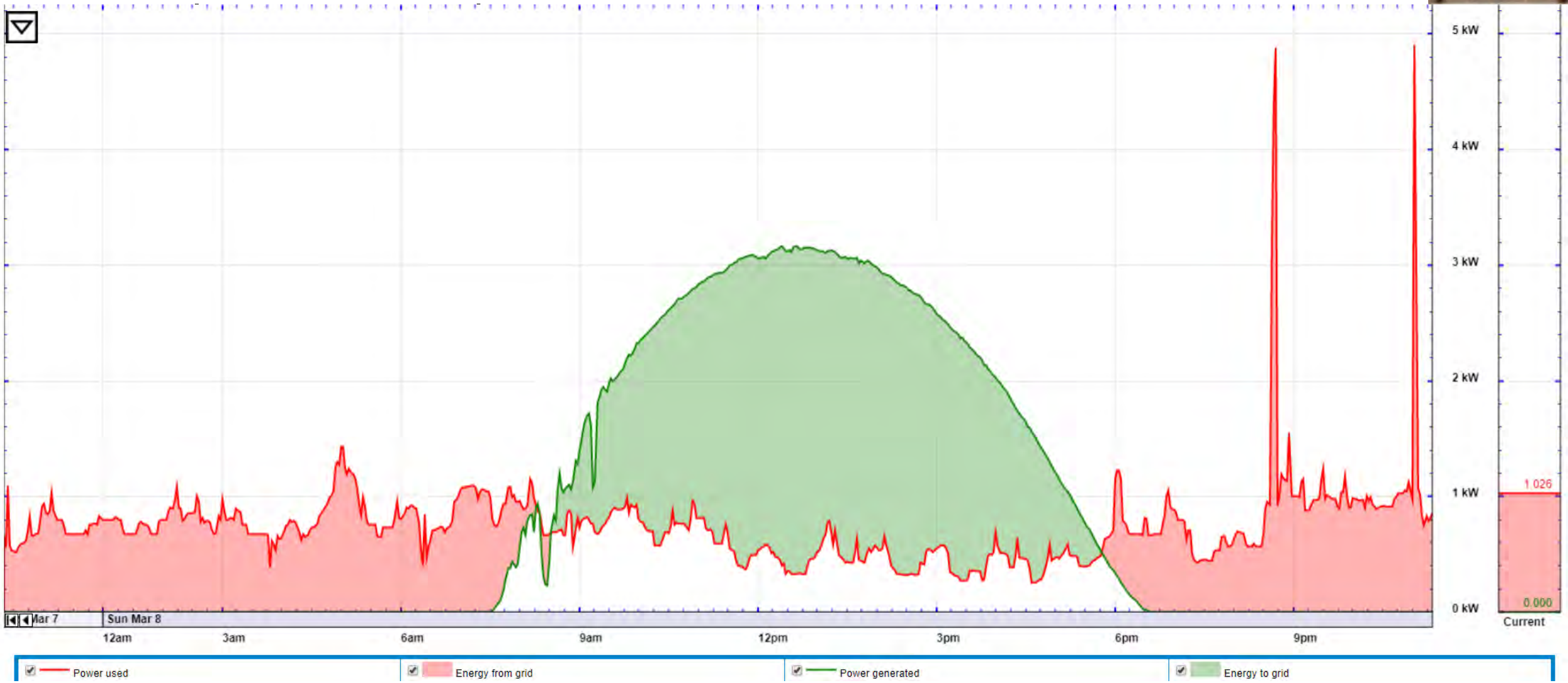


Type: Single family
Occupants: 4
Location: Illinois
CPHC: Ryan Abendroth

WUFI-Passive used as modeling tool

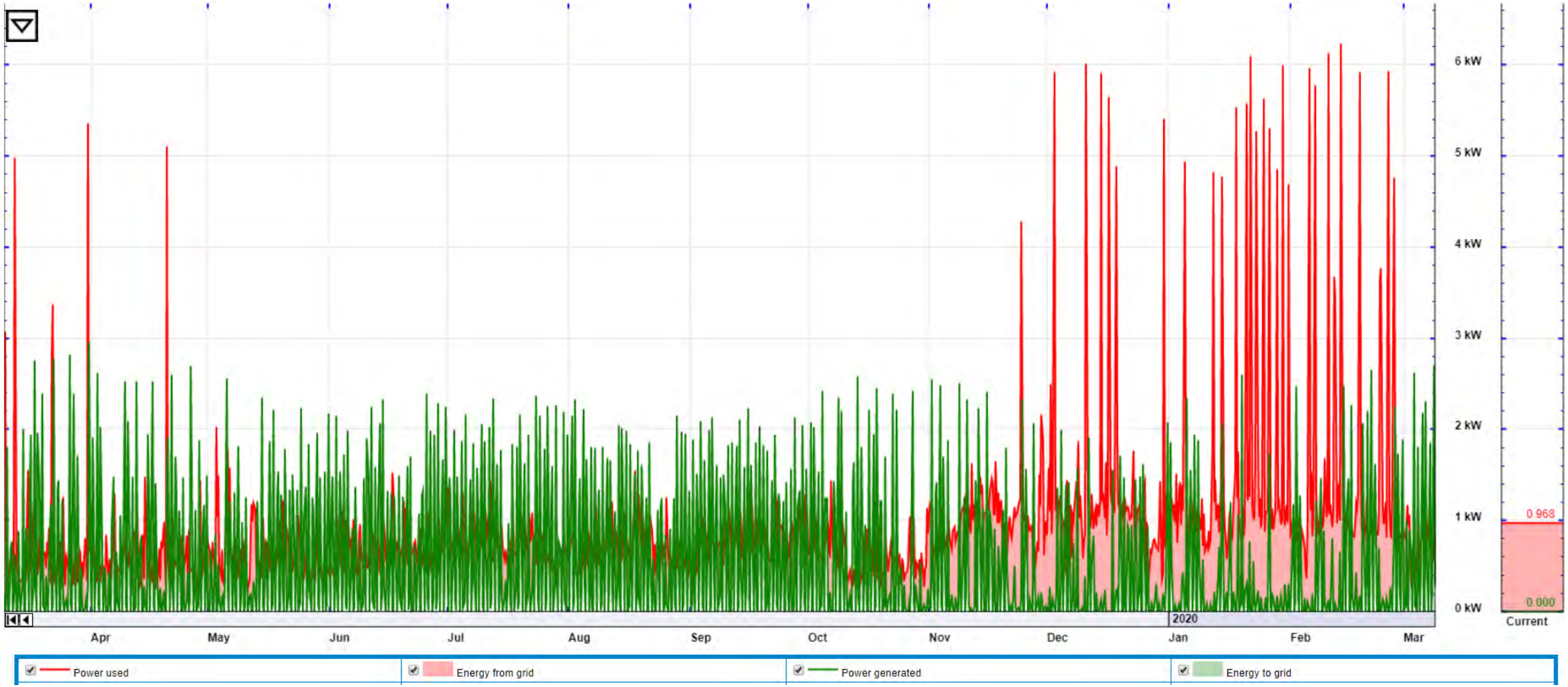
LOUGHRAN RESIDENCE

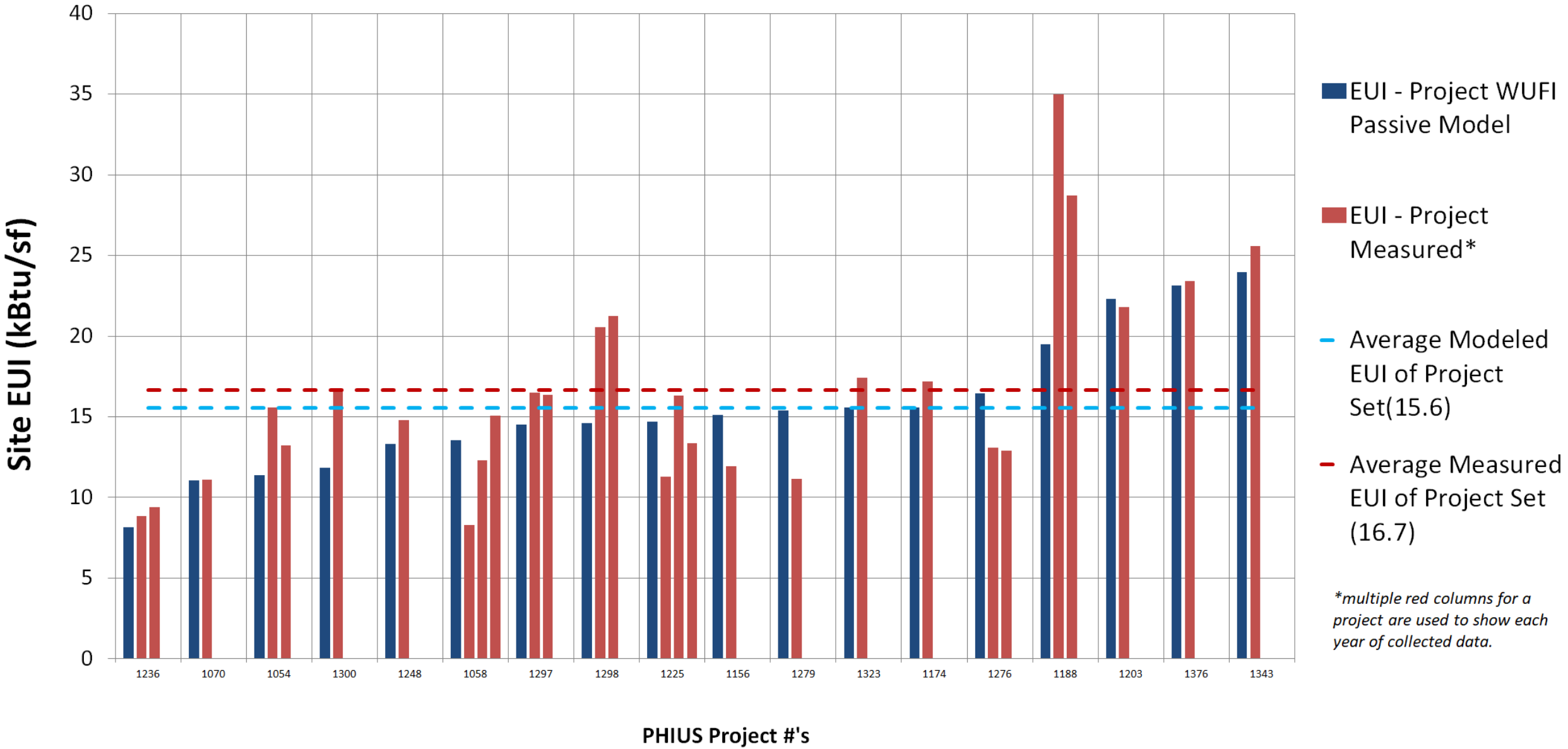
Sitesage Portal



LOUGHRAN RESIDENCE

March 2019 - March 2020




Site EUI (kBtu/sf)
40
35
30
25
20
15
10
5
0
1236
1070
1054
1300
1248
1058
1297
1298
1225
1156
1279
1323
1174
1276
1188
1203
1376
1343
PHIUS Project #'s
EUI - Project WUFI Passive Model
EUI - Project Measured*
Average Modeled EUI of Project Set(15.6)
Average Measured EUI of Project Set (16.7)
*multiple red columns for a project are used to show each year of collected data.

LESSONS LEARNED *from PHIUS+ project teams*

- Assigning roles/responsibilities upfront is critical.
  Need a point of contact for design, installation, monitoring, debugging, resident.

- Monitoring never seems to be a priority, just “nice to have”.
  Hard to place priority on that over other budgetary/time constraints.

- Systems work incorrectly (or not at all) quite often. Meters also break.
  Whose responsibility is it to check up on that, and then fix it?

- Monitoring should be part of the design process at the start, not finish.
  And maintained throughout all phases of design.

- Critical to follow through with plan during construction.
  And inspect/track after final installation.


THANKS!