425 Grand Concourse, NY, NY

PHIUS

www.phius.org

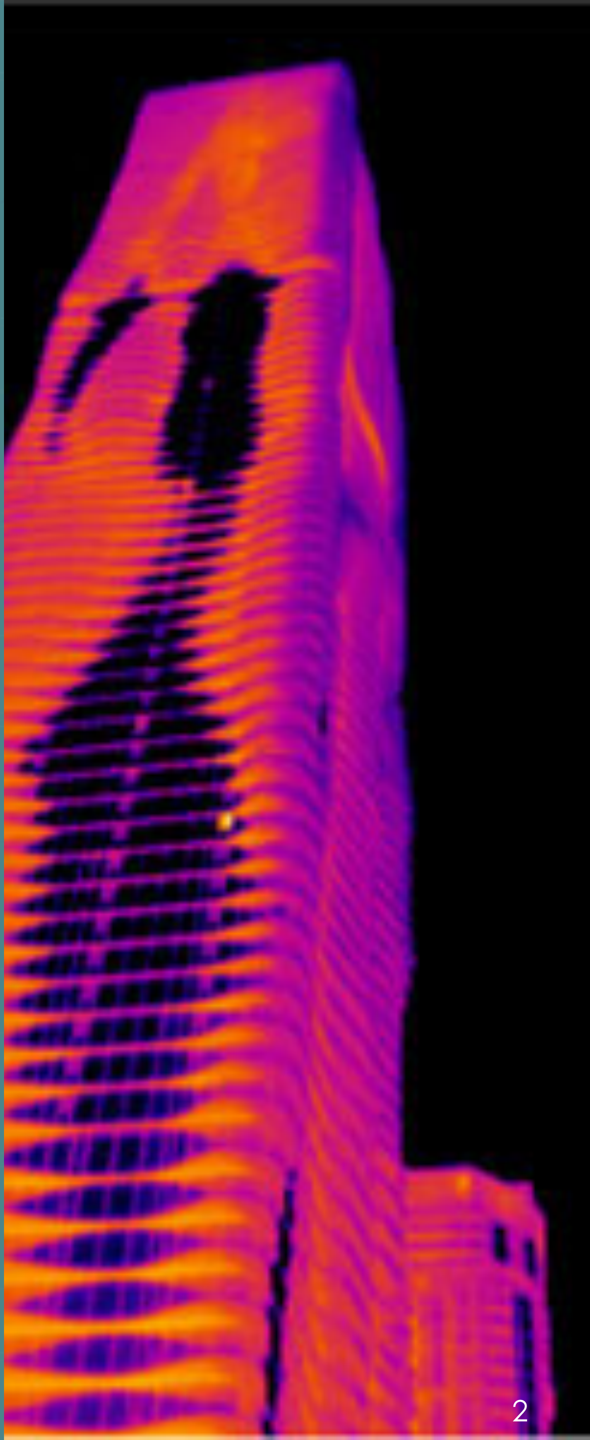
PASSIVE BUILDING CASE STUDIES

LESSONS LEARNED

PASSIVE BUILDING

CONTEXT & TRENDS
PRINCIPLES & STANDARDS
LESSONS LEARNED

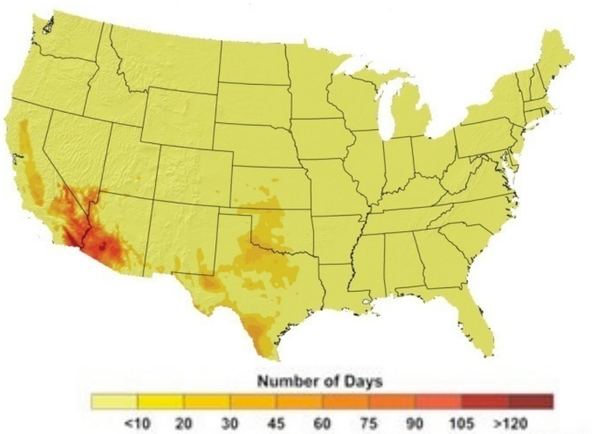
NEXT FRONTIERS



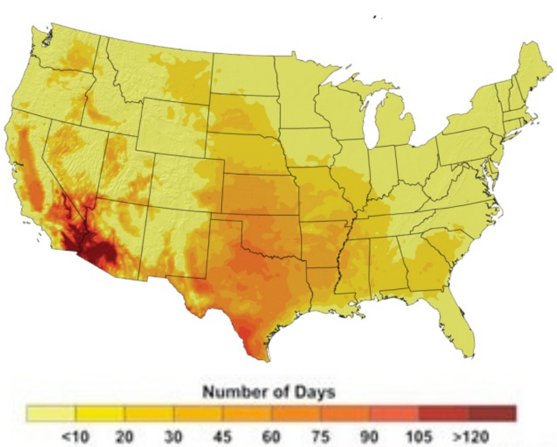
OUR CLIMATE IS CHANGING

The number of days in which the temperature exceeds 100˚F/ 38˚C by late this century

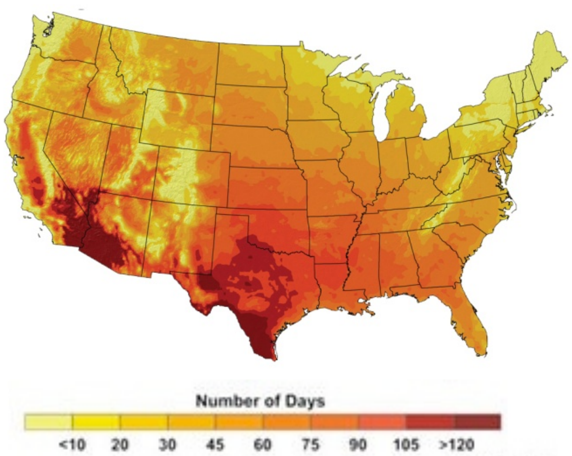
Recent Past, 1961 - 1979



Lower Emissions Scenario, 2080-2099

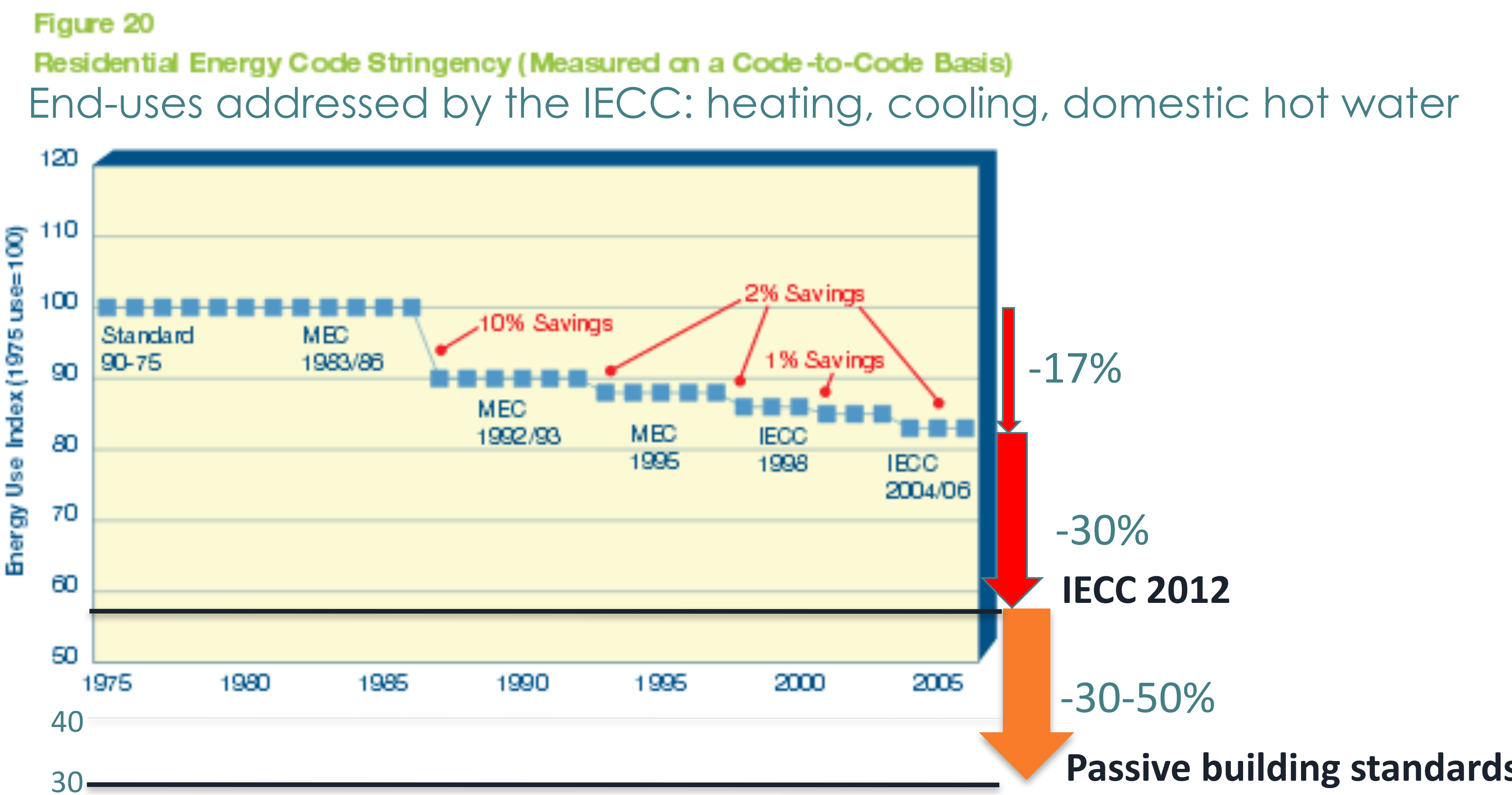


Higher Emissions Scenario, 2080-2099



temperature map images: U.S. Global Change Research Program

WHERE TODAY'S US ENERGY CODES ARE - DEVELOPMENT SINCE THE **ENERGY CRISIS**



(Source : U.S. Department of Energy: Energy Efficiency Trends in Residential and Commercial Buildings)

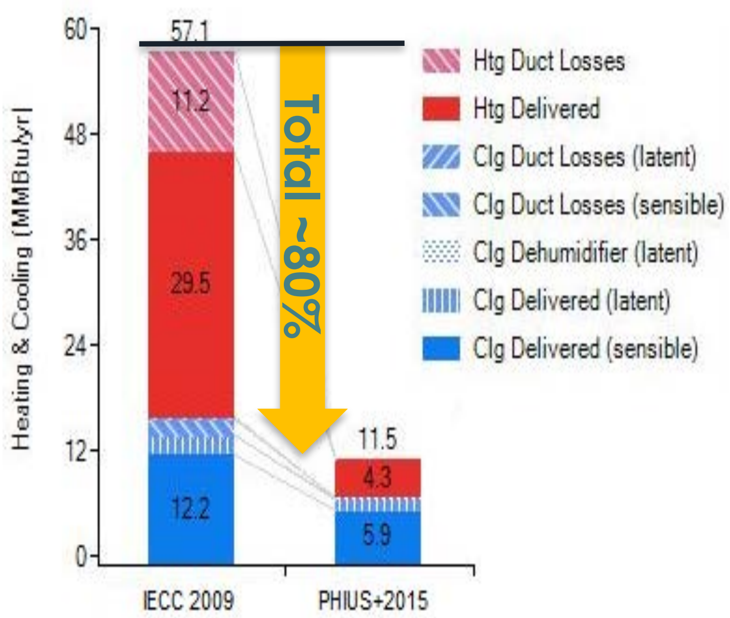
PHIUS+2015/SOURCE ZERO NEXT STEP ON:
DEPARTMENT OF ENERGY PERFORMANCE STAIRCASE

IECC 2009	IECC 2012	ENERGY STAR v3	ENERGY STAR v3.1	ZERH	PHIUS+	PHIUS+ SourceZero
						Source Zero Renewable Energy System
					Balanced Ventilation HRV/ERV	Balanced Ventilation HRV/ERV
				SOLAR READY Depends on climate	SOLAR READY ALWAYS	SOLAR READY ALWAYS
				Eff. Comps. & H2O Distrib	Eff. Comps. & H_2O Distrib	Eff. Comps. & H_2O Distrib
				EPA Indoor Air Pacakge	EPA Indoor Air Pacakge	EPA Indoor Air Pacakge
				Ducts in Condit. Space	Ducts in Condit. Space	Ducts in Condit. Space
		HVAC QI w/WHV	HVAC QI w/WHV	HVAC QI w/WHV	Micro-load HVAC QI	Micro-load HVAC QI
		Water Management	Water Management	Water Management	Water Management	Water Management
		Independent Verification	Independent Verification	Independent Verification	Independent Verification	Independent Verification
IECC 2009 Enclosure	IECC 2012 Enclosure	IECC 2009 Enclosure	IECC 2012 Enclosure	IECC 2012/15 Encl./ES Win.	Ultra-Efficient Enclosure	Ultra-Efficient Enclosure
HERS 85-90	HERS 70-80	HERS 65-75	HERS 55-65	HERS 48-55	HERS 35-45	HERS < 0

PHIUS+2015 REDUCTION VS USA CODE

Table 16. All-Points Median Percentage Reductions From Benchmark

	Proposed Standards (With Duct Loss in Benchmark)	Proposed Standards (Excluding Duct Loss)	PV Start Points (Excluding Duct Loss)
Heating Demand	~86	77	68
Cooling Demand	~46	29	35
Heating Capacity	77	77	74
Cooling Capacity	69	69	67



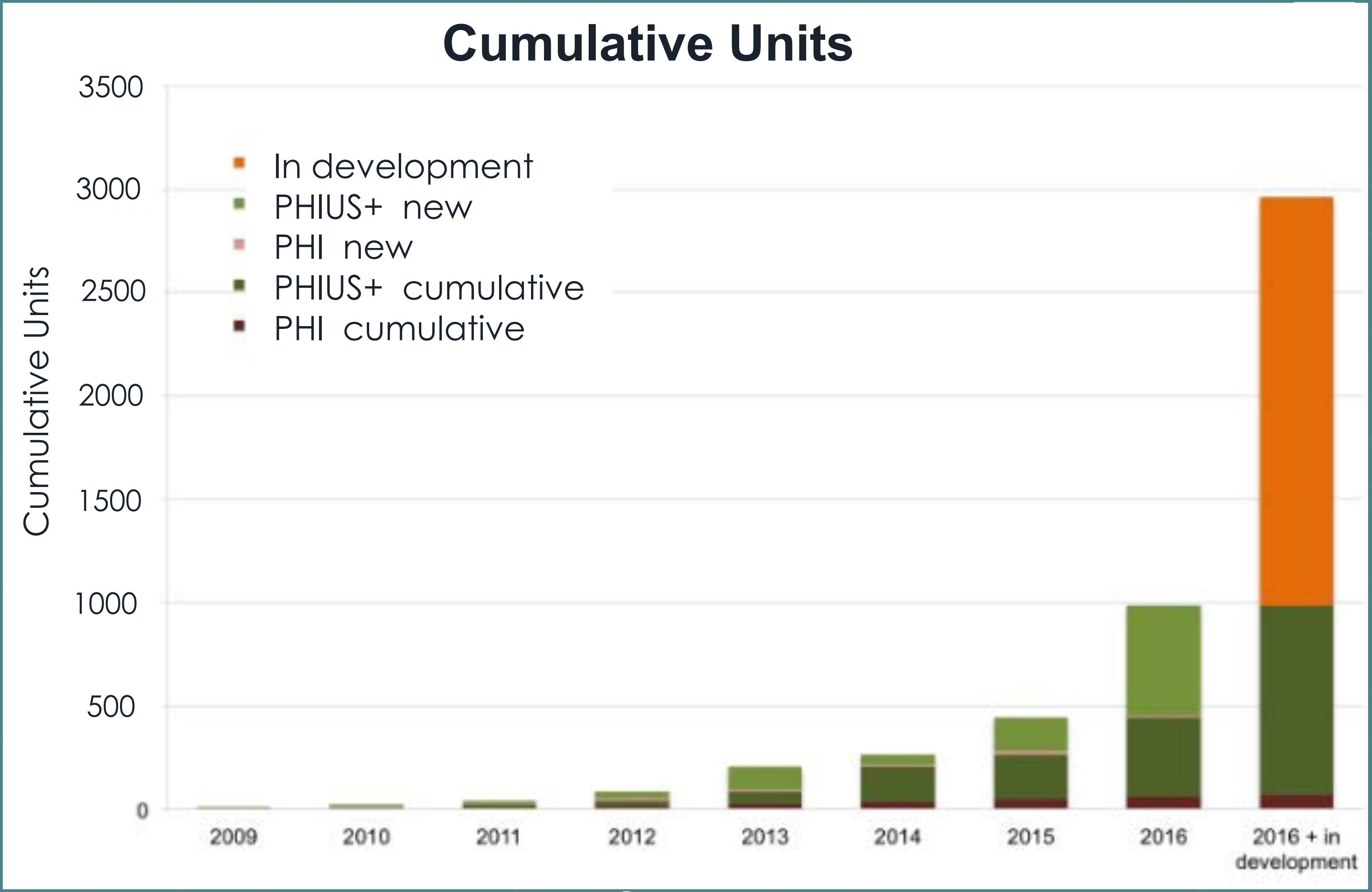
WITHOUT ADDING SOLAR PV PASSIVE STANDARDS PERFORM TODAY AT 80% OF THE **2030 CHALLENGE**

U.S. Averages for Site Energy Use and 2030 Challenge Energy Reduction Targets by Space/Building Type[1] From the Environmental Protection Agency (EPA): Use this chart to find the site fossil-fuel energy targets									
Primary Space / Building Type[2]	Available in Target Finder[3]	Average Source EUI[4] (kBtu/Sq.Ft./Yr)	Average Percent Electric	Average Site EUI[4] (kBtu/Sq.Ft./Yr)	2030 Challenge Site EUI Targets (kBtu/Sq.Ft./Yr)				
					50% Target	60% Target	70% Target	80% Target	90% Target
Residential Space / Building Type[6, 7]									
Single-Family Detached		76.6	-	43.8	**21.9**	17.5	13.1	8.8	4.4
Single-Family Attached		70.7	-	43.7	**21.9**	17.5	13.1	8.7	4.4
Multi-Family, 2 to 4 units		93.2	-	58.2	**29.1**	23.3	17.5	11.6	5.8
Multi-Family, 5 or more units		99.4	-	49.5	**24.8**	19.8	14.9	9.9	5.0
Mobile Homes		153.2	-	73.4	**36.7**	29.4	22.0	14.7	7.3

Source: www.architecture2030.org

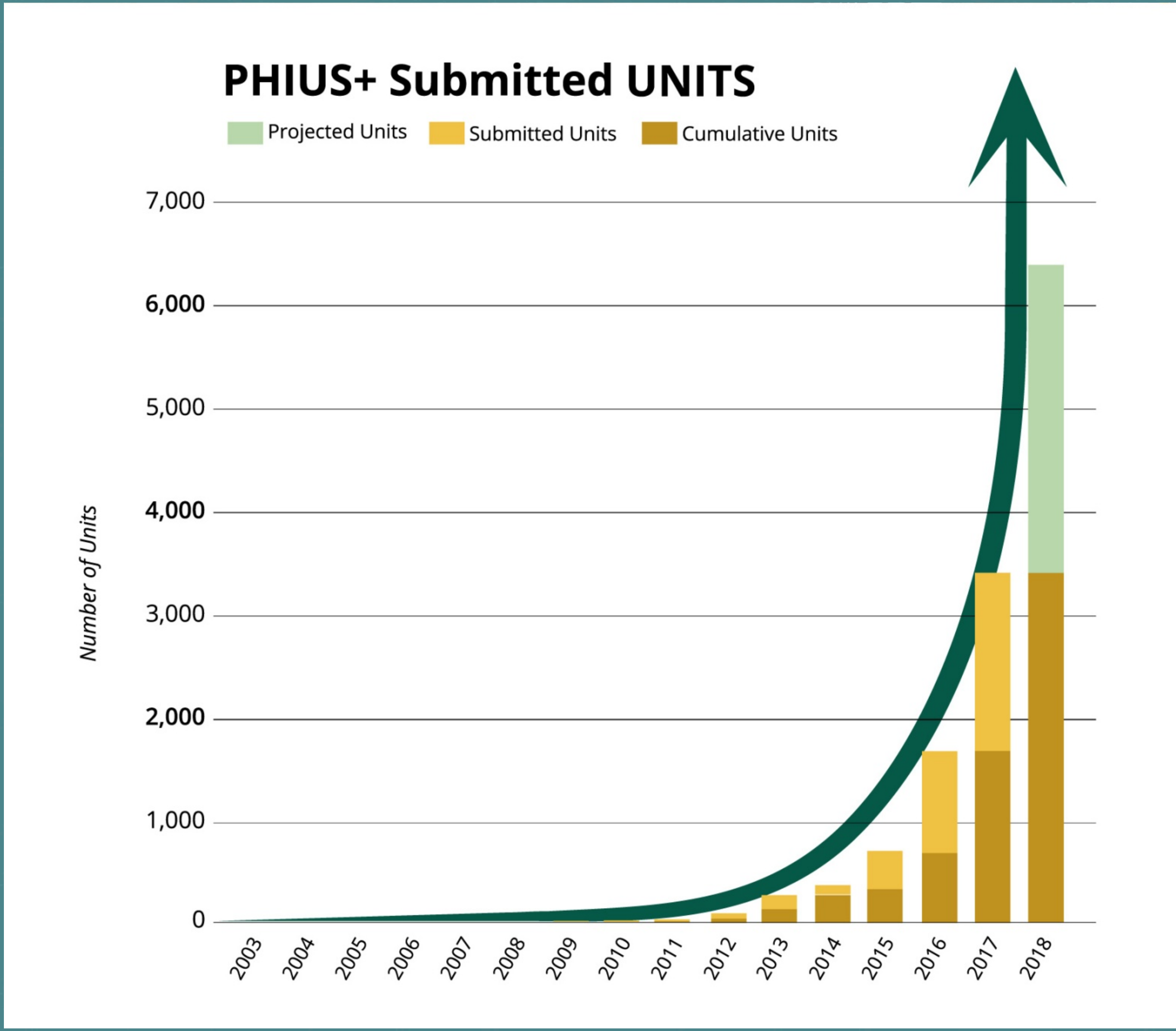
CERTIFICATION TRENDS IN NA:

