We will be starting soon!

Thanks for joining us

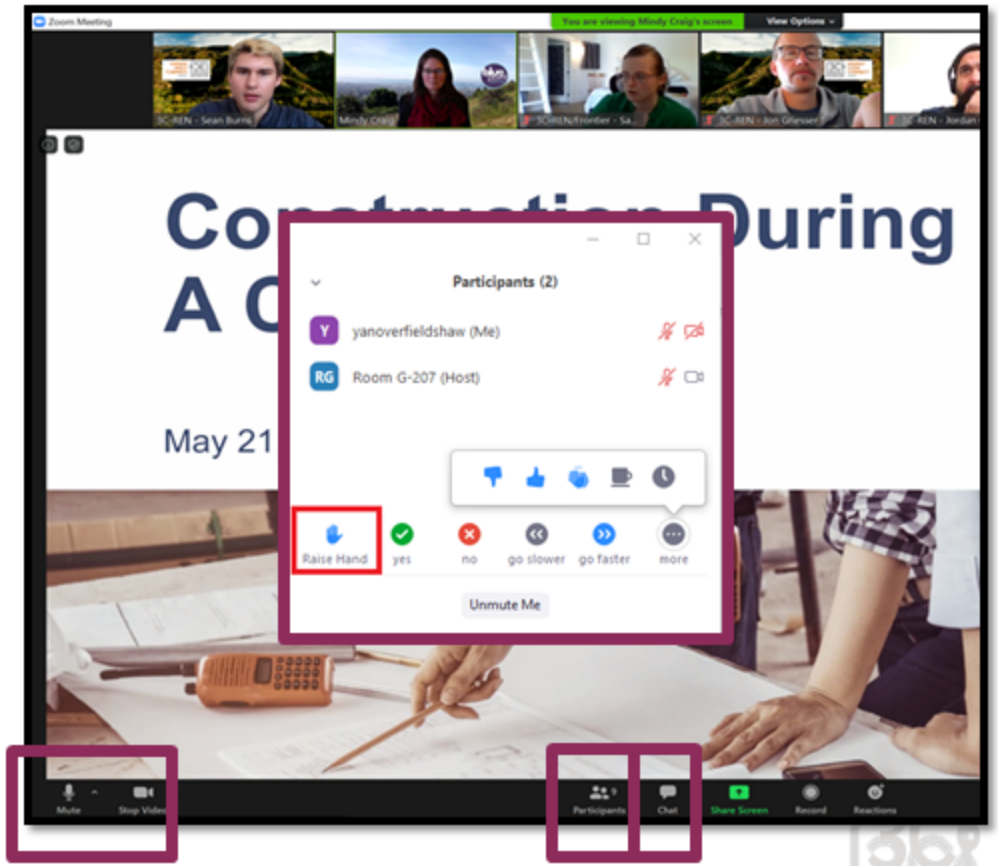
Introduction to Passive House Retrofits

Steve Mann, The Passive House Network and Home Energy Services

September 11, 2023

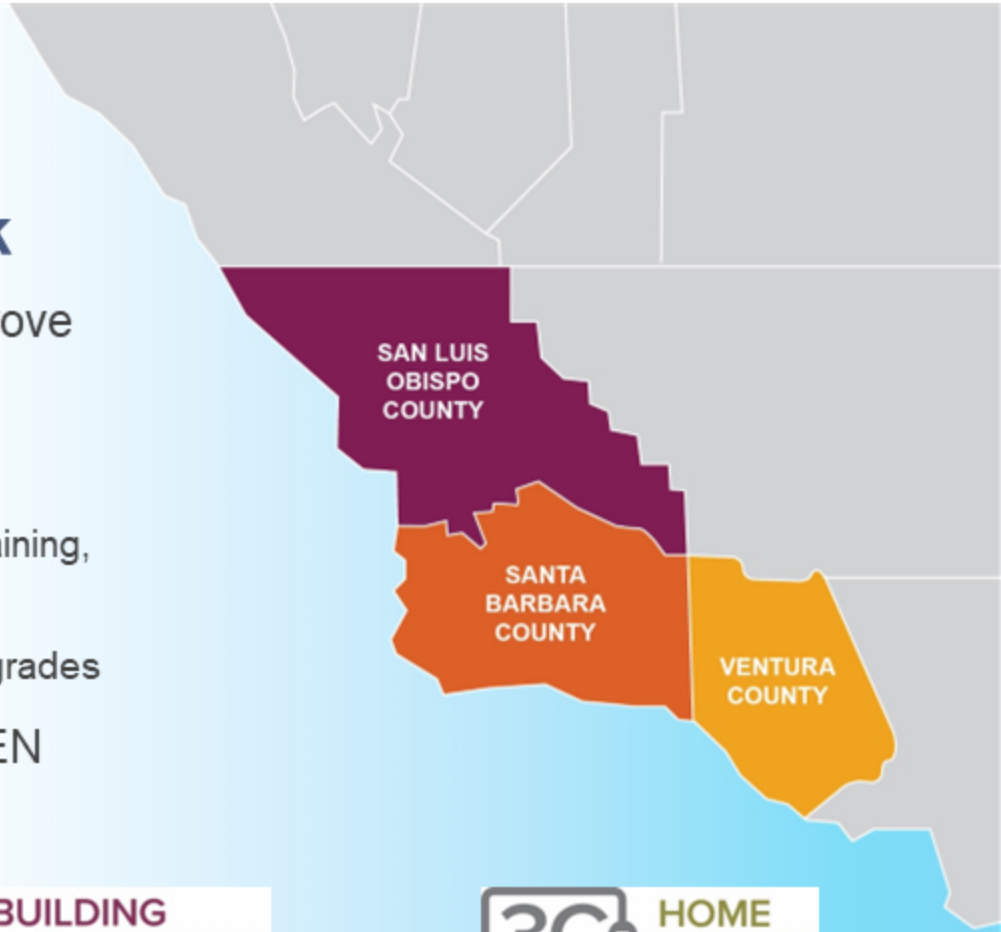
Zoom Orientation

- Please be sure your full name is displayed
- Please mute upon joining
- Use "Chat" box to share questions or comments
- Under "Participant" select "Raise Hand" to share a question or comment verbally
- The session may be recorded and posted to 3C-REN's on-demand page. Feel free to ask questions via the chat and keep video off if you want to remain anonymous in the recording.



3C-REN: Tri-County Regional Energy Network

- Three counties working together to improve energy efficiency in the region
- Services for –
  - **Building Professionals:** industry events, training, and energy code compliance support
  - **Households:** free and discounted home upgrades
- Funded by ratepayer dollars that 3C-REN returns to the region



3C REN ENERGY CODE CONNECT

3C REN BUILDING PERFORMANCE TRAINING

3C REN HOME ENERGY SAVINGS

3C REN ENERGY CODE CONNECT

- Serves all building professionals
- Three services –
  - **Energy Code Coach**
  - **Training and Support**
  - **Regional Forums**
- Makes the Energy Code easy to follow

Energy Code Coach:
3c-ren.org/codes
805.781.1201

Event Registration:
3c-ren.org/events

BUILDING PERFORMANCE TRAINING

- Serves current and prospective building professionals
- Expert instruction:
  - **Technical skills**
  - **Soft skills**
- Helps workers to thrive in an evolving industry

Event Registration:
3c-ren.org/events

3C REN HOME ENERGY SAVINGS

Multifamily (5+ units)

- No cost technical assistance
- Rebates up to $750/apartment plus additional rebates for specialty measures like heat pumps

Single Family (up to 4 units)

- Sign up to participate!
- Get paid for the metered energy savings of your customers

Enrollment:
3C-REN.org/contractor-participation

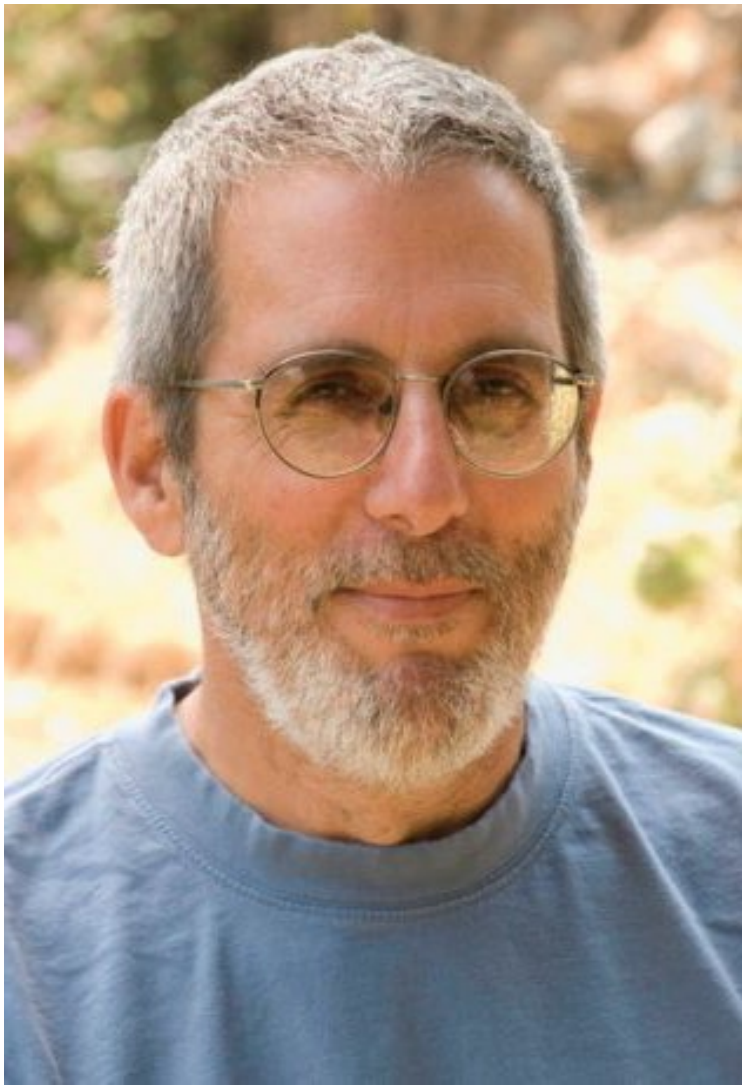
3C-REN
Staff Online

Introduction to Passive House Retrofits

4-Hour Course

The Passive House Network

Presenter Info



Steve Mann

CPHD, CPHT,& PHI Certifier
Principal / Home Energy Services
Trainer / PHN

Agenda

- Introduction
- The EnerPHit Certifications
- Passive House Principles
- Passive House Envelope
- Passive House HVAC Systems
- Passive House Modeling and Design Evaluation

Member Of A Continental Network

The Passive House Network

The Passive House Network

12 Regional Groups Working in Cooperation

in support of professionals working with the **international Passive House Standard**

Passive House Institute

International PASSIVE HOUSE Association iPHA

Prepare to revise your thinking…

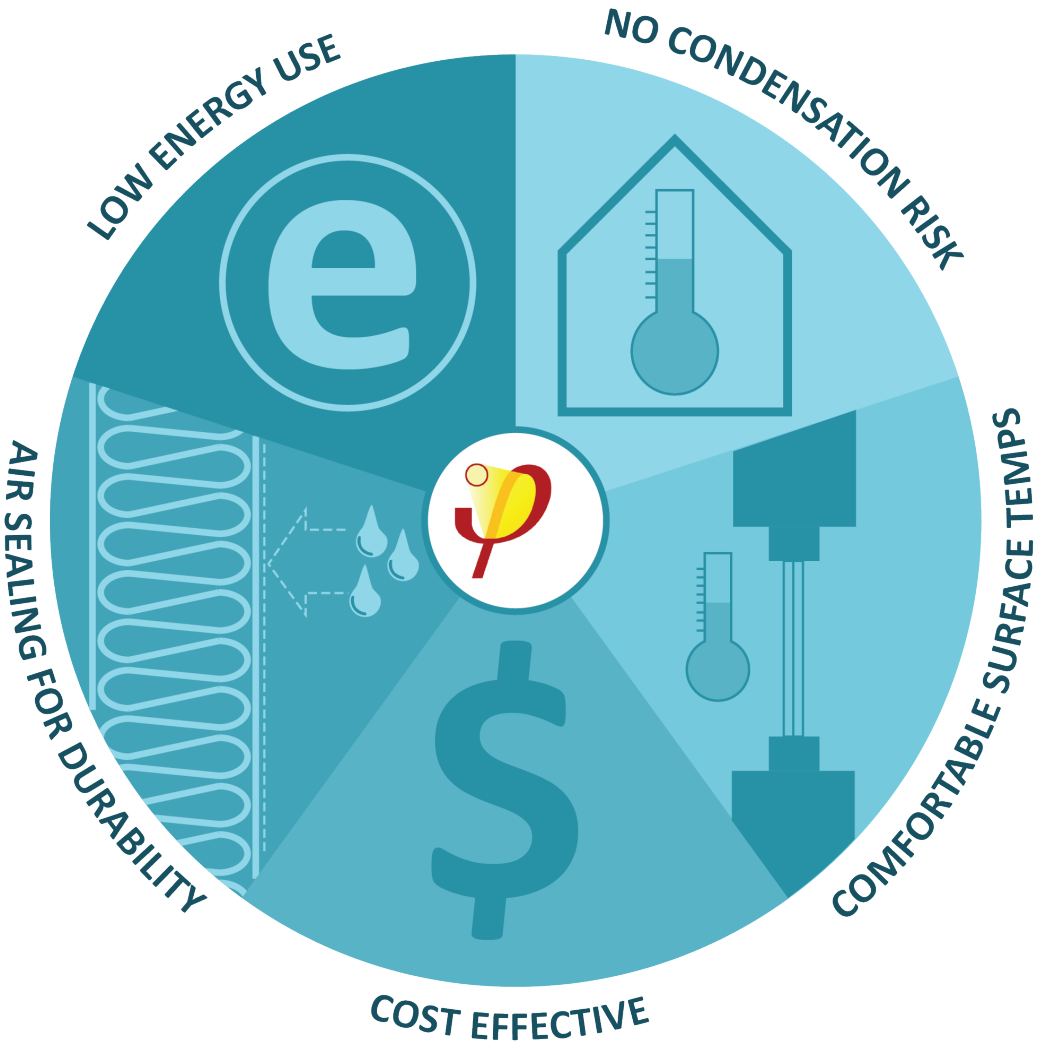
Comfort Drives Performance

What Is A ‘Passive House’?

Performance Standard

- High Occupant Comfort
- High Durability
- Low Energy Use
- Low Peak Loads (Grid Friendly)
- Predictable Performance

The Passive House Standard



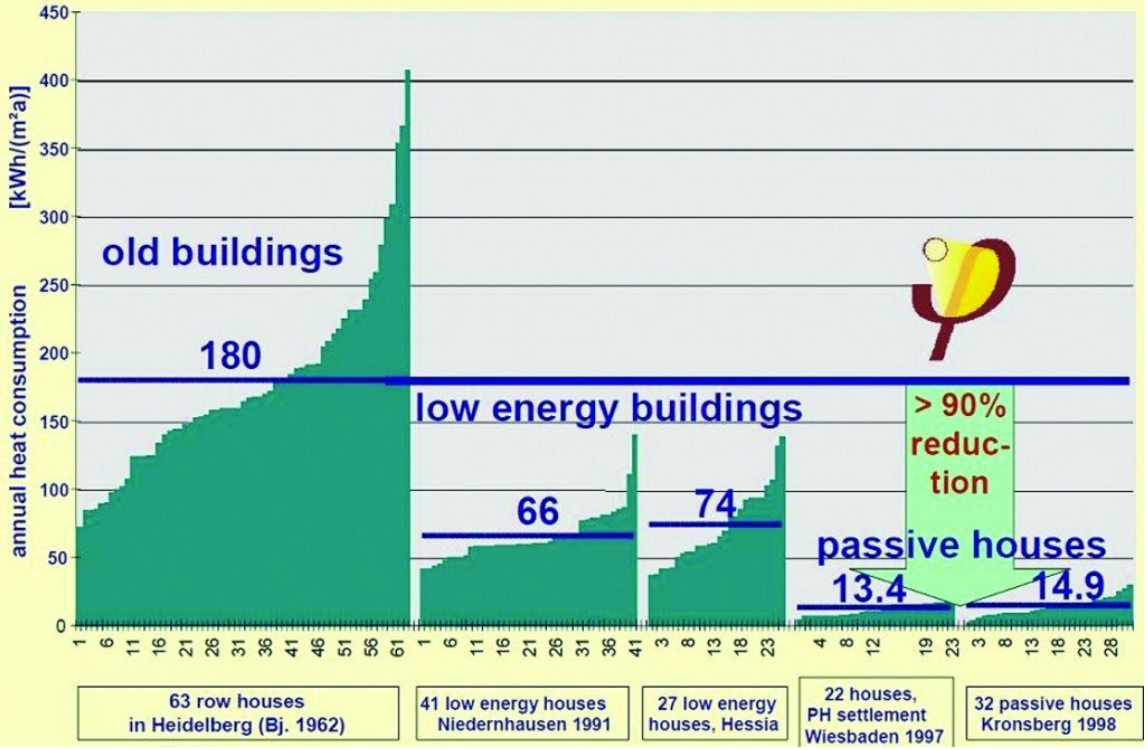
Resulting In Dramatic Energy Savings

Approx **90%**

reduction in heating & cooling

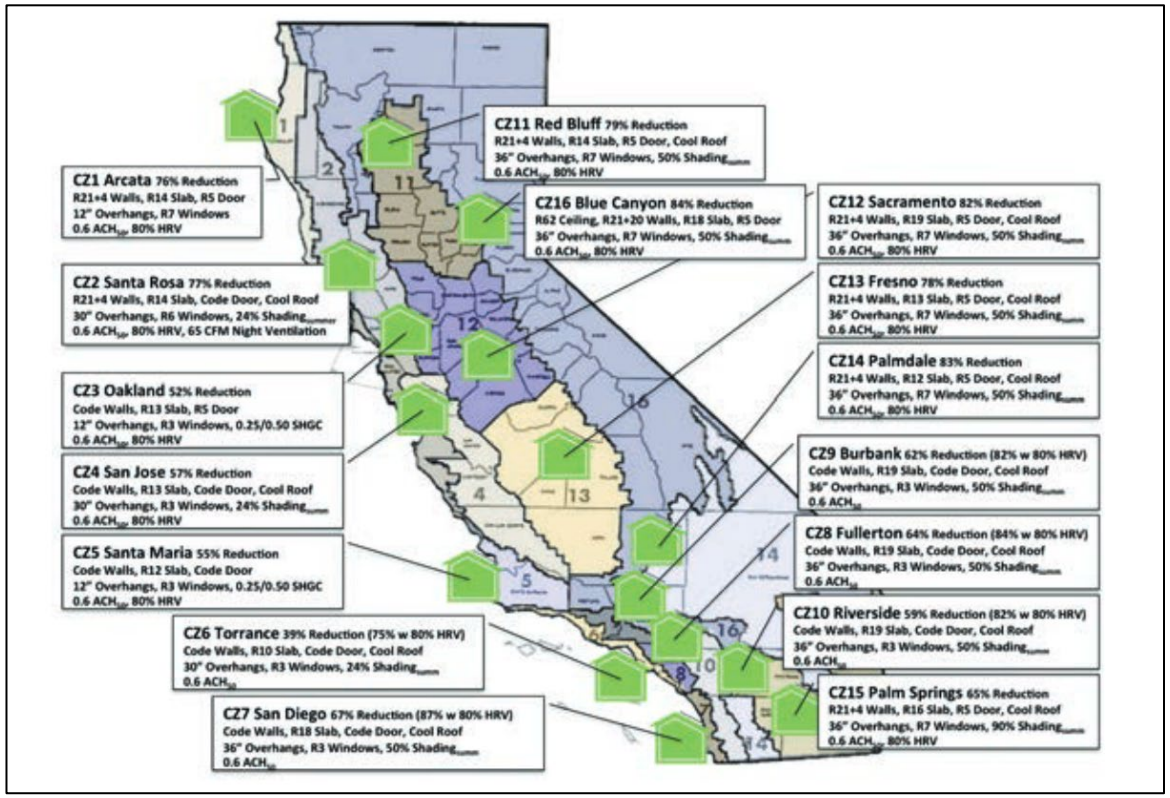
Up to **75%**

reduction in total energy usage.