95% of US certified m² = PHIUS+



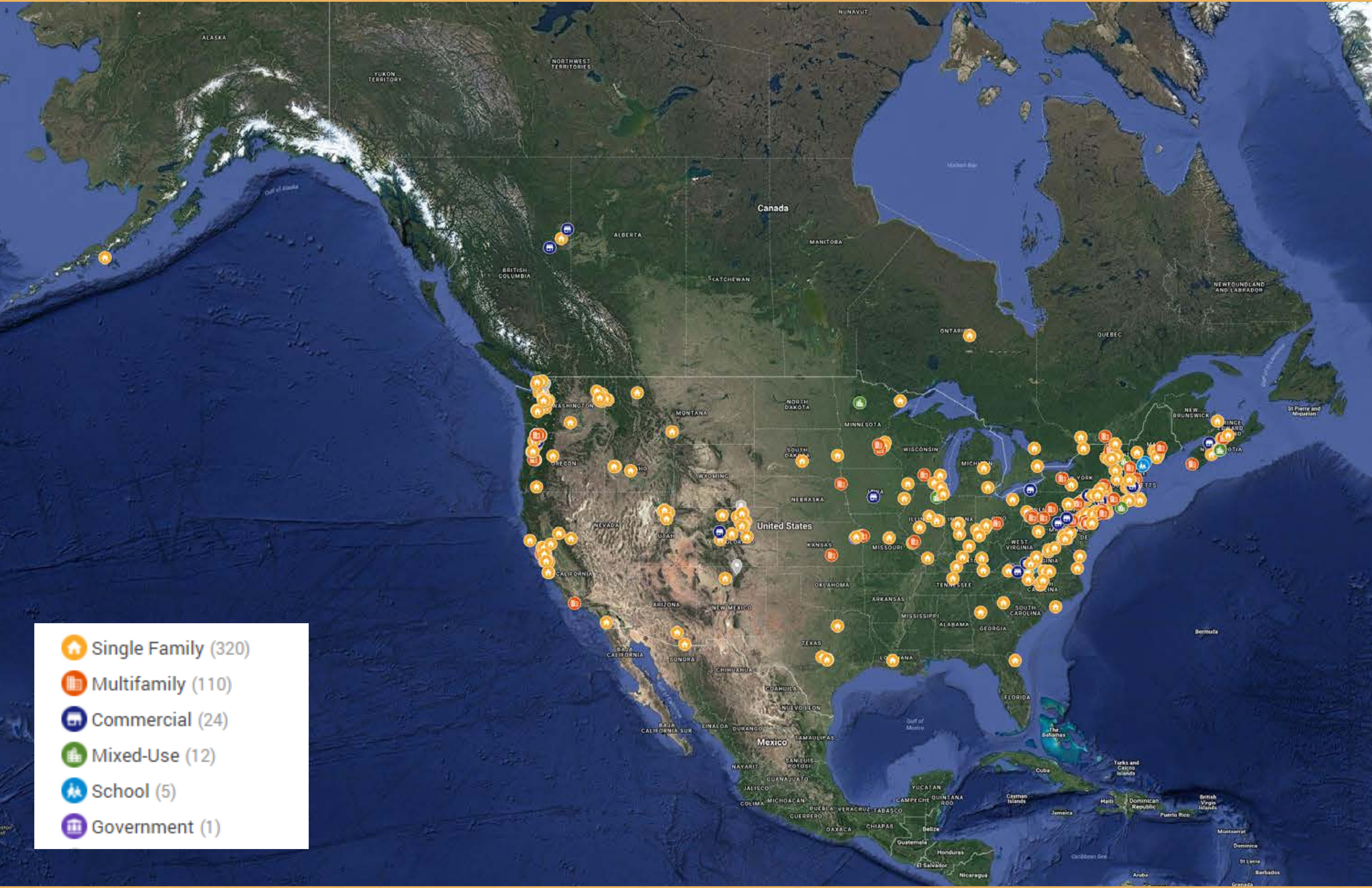
Source: www.pembina.org/pub/passive-house-report

PASSIVE HOUSE US DATABASE



Source: www.phius.org

~500+ PROJECTS IN NORTH AMERICA



PROJECTS NATIONWIDE

80+ MULTIFAMILY SUBMITTED, PRE-CERTIFIED, CERTIFIED

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

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

LEGISLATION & INCENTIVES

MASSACHUSETTS SIGILLUM REIPUBLICÆ

CITY OF VANCOUVER

NEW YORK STATE OF OPPORTUNITY. | NYSERDA

NYC

seattle.gov

PRIORITYGREEN
Streamlining Sustainable Development

SF Environment
Our home. Our city. Our planet.

US DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT

CONNECTICUT HOUSING FINANCE AUTHORITY
The Key To Affordable Housing

ILLINOIS HOUSING DEVELOPMENT AUTHORITY

Homes and Community Renewal

PHFA

Enterprise®

ORCHARDS AT ORENCO I+II, HILLSBORO OREGON

ELM PLACE

Burlington, VT
30 Units
DWA/Cathedral Square
$183/sf (1-2% upcharge)

CHOM

CHOM, Portland, ME,
45 Units
Thornton Tomasetti
2.5% upcharge

ELM PLACE, BURLINGTON VERMONT
CHOM, PORTLAND MAINE

HILLCREST

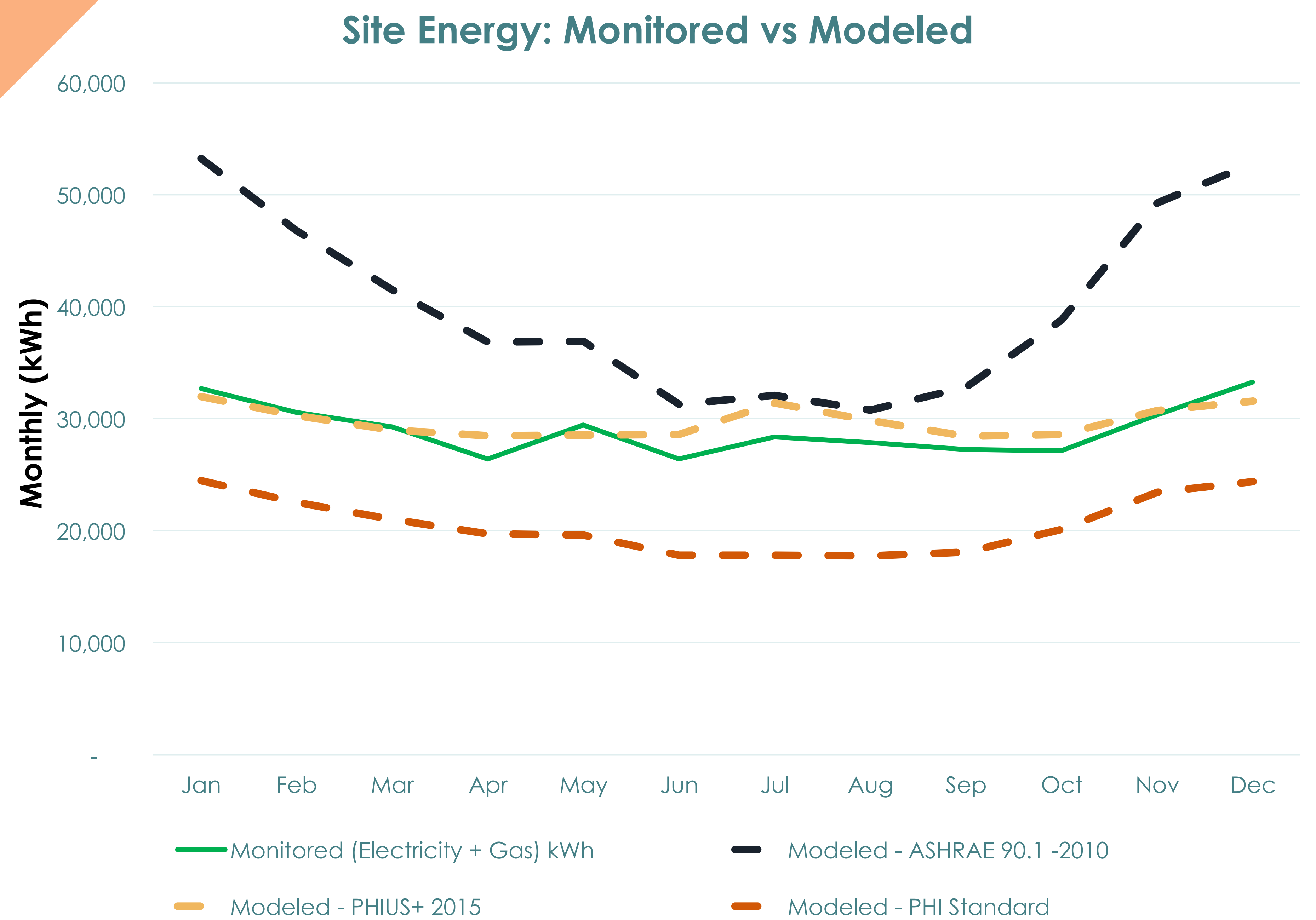
Pittsburgh, PA

66 Units

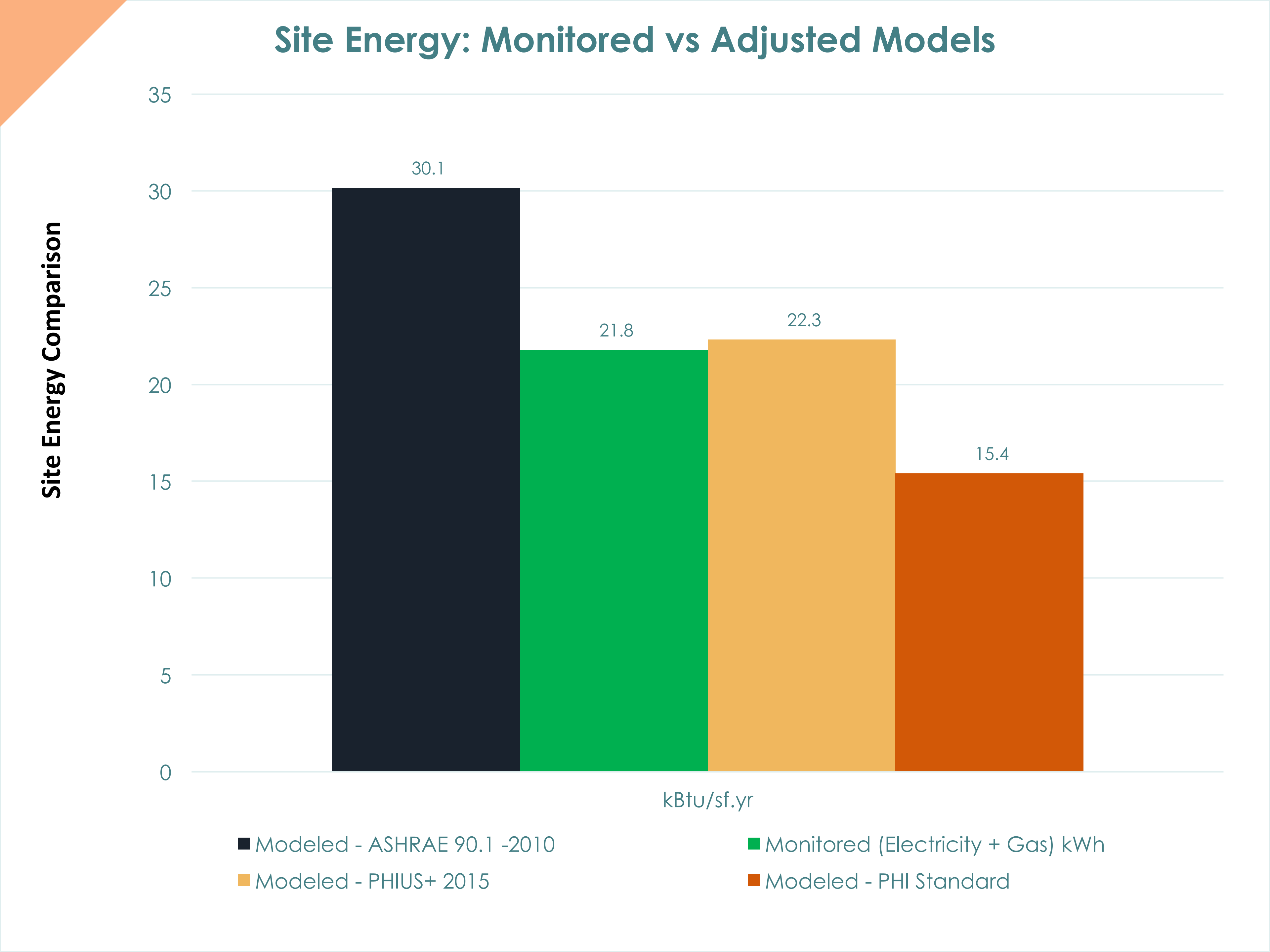
Community Builders/RDL/Sota

$150/sf: 2% above code building

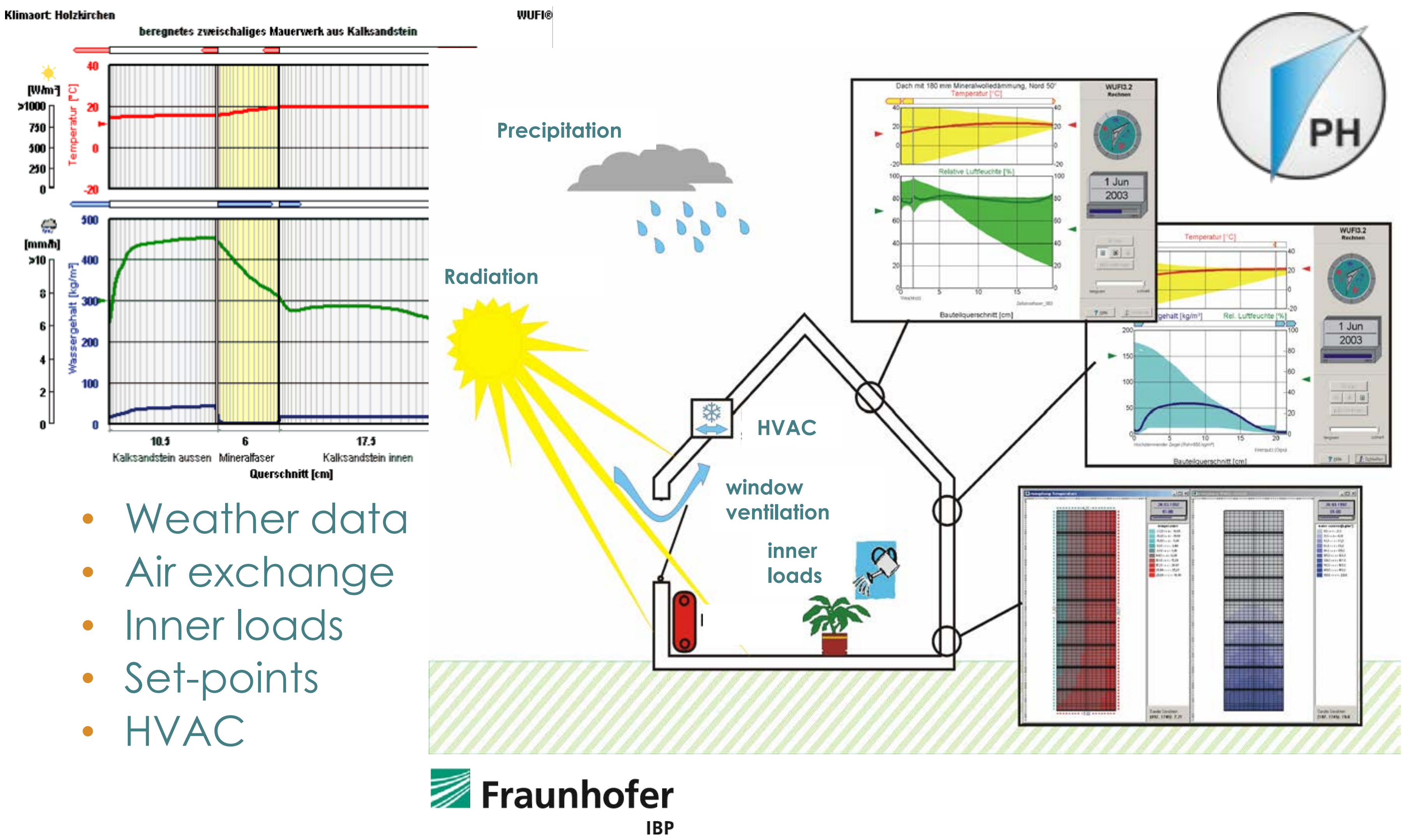
HILL CREST, PITTSBURGH PA



Site Energy: Monitored vs Modeled
Monthly (kWh)
60,000
50,000
40,000
30,000
20,000
10,000
-
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Monitored (Electricity + Gas) kWh
Modeled - ASHRAE 90.1 -2010
Modeled - PHIUS+ 2015
Modeled - PHI Standard

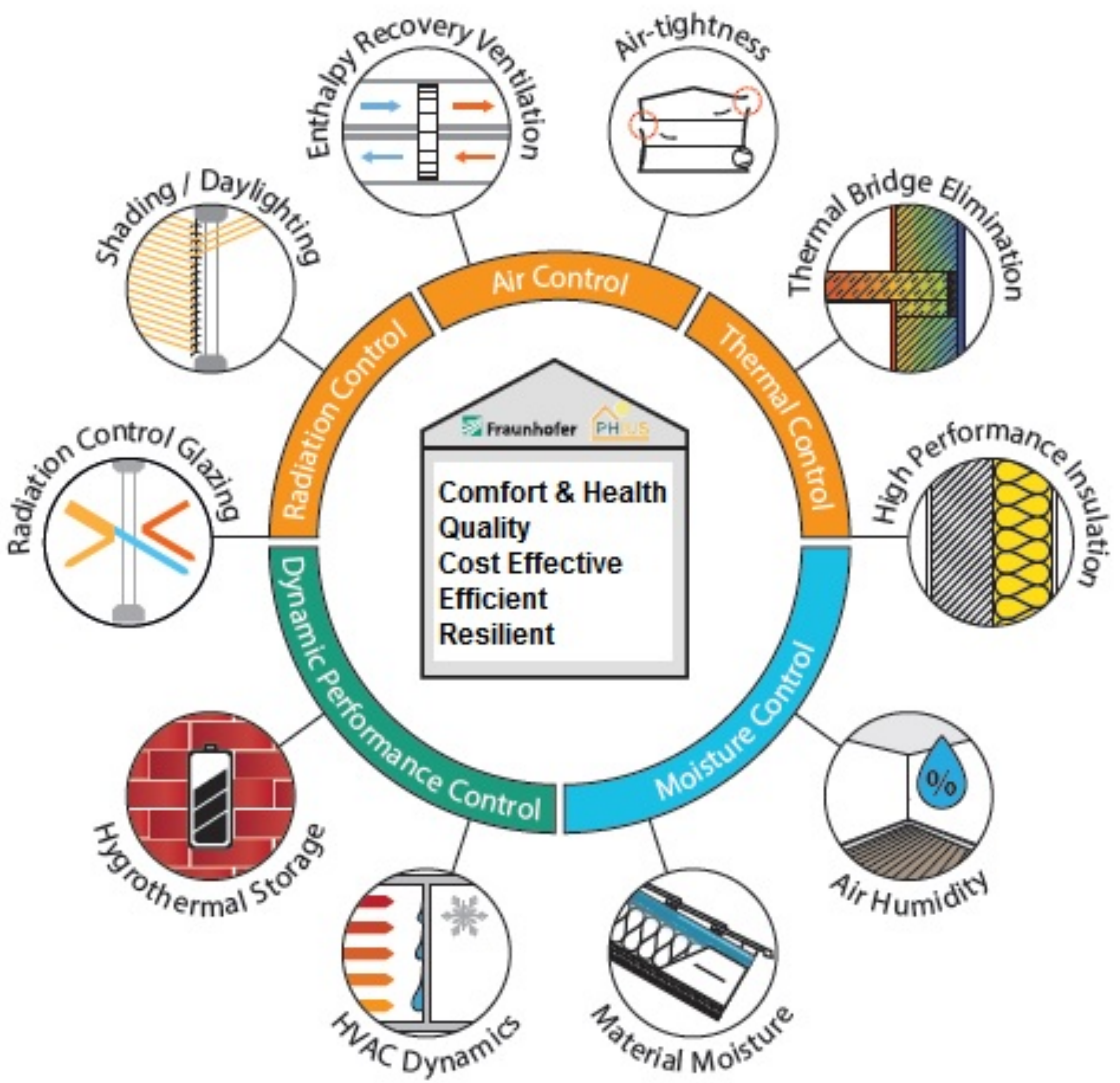

Site Energy: Monitored vs Adjusted Models
Site Energy Comparison
35
30
25
20
15
10
5
0
30.1
21.8
22.3
15.4
kBtu/sf.yr
Modeled - ASHRAE 90.1 -2010
Monitored (Electricity + Gas) kWh
Modeled - PHIUS+ 2015
Modeled - PHI Standard

INTEGRATED DESIGN FROM COMPONENTS TO WHOLE BUILDING ENERGY BALANCE



- Weather data
- Air exchange
- Inner loads
- Set-points
- HVAC

PASSIVE BUILDING PRINCIPLES



PHIUS+ 2015

PASS/FAIL PERFORMANCE STANDARD

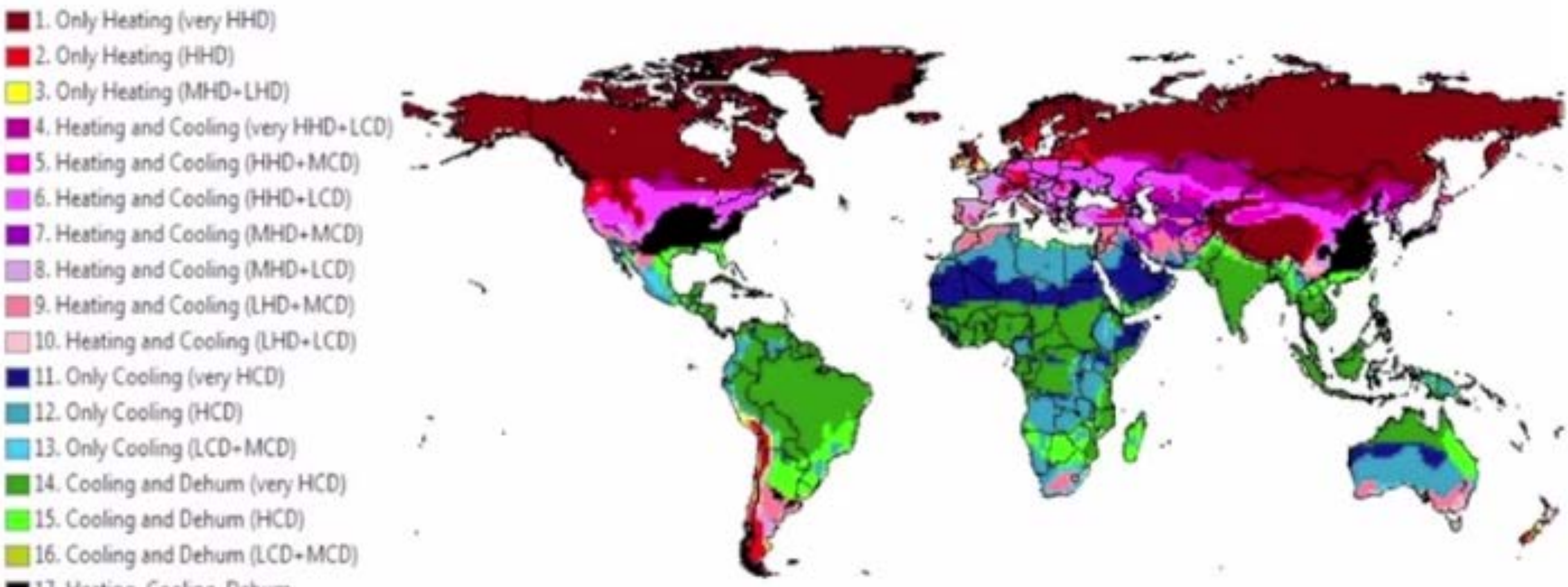
3 PERFORMANCE "PILLARS"

1. Space Conditioning
2. Source Energy
3. Air-Tightness

1 ADDITIONAL CERTIFICATION

1. PHIUS+ Source Zero

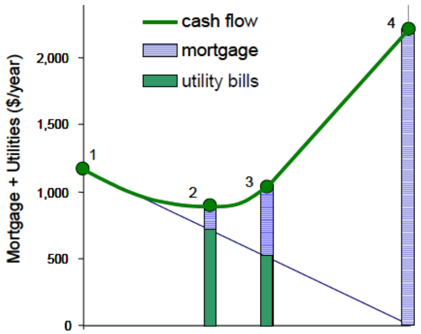
CLIMATE SPECIFIC STANDARDS: ONE SIZE DOES NOT FIT ALL



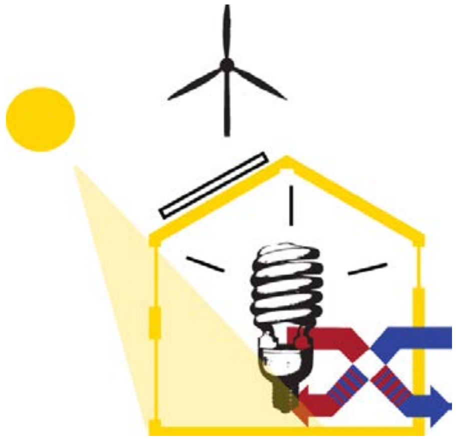
Graph Courtesy of Global Buildings Performance Network

COST & CLIMATE OPTIMIZED

Climate Specific & Cost Optimal Standards



NREL BEopt optimizes upgrade package by climate



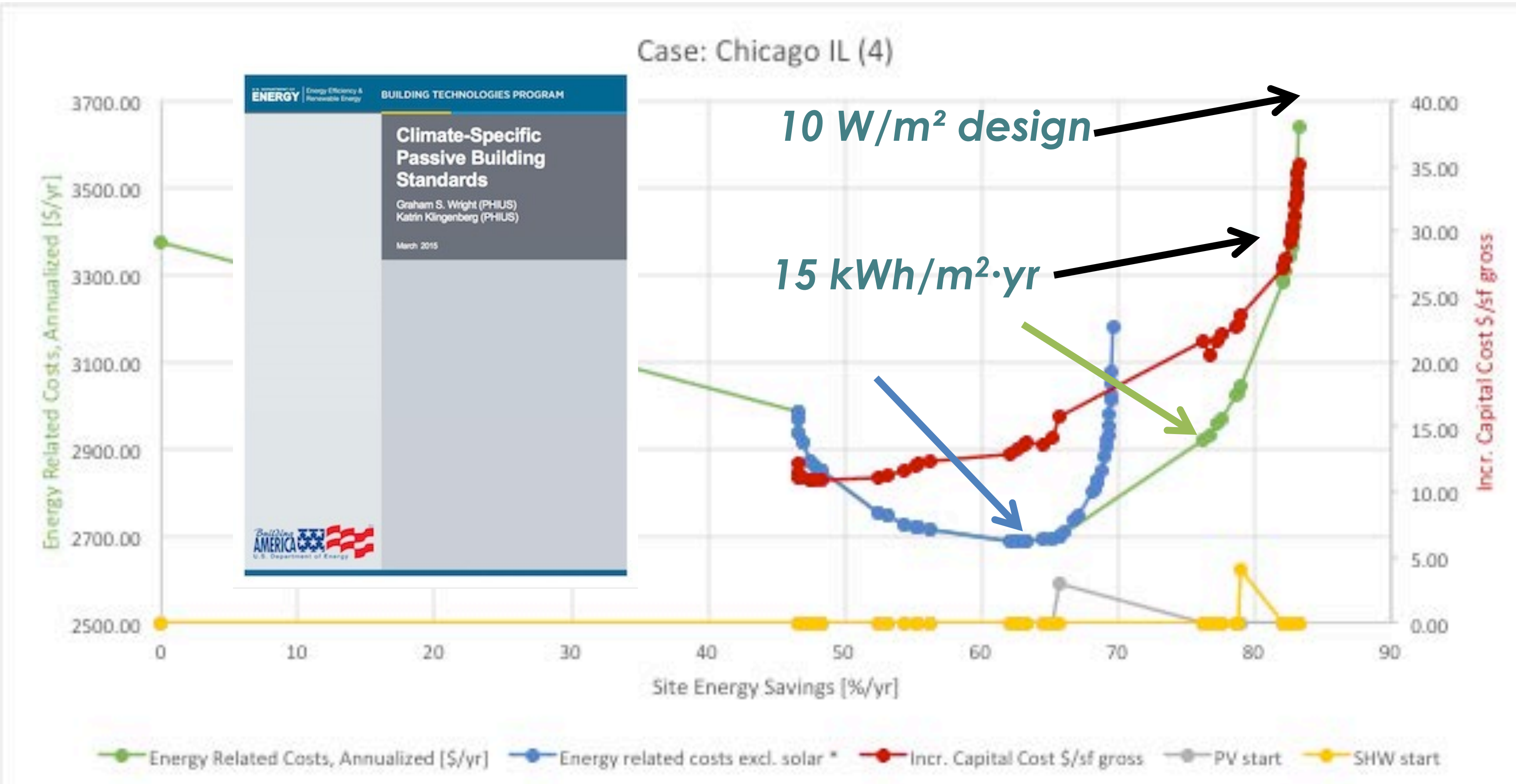
Standards defined as cost optimal/competitive sweetspot between conservation and generation

on the path to zero

CERTIFICATION TARGETS

	PHIUS+ 2015
Annual Heat Demand (kBTU/ft^2.yr)	Varies by Climate
Annual Heating Load (BTU/ft^2.hr)	Varies by Climate
Annual Cooling Demand (kBTU/ft^2.yr)	Varies by Climate
Annual Cooling Load (BTU/ft^2.hr)	Varies by Climate
Airtightness	*0.05 cfm/ft^2 (Based on Envelope Area)
Source Energy Factor (Residential)	6,200 kWh/person.yr

COST MATTERS AND HAS TO BE DEALT WITH - STANDARDS WERE SET JUST PAST THE **ECONOMIC** OPTIMUM

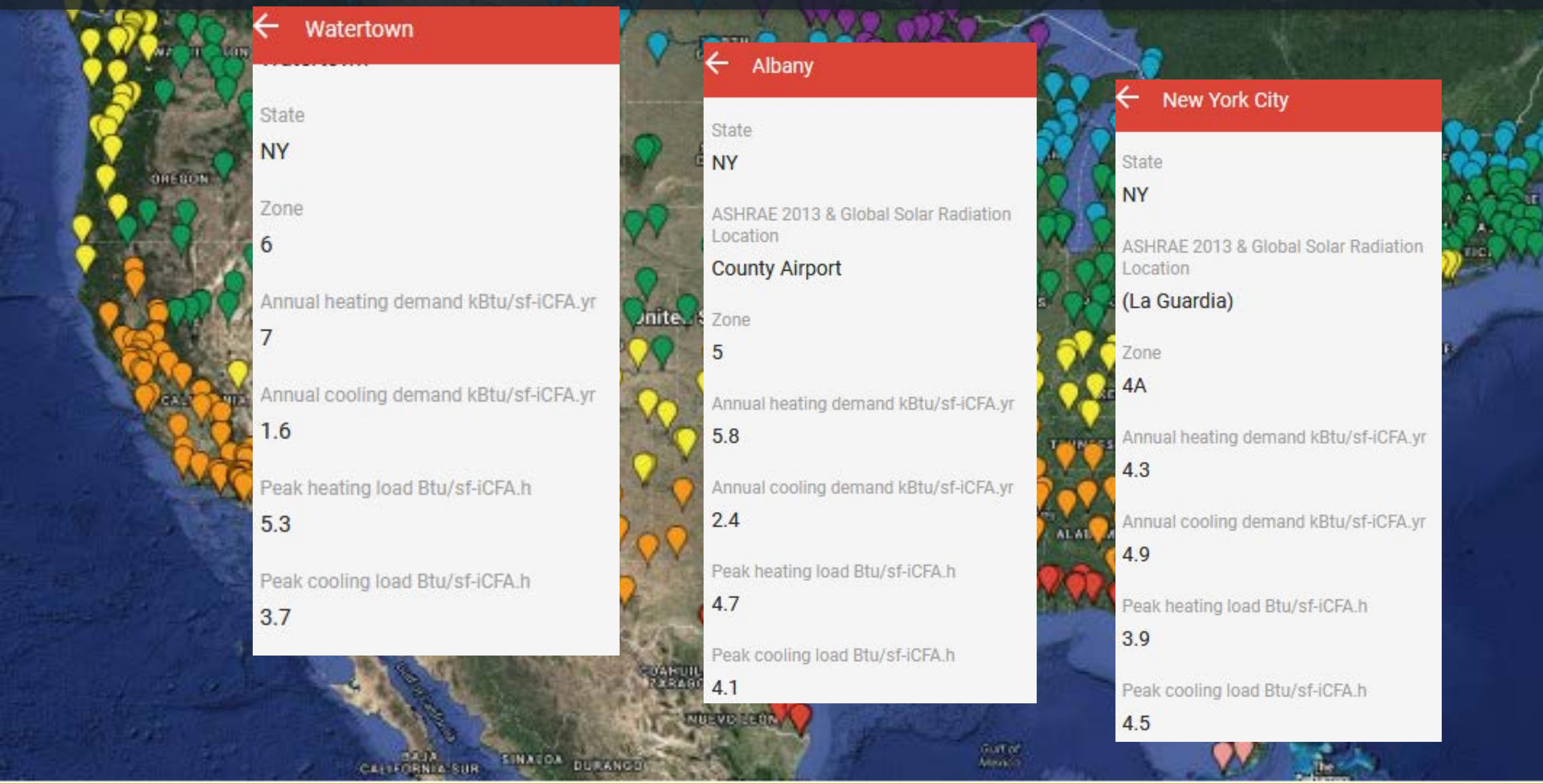


http://www.nrel.gov/docs/fy15osti/64278.pdf15 kWh/m²·yr

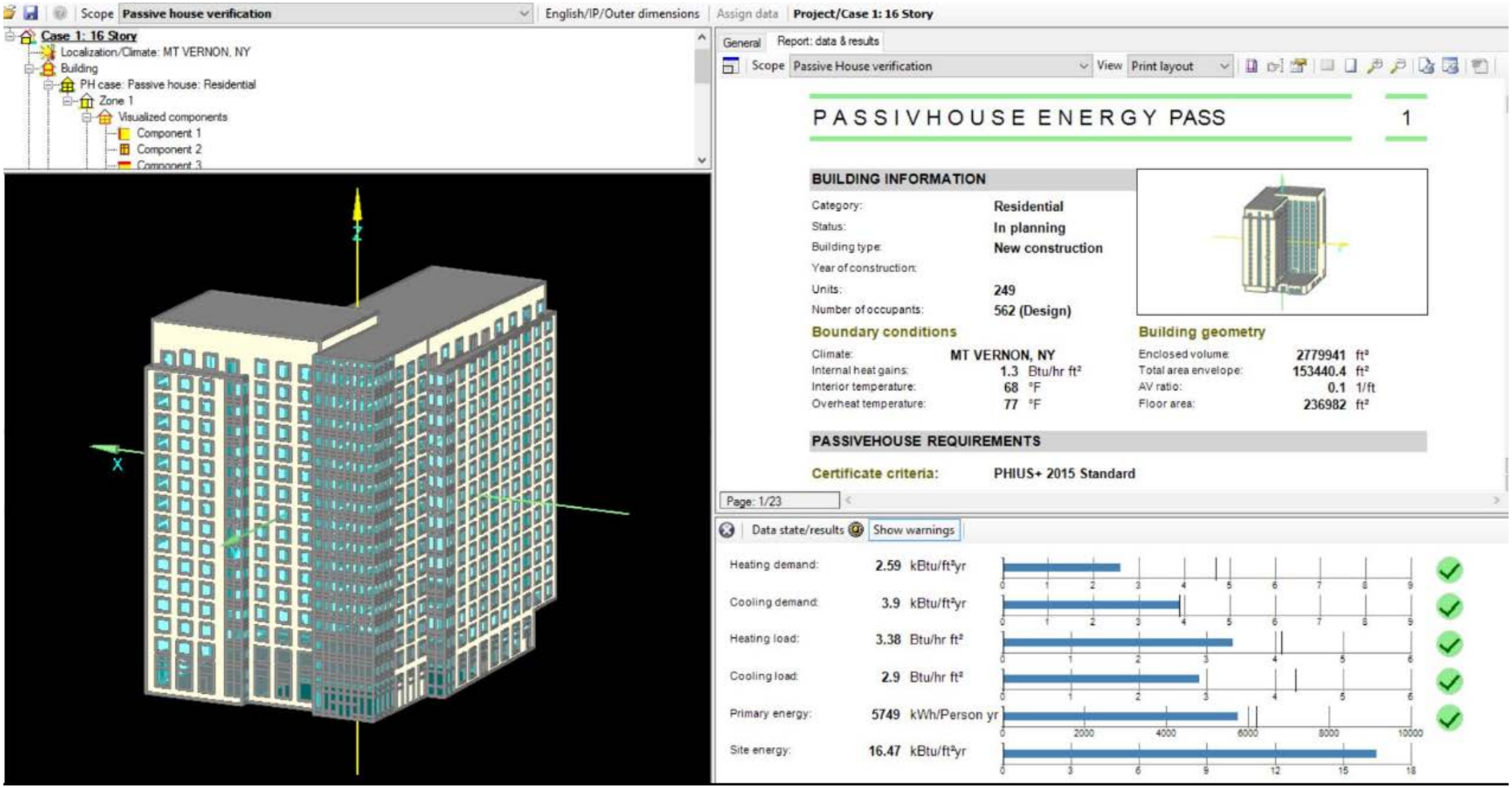
CLIMATE SPECIFIC METRICS

OPTIMIZING THERMAL COMFORT AND COST

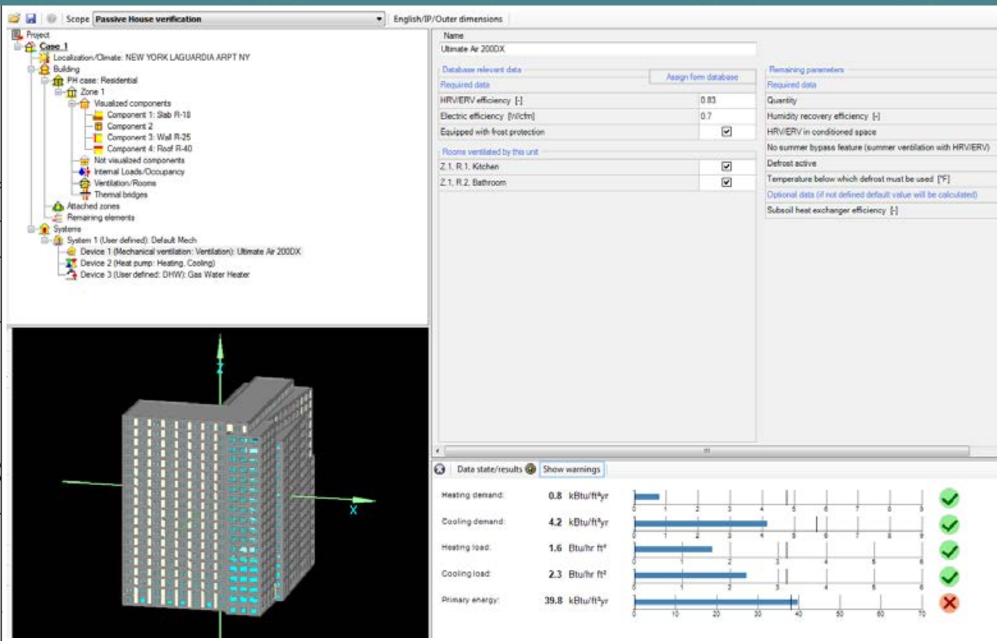
PASSIVE STANDARDS IN VARYING CLIMATES



BUILDING TYPOLOGIES MATTER



SMALL SINGLE FAMILY ONE STORY VS HI-RISE - SURFACE TO VOLUME RATIO VARIES, INTERNAL LOADS

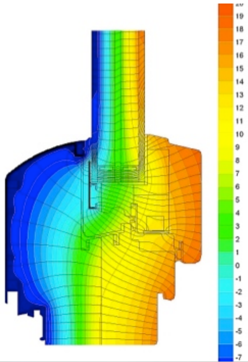


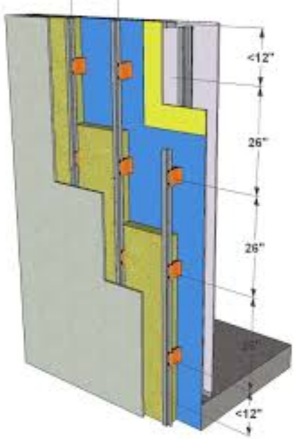
R-50 WALLS
R-90 ROOF
R-50 SLAB
R-8 WINDOWS