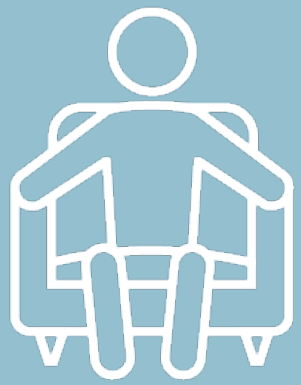
Resulting In Dramatic Energy Savings

In California,
39% to **83%** reduction in heating & cooling



Source credit: Graham Irwin – Essential Habitat

Comfortable

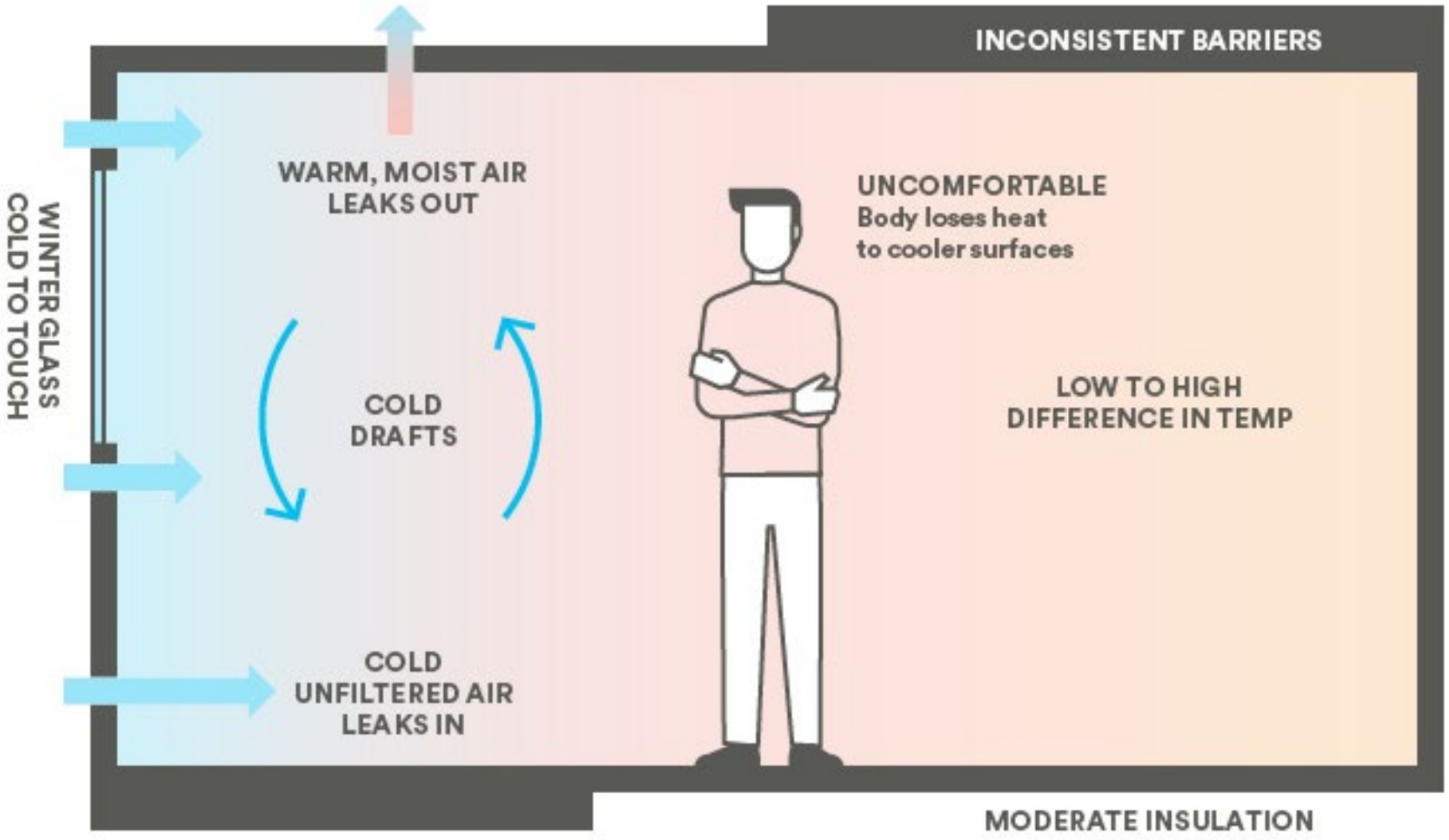


Thermal Comfort

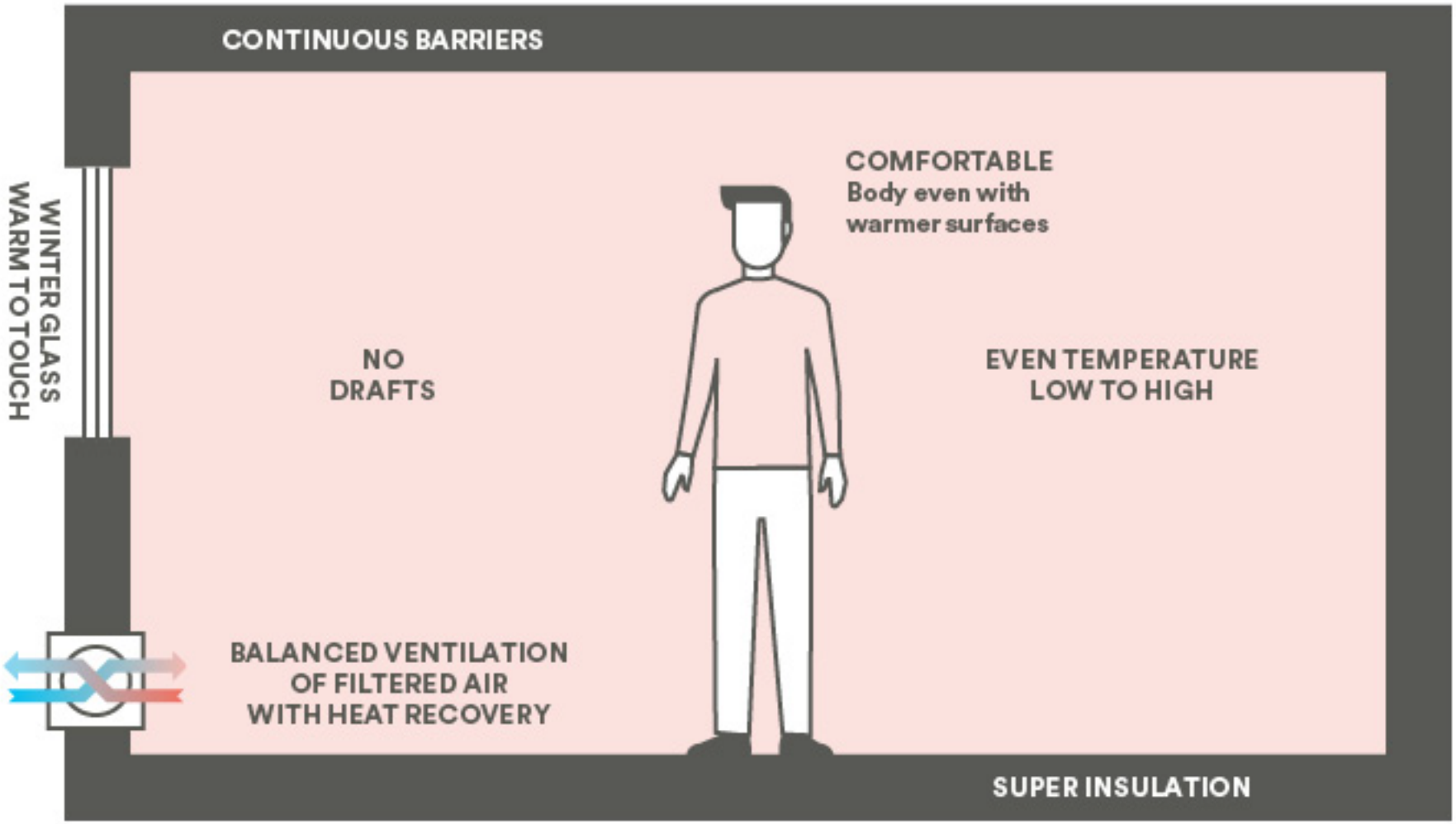
Essential factors which influence thermal comfort

- Air temperature
- Surface temperatures
- Local temperature differences (vertical and horizontal)
- Drafts
- Relative humidity of the air
- Clothing and degree of activity

Thermal Comfort In A Normal Building?



Thermal Comfort In A Passive House




STOP
THE
JET NOISE


RAIL ROAD
CROSSING

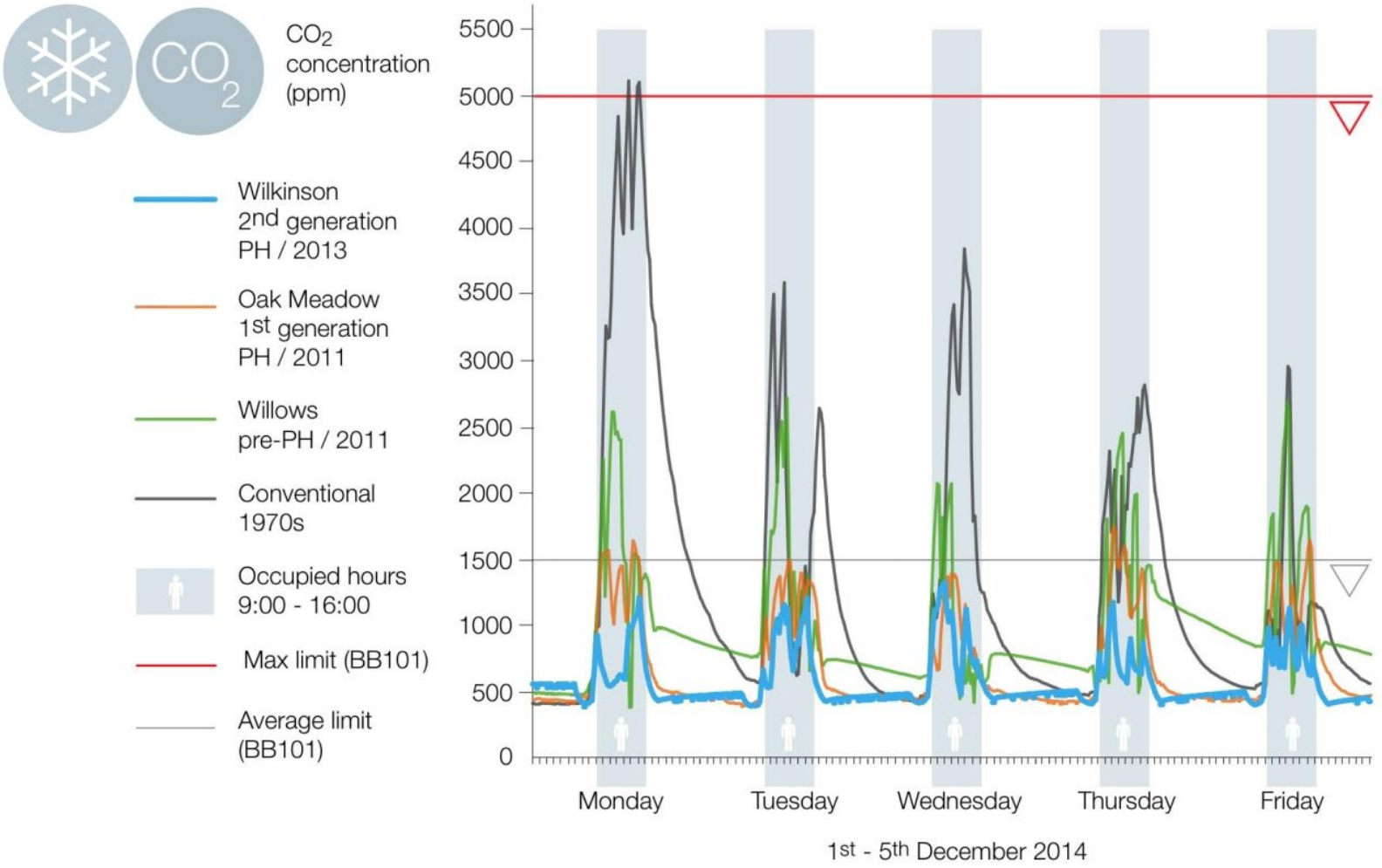

BART

Deep Energy Retrofit Outcomes

Healthy

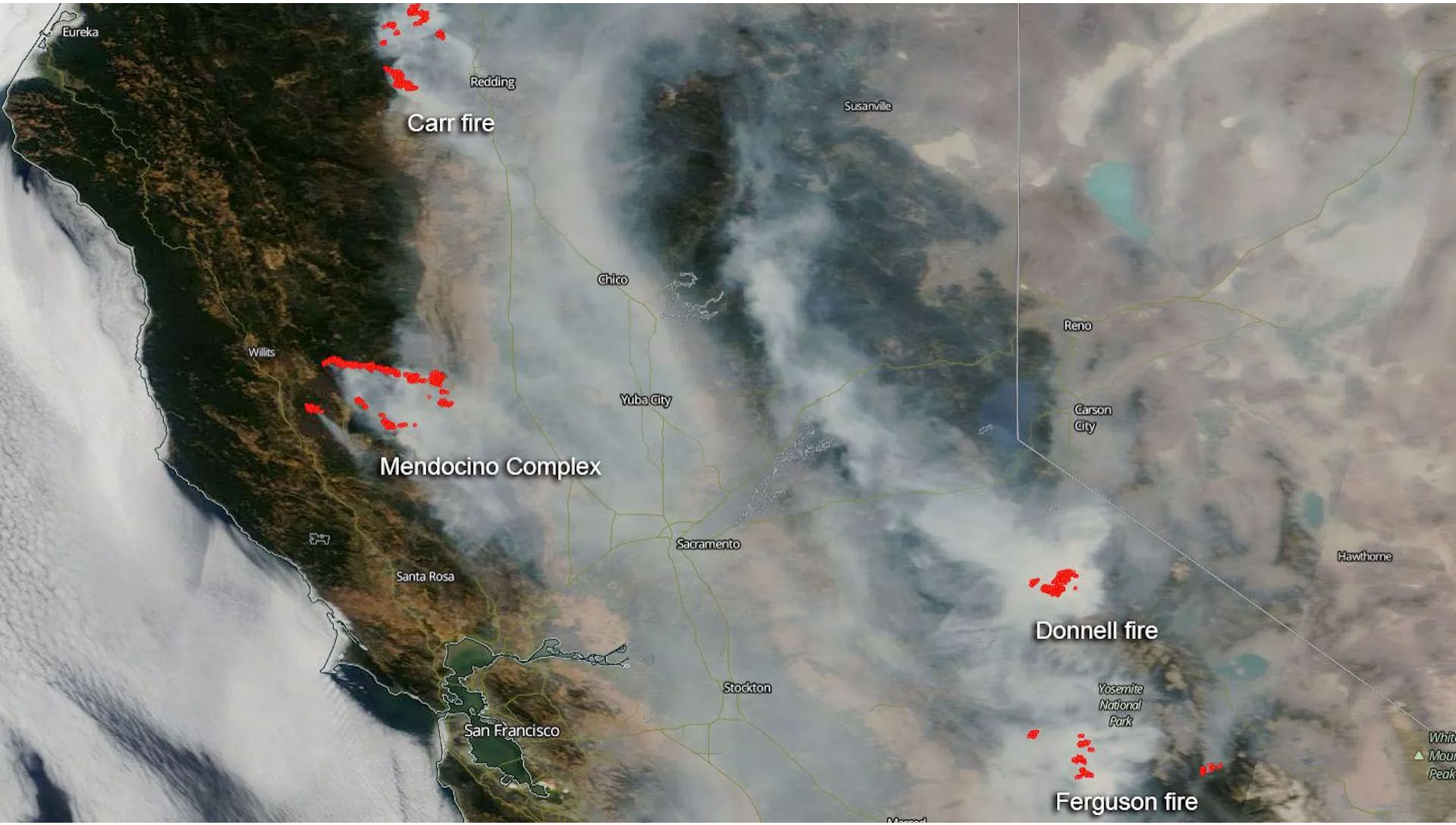
Green Buildings: Consistent, Healthy Air

Post-Occupancy Monitoring: Indoor Air Quality, CO2, Winter (Architype, UK)



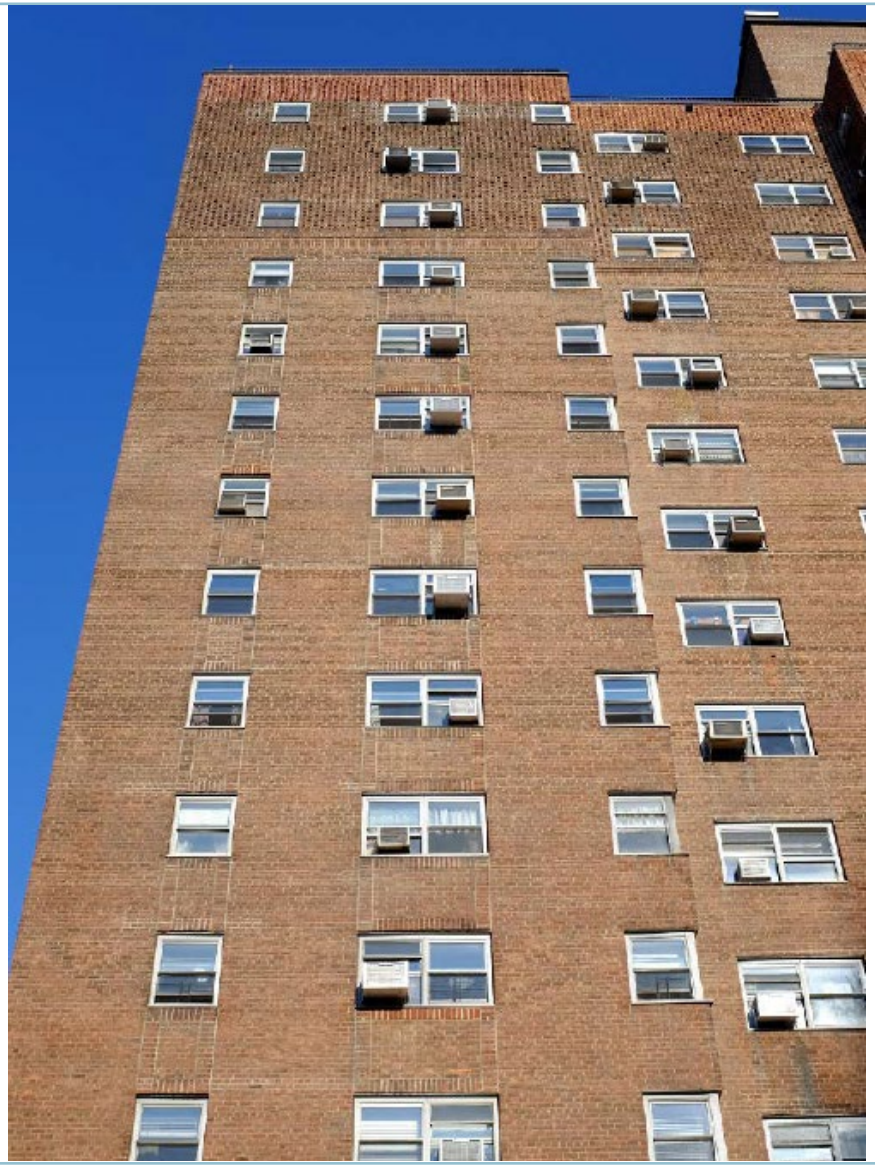
https://sdfoundation.org.uk/wp-content/uploads/2018/02/PHT-2018-Debate-Chryssa-Thoua-Architype.pdf

California – Gasping for Passive House!



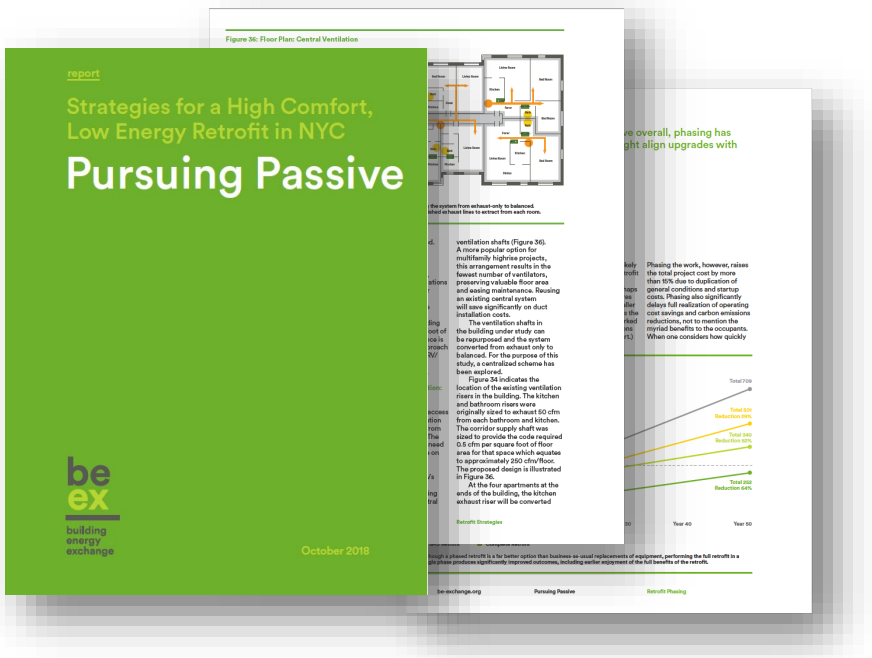
Ultra-Low Energy Use

“Pursuing Passive”

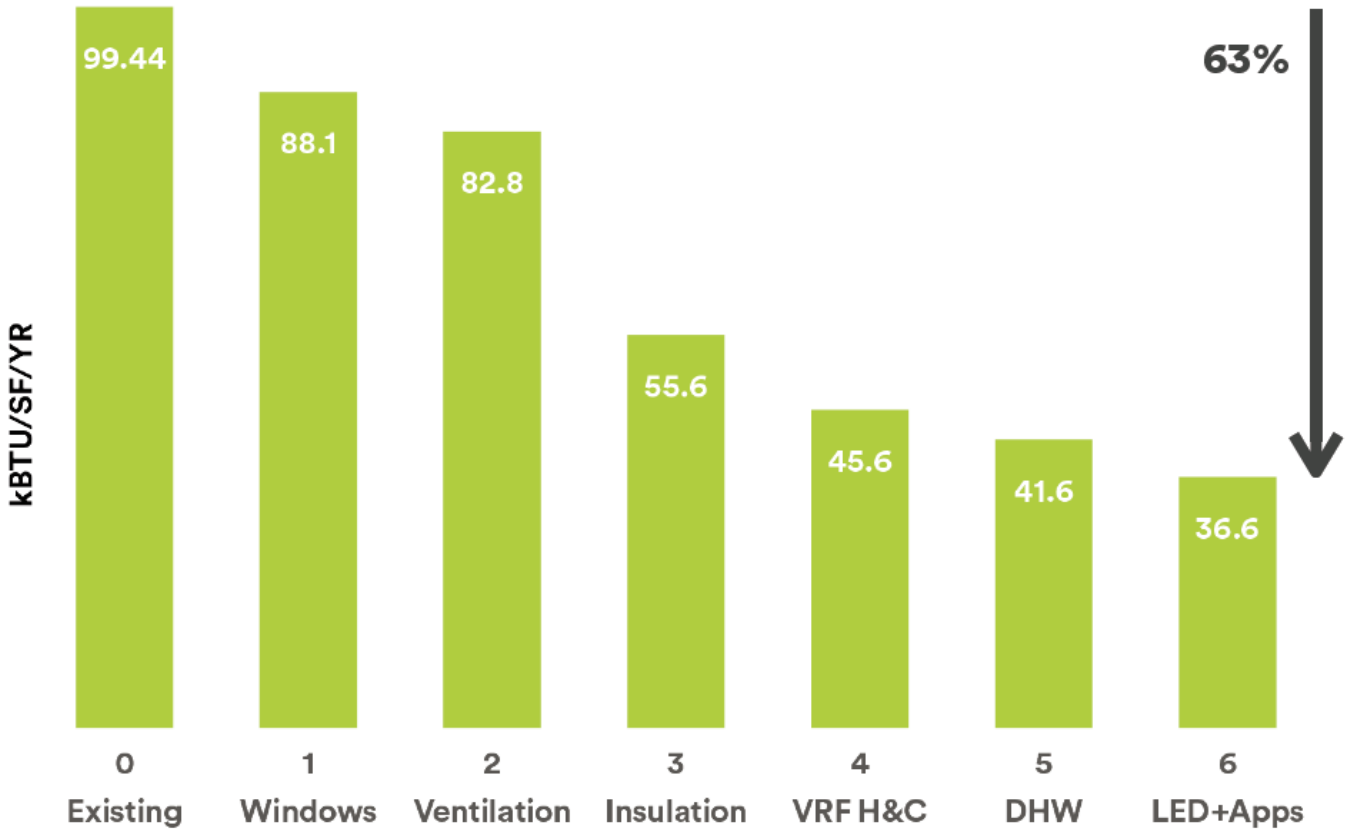


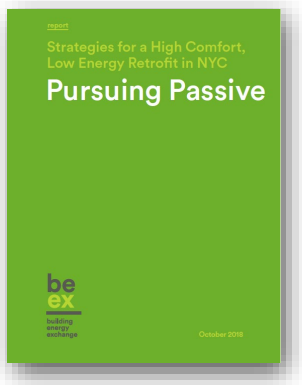
By:
Building Energy Exchange
Passive House Institute
Steven Winters Associates, Inc.

Evaluated retrofit strategies for large multi-family masonry construction



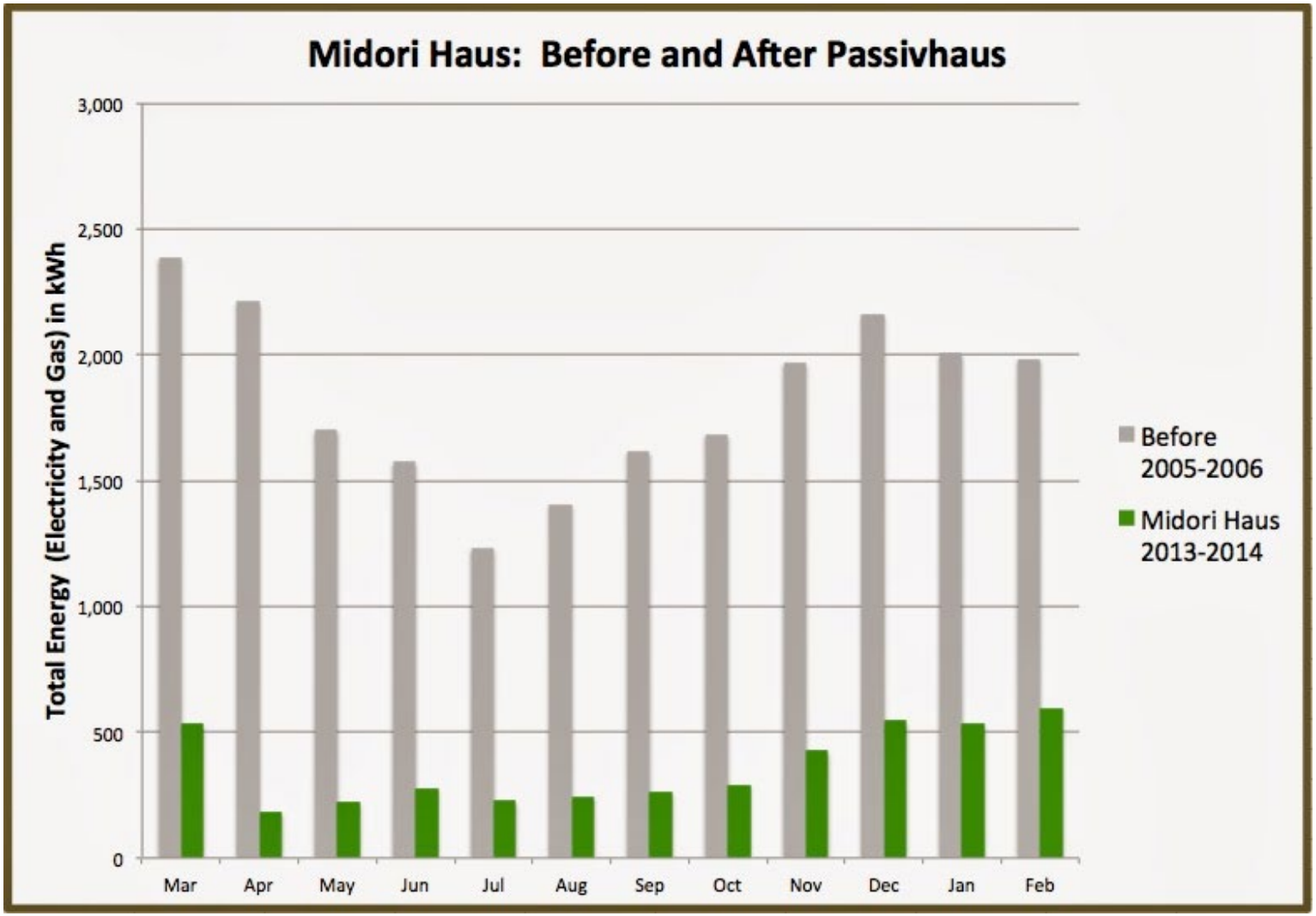
Total Energy Reductions?





Predictable & Resilient

MIDORI HAUS RETROFIT in Santa Cruz, CA



http://midorihaus.com/tag/energy-data/

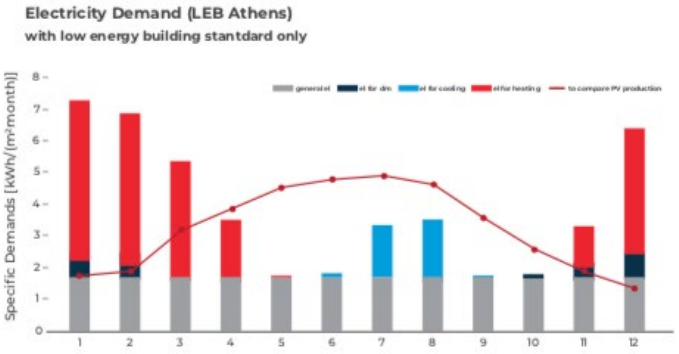
photo: David Shankbone, Wikimedia Commons

Resilient:
Solar + Storage

What's your PEAK LOAD?

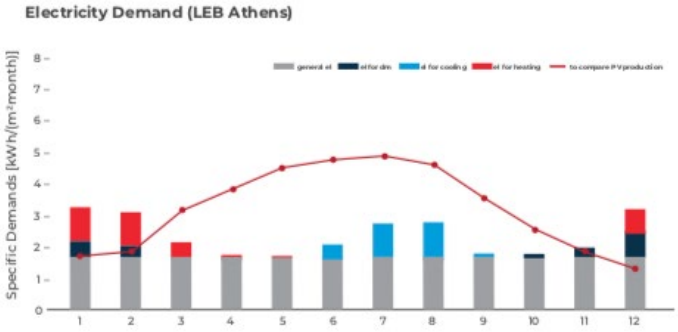
Both these buildings are 'ZNE'

(only one is a Passive House.)



Building Regs
+ Renewables

NET ZERO

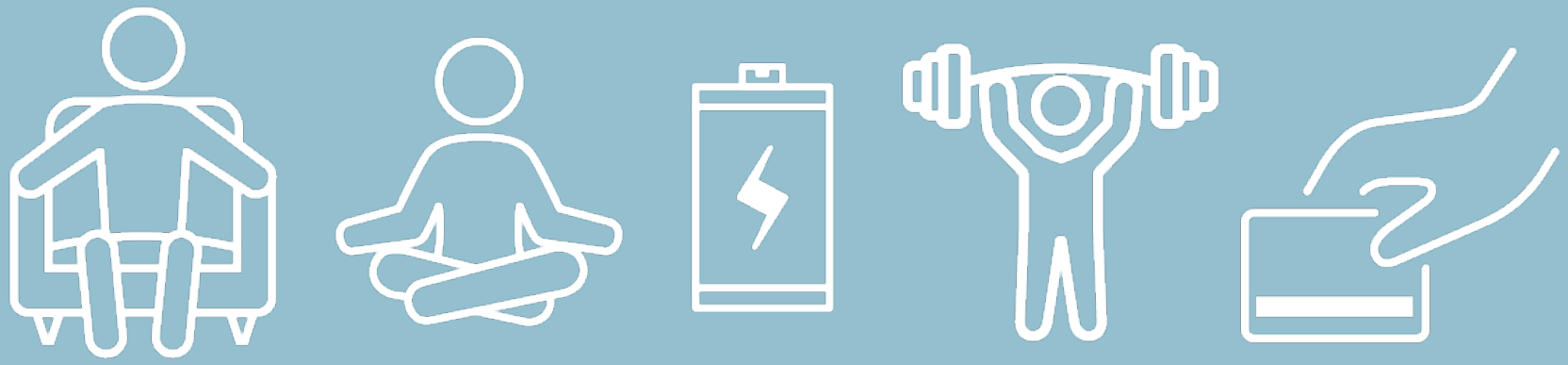


Passive House Classic
+ Renewables

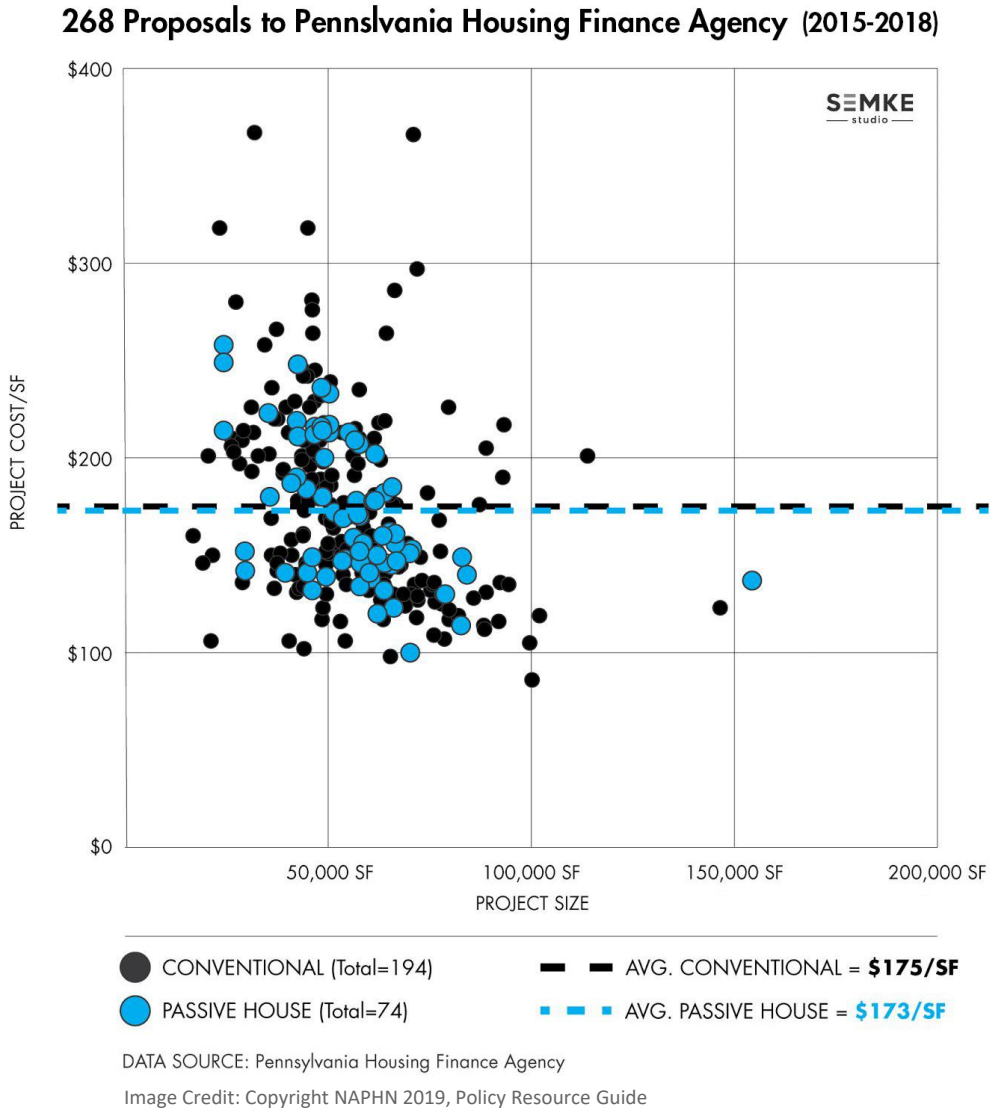
PASSIVE HOUSE

Image Credit: Copyright NAPHN 2019, based on illustrations by UK Passivhaus Trust & Stephan Pallantzas of Hellenic PH Institute

Cost Effective



Passive House Costs Less! (With Practice)

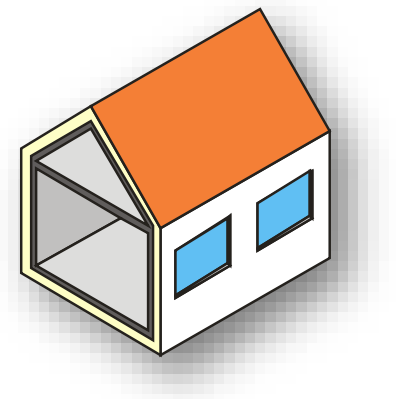


The Enerphit Certifications

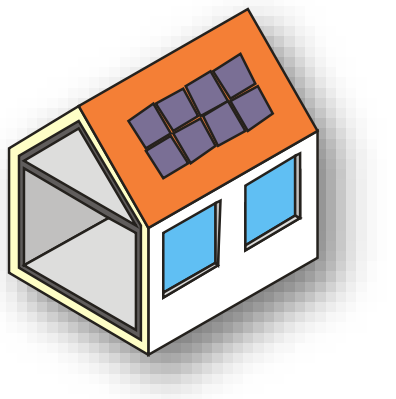
Passive House Worldwide

- Source: https://database.passivehouse.com/buildings/map/

Three New-build Certification Options



Certified Passive House
Passive House Institute
| **classic** | plus | premium |



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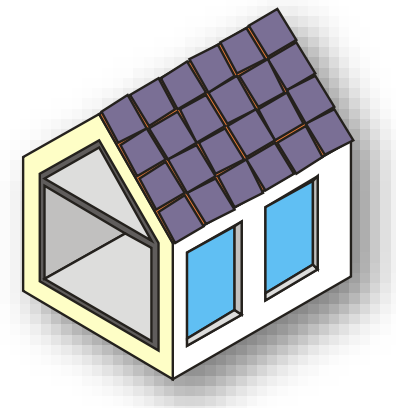
| classic | **plus** | premium |



Certified Passive House
Passive House Institute
| classic | plus | **premium** |

+ renewable energy generation on site or nearby and/or higher energy efficieny

Three Retrofit Passive House Classes

- EnerPHit standard first introduced by PHI in 2010
- Can be reached in one step, or several steps
- If phased, follow an EnerPHit Retrofit Plan (ERP)
- When PER (primary energy renewable) has been reduced by 20%, first ‘pre-certification’ can be issued by the certifier

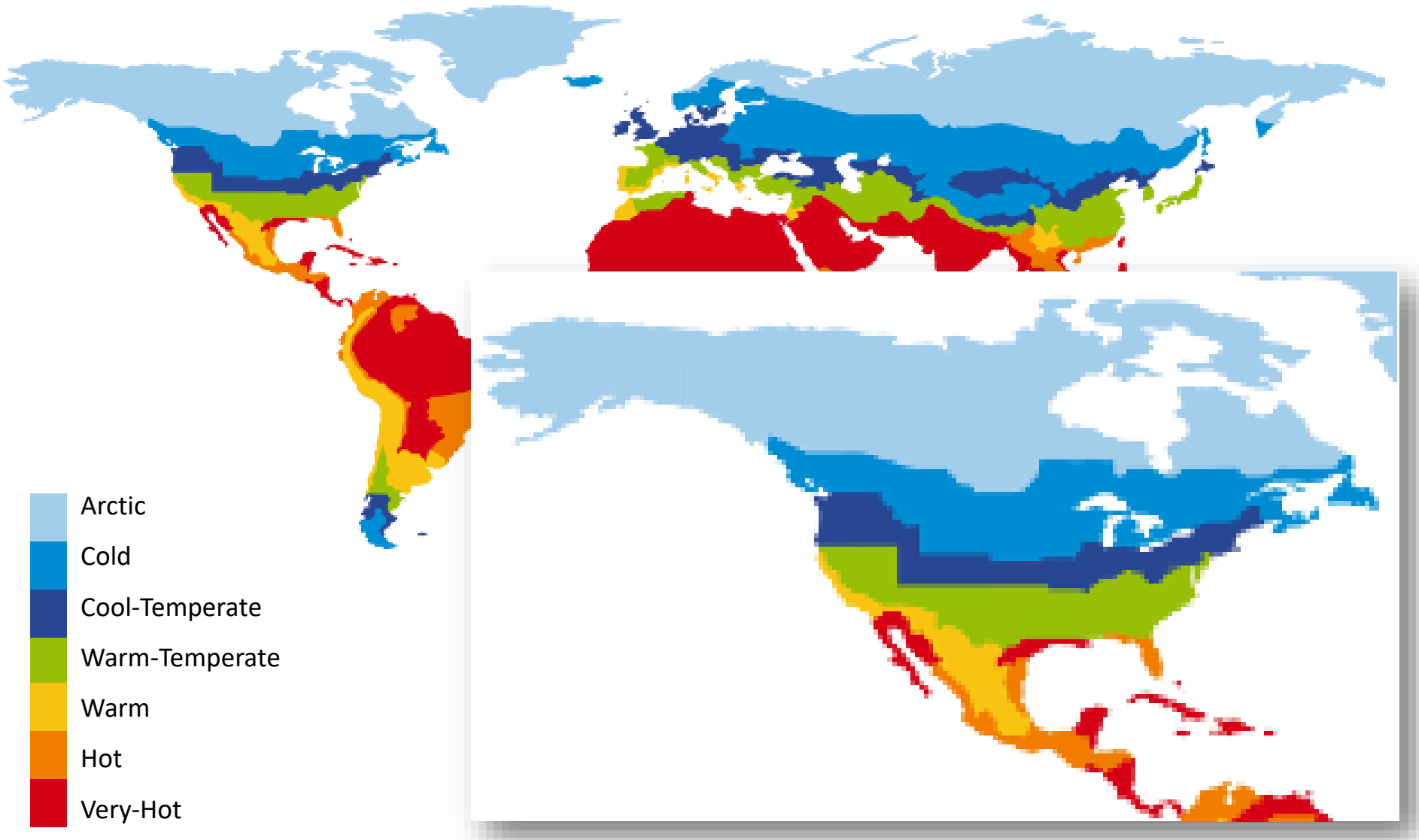
Two Paths To Enerphit Certification

1. Building Component Method

2. Heating Energy Demand Method

3. General EnerPHit Criteria
Applicable irrespective of which certification method is used

Ph Climate Zones



Enerphit Path 1: Building Component Method

Climate Zone (PHI)	Min. Wall R-Value [hr-sf-F/Btu]		Max. Window U-Value	Ventilation	
	Exterior	Interior	Vertical	Min. Heat Recovery %	Min. Humidity Recovery %
Arctic	63	23	0.08	80	-
Cold	47	19	0.11	80	-
Cool-Temperate	38	16	0.15	75	-
Warm-Temperate	19	11	0.18	75	-
Warm	11	8	0.22	-	-
Hot	11	8	0.22	-	60
Very Hot	23	13	0.18	-	60

Enerphit Path 2: Energy Demand Method

Climate Zone (PHI)	Annual Specific Energy Demand Limits [kBtu/sf-yr]		
	Heating	Sensible Cooling	Latent Cooling
Arctic	11.0	4.75	Varies by region
Cold	9.5	4.75	
Cool-Temperate	7.9	4.75	
Warm-Temperate	6.3	4.75	
Warm	4.7	4.75	
Hot	-	4.75	
Very Hot	-	4.75	

Certified Passive House

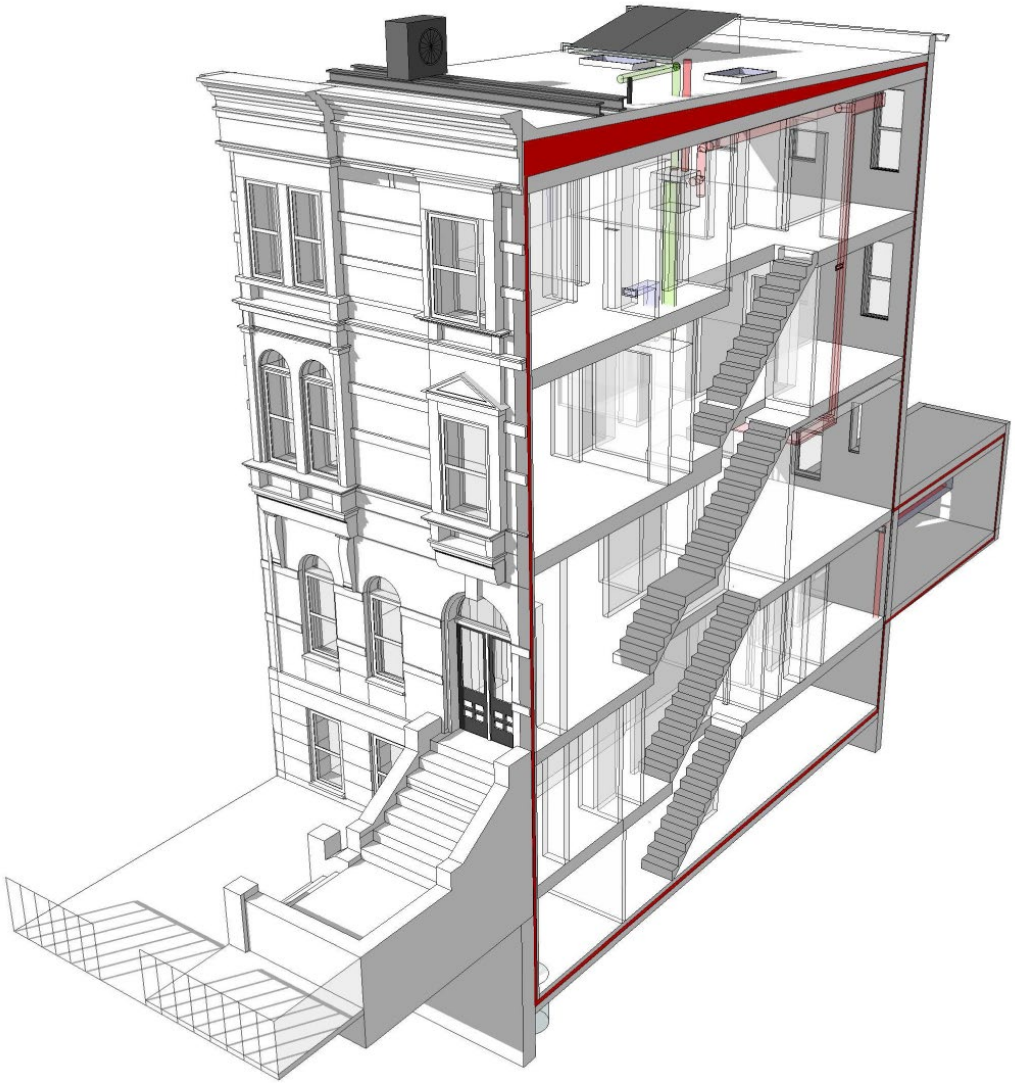
MidoriHaus, Santa Cruz
Essential Habitat

O’Neil Retrofit, Sonoma – 1st Certified Retrofit

O’Neill Residence
Essential Habitat

Retrofit Of Existing Buildings

Certified Passive House: Enerphit



- Slab below grade R21 (Closed Cell Soy based foam)
- Walls R21 (closed cell soy based foam)
- Roof R50-R70 (Cellulose fill)
- Front Windows: u 0.14 (Optiwin)
- Slab on grade R-14 - rigid foam
- Rear windows U-0.19 (Thermotech)
- Air barrier – closed cell foam and Sto-Guard elastomeric coating

CERTIFIED PASSIVE HOUSE: ENERPHIT

Park Pl. Brooklyn
Fabrica 718 Architects
ZeroEnergy Design: PH Engineering

8thSt. Brooklyn
Red Top Architects
Baukraft Engineering

88th st. Manhattan
Baxt | Ingui Architects

Certified Passive House: Historic Facades

NYC's first certified passive house townhouse in a protected historic district

Brooklyn Heights Townhouse
Baxt | Ingui Architects

Complex Buildings In Varied Climates

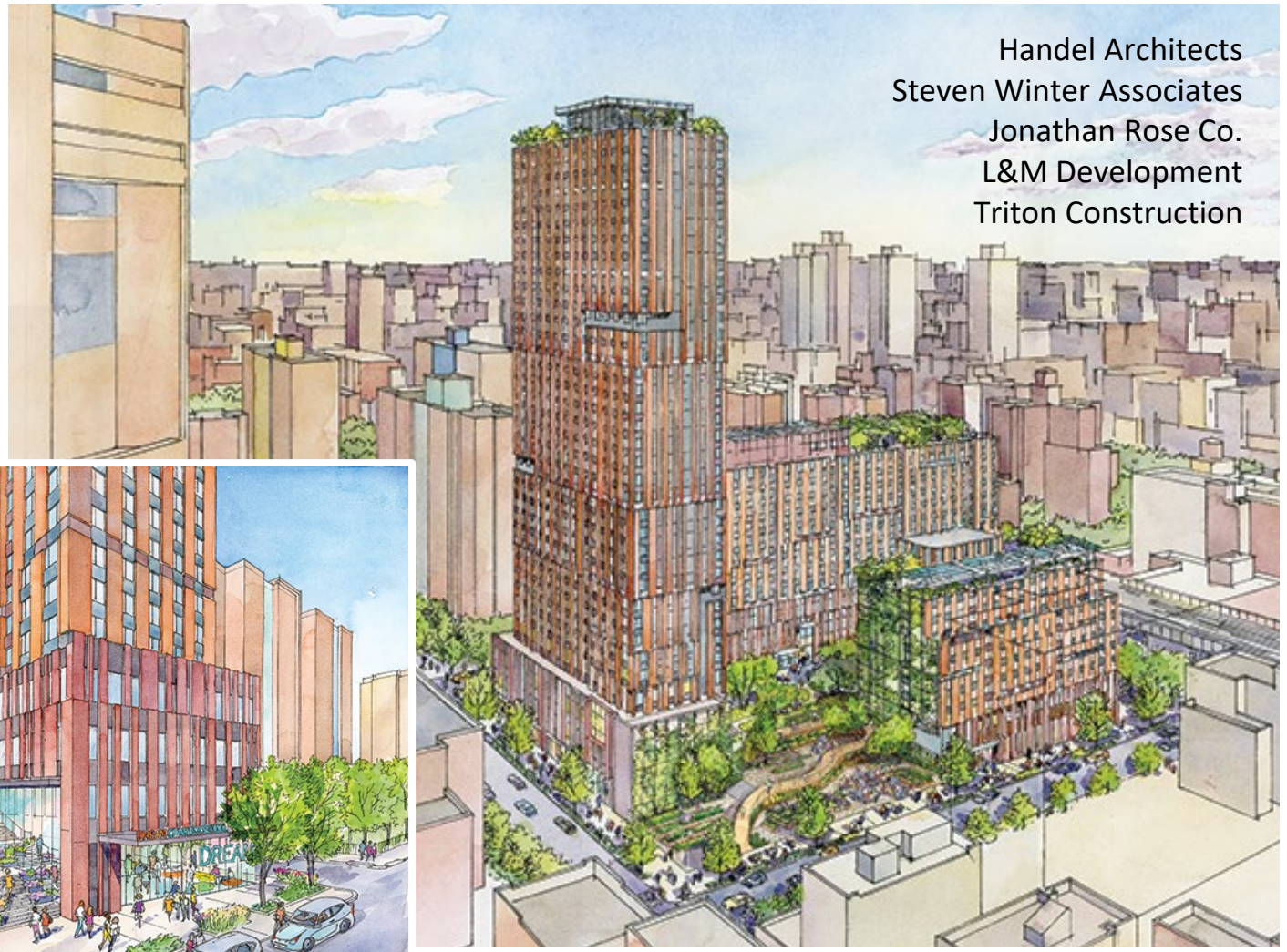
Certified Passive House: Cornell Dormitory

Pre-certified Passive House: Sendero Verde

East 111th Street, East Harlem, New York.