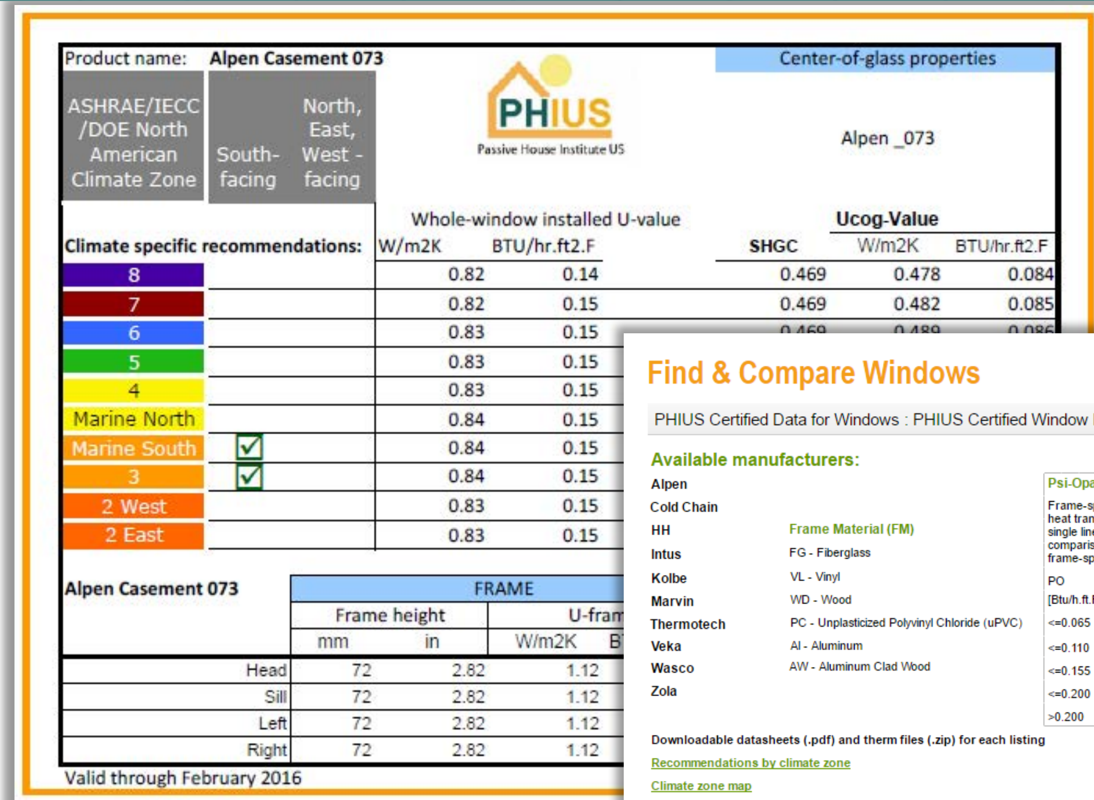
R-25 WALLS
R-40 ROOF
R-20 SLAB
R-5 WINDOWS

COMPONENTS

ARE CLIMATE & TYPOLOGY SPECIFIC







Product name: **Alpen Casement 073**

PHIUS Passive House Institute US

Center-of-glass properties

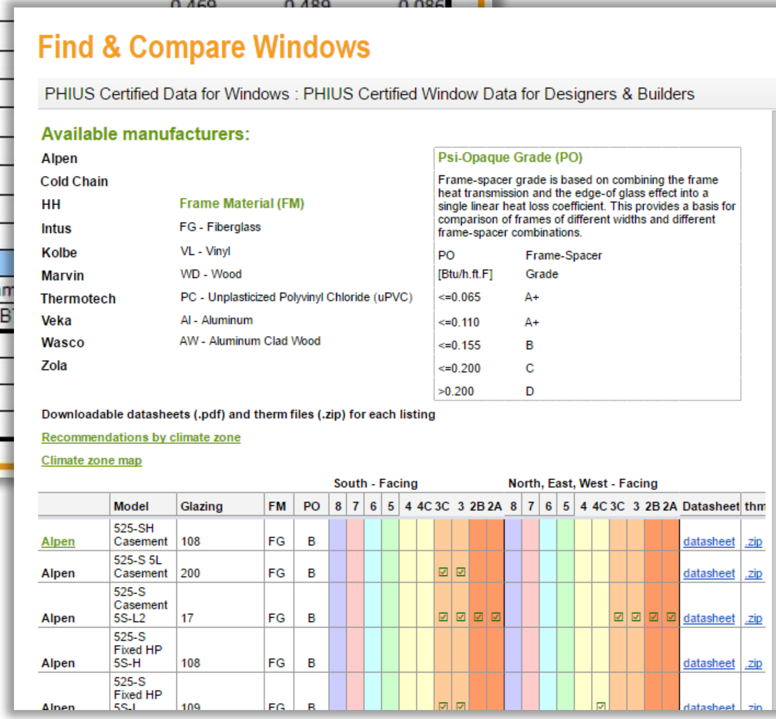
Alpen _073

ASHRAE/IECC /DOE North American Climate Zone	South-facing	North, East, West - facing	Whole-window installed U-value W/m2K	BTU/hr.ft2.F	SHGC	Ucog-Value W/m2K	BTU/hr.ft2.F
Climate specific recommendations:							
8			0.82	0.14	0.469	0.478	0.084
7			0.82	0.15	0.469	0.482	0.085
6			0.83	0.15	0.469	0.489	0.086
5			0.83	0.15			
4			0.83	0.15			
Marine North			0.84	0.15			
Marine South	✓		0.84	0.15			
3	✓		0.84	0.15			
2 West			0.83	0.15			
2 East			0.83	0.15			

Alpen Casement 073

	FRAME			
	Frame height		U-fram	
	mm	in	W/m2K	B
Head	72	2.82	1.12	
Sill	72	2.82	1.12	
Left	72	2.82	1.12	
Right	72	2.82	1.12	

Valid through February 2016



Find & Compare Windows

PHIUS Certified Data for Windows : PHIUS Certified Window Data for Designers & Builders

Available manufacturers:

- Alpen
- Cold Chain
- HH
- Intus
- Kolbe
- Marvin
- Thermotech
- Veka
- Wasco
- Zola

Frame Material (FM)

- FG - Fiberglass
- VL - Vinyl
- WD - Wood
- PC - Unplasticized Polyvinyl Chloride (uPVC)
- AI - Aluminum
- AW - Aluminum Clad Wood

Psi-Opaque Grade (PO)

Frame-spacer grade is based on combining the frame heat transmission and the edge-of glass effect into a single linear heat loss coefficient. This provides a basis for comparison of frames of different widths and different frame-spacer combinations.

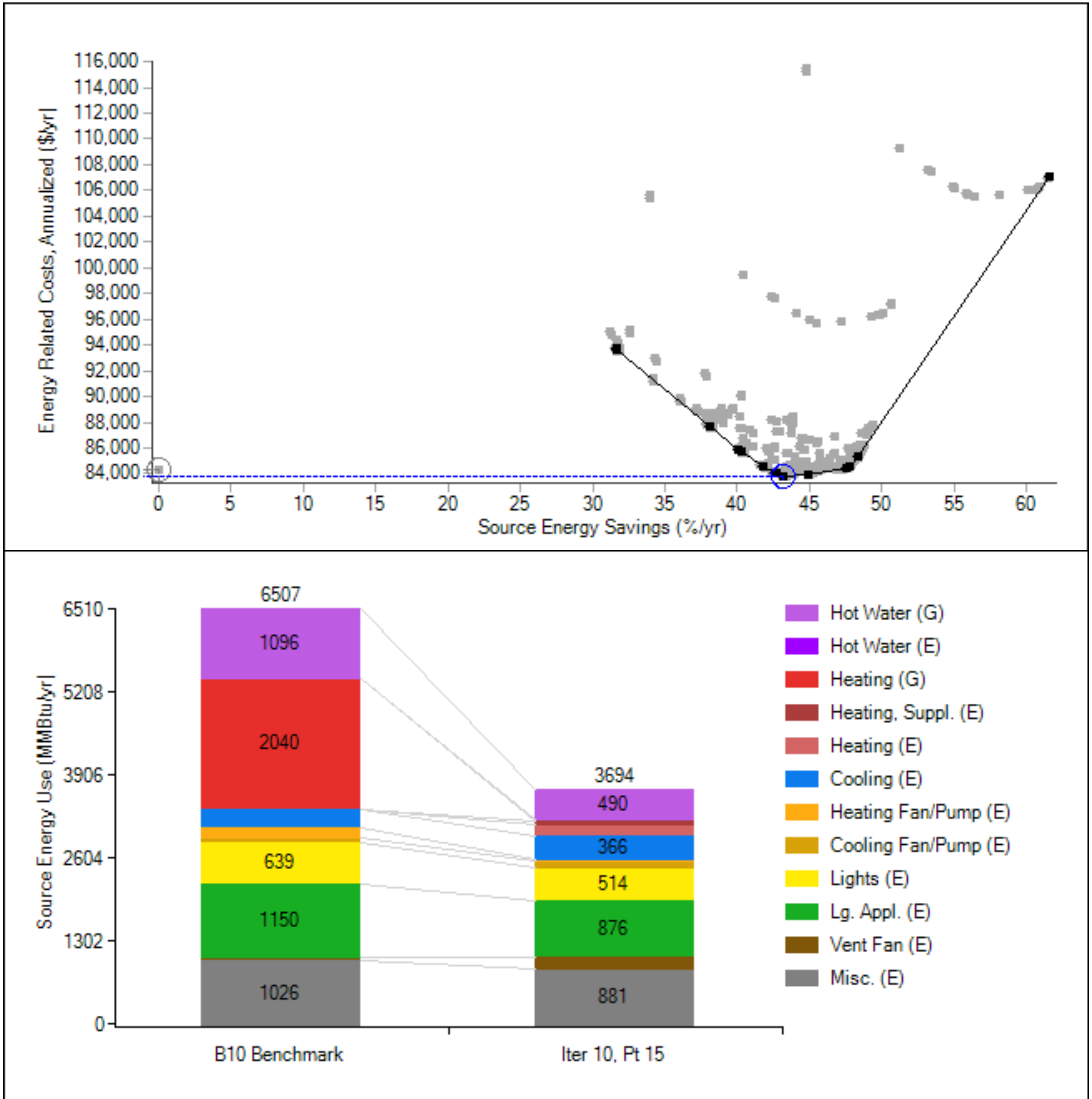
PO [Btu/h.ft.F]	Frame-Spacer Grade
<=0.065	A+
<=0.110	A+
<=0.155	B
<=0.200	C
>0.200	D

Downloadable datasheets (.pdf) and therm files (.zip) for each listing

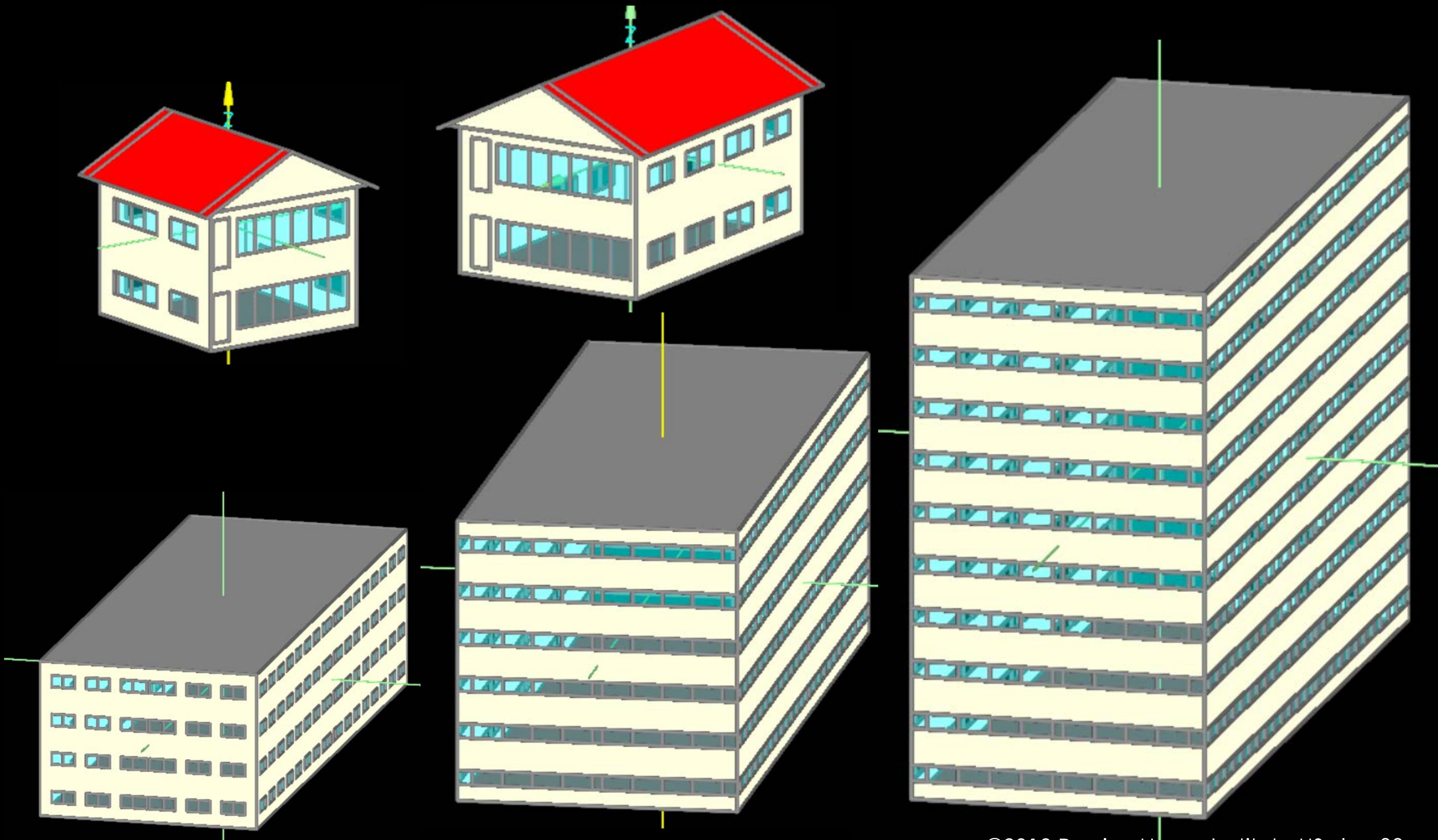
Recommendations by climate zone

Climate zone map

	Model	Glazing	FM	PO	South - Facing 8	7	6	5	4	4C	3C	3	2B	2A	North, East, West - Facing 8	7	6	5	4	4C	3C	3	2B	2A	Datasheet	thm
Alpen	525-SH Casement	108	FG	B																					datasheet	.zip
Alpen	525-S 5L Casement	200	FG	B							☑	☑													datasheet	.zip
Alpen	525-S Casement 5S-L2	17	FG	B							☑	☑	☑	☑							☑	☑	☑	☑	datasheet	.zip
Alpen	525-S Fixed HP 5S-H	108	FG	B																					datasheet	.zip
Alpen	525-S Fixed HP 5S-L	109	FG	B							☑	☑								☑					datasheet	.zip


116,000
114,000
112,000
110,000
108,000
106,000
104,000
102,000
100,000
98,000
96,000
94,000
92,000
90,000
88,000
86,000
84,000
Energy Related Costs, Annualized ($/yr)
0
5
10
15
20
25
30
35
40
45
50
55
60
Source Energy Savings (%/yr)
6507
6510
5208
3906
2604
1302
0
Source Energy Use (MMBtu/yr)
1096
2040
639
1150
1026
3694
490
366
514
876
881
B10 Benchmark
Iter 10, Pt 15
Hot Water (G)
Hot Water (E)
Heating (G)
Heating, Suppl. (E)
Heating (E)
Cooling (E)
Heating Fan/Pump (E)
Cooling Fan/Pump (E)
Lights (E)
Lg. Appl. (E)
Vent Fan (E)
Misc. (E)

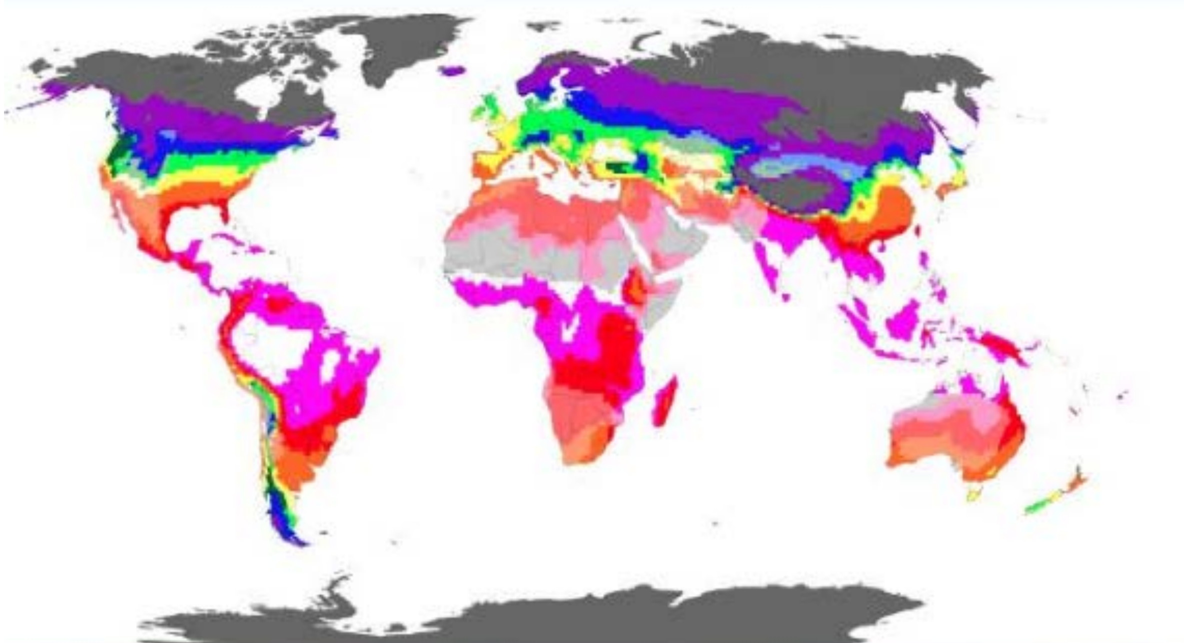
OPTIMIUM LEVELS BASED ON BUILDING SIZE AND OCCUPANT DENSITY (15 scenarios)



Global Climate Zones – ASHRAE Standard 169-2013

Key Parameters:

- Heating/Cooling Degree days using Max/Min daily temperatures
- Annual precipitation