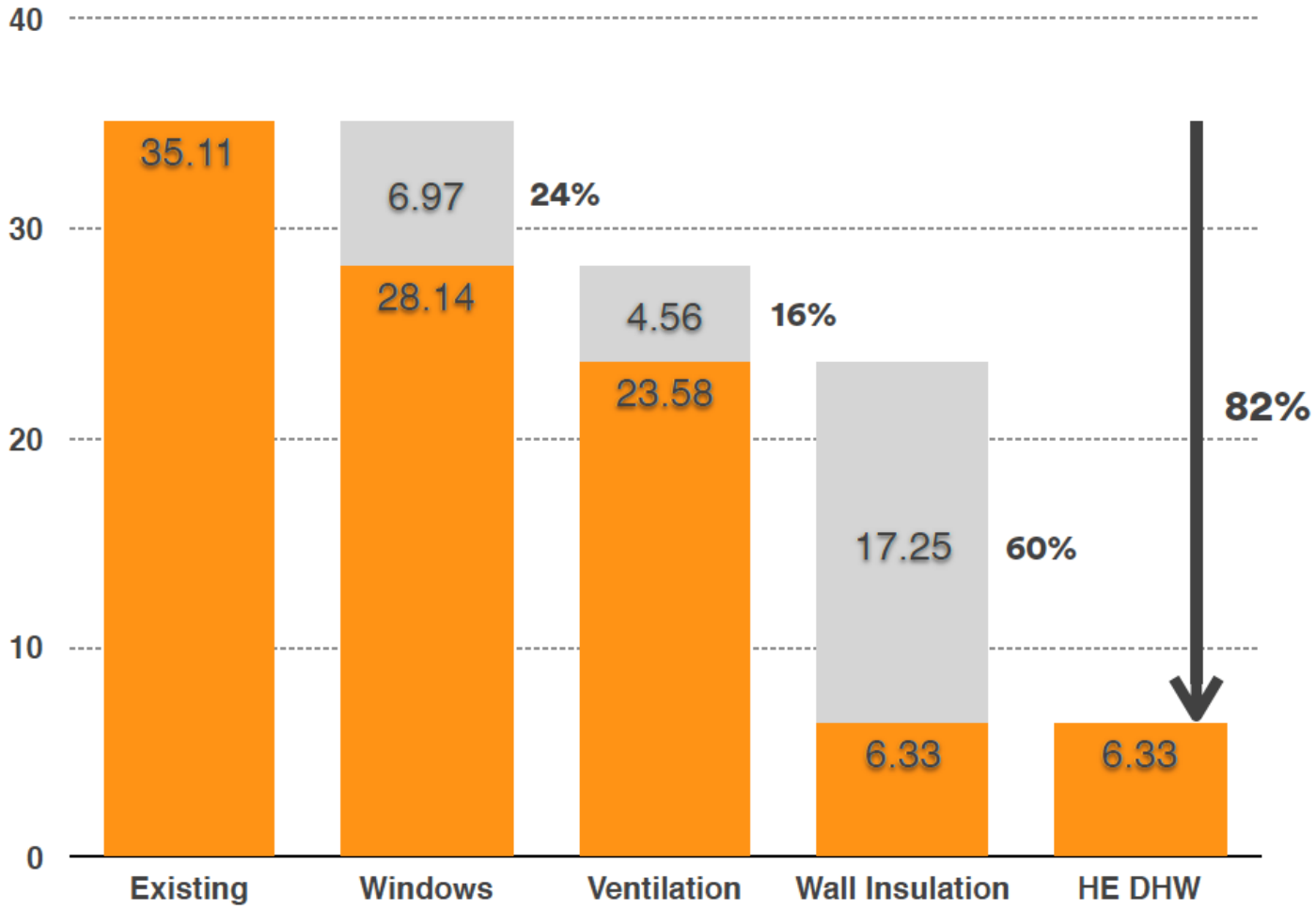
Largest Passive House certified project in the nation.

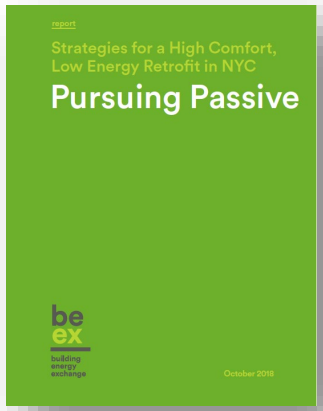
655 affordable units



Handel Architects
Steven Winter Associates
Jonathan Rose Co.
L&M Development
Triton Construction

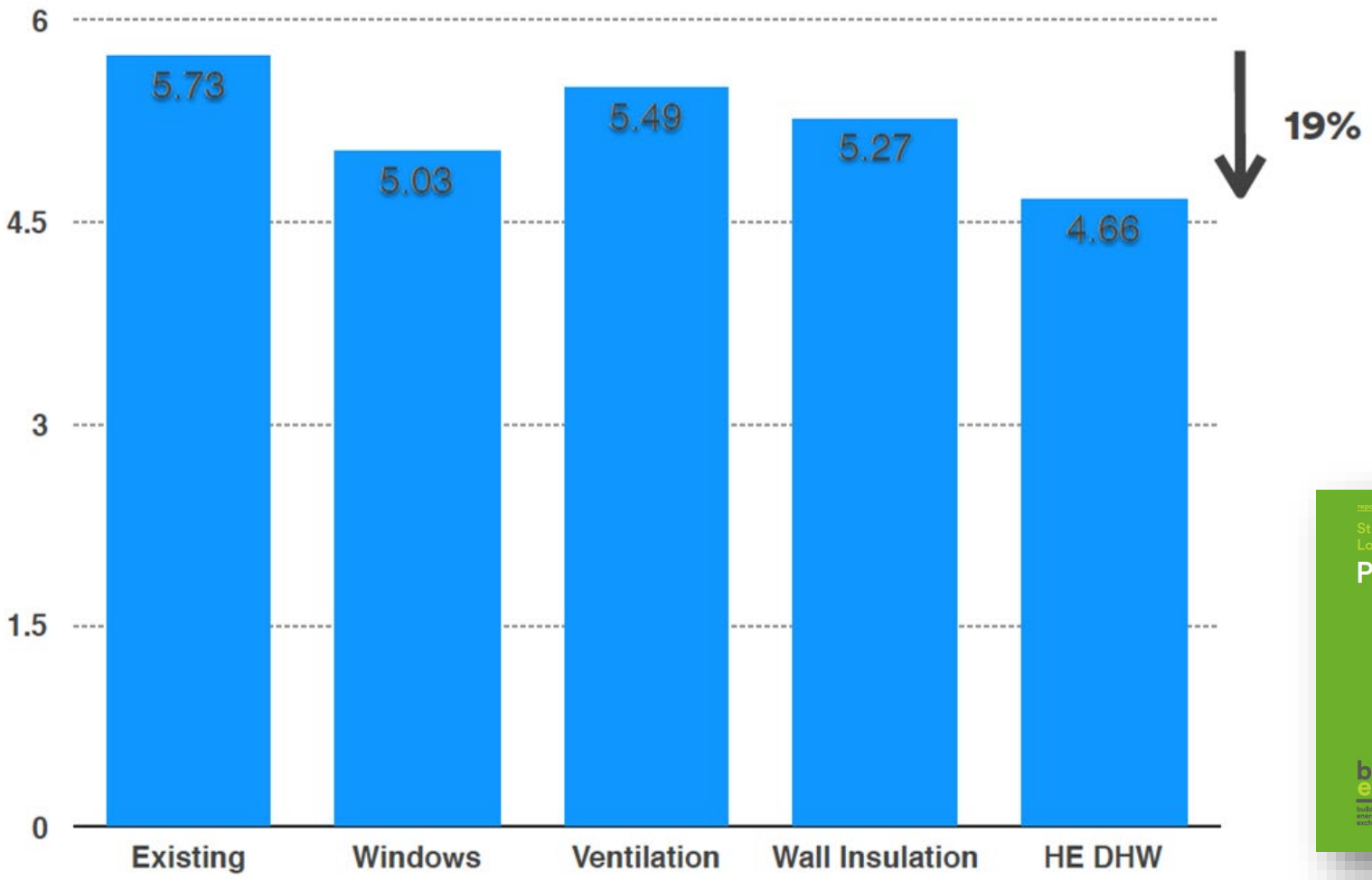
“Pursuing Passive” Heating Demand

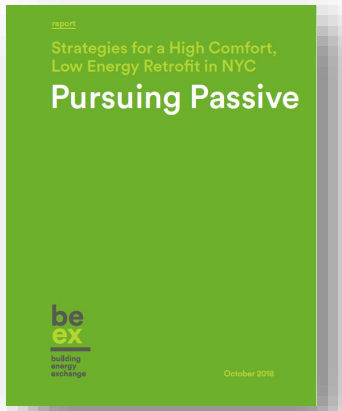




be-exchange.org

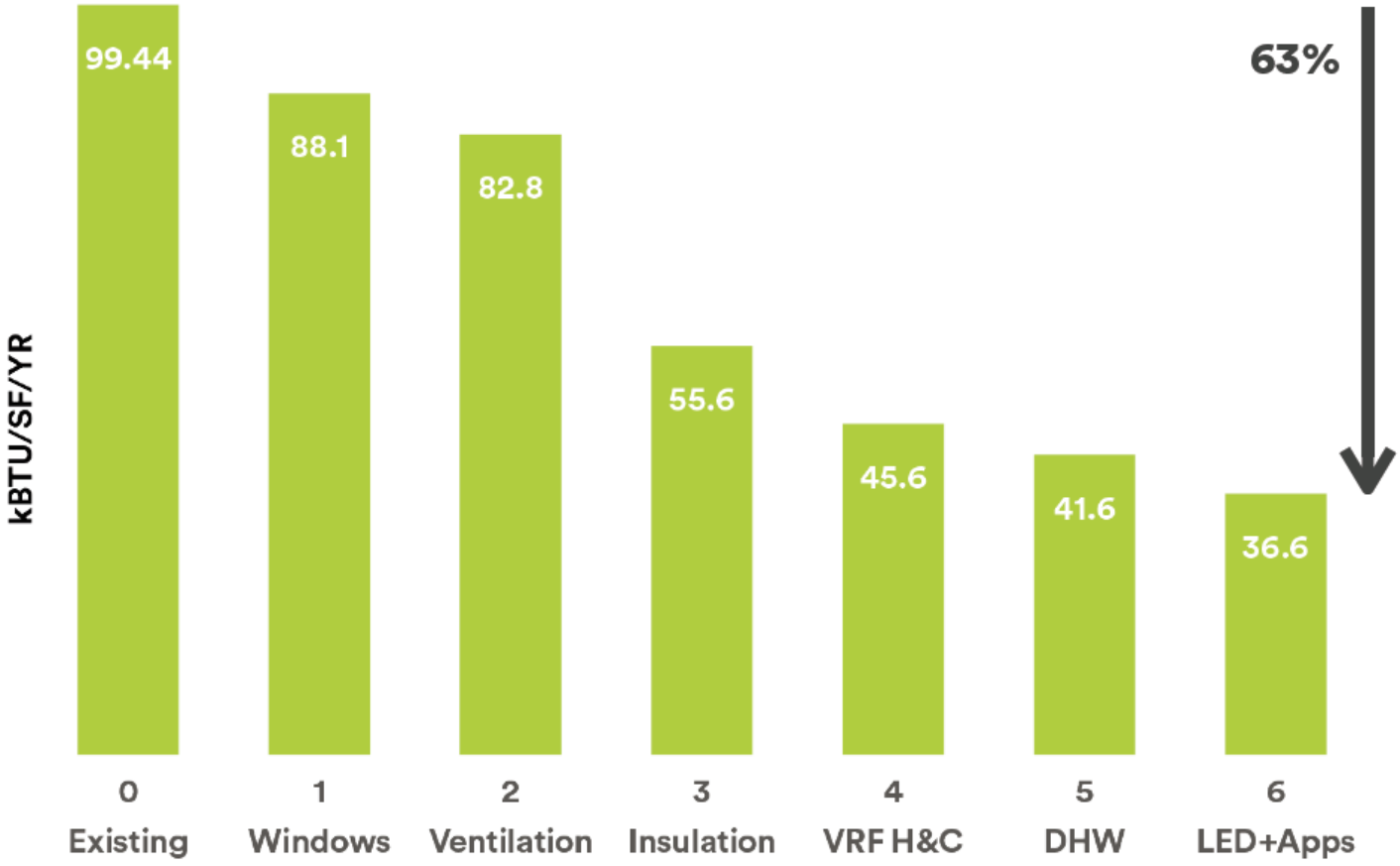
“Pursuing Passive” Cooling Demand

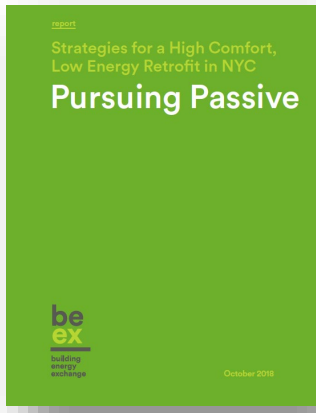




be-exchange.org

“Pursuing Passive” Primary (Source) Demand





be-exchange.org

Passive House Retrofit Principles

Netherlands, HOUSING/RETROFIT, KAW Architecten & Adviseurs

How To Deeply Retrofit?

Goal: provide the most comfortable building using the least energy

- We need buildings that are both efficient and effective
- Better ventilation might increase energy use
- Adding cooling will increase energy use
- But both essential in most typologies

In general, a deep energy retrofit:

- Targets an energy use reduction of 40% – 60%
- Touches every building system, including the envelope
- Is implemented through multiple projects, sequenced to maximize energy savings potential

How To Deeply Retrofit?

First . . .

- Reduce internal loads (plugs, appliances, lighting)
- Reduce external loads (airtight, well insulated, good windows)

Then . . .

- Ensure comfortable, healthy ventilation

Now that loads are reduced . . .

- Select high efficiency heating/cooling
- Ensure proper commissioning
- Enact strong operations & maintenance protocols