PHIUS+2018 PILOT

PHIUS+ 2018
Space Conditioning Criteria Estimator

ASHRAE Climate Zone: **5B**

Floor Area (ft²): **2,500** — **or enter here:** 2500

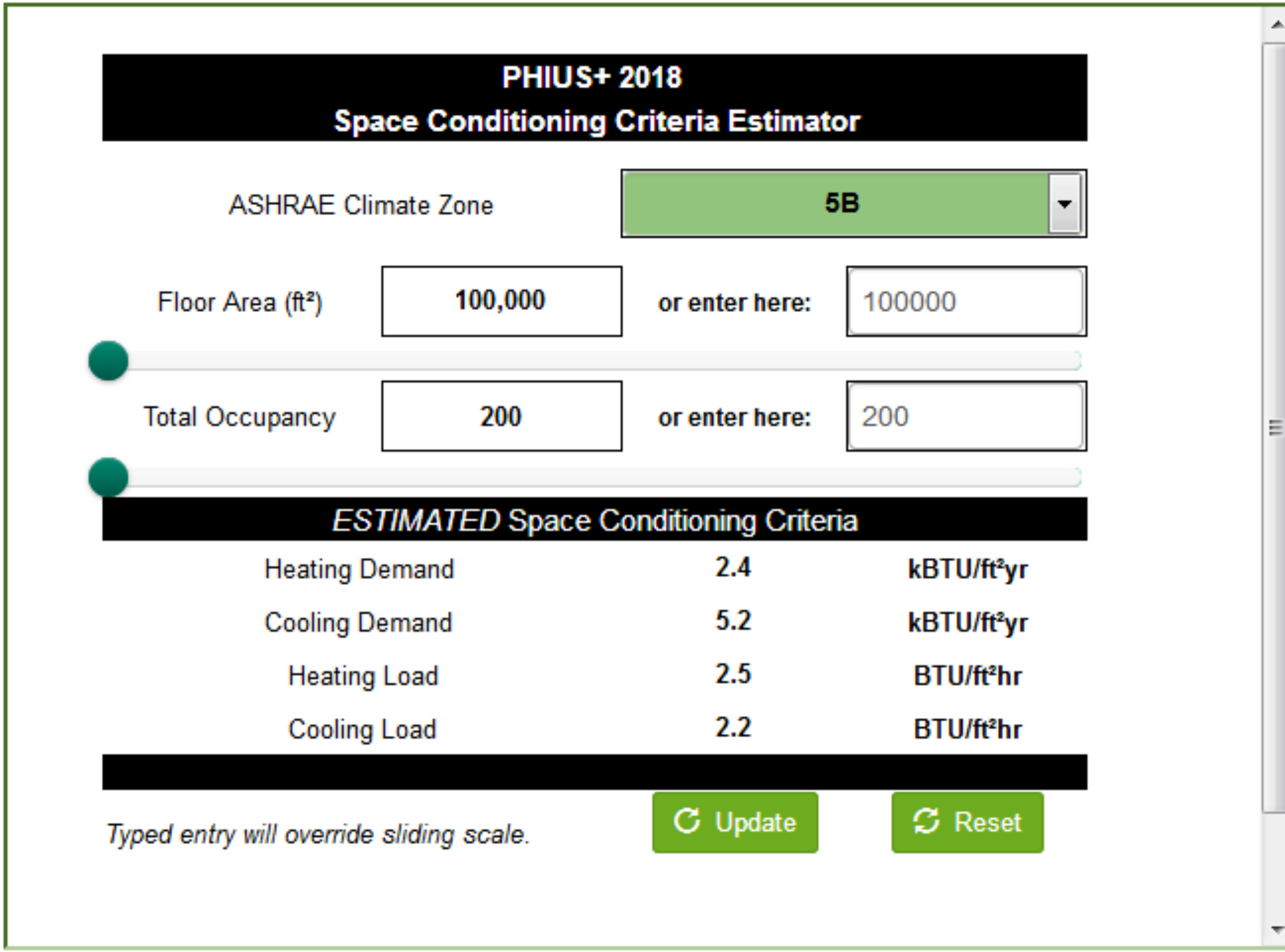
Total Occupancy: **4** — **or enter here:** 4

ESTIMATED Space Conditioning Criteria		
Heating Demand	**8.2**	**kBTU/ft²yr**
Cooling Demand	**6.8**	**kBTU/ft²yr**
Heating Load	**5.8**	**BTU/ft²hr**
Cooling Load	**4.1**	**BTU/ft²hr**

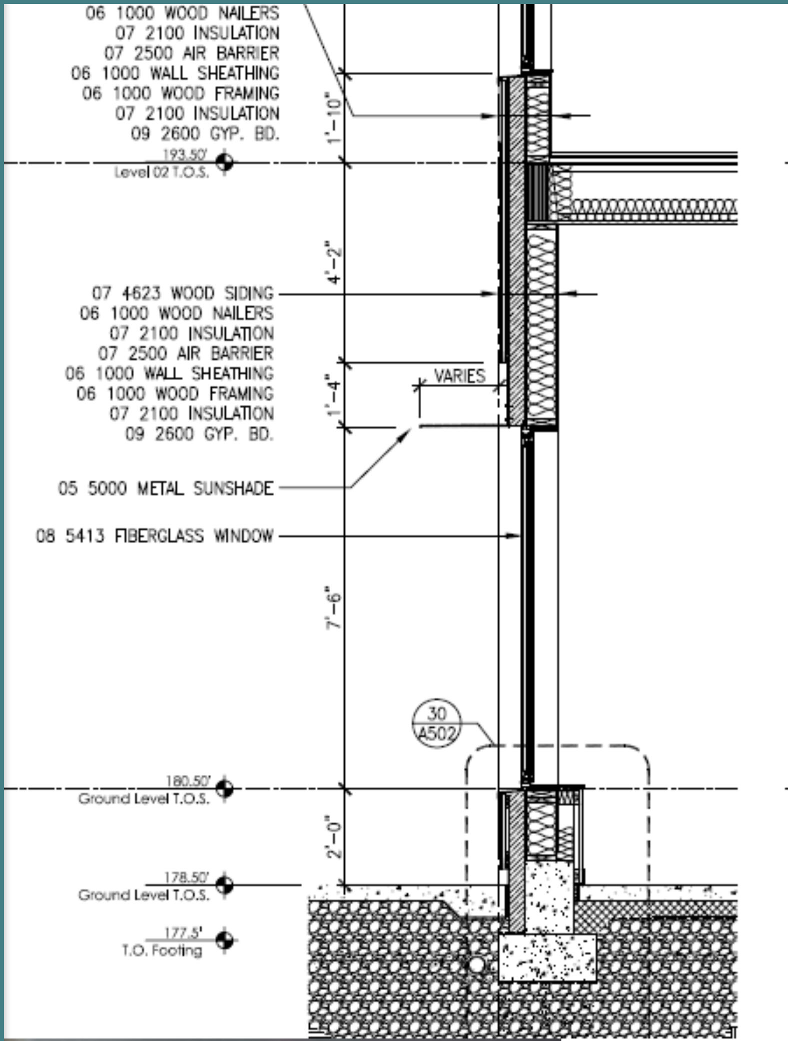
Typed entry will override sliding scale.

Update   Reset

PHIUS+2018 PILOT



MUTIFAMILY PROJECT **EXTERIOR FOAM** AND CLADDING IN OREGON



UPTOWNLOFTS PA

Exterior foam

- Polyisocyanurate foil-faced exterior insulation system

Metal panels and brick exterior finishes

- Thermally broken attachments

Source: Jesse Thompson - Uptown Lofts, Pittsburgh, PA

AIRBARRIER

UPTOWN LOFTS PITTSBURGH

ORCHARDS AT ORENCO

PHI STANDARD: 2X10 Structure

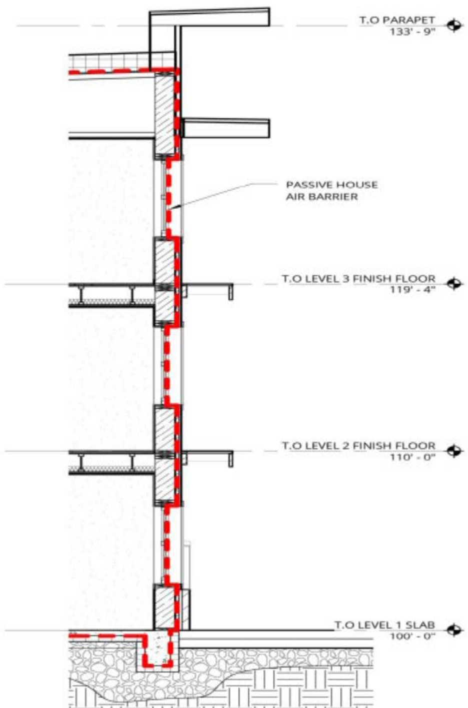
- High-density blown in fiberglass
- Sheathing
- 2” exterior mineral wool
- Fiber-cement siding, brick, rain screen

Sun shading, parapets, balconies

- Thermally broken attachments

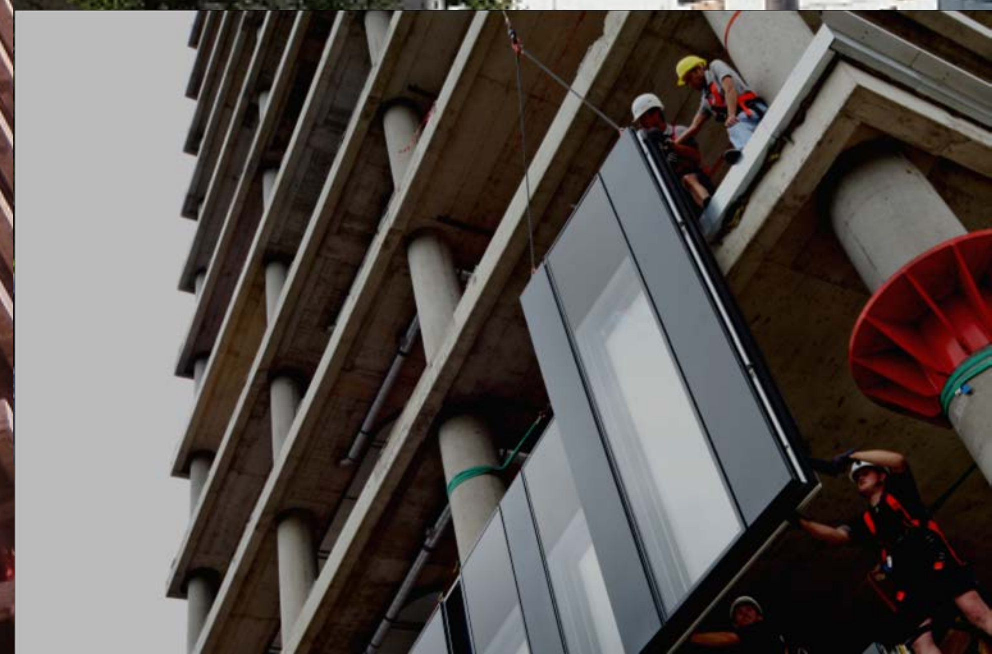
PHIUS+2015: 2X6 Structure

- High-density blown in fiberglass
- Sheathing
- 1.5” exterior mineral wool
- Fiber-cement siding, brick, rain



Source: www.prosoco.com/r-guard

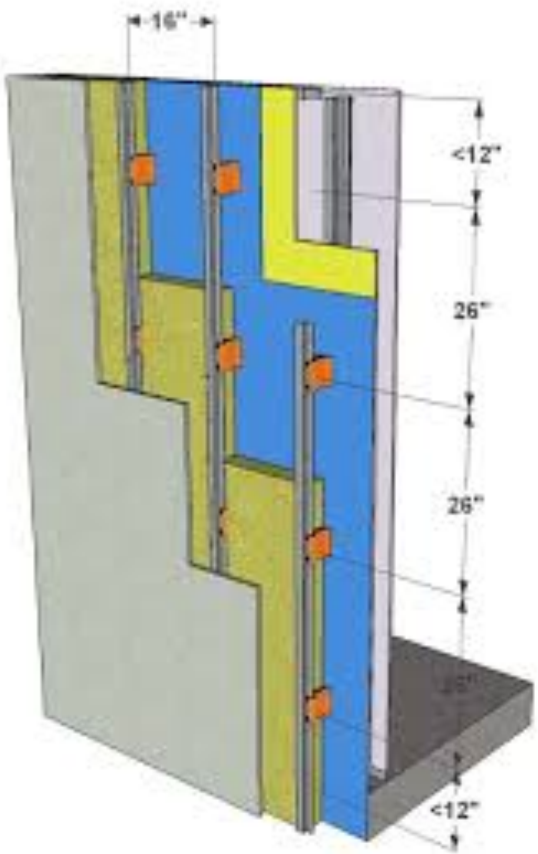
EXTERIOR AIR BARRIERS



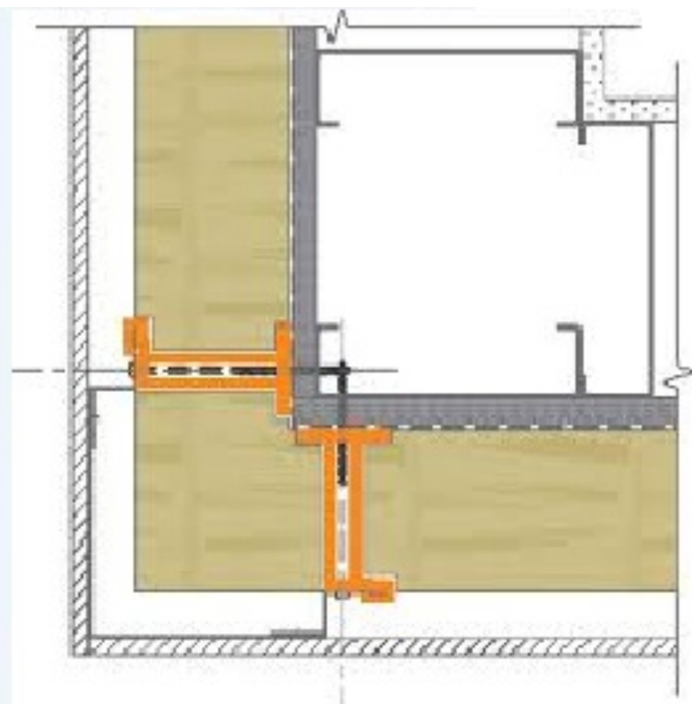
CONTINUOUS INSULATION

INSULATED CONCRETE FORMS

THERMAL BREAKS

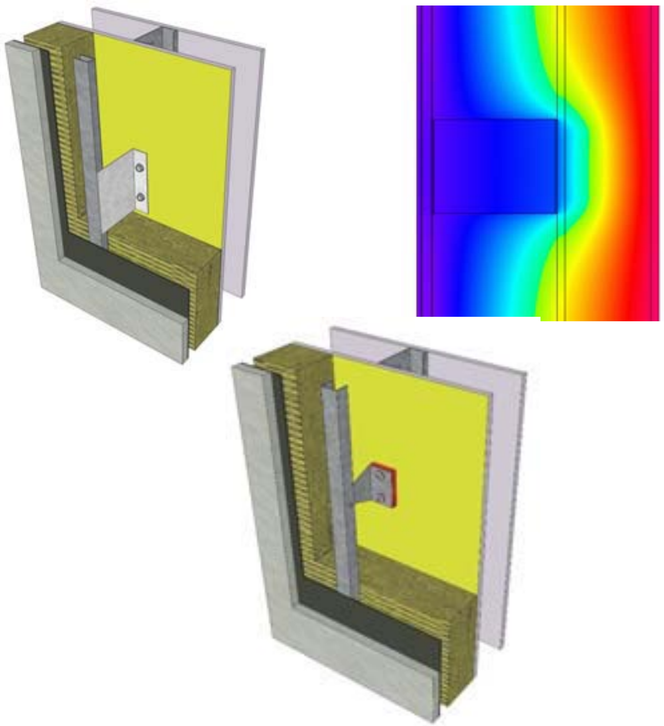


Cascadia Clip® system



MINIMIZE POINT TB LOSS

Photo courtesy Jesse Thompson



Illustrations by RDH, Shawn Colin, NAPHC 2014

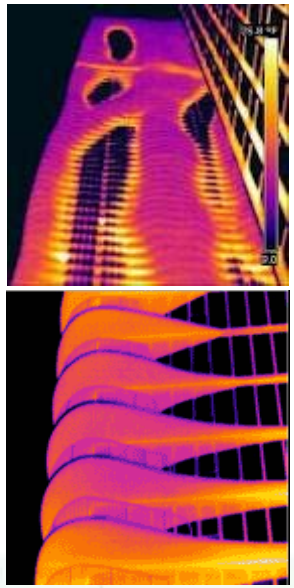
STRUCTURAL THERMAL BRIDGING CAUSED BY CLADDING SYSTEMS ATTACHMENT – RED SPACER BEHIND STAND-OFF=THERMAL BREAK

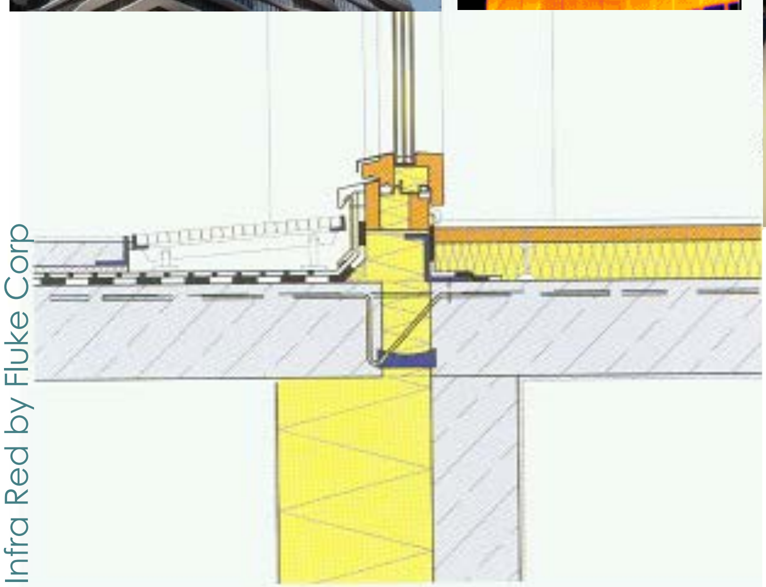
UPTOWN LOFTS STRUCTURAL THERMAL BRIDGE ISSUE: SEPARATION TO UNCONDITIONED PARKING DECK

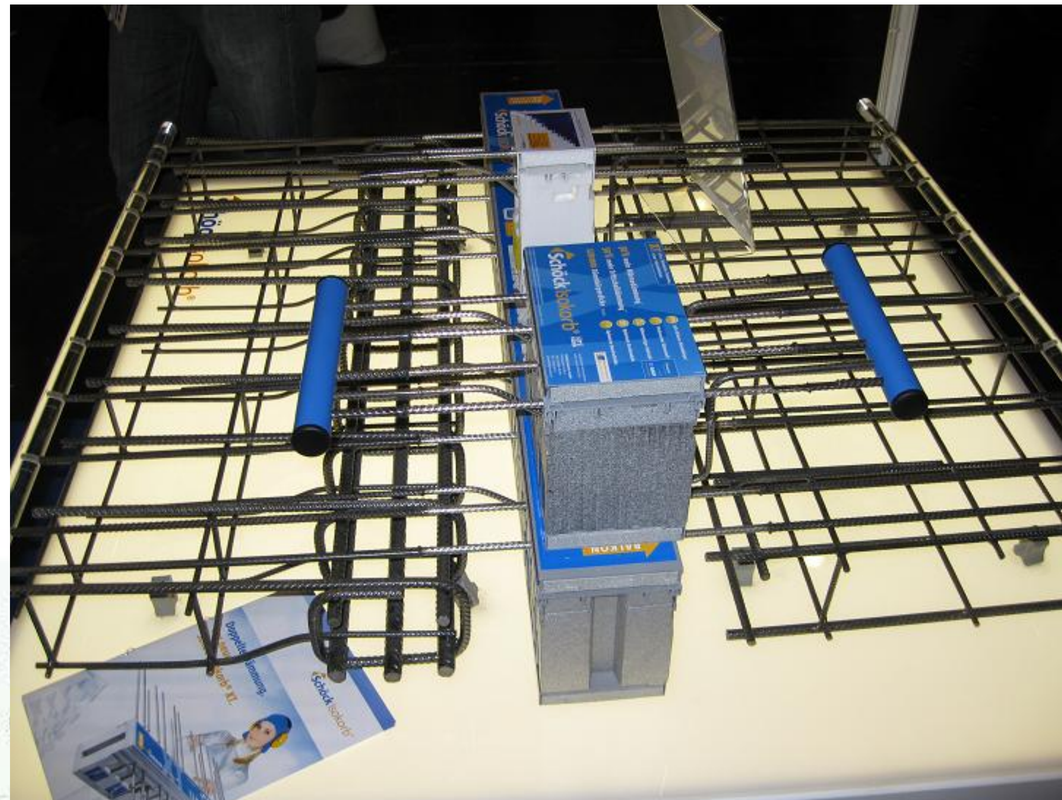
Mechanical Properties			
Tensile Strength	PSI	ASTM D638	9,400
Flexural Strength	PSI	ASTM D790	22,300
Compressive Strength	PSI	ASTM D695	38,900
Compressive Modulus	PSI	ASTM D695	1,450,377
Shear Strength	PSI	ASTM D732	13,400
Thickness	in	-	1/4", 1/2", 1"
Flame Resistance			
Oxygen Index	%O_2	ASTM D2863	21.8
Thermal Properties			
Coefficient of Thermal Expansion	in/in/°Cx10^{-5}	ASTM D696	2.2
Thermal Conductivity	BTU/Hr/ft²/in/°F W/m*K	ASTM C177	1.8** 0.259
** *Reference:* Thermal Conductivity of Steel	BTU/Hr/ft²/in/°F W/m*K		374.5 54.0

Additional Products for Building & Construction

STRUCTURAL THERMAL BREAKS



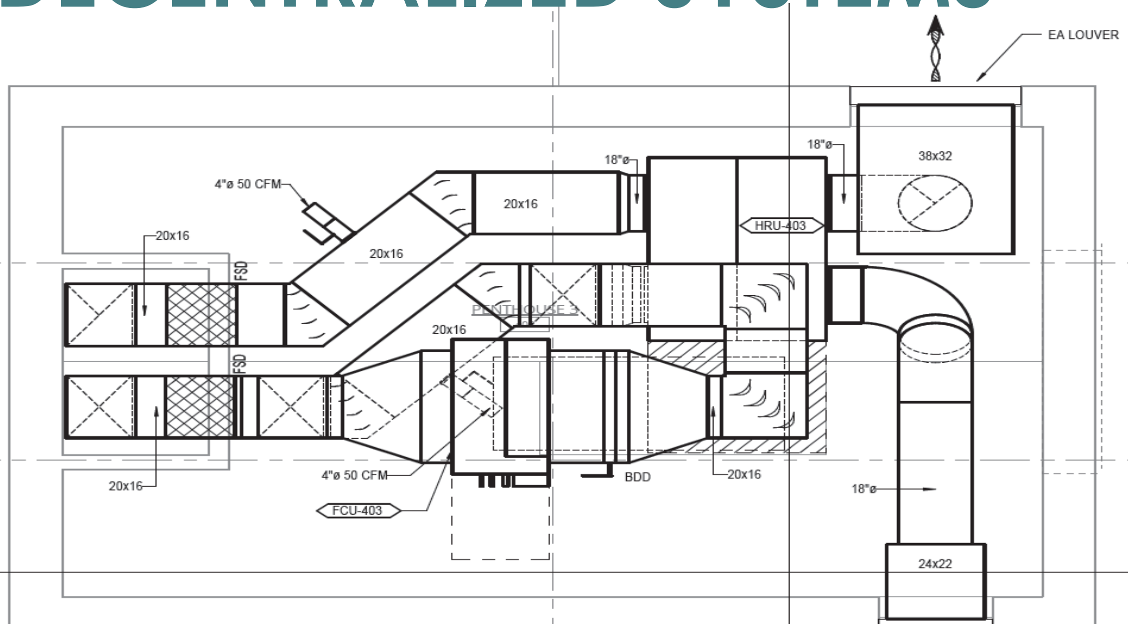


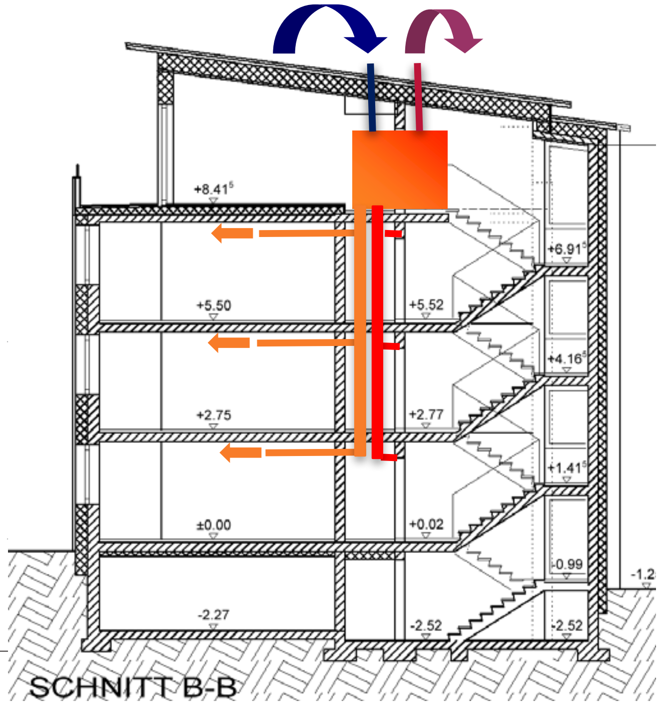


Source: Building Science Corporation Newsletter #49: Aqua Tower and Infra Red by Fluke Corp

MF VENTILATION AND SPACE CONDITIONING:

CENTRALIZED, DECENTRALIZED AND SEMI-DECENTRALIZED SYSTEMS





Source: 2014 NAPHC Proceedings, Orchards at Orenco

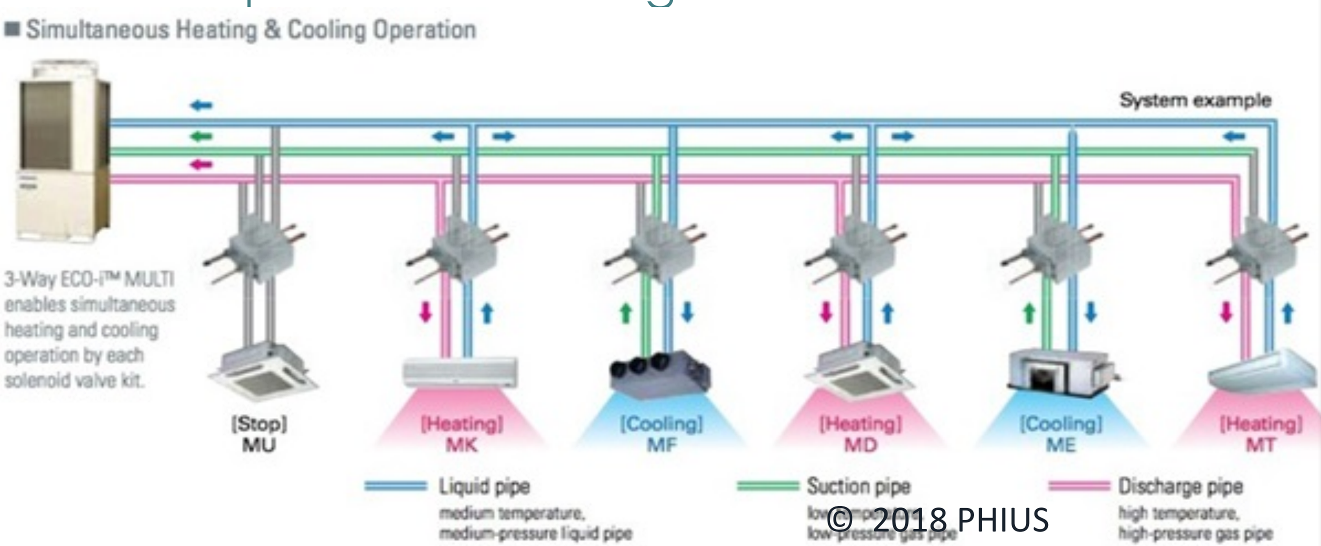
SEMIDECENTRALIZED

Most common solution - Individual ventilator in each unit

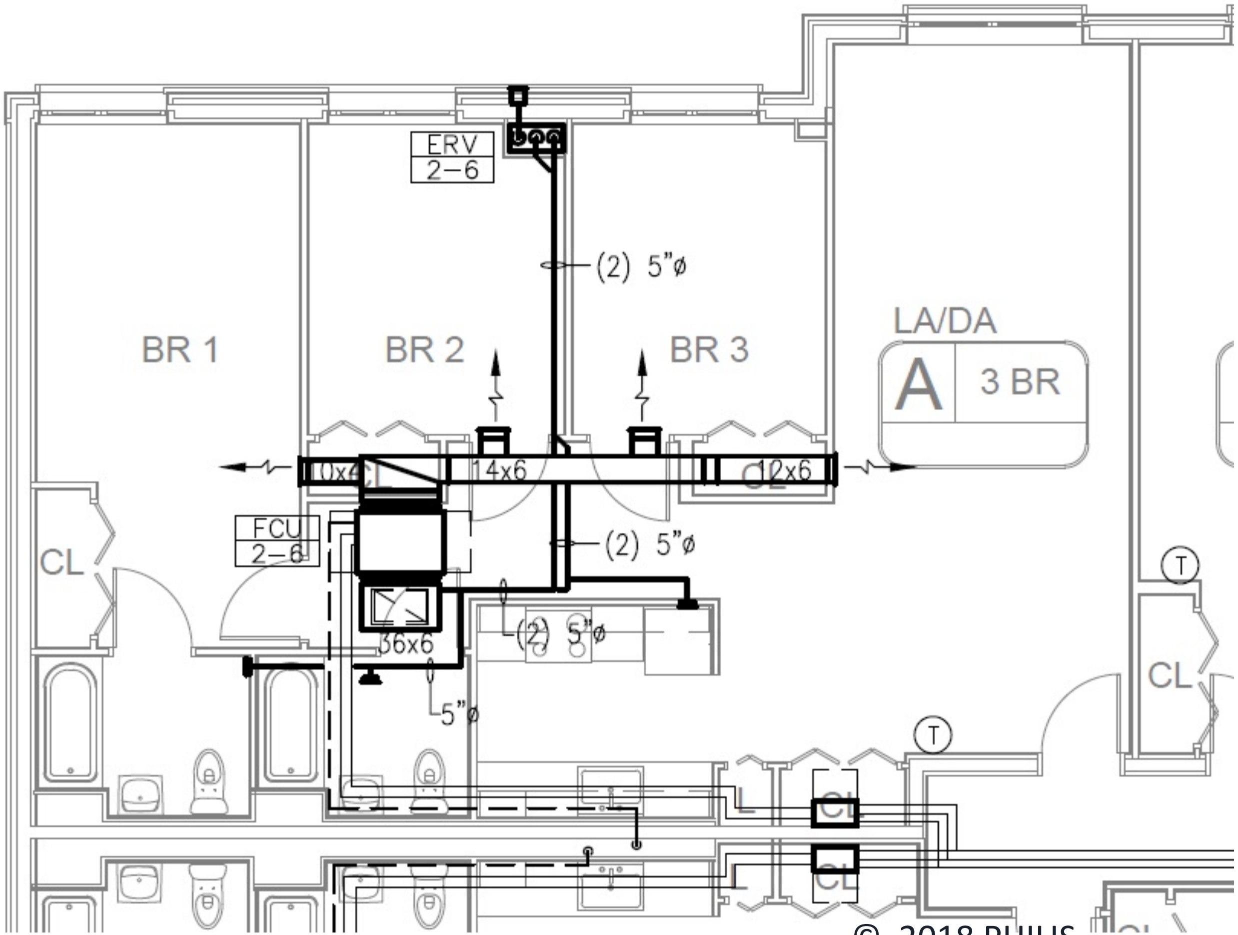
- Individual controls, more accurate ventilation air delivery
- Solution for local codes where exhaust can not be drawn from all apartments and go through a common air to air heat exchanger

Space conditioning via central VRF system

- Separate supply ducts from ventilation air due to different air velocities during space conditioning



APARTMENT SPACE CONDITIONING AND VENTILATION LAYOUT - COMBINED DISTRIBUTION DUCTS



Ventilator next to exterior wall

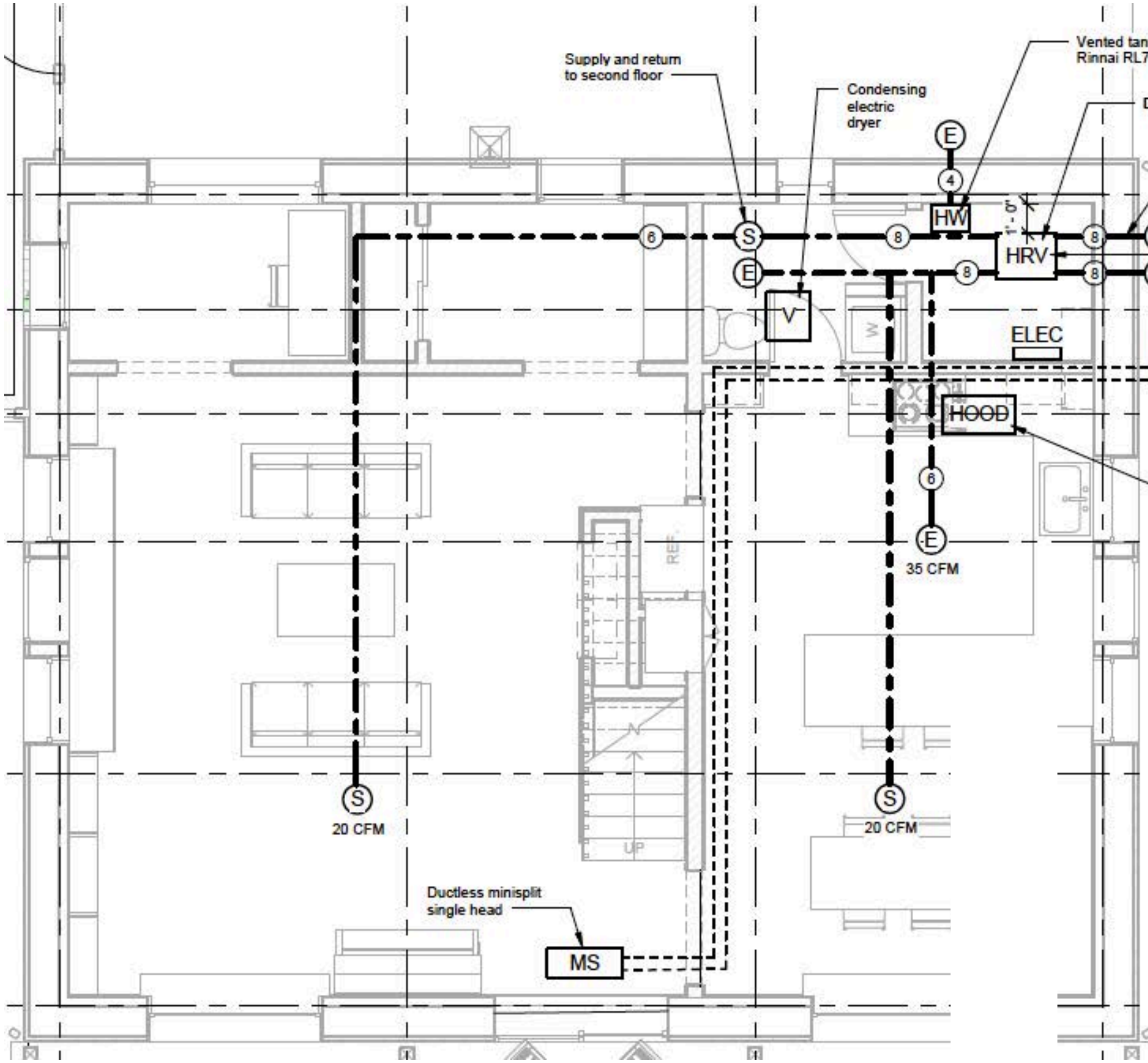
- short exhaust and supply ducts
- keep distribution separate

VRF air handler

- Centrally located, short ductwork

Source: The Bluestone Organization

DECENTRALIZED SOLUTION

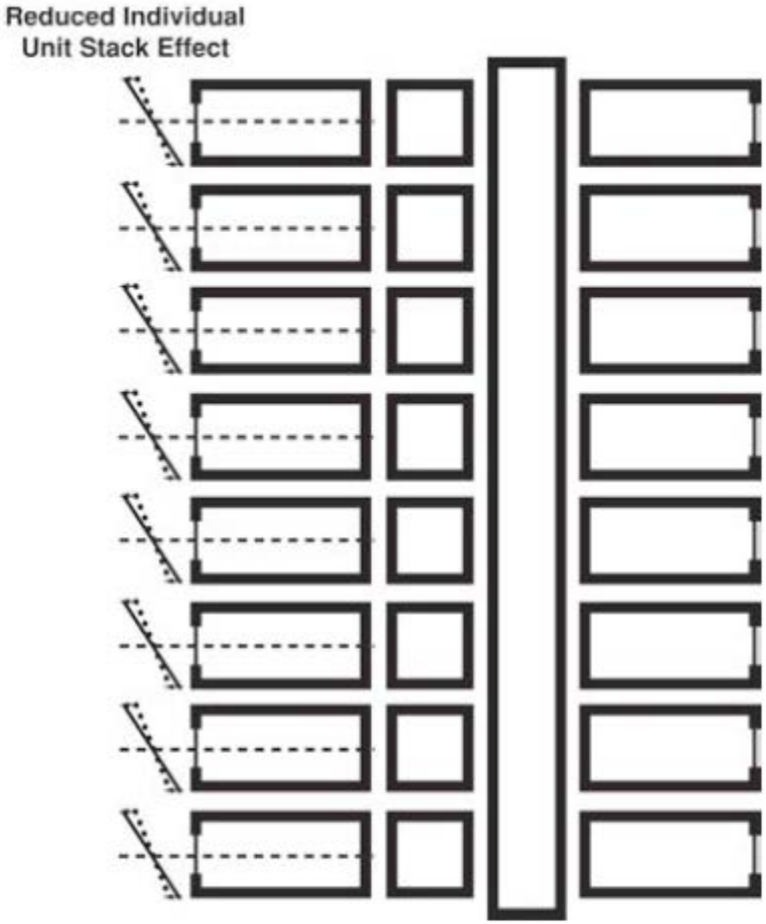


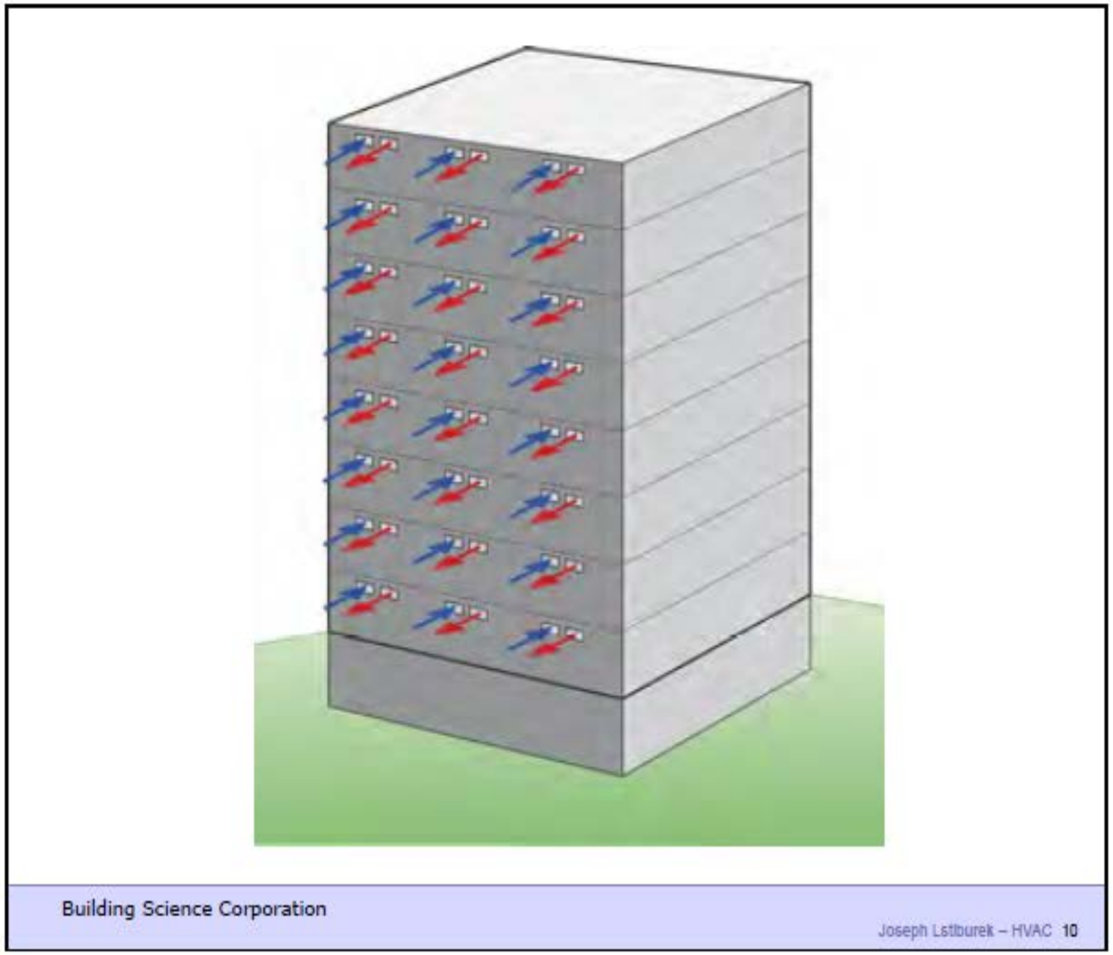
Ventilation Notes

1. Exterior ventilation hoods to be weather and insect protected.
2. Provide door undercut or transfer grills for transfer air.
3. Supply ducts to be located near ceiling for coanda effect.
4. Provide soundproofing at mechanical room.