This approach puts non-mechanical or “passive” measures first

Passive House Principles

Building Energy Exchange

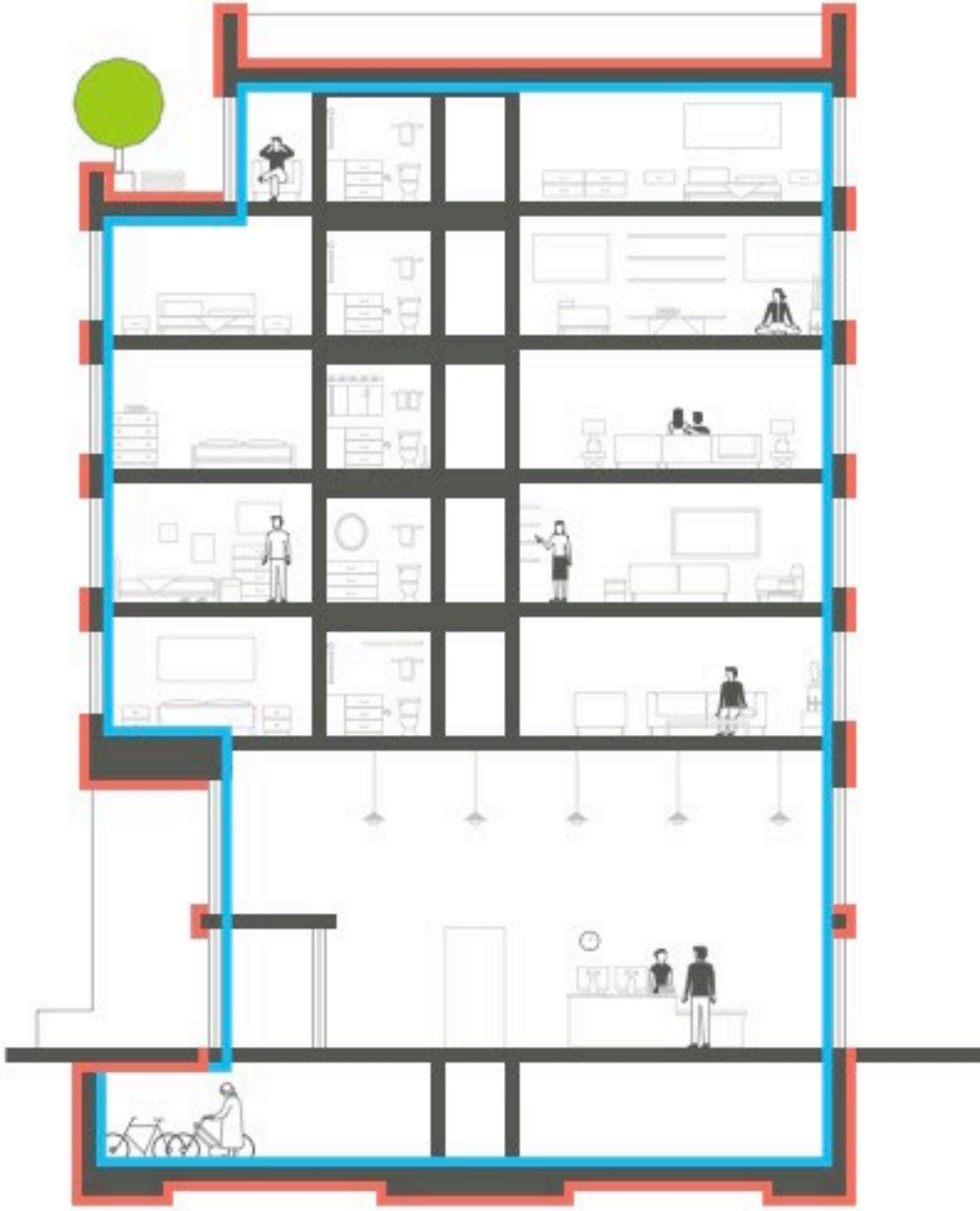
Passive House Principles

airtightness

Passive House Principles

airtightness

continuous insulation



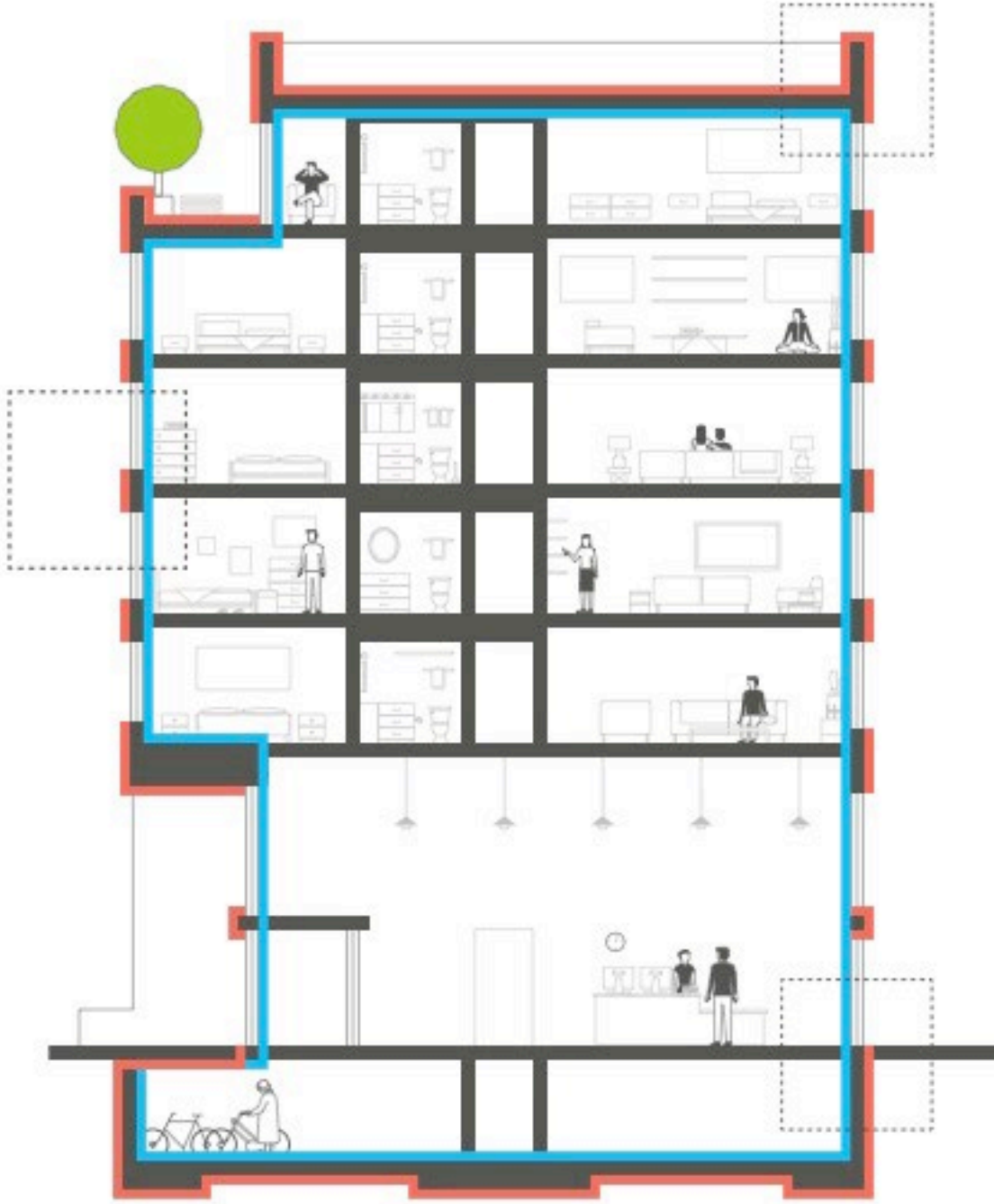
Building Energy Exchange

Passive House Principles

airtightness

continuous insulation

thermal bridge free construction



Building Energy Exchange

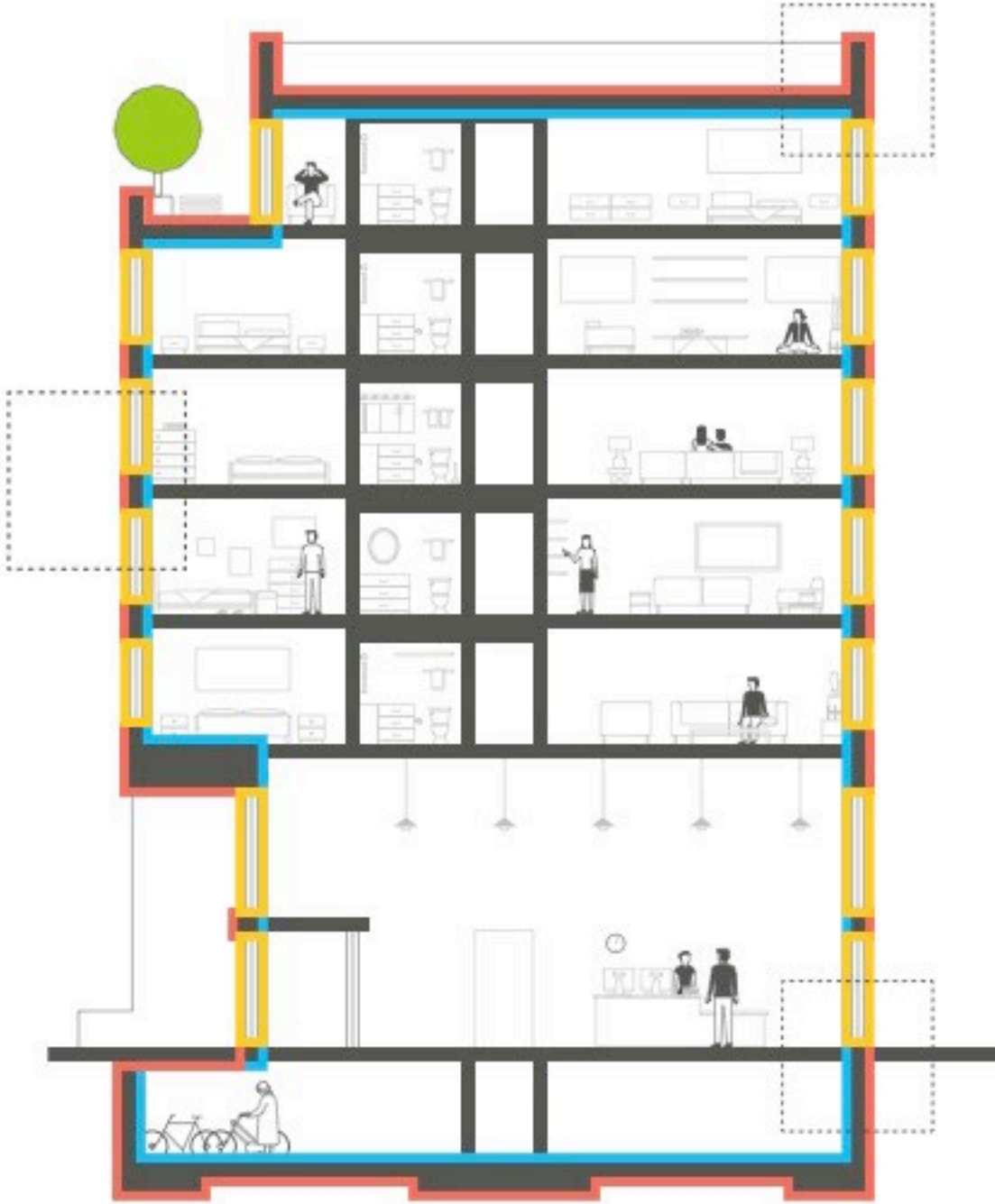
Passive House Principles

airtightness

continuous insulation

thermal bridge free construction

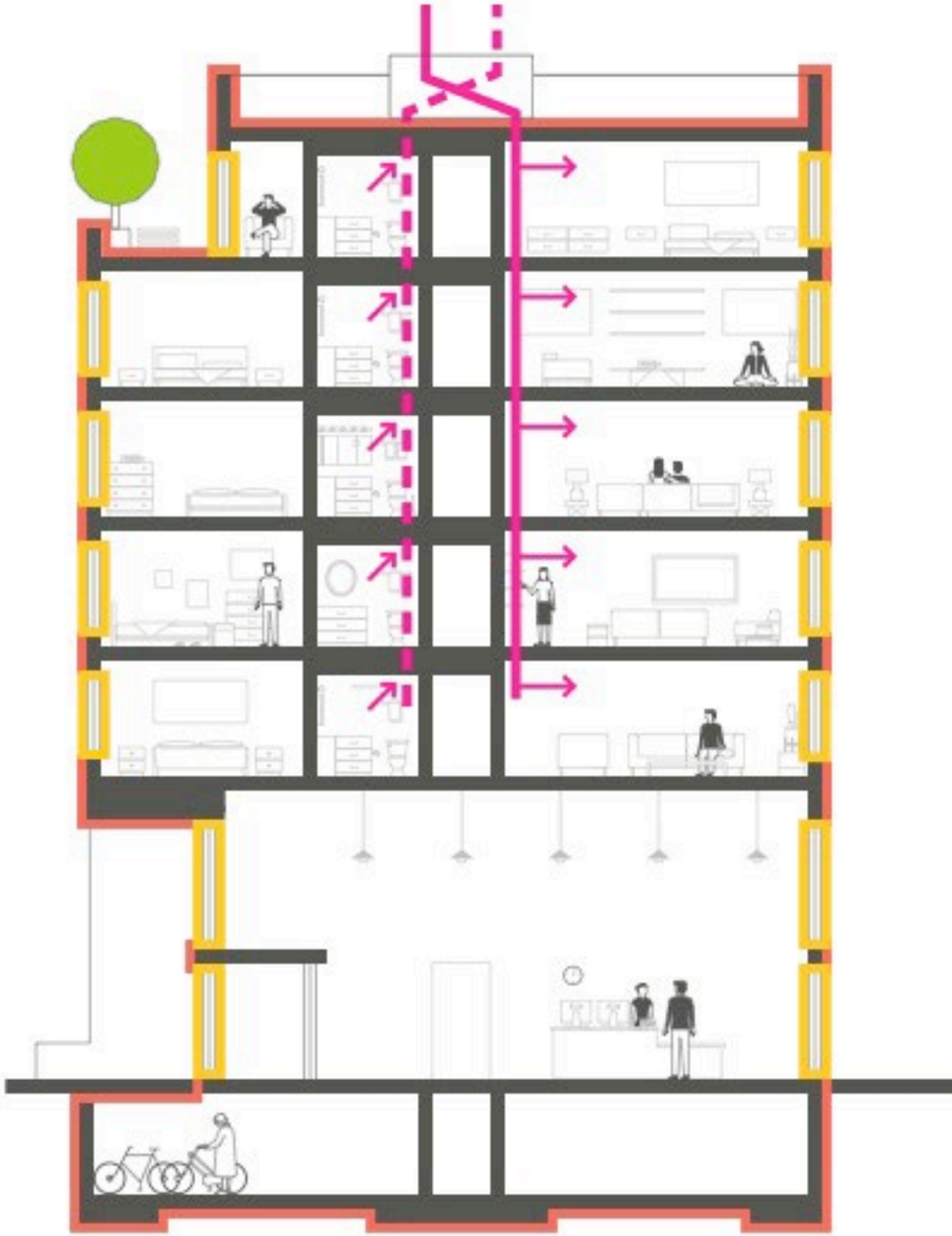
high performance doors and windows



Building Energy Exchange

Passive House Principles

- airtightness
- continuous insulation
- thermal bridge free construction
- high performance doors and windows
- energy recovery ventilation

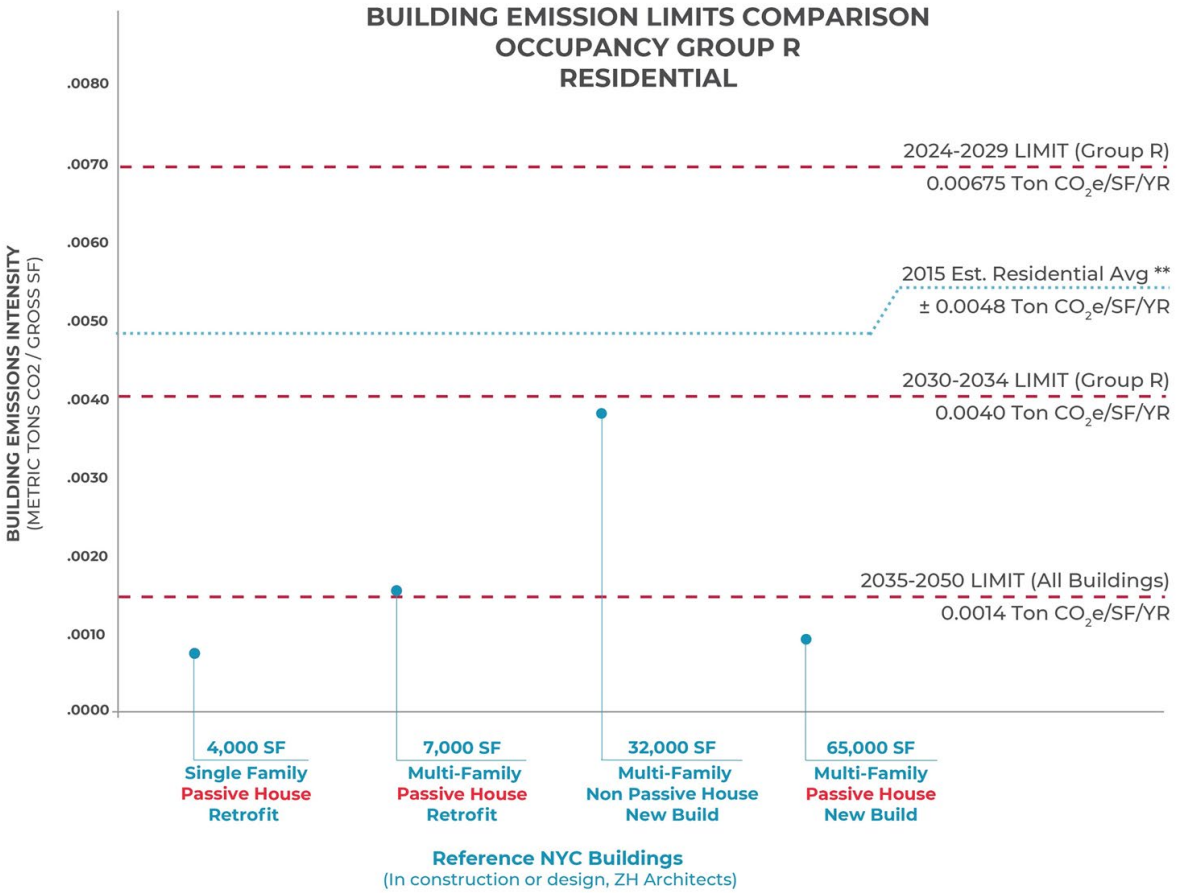


Building Energy Exchange

Passive House Retrofit Techniques

Orient, New York, ARTIST STUDIO, Ryall Sheridan Architects

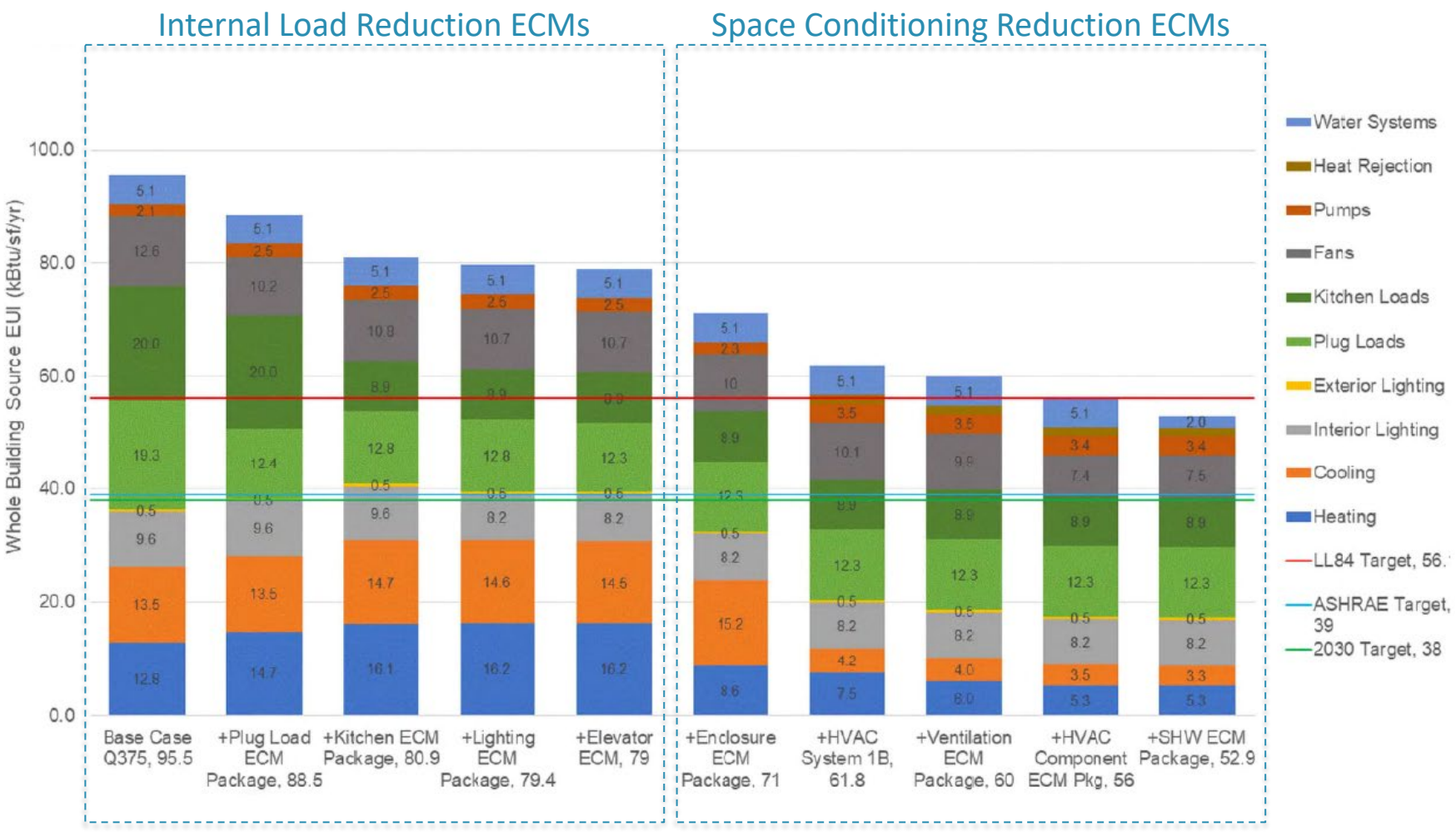
NYC's 2019 Climate Mobilization Act



** Residential Average based on data from Mayor's office of sustainability, inventory of New York City's Greenhouse Gas Emissions, April 2017 and NYC MAP Pluto data on residential square footage totals for NYC

Image Credit: Copyright NAPHN 2019, Policy Resource Guide

Stacked ECM Packages



From: NYC's Path to 2030 Local Law 31 of 2016 Feasibility Study. SWA, April 2018

Internal Load Reductions: Lighting Upgrades

Space Type	LED Power Savings	ASHRAE 90.1 Baseline LPD (W/sf)	Reduced LPD (W/sf)
Classroom	62%	1.4	0.53
Conference	70%	1.3	0.39
Corridor	70%	0.5	0.15
Library	60%	1.1	0.43
Office	60%	1.1	0.43

From: NYC's Path to 2030 Local Law 31 of 2016 Feasibility Study. SWA, April 2018

Internal Load Reductions: Office Equipment

Space Type	Typical EPD (W/sf)	Reduced EPD (W/sf)	Reduction
Classroom	0.59	0.12	80%
Library	0.59	0.12	80%
Office	0.47	0.13	72%

Equipment:

- Micro-sized, or thin-client desktops
- OLED Displays
- Reduce # of printers
- Remove fax machines
- Solid state hard drives

Management

- Power strip w/ Occ. Sensor
- Reduce active power modes
- Network reduction options

From: NYC's Path to 2030 Local Law 31 of 2016 Feasibility Study. SWA, April 2018

Schools offer the same opportunity…!

Architects, NYC School Construction Authority complete first Passive House pre-kindergarten

By **Buckshon** - June 30, 2019 254 0

The New York City School Construction Authority (SCA) and **CTA Architects P.C. (CTA)** have completed the first-ever pre-Kindergarten built within a passive house building and designed to meet passive house standards in the U.S.

He said that CTA was able to determine that this particular pre-Kindergarten could operate with much lower energy consumption than a typical one, which include computer systems, demanding lighting systems, high plug loads, and extensive cooking facilities. Using all of these high-energy elements, the project would not have made the passive house requirements that limit the amount of energy used per square foot.

https://www.newyorkconstructionreport.com/architects-nyc-school-construction-authority-complete-first-passive-house-pre-kindergarten/

principle 1:
airtightness

airtightness
—
strategies & components

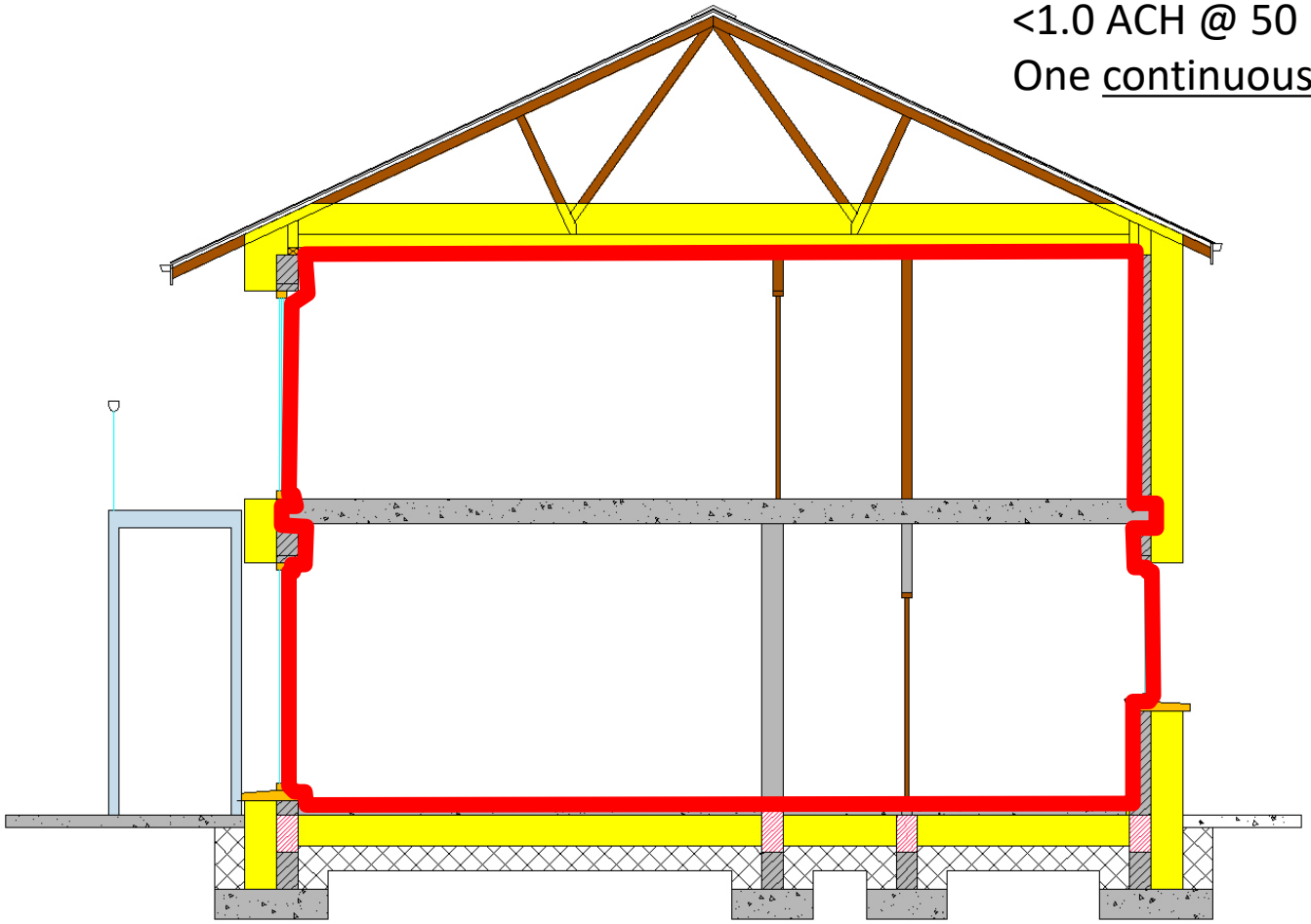
photos: A2M Architecture

Comfort + Health

Reduce drafts

Stop ‘filtering’ air through cracks in the building envelope

The “Red Line” Test



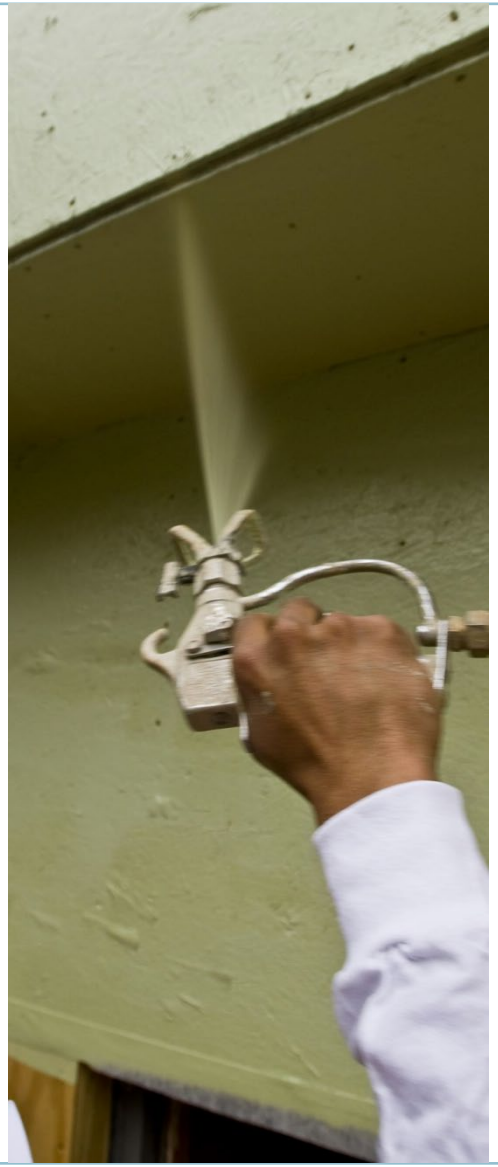
Airtightness:

<1.0 ACH @ 50 Pa

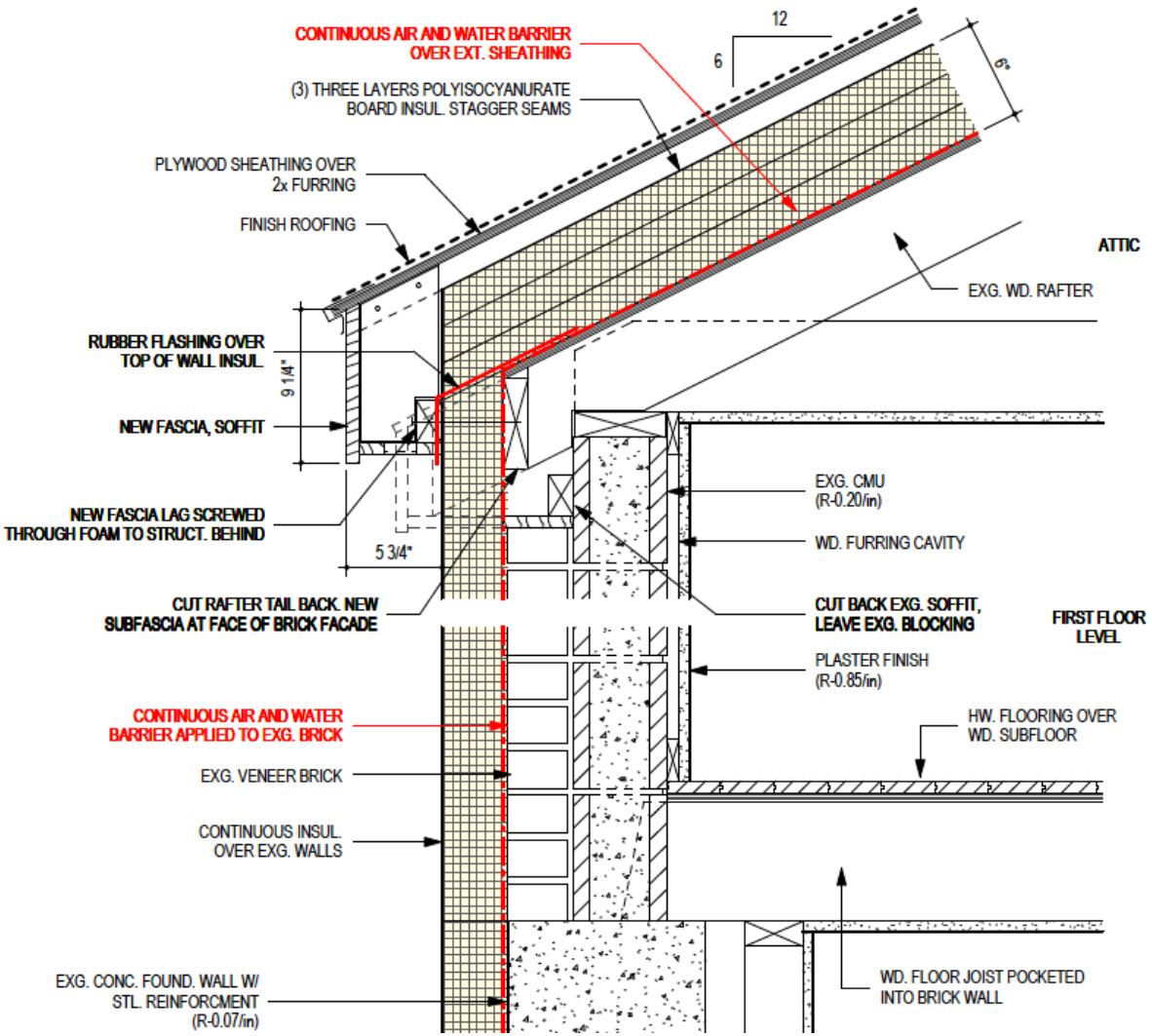
One continuous air-tight layer:

Non-airtight Materials

Airtight Materials



Exterior Liquid Applied



Source: BLDGtyp, llc

Interior Liquid Applied

Source: BLDGtyp, llc

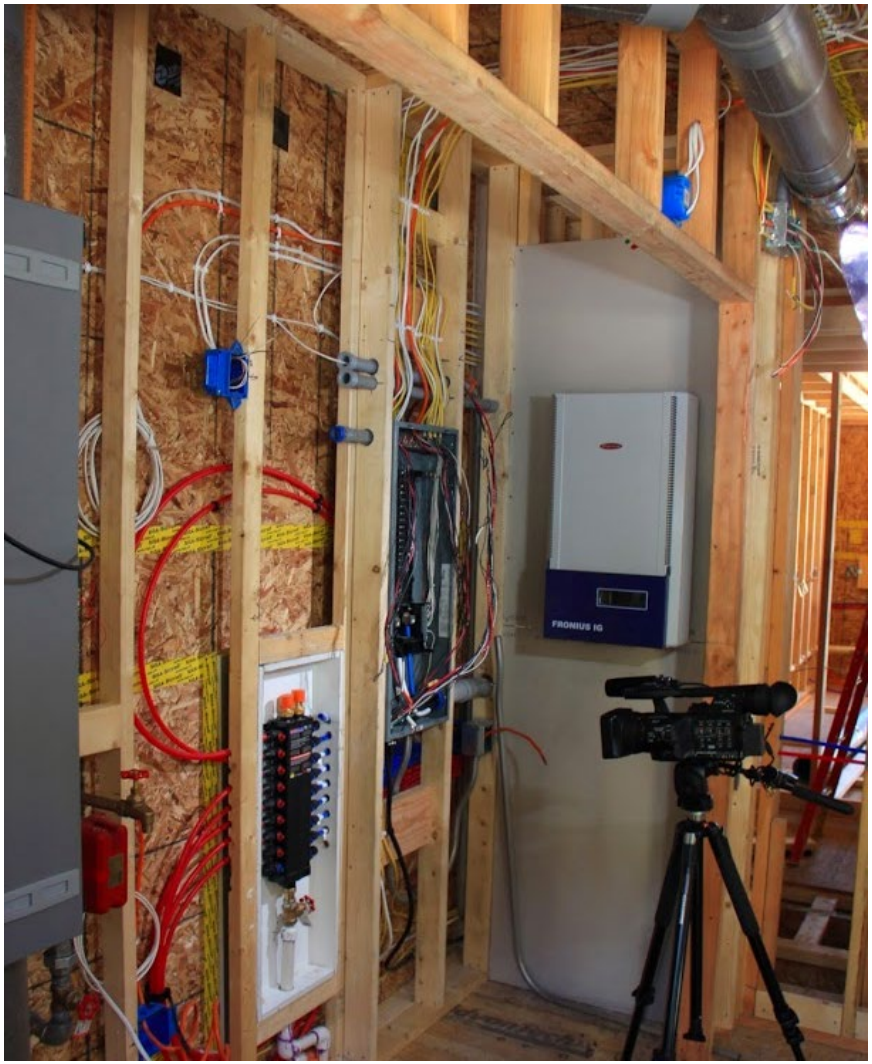
Interior Spray Applied

Source: BLDGtyp, llc

Interior Membrane + Tapes

Penetrations

Service Cavity Inboard



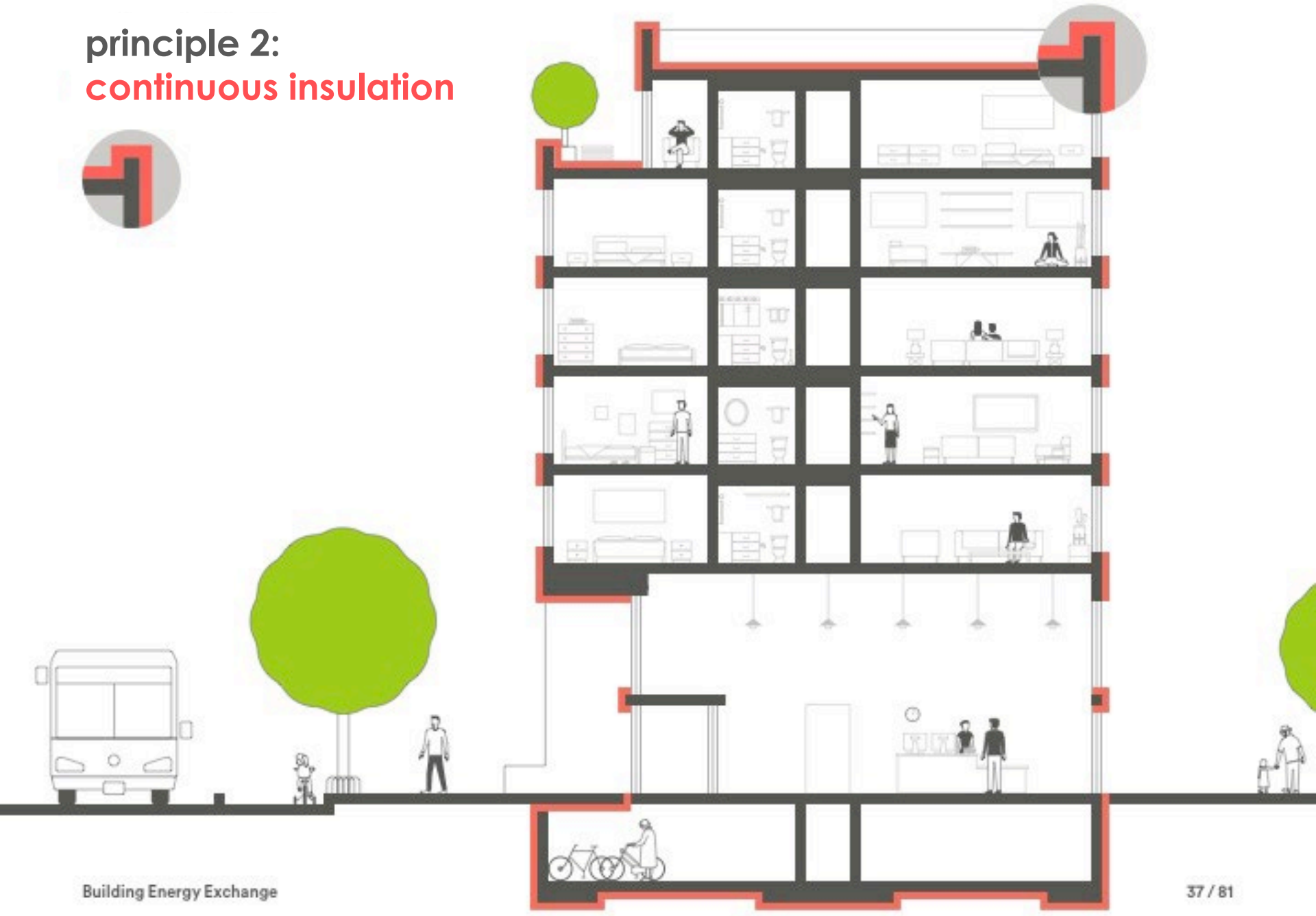
Source: BLDGtyp, llc

airtightness

testing

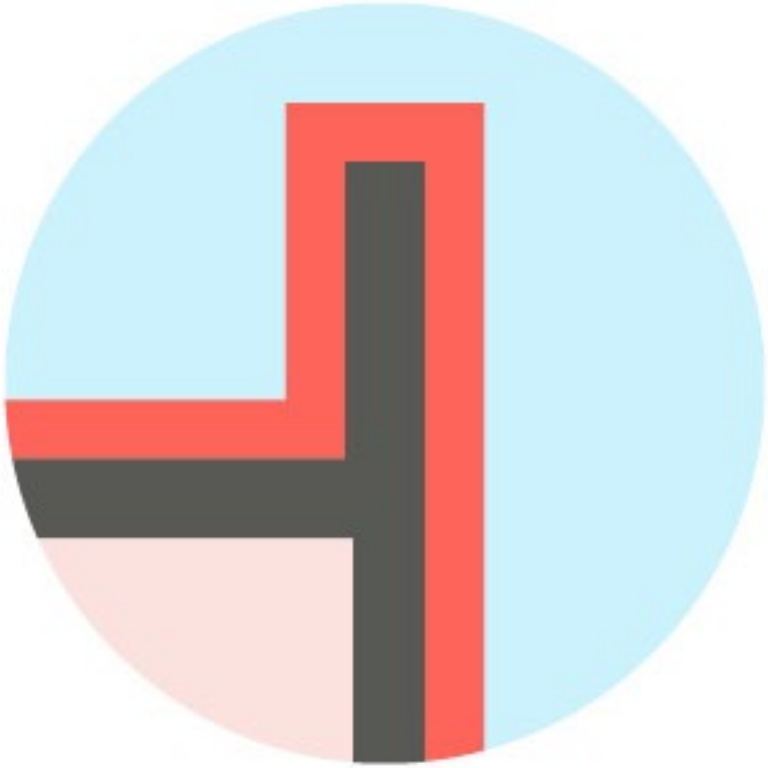
photo courtesy of ZH Architects

principle 2:
continuous insulation



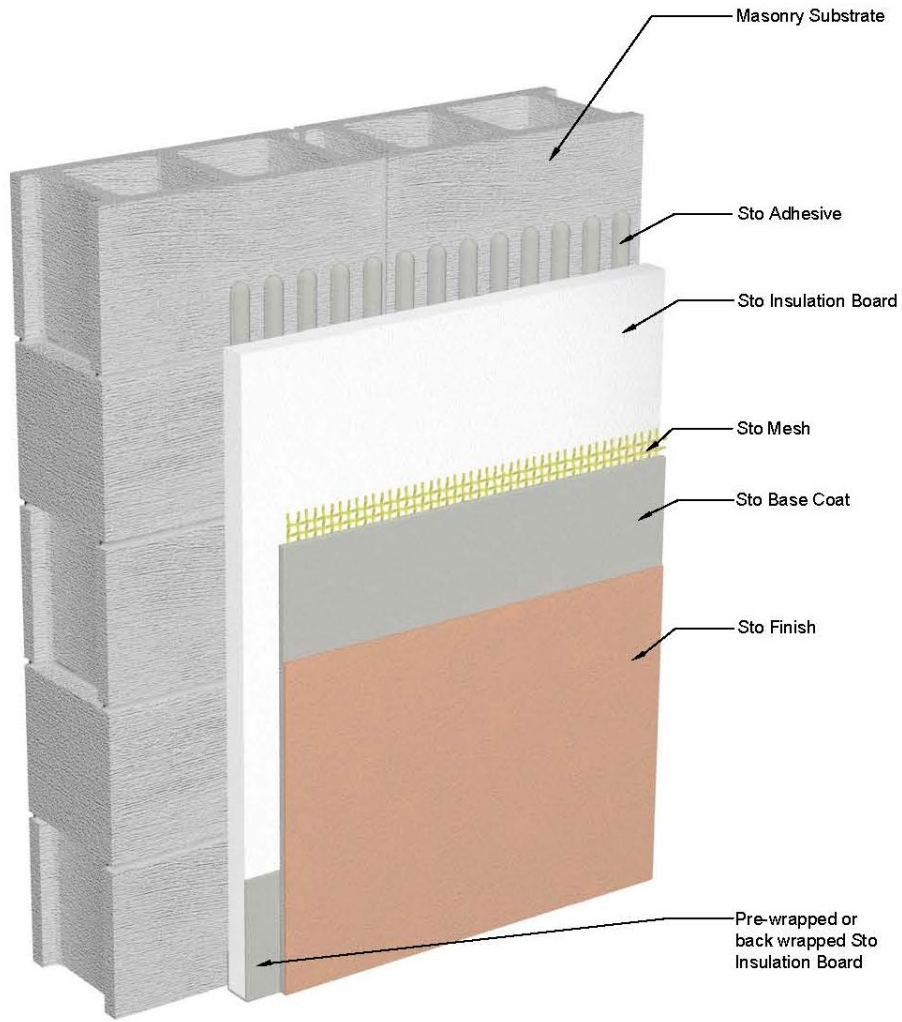
Continuous Insulation

Conventional Construction

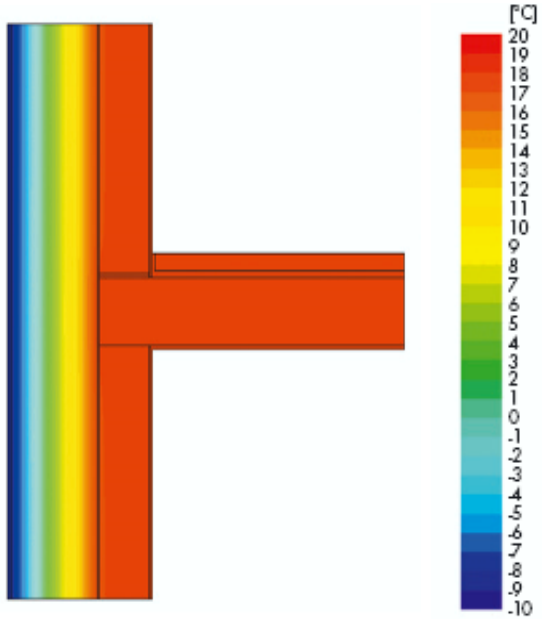


High Performance Construction

Insulation: Exterior EIFs



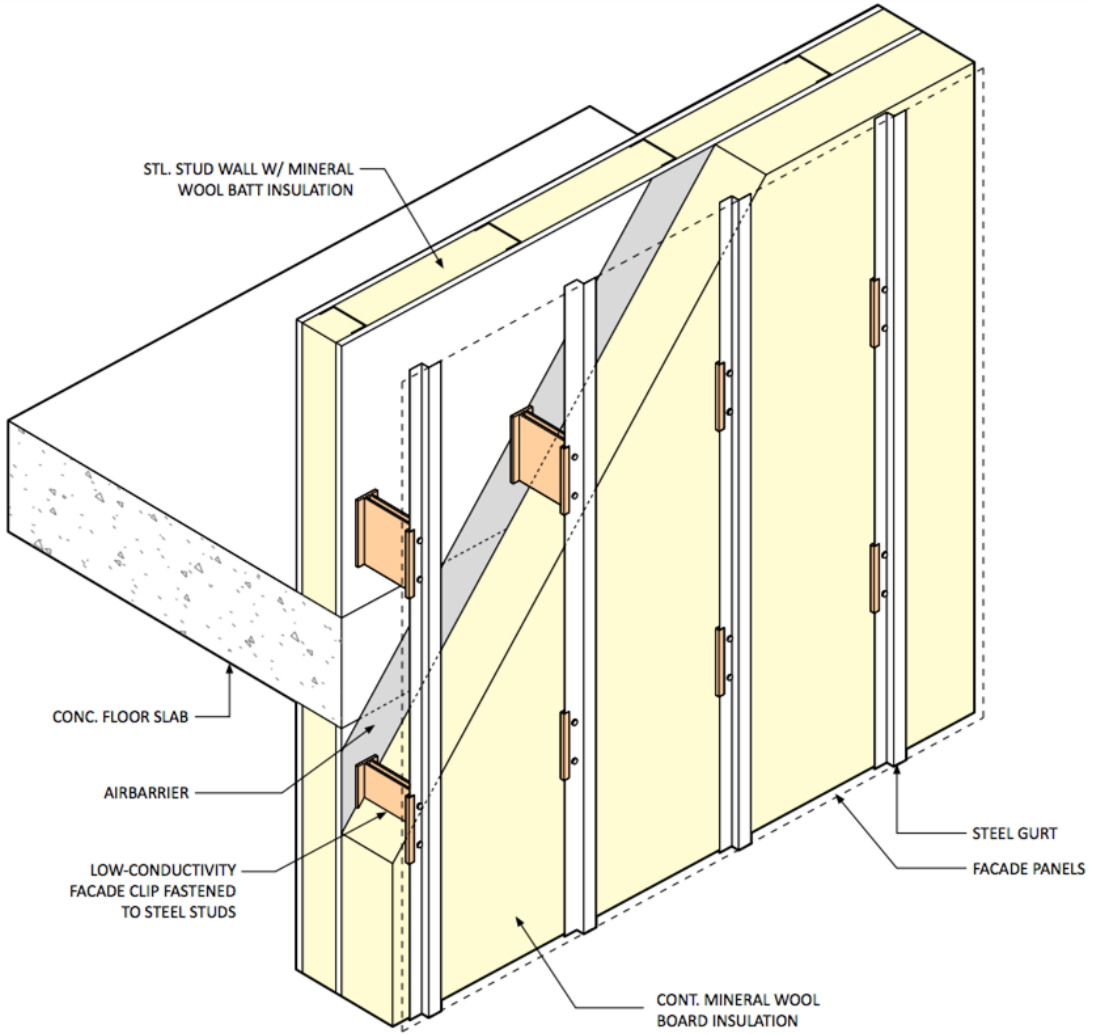
Source: Sto Therm



Insulation: Exterior EIFs

Source: BLDGtyp, llc

Insulation: Exterior Rainscreen + Panels

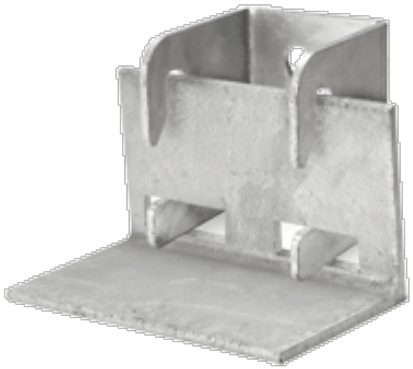


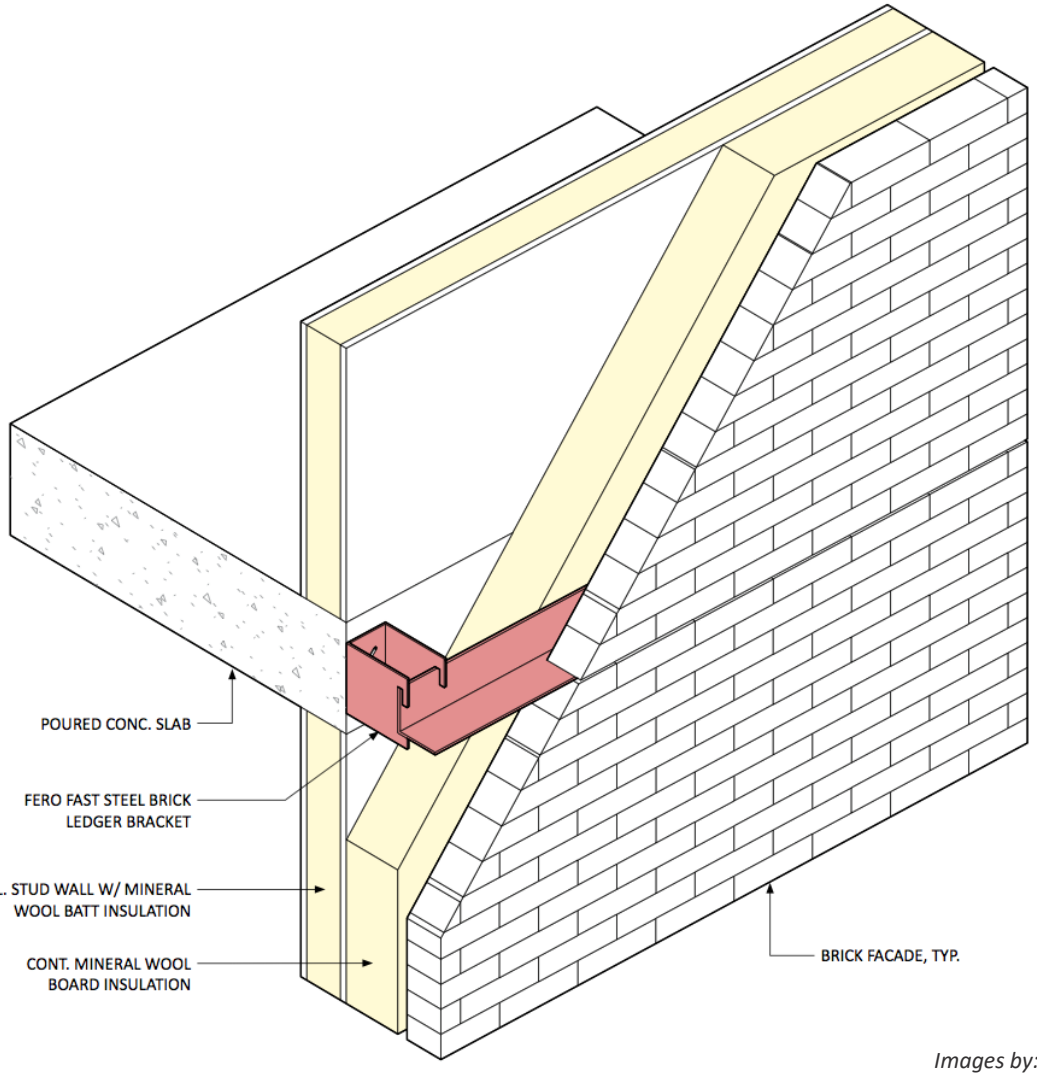
Images by: BLDGtyp, llc

Insulation: Exterior Rainscreen + Panels

Source: BLDGtyp, llc

Insulation: Exterior Brick On Outriggers

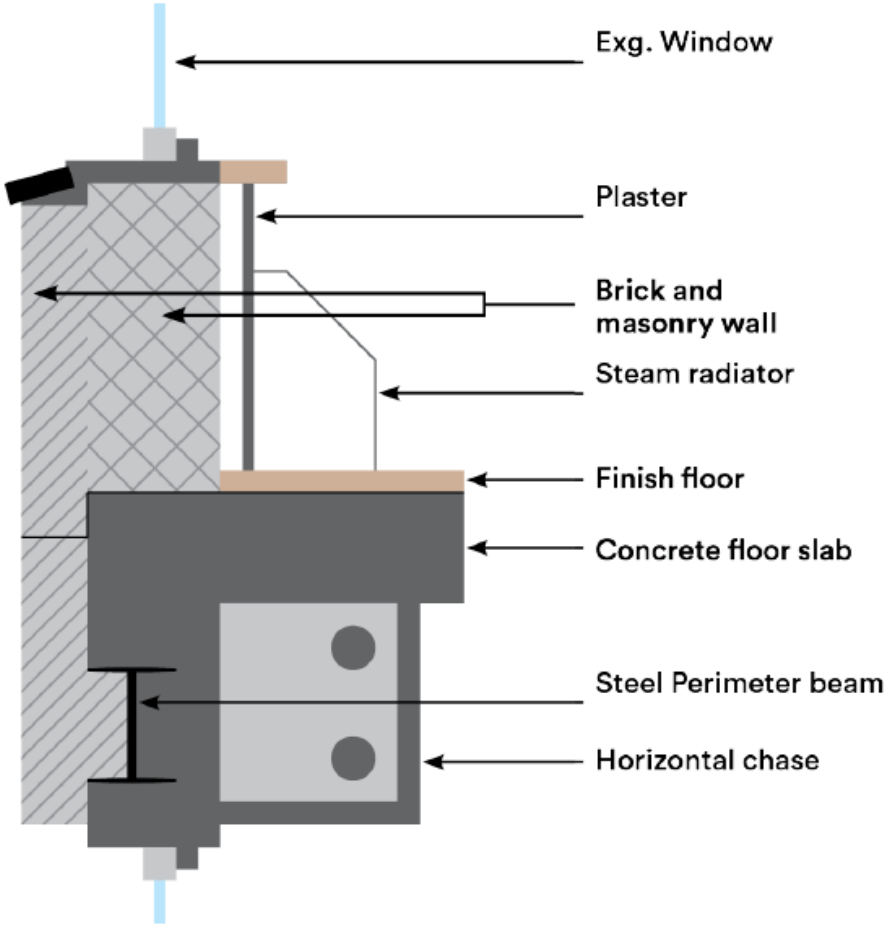




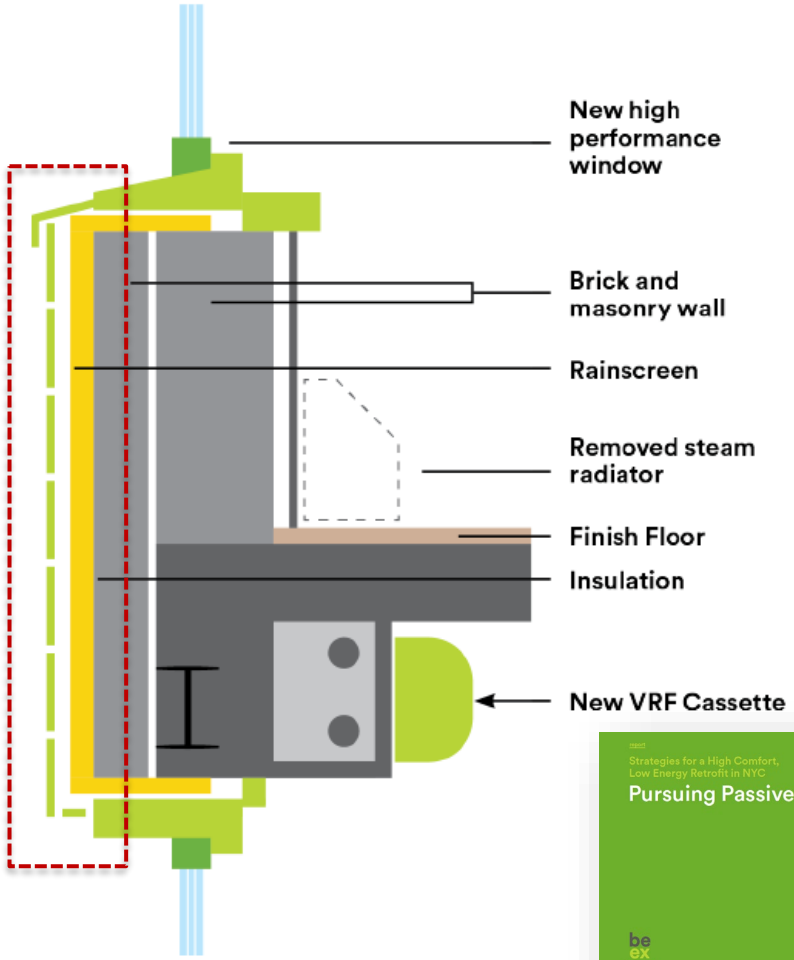
Images by: BLDGtyp, llc

Insulation: Exterior [“Pursuing Passive”]

EXISTING BUILDING

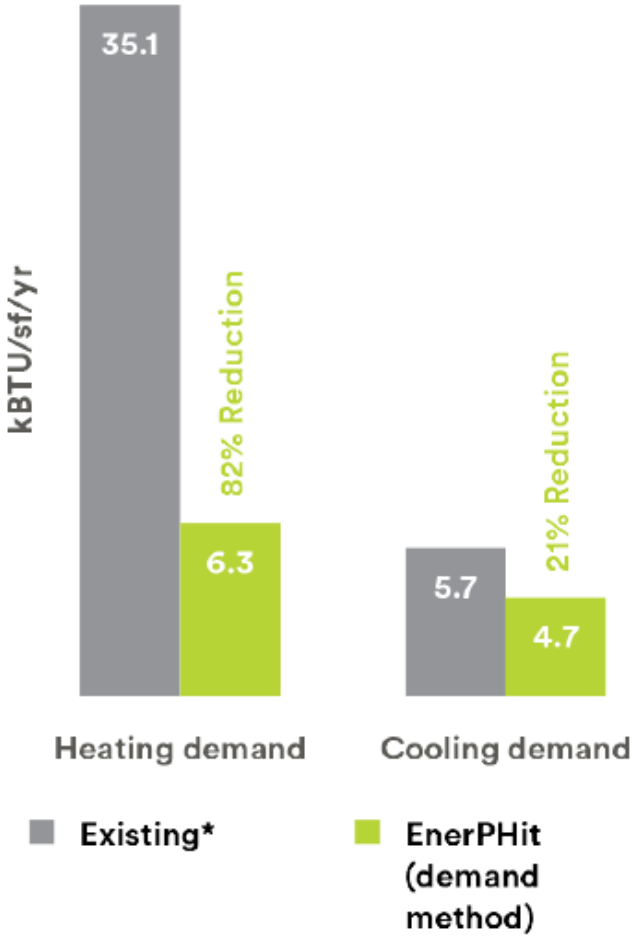


UPGRADED BUILDING

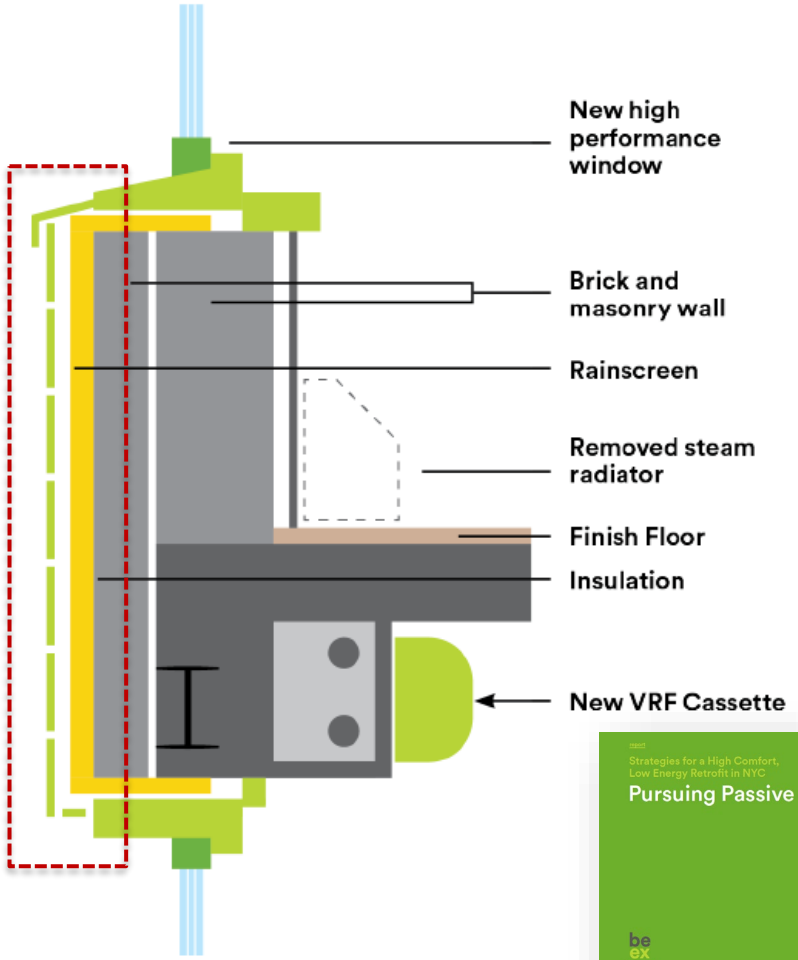


Insulation: Exterior [“Pursuing Passive”]

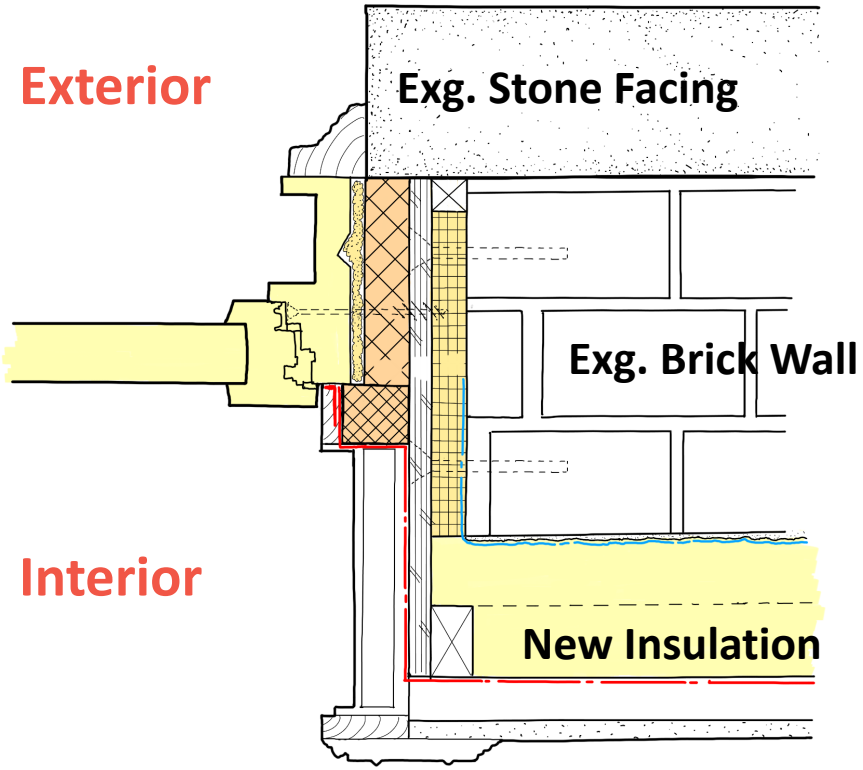
ENERGY DEMAND



UPGRADED BUILDING



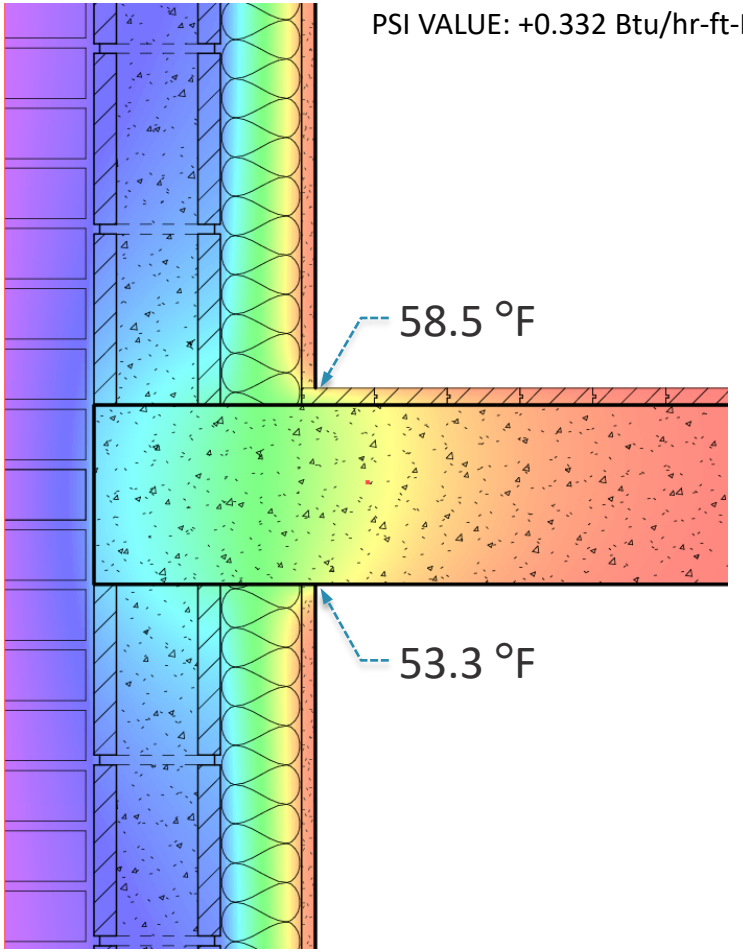
Insulation: Interior



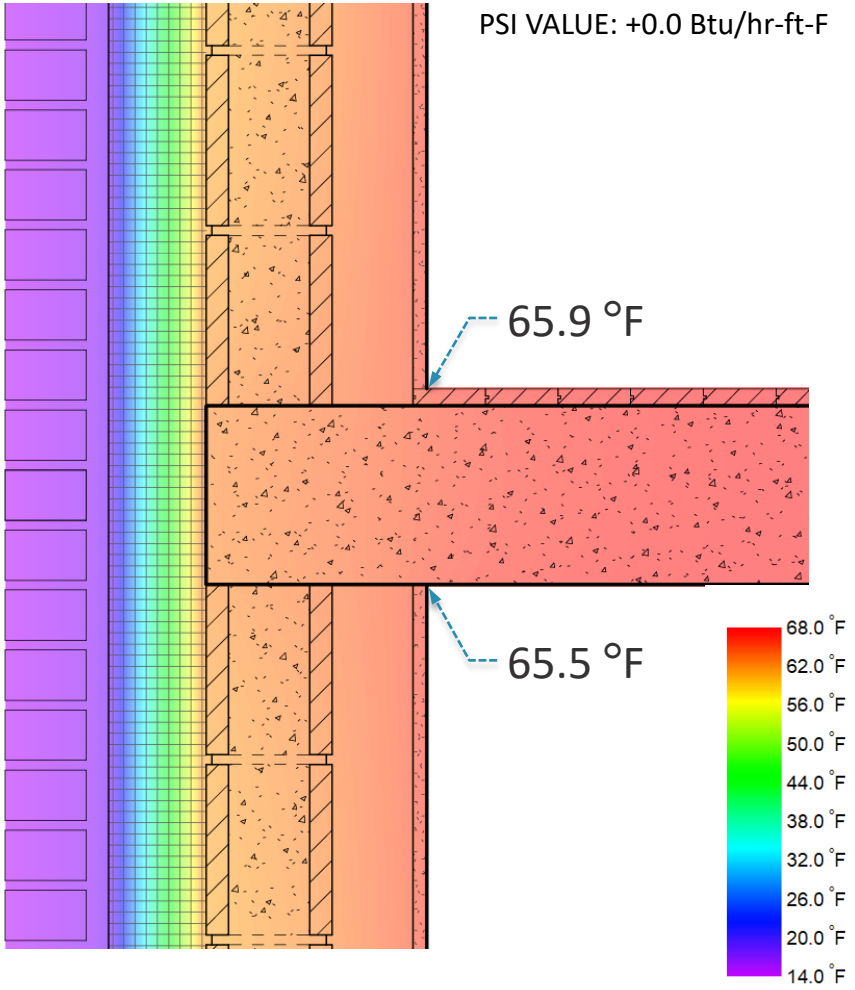
Source: BLDGtyp, llc

Insulation: Interior & Slab Edges

INTERIOR INSULATION

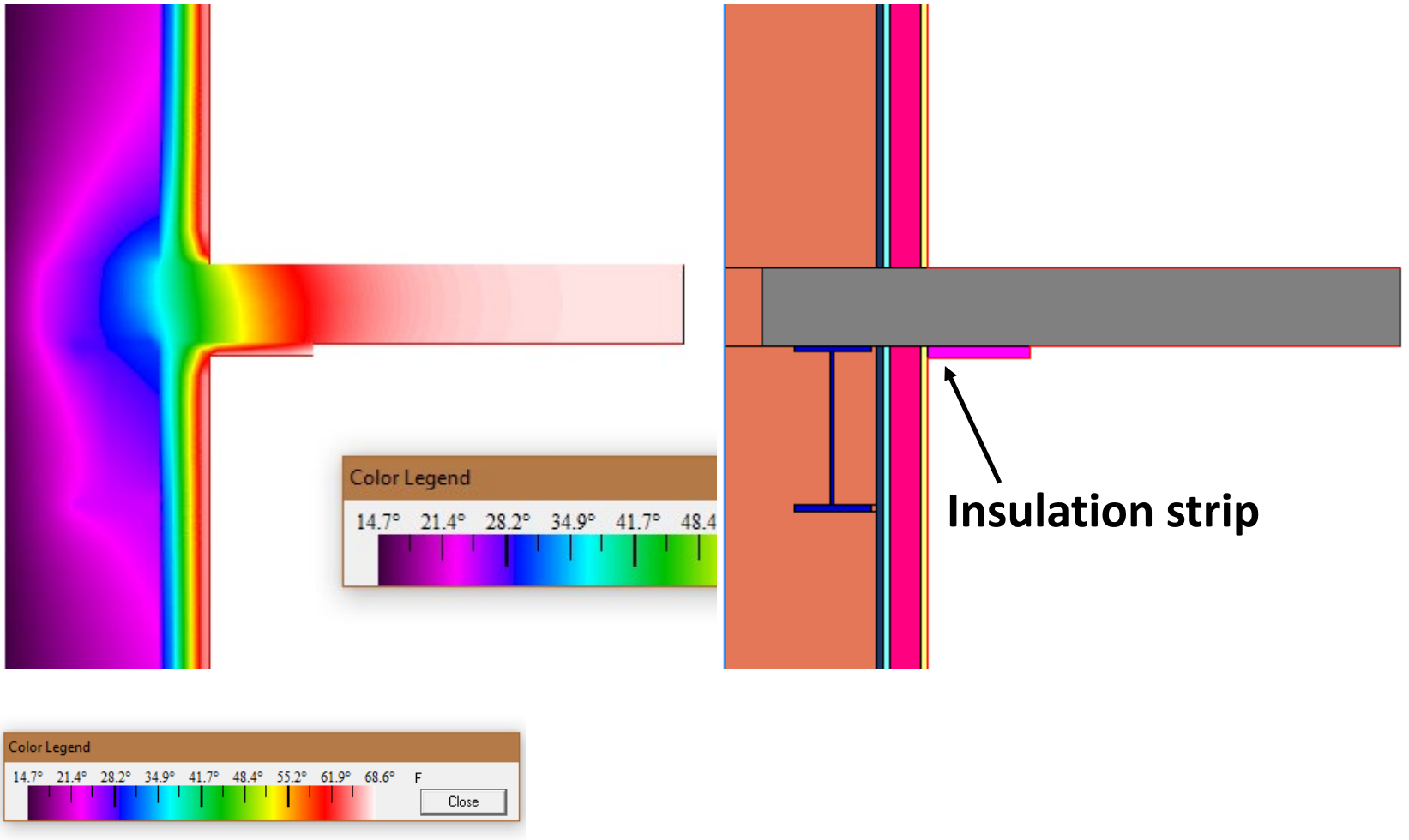


EXTERIOR INSULATION



Source: BLDGtyp, llc

Insulation: Interior & Slab Edges



Source: Steven Winters Associates

Insulation: Interior & Slab Edges

Source: Steven Winters Associates

Insulation: Interior & Moisture

"When considering the interior insulation of a masonry building, a series of steps are recommended to assess the risks associated with this retrofit, with greater certainty with added steps, as follows:

1. ***Site Visit Assessment*** *(assessment of rain leakage, poor detailing, existing freeze-thaw damage)*

2. ***Simple Tests & Modeling*** *(dry density, liquid water uptake, saturation moisture content, and basic hygrothermal/WUFI modeling)*

3. ***Detailed Tests & Modeling*** *(thermal conductivity, Fagerlund's Critical Degree of Saturation or Scrit)*

4. ***Site Load Assessment*** *(assessment of driving rain load, run down patterns; monitoring of rain deposition with driving rain gauges)*

5. ***Prototype Monitoring*** *(retrofit of a small area of the building, and monitoring of temperature and moisture content, including comparisons to models)*

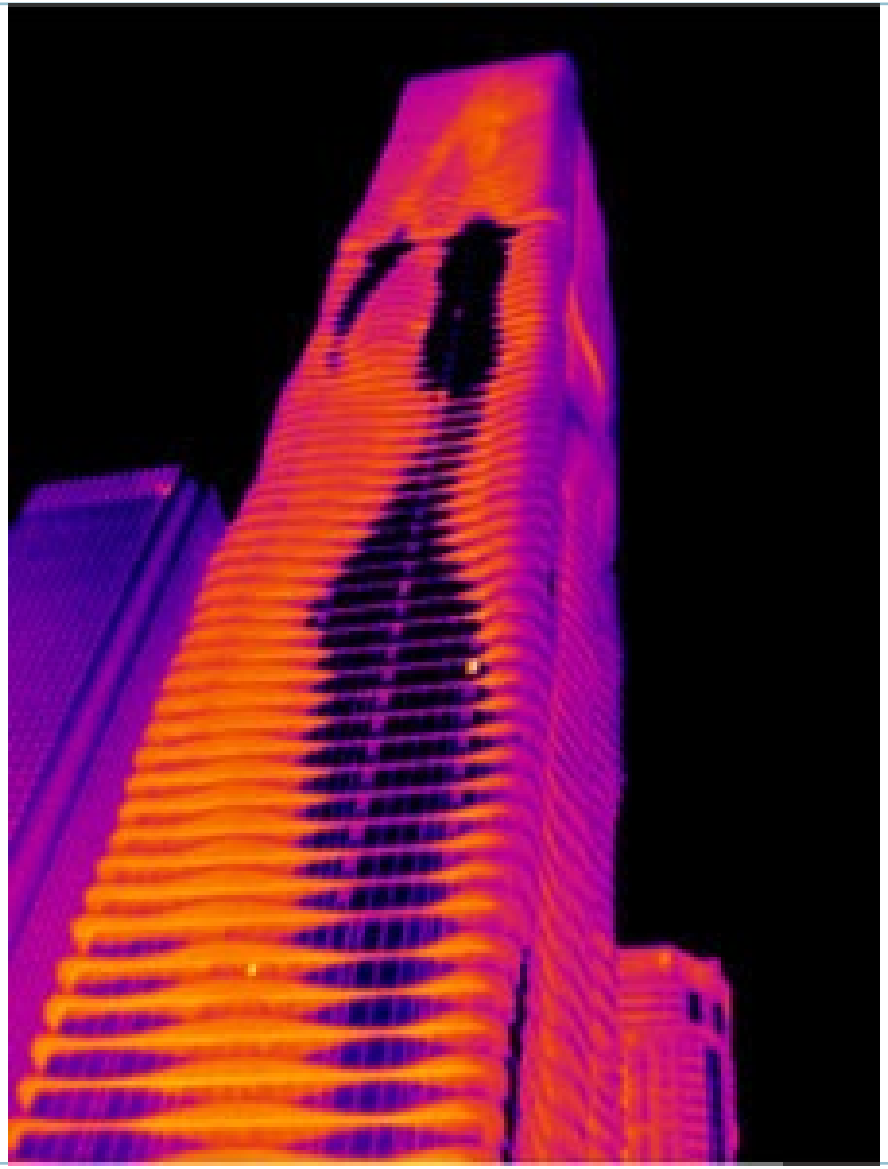
6. ***Maintenance and Repair*** *(creating a recommended program of inspection/repair, perhaps in the form of a building owner's manual)"*

John Straube, Kohta Ueno, Christopher Schumacher, Dec. 21, 2011

https://www.buildingscience.com/documents/bareports/ba-1105-internal-insulation-masonry-walls-final-measure-guideline/view

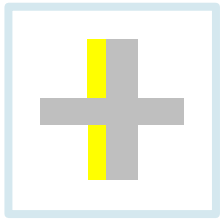
principle 3:
thermal bridge free construction

Thermal Bridges

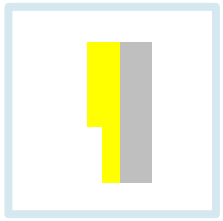


What Is A Thermal Bridge?