Balanced Ventilation Chart

Supply		Exhaust	
Living Room	20cfm	1/2 Bath	23cfm
Kitchen	20cfm	Kitchen	35cfm
Bedroom 1	22cfm	Bath 1	24cfm
Bedroom 2	22cfm	Bath 2	24cfm
Bedroom 3	22cfm		
Total	106cfm		106cfm





COMPARTMENTALIZATION OF UNITS TO **CONTROL STACK** EFFECT IDEALLY ONE **VENTILATOR** PER UNIT FOR INDIVIDUAL CONTROL

PHIUS+ Certification Process : Third Party Verified QAQC IS CRITICAL!

Step 1:

Find CPHC

- **Design** Review via PHIUS
- **Verified PRE-CERT**

Step 2:

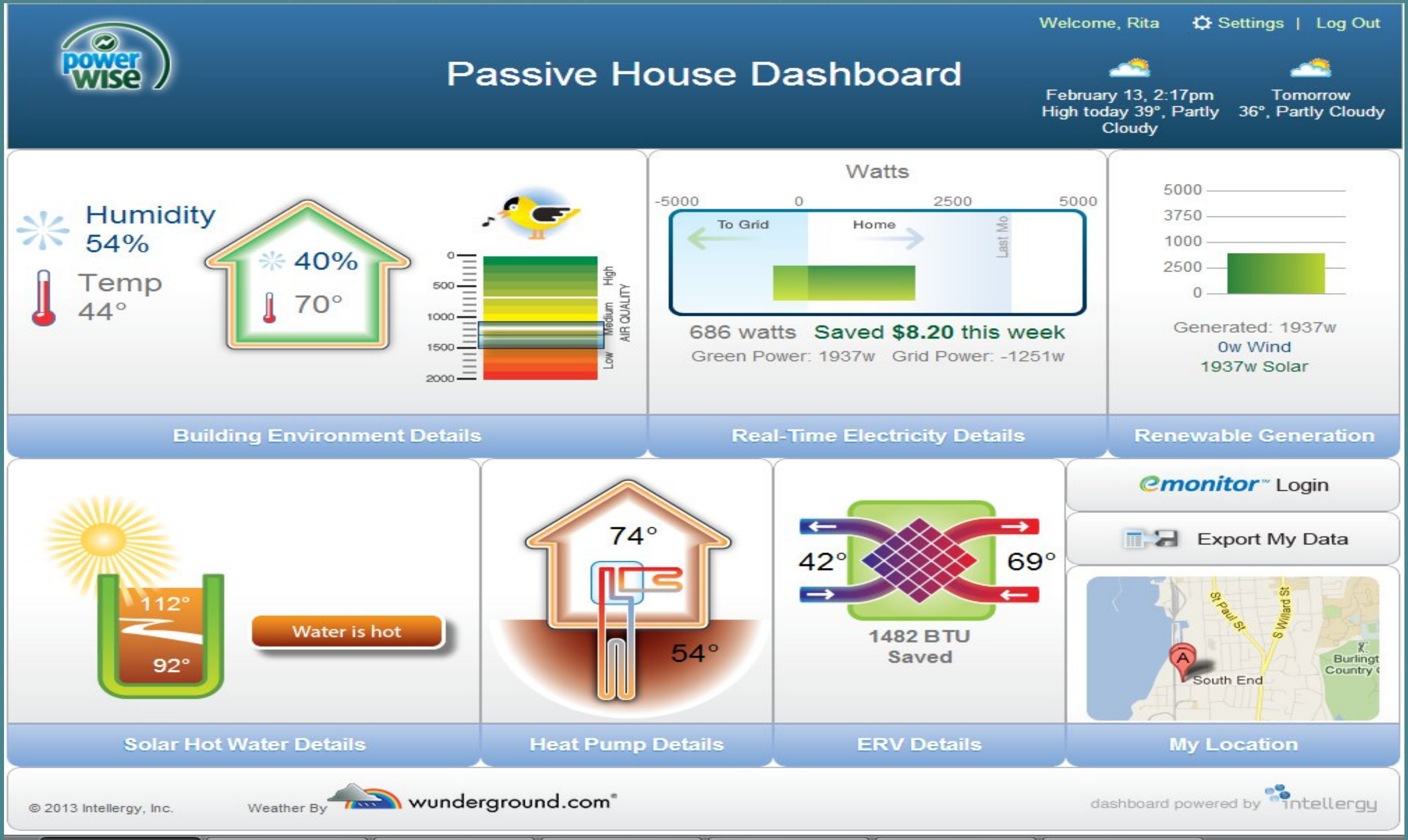
Find PHIUS+ Rater/Verifier

- **Inspection** Update via Rater to PHIUS
- **Verified QAQC**

FINAL CERTIFI-CATION

Recommended, Not Required:

Post-occupancy performance monitoring & verification: CONTINUOUS COMMISSIONING:



SUITE OF PROFESSIONAL CERTIFICATES

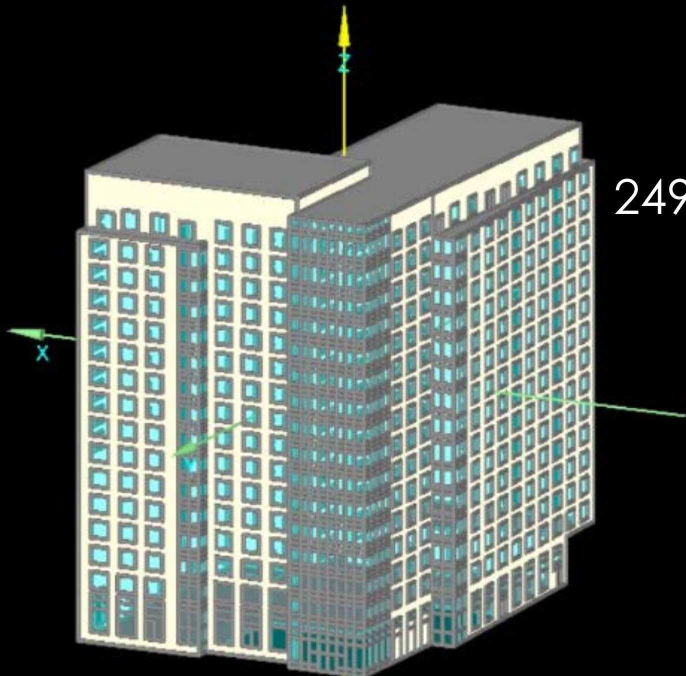
CERTIFIED PASSIVE HOUSE CONSULTANT, CPHC®

PHIUS CERTIFIED BUILDER

PHIUS+ CERTIFIED RATER

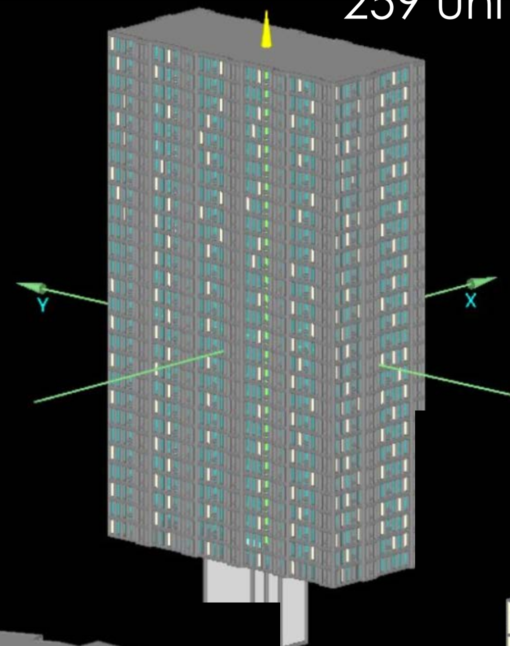
PHIUS+ CERTIFIED VERIFIER

FEASIBILITY STUDIES

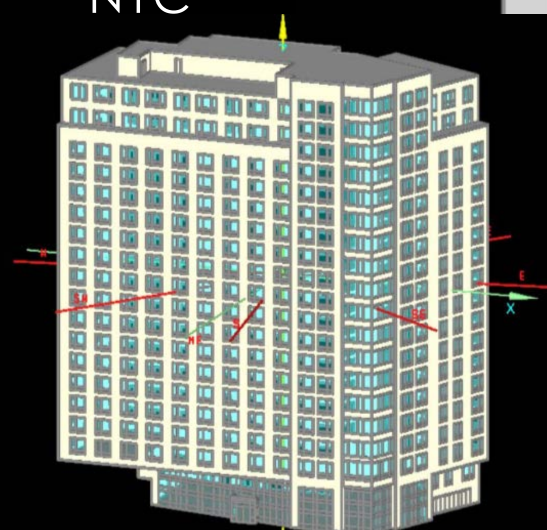


249 unit - NYC

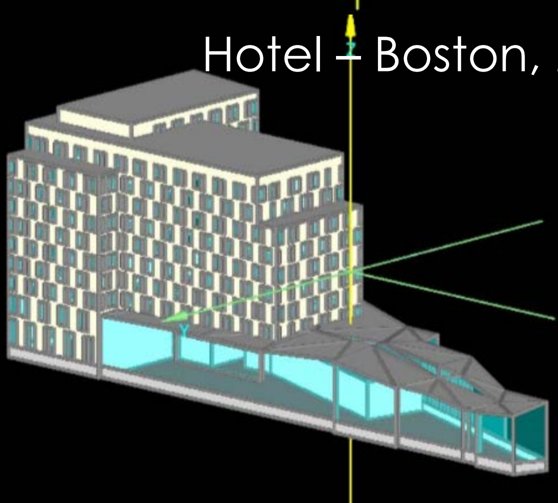
259 unit – Chicago, IL

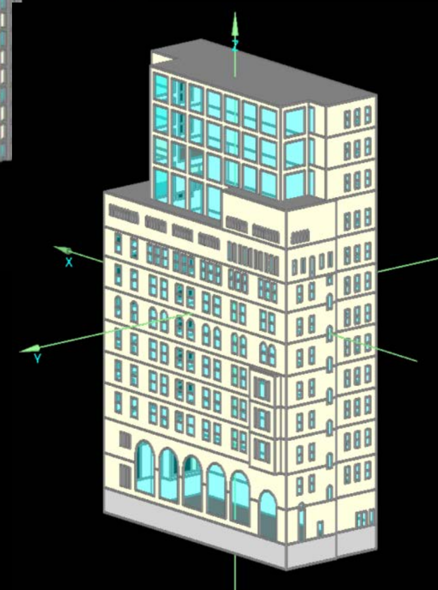


209 unit - NYC



Hotel – Boston, MA

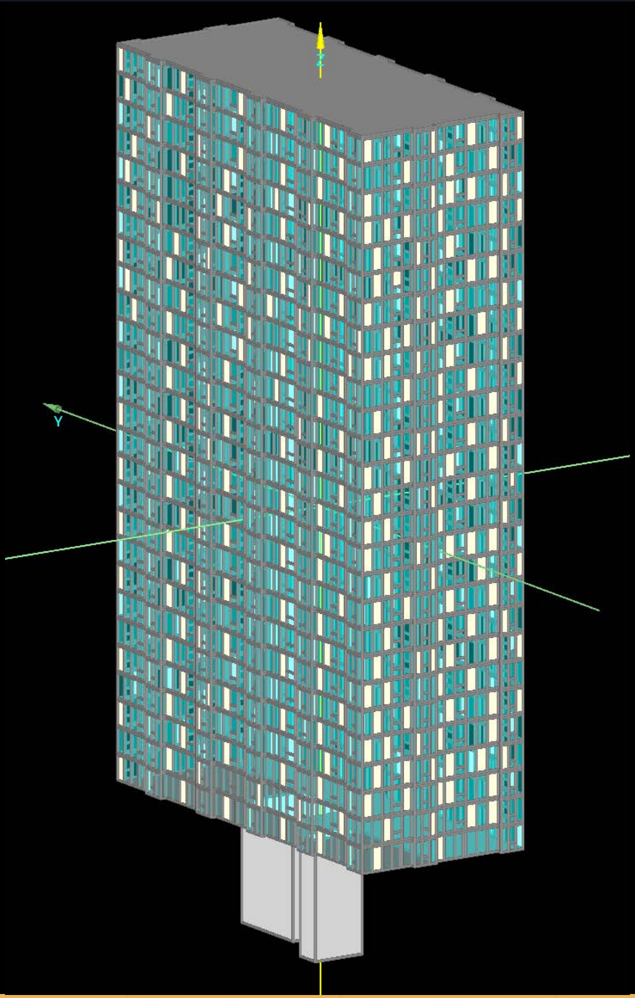




Hotel – Pittsburgh, PA

High Rise Case Studies

Residential



Residential Tower

Envelope Improvements

	PROPOSED	PHIUS+ 2015	
Envelope			
Windows	Uw-0.38 SHGC: 0.4	Uw-0.22 SHGC: 0.3	+42%
Opaque Wall Panels	R20.5	R20.5	SAME
Roof	R25	R35	
Ceiling of Parking Garage	R30	R30	
Slab on Grade	R15	R15	
Airtightness	0.32 cfm/ft2 @ 50Pa .4 cfm/ft2 @ 75 Pa	0.08 cfm/ft2 @50 Pa 0.1 cfm/ft2 @75 Pa	+75%

Residential Tower

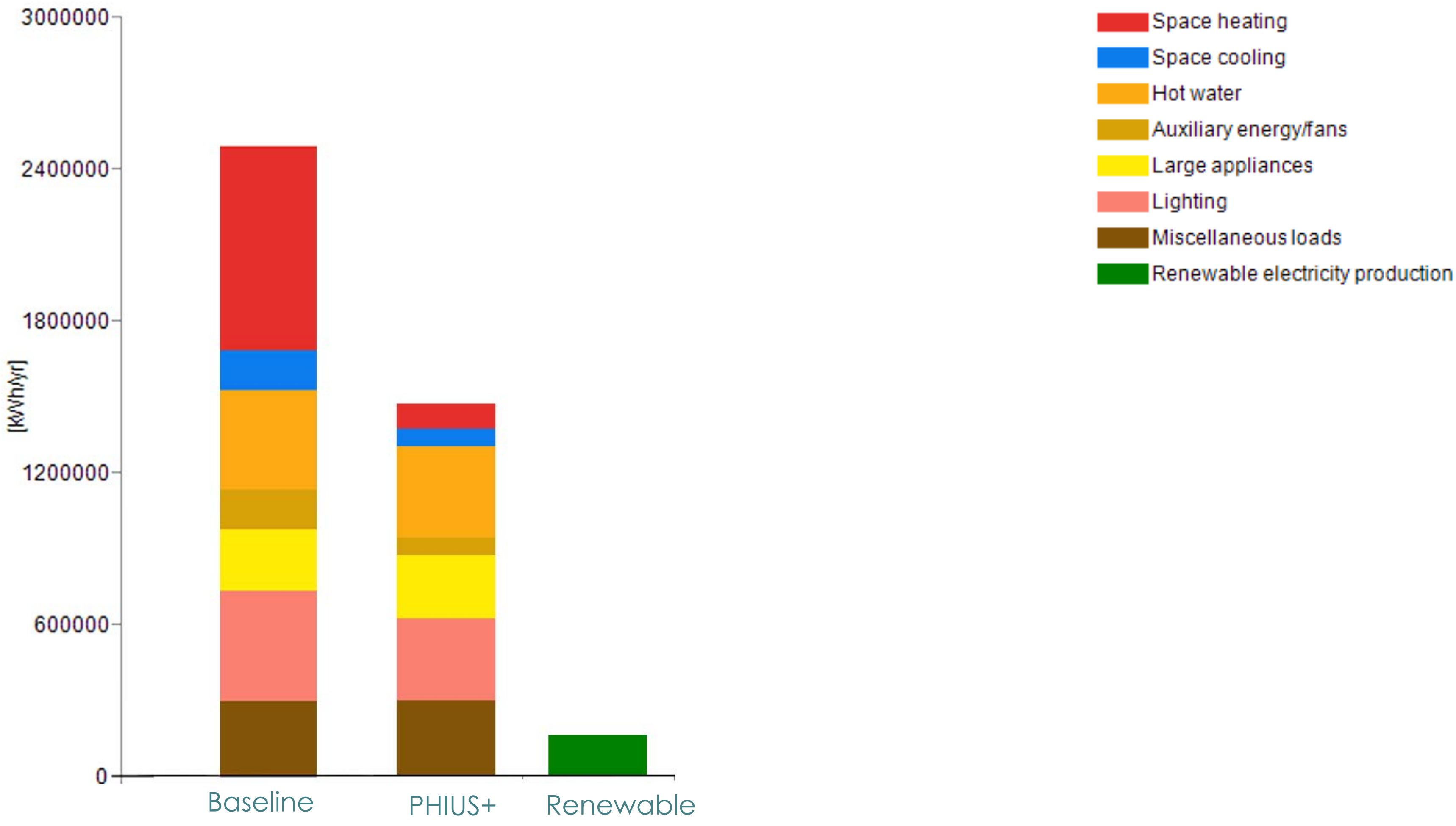
Lighting & HVAC Improvements

	PROPOSED	PHIUS+ 2015
Lighting Power Density		
Halls/Corridors	0.7 W/sf	0.5 W/sf for 18 hrs/day. For 6hrs/day, 0.25 W/sf with occupancy sensors, reducing average of 6 hours to 0.39 W/sf.
Mechanical System		
Cooling SEER	13	17
ERV - Efficiency	50%	85%
Heating	50% Heat Pump with COP of 3 50% Electric Heating	Heat Pump with COP of 4
Hot Water	Gas Hot Water Heater - 83% efficient	Gas Hot Water Heater - 95% efficient

-45%

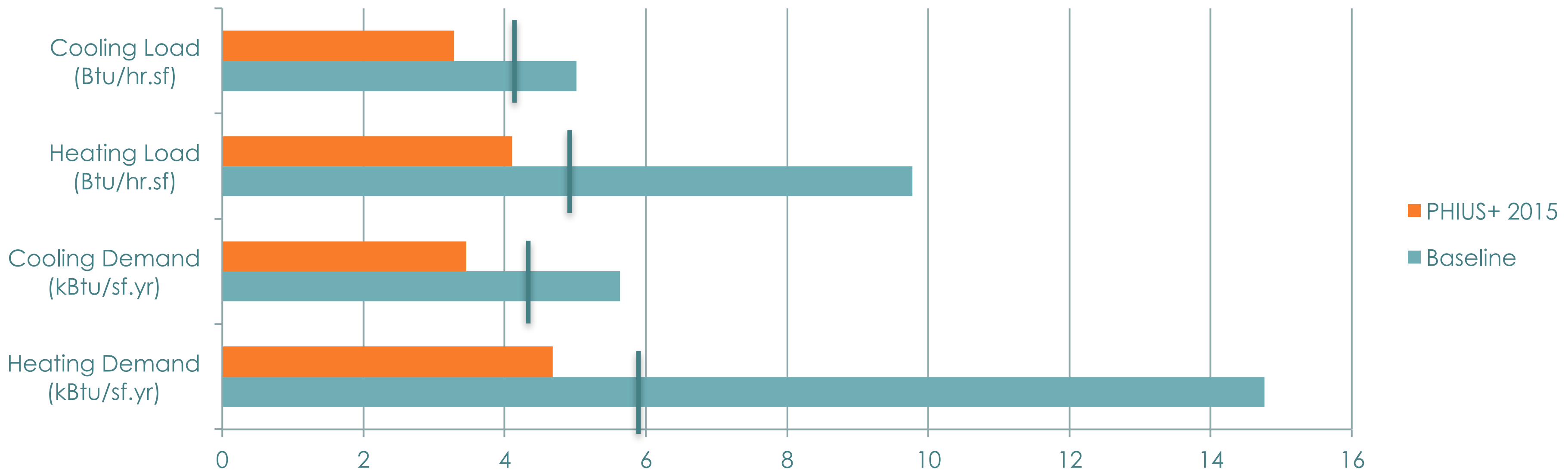
Residential Tower

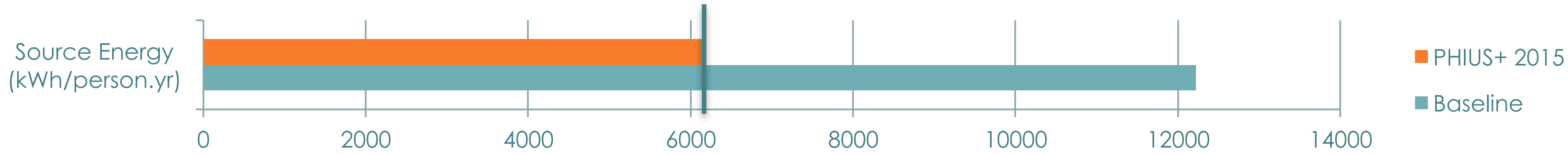
Lighting & HVAC Improvements

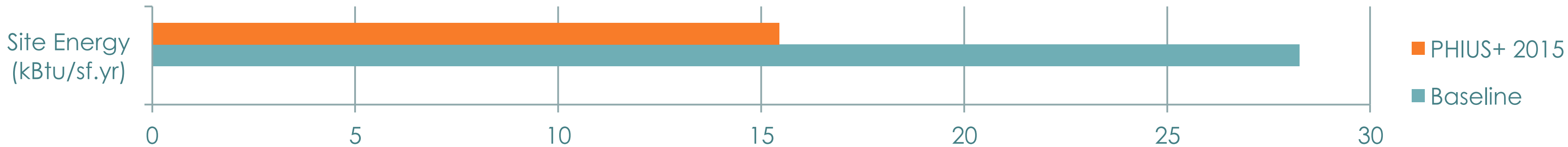


Residential Tower

Improvements







Residential Tower

SUMMARY

- Internal Load Dominated
    - Common Lighting (Hallways) = Largest Energy Hog

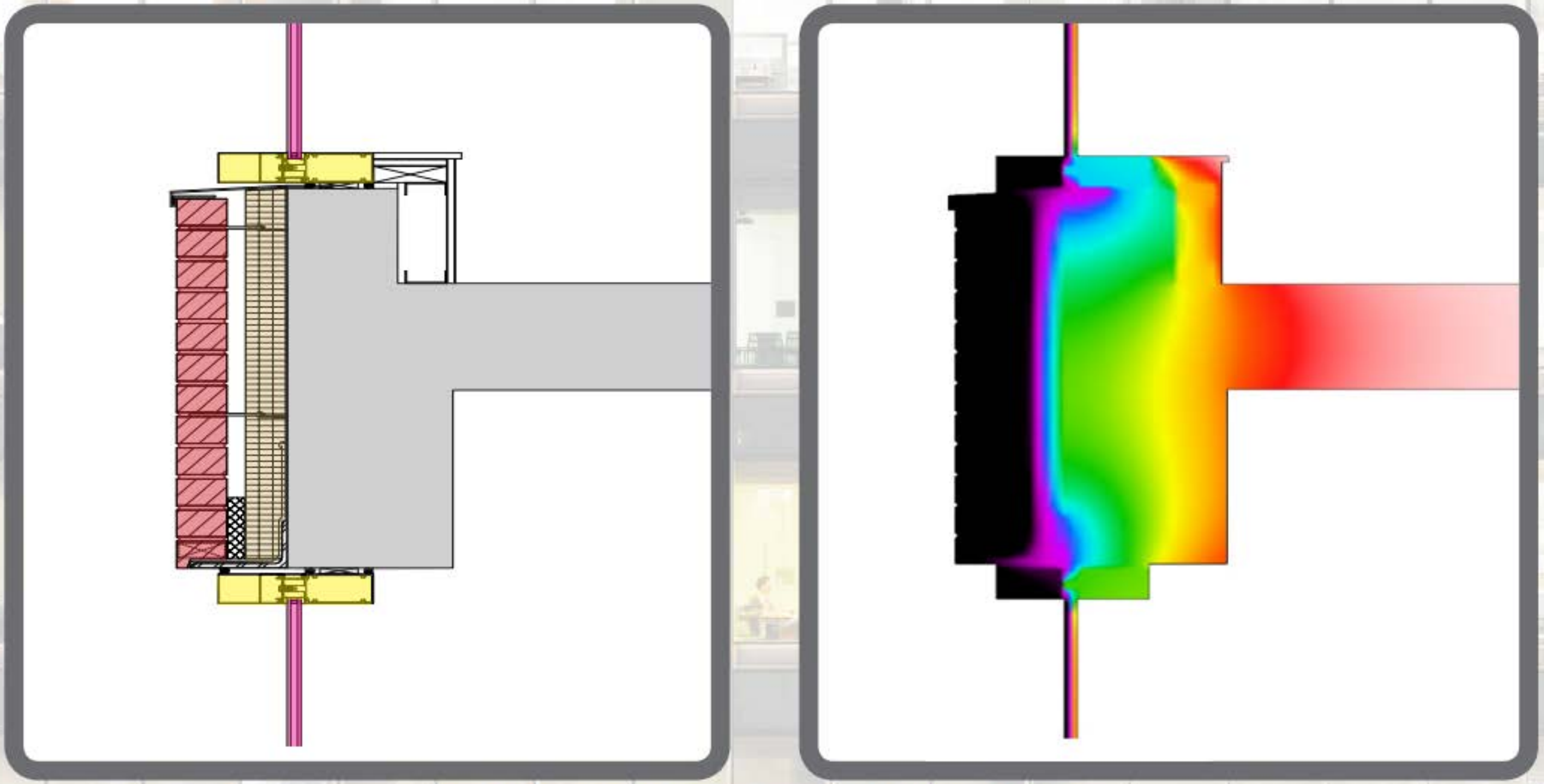
- Windows, windows, windows -
    - Optimize gains/losses = Heating/Cooling

- Walls/Roof
    - Moderate R-values = Ok!

- Peak Loads
    - + Efficiency Mechanical Systems

- Careful Design – A little PV goes a long way

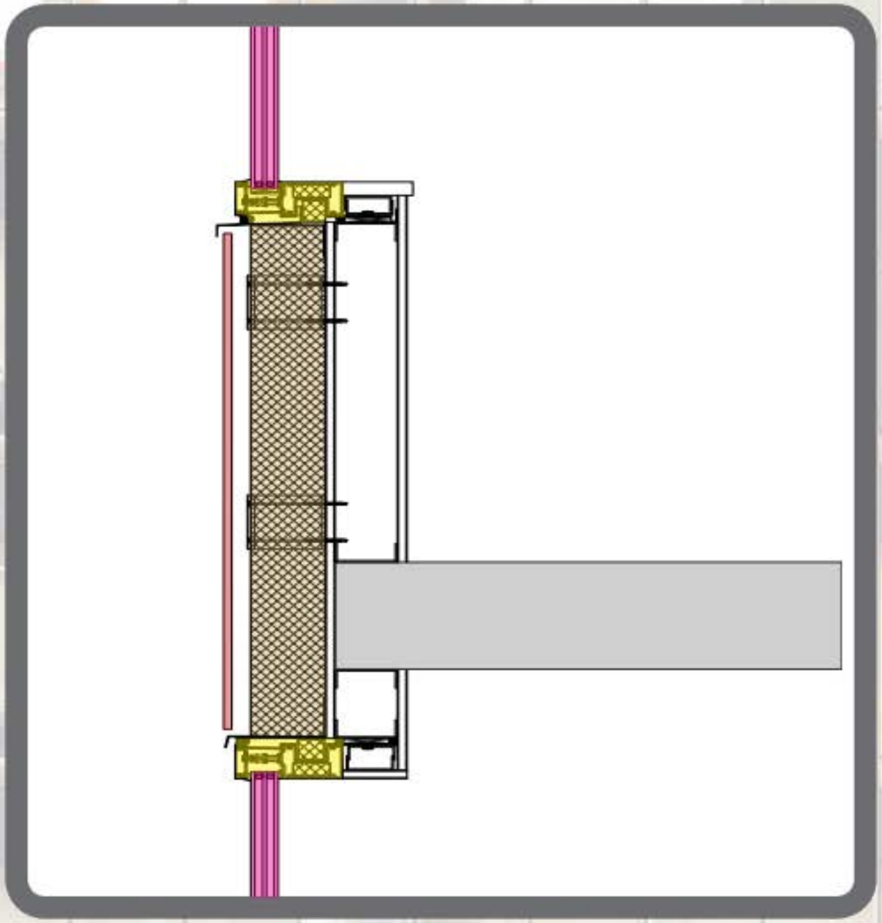
Hypothetical Details

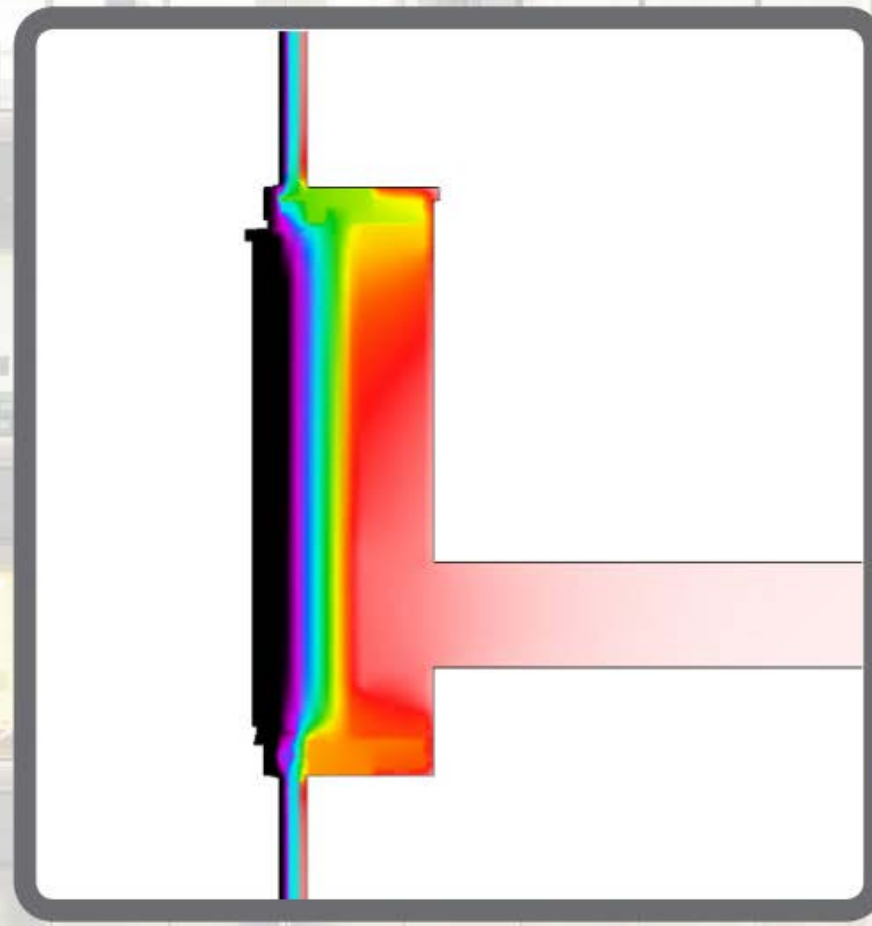


REFERENCE BUILDING WALL

Jason Sippel & Duane Carter w/

Hypothetical Details





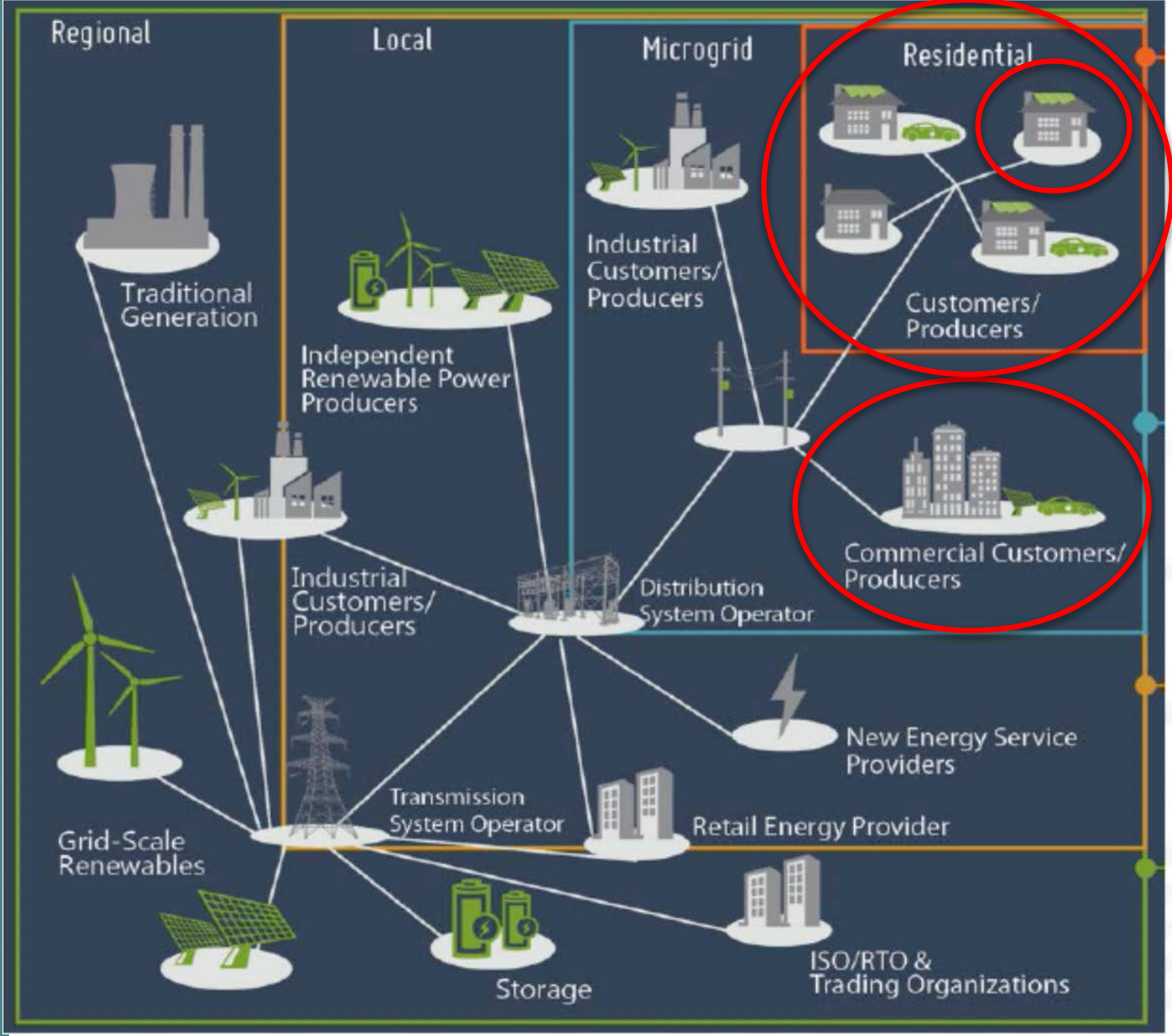
IMPROVED WALL

Jason Sippel & Duane Carter w/

ADVOCACY & RESOURCE SHARING COMMERCIAL/LARGE MULTIFAMILY RESOURCE CENTER www.phius.org

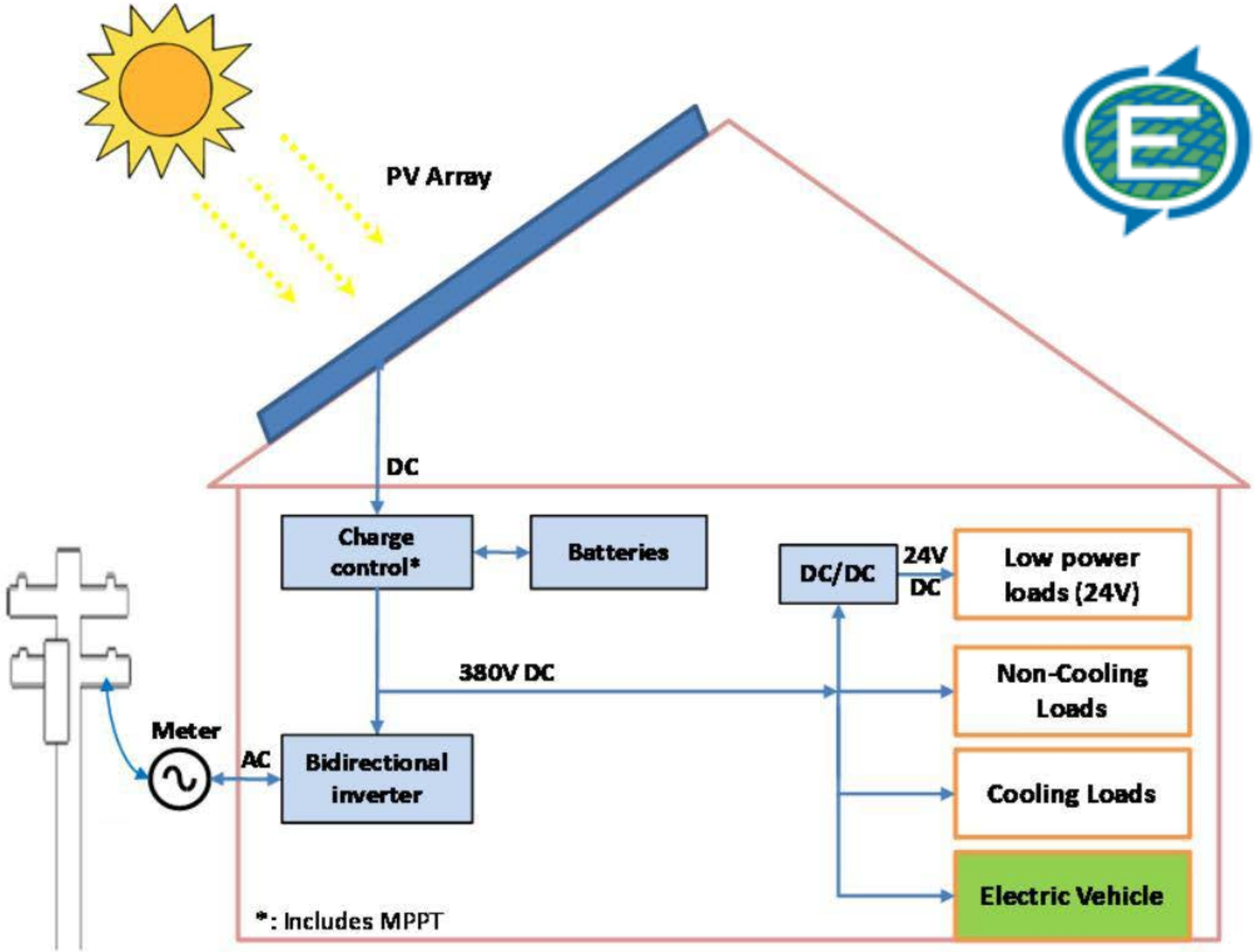
NEXT FRONTIERS

PASSIVE BUILDINGS AT THE CORE OF **TRANSACTIVE** ENERGY SYSTEMS



Source: Melton, R. PNNL, 2004. Transactive Energy, Presentation

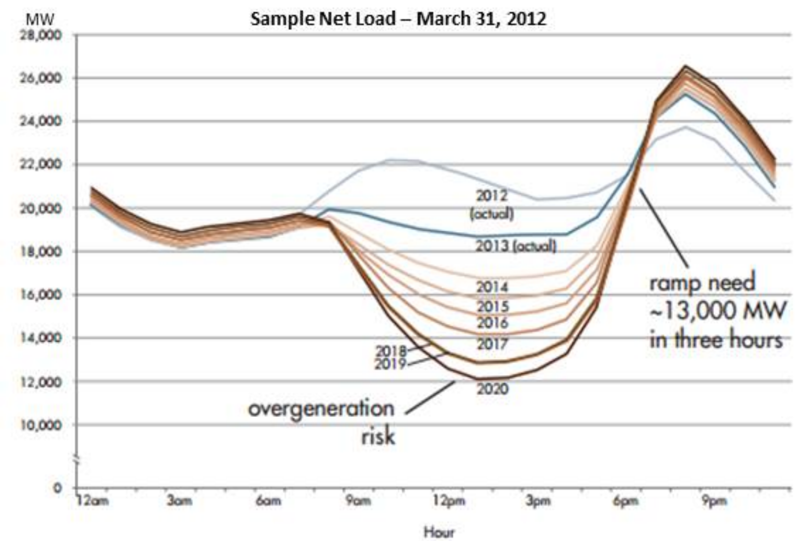
DIRECT CURRENT MICROGRID



http://energy.gov/sites/prod/files/2015/03/f20/DC_Microgrid_Scoping_Study_LosAlamos-Mar2015.pdf

THERMAL STORAGE & ENERGY STORAGE

The duck curve shows steep ramping needs and overgeneration risk



(from the California Independent System Operator)

Beach Green North, New York, NY

LARGEST MIDRISE IN QUEENS, COMPLETED WITH 101 UNITS, 1% ADDITIONAL COST

Sol-Lux Alpha, San Francisco, C

Rocky Mountain Institute Innovation Center, Basalt, CO

NEW RMI HEADQUARTERS IN BASALT

JOIN US!

PATH TO ZERO, COMFORT&HEALTH, CARBON ACTION

PASSIVE BUILDING

IS PART OF THE SOLUTION

Katrin Klingenberg, Executive Director
www.PHIUS.org/www.PHAUS.org