Part of the building envelope where the otherwise uniform thermal resistance is significantly reduced by:

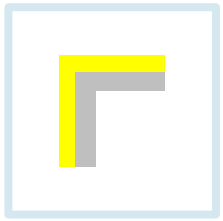


full or partial penetration of the insulating layers by materials with a different thermal conductivity



and/or

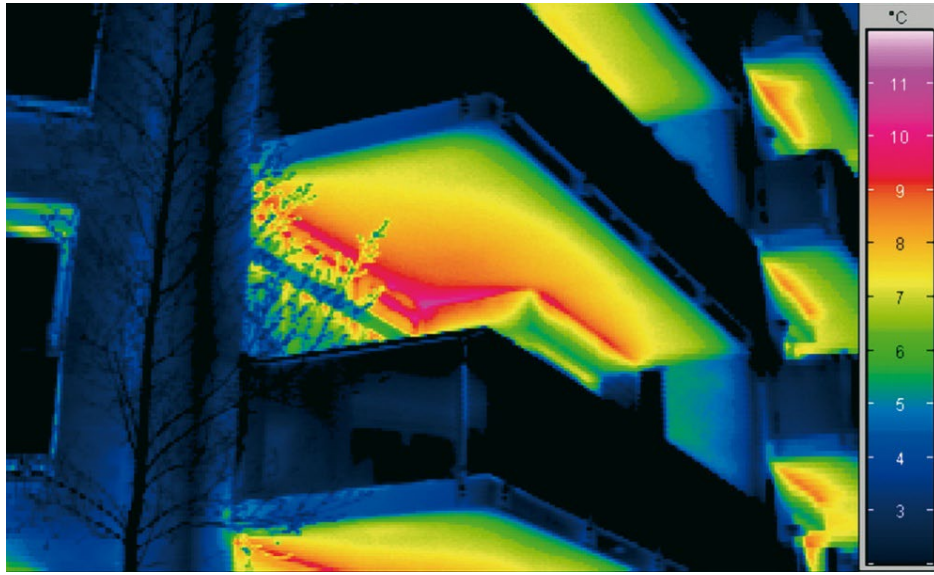
a change in thickness of the insulating layers



and/or

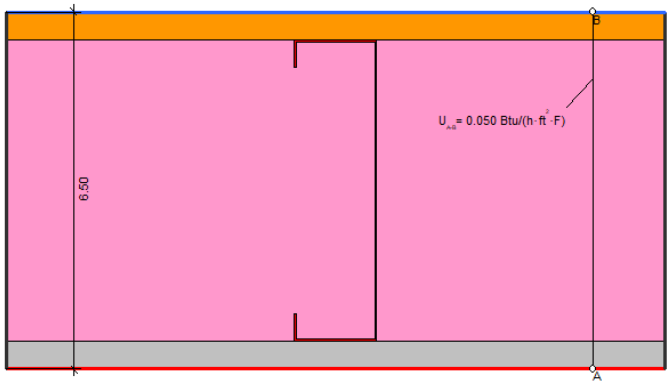
a difference between internal and external areas, such as occurs at wall/floor/ceiling junctions.

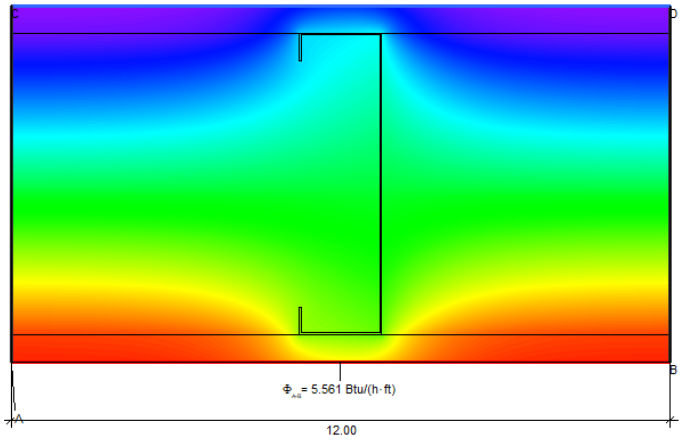
Heat Loss, Condensation & Mold Risk



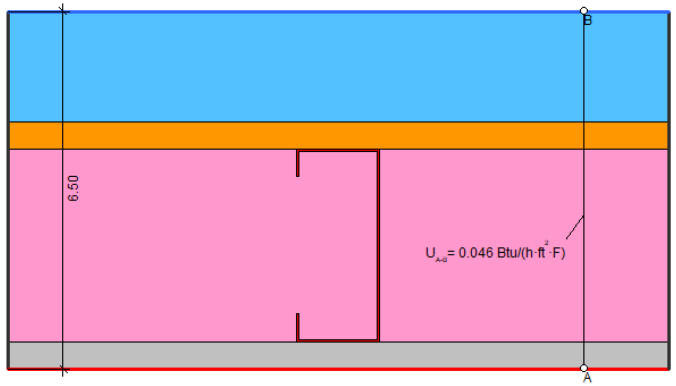
Repeating Thermal Bridges (Studs)

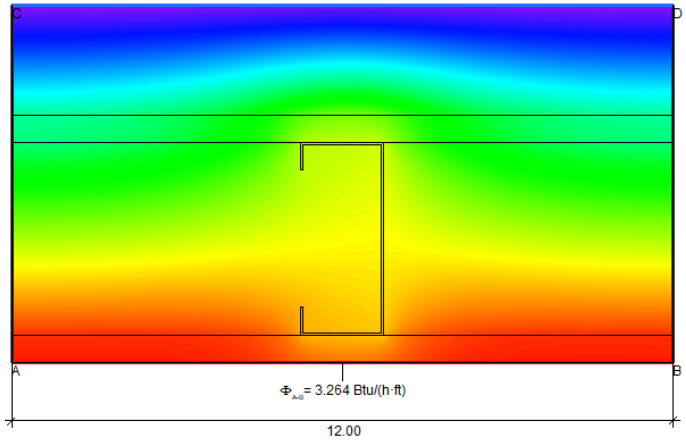
Steel stud wall, insulated cavity:
Nominal R-value: R-20.0
Actual R-value (incl. framing): R-9.7





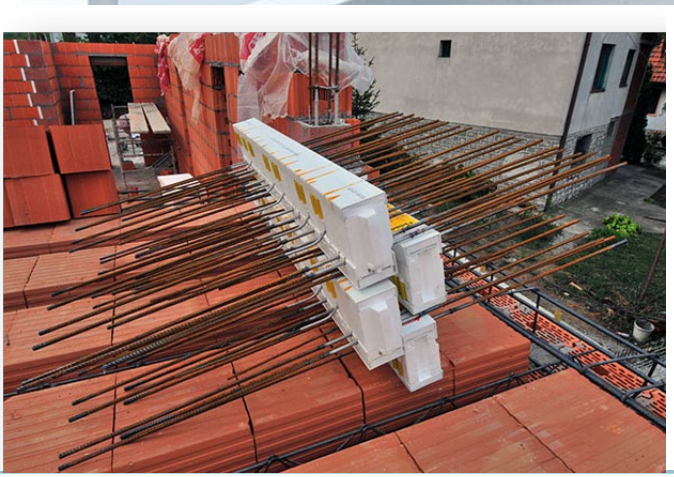
Steel stud wall + Continuous Exterior:
Nominal R-value: R-21.7
Actual R-value (incl. framing): R-16.6





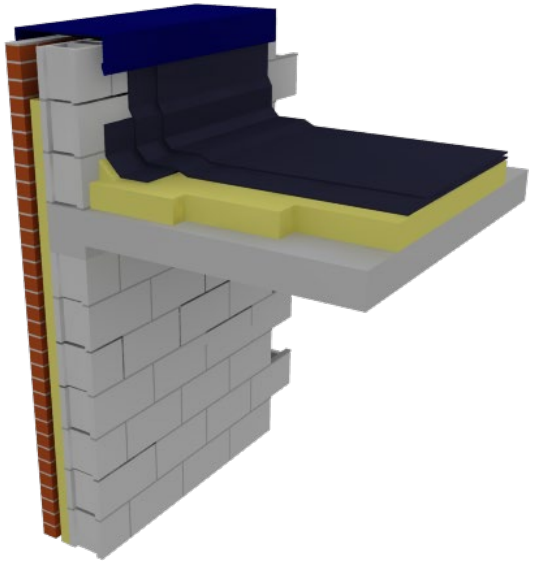
Source: BLDGtyp, llc

Balcony Thermal Isolators



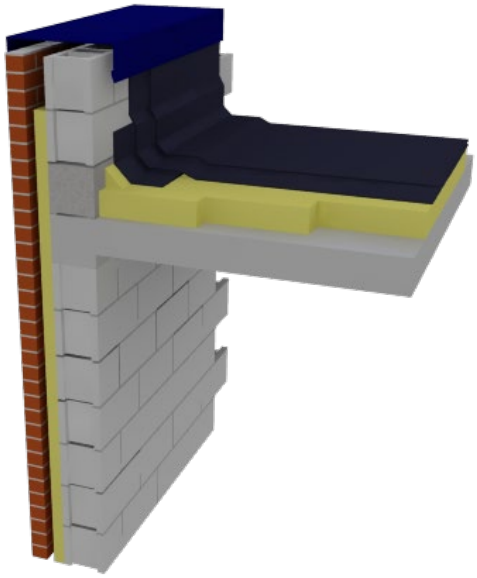
Parapet Connection: Improvement Options

Typical detail – poor thermal bridge



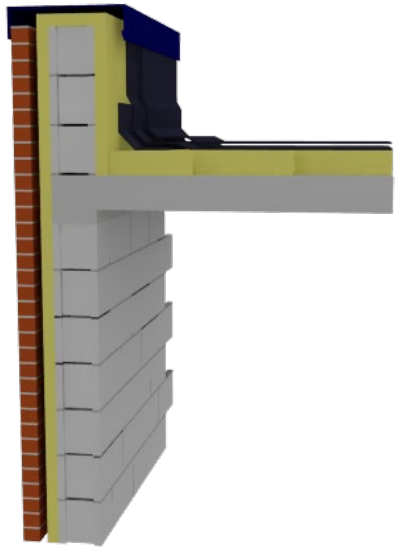
0.247 BTU/hr.ft.ºF

Option 1: Insert thermal break



0.010 BTU/hr.ft.ºF

Option 2: Wrap the parapet

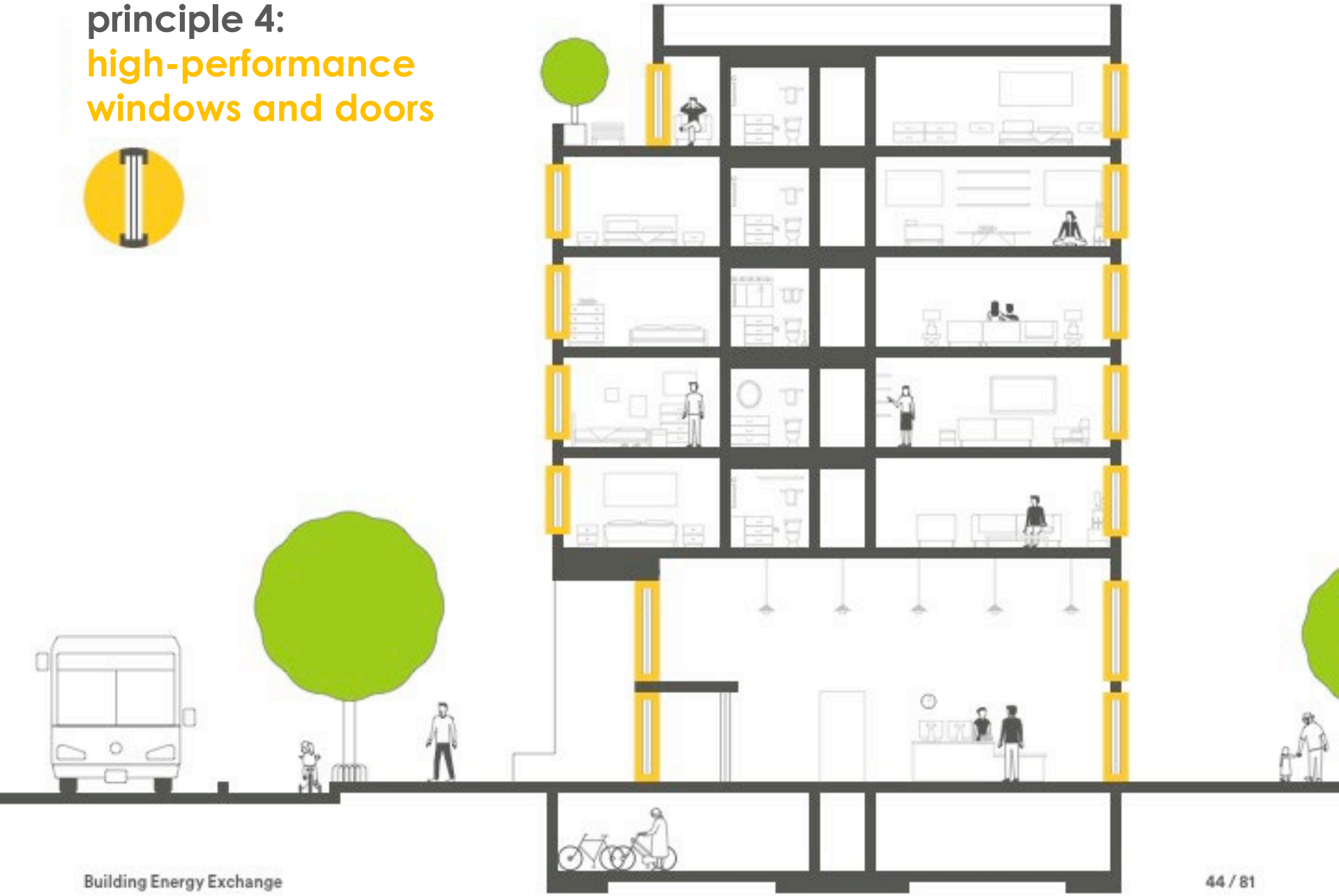


0.039 BTU/hr.ft.ºF

Parapet Connection: Improvement Options

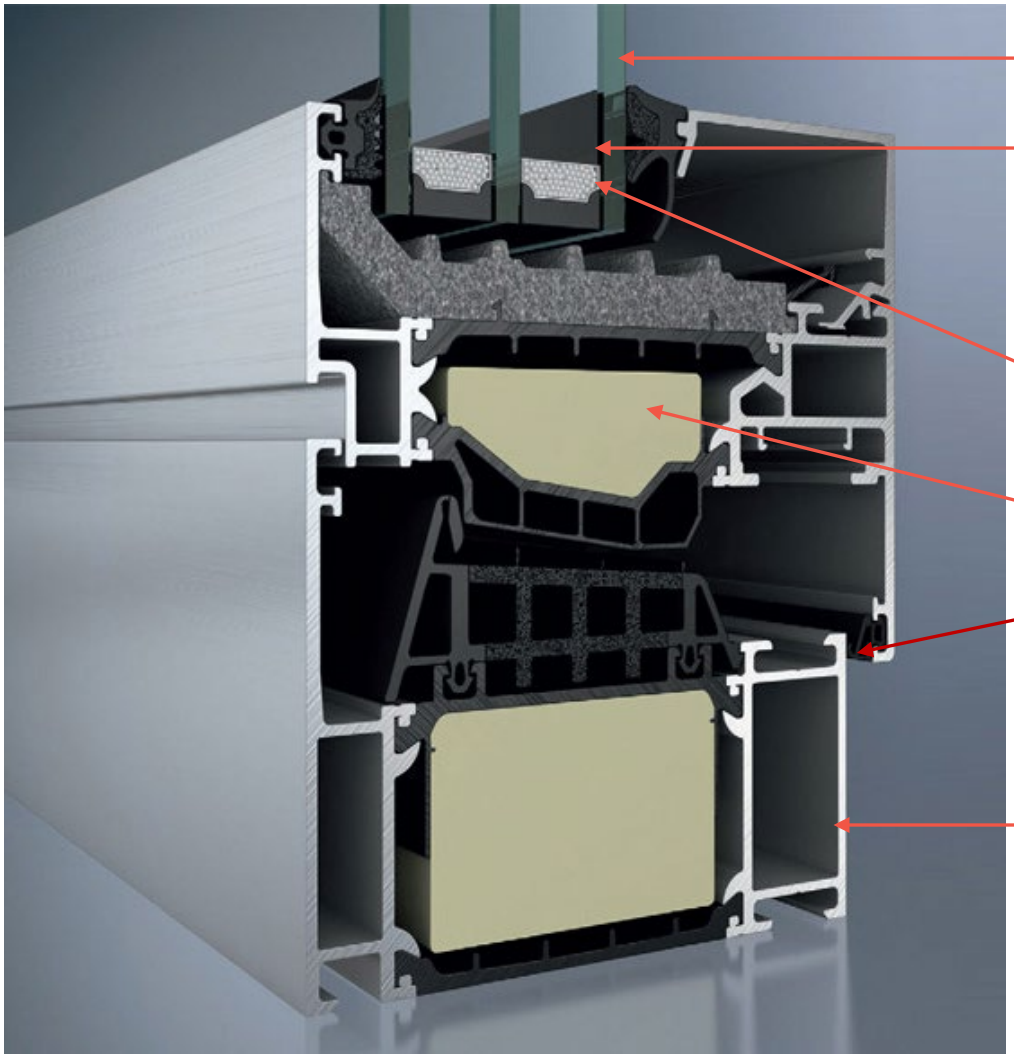
Source: BLDGtyp, llc

principle 4:
high-performance windows and doors



Windows And Thermal Comfort

High Performance Windows



2 or 3 layers of glass (glazing)

Insulating gas (Argon, Krypton) filled cavities

Spacers

Insulation

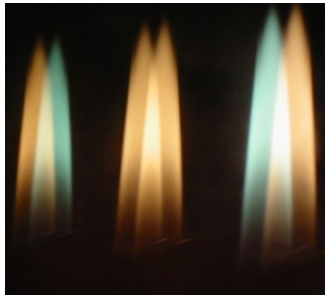
Gaskets

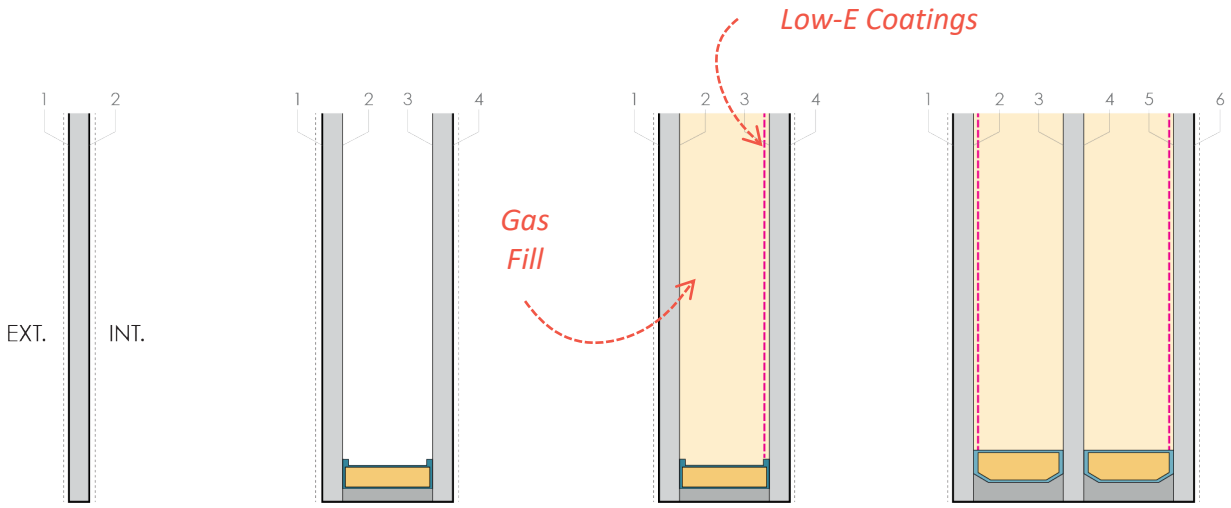
Frame

Source: Schuco AWS 90.SI+

IGU And Heat Loss

Coating position, quick test



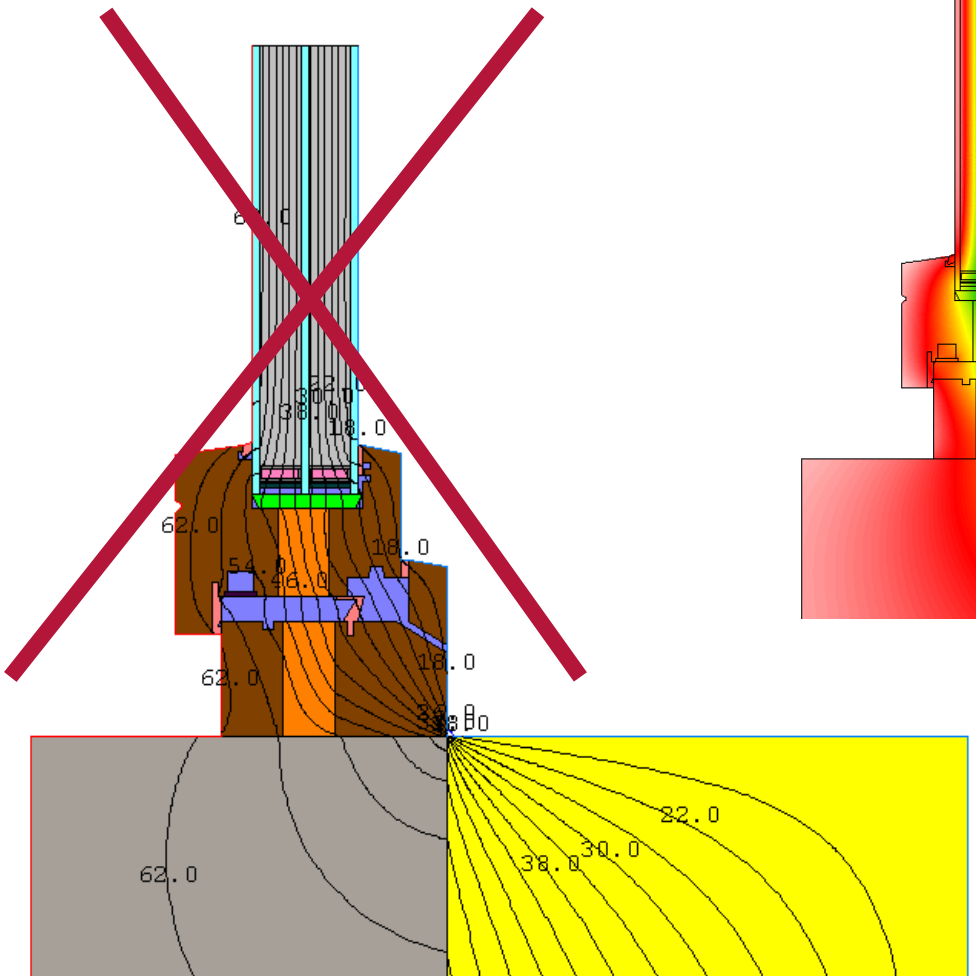


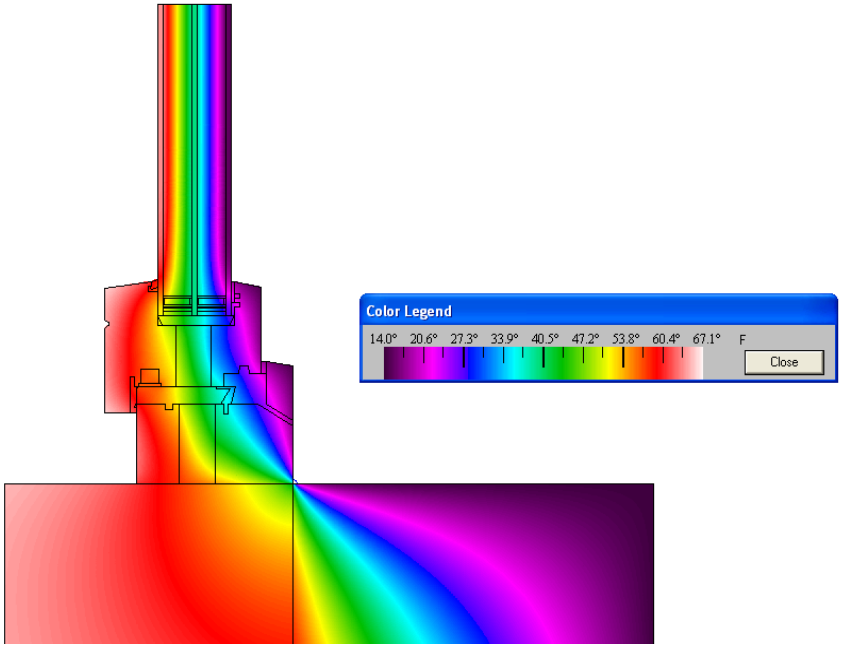
Glazing	Single	Double with air fill + Aluminum Spacers	Double Low-E with gas fill + Aluminum spacers	Triple Low-E with gas fill + Plastic Spacers
U-Value	1.00	0.50	0.18 – 0.28	0.09 – 0.14
Int. Surface Temp*	29 °F	48 °F	60 °F	64 °F
SHGC	85%	75%	50 - 70%	40 - 60%

**With Exterior at 14°F, Interior at 68°F*

Source: Passipedia.org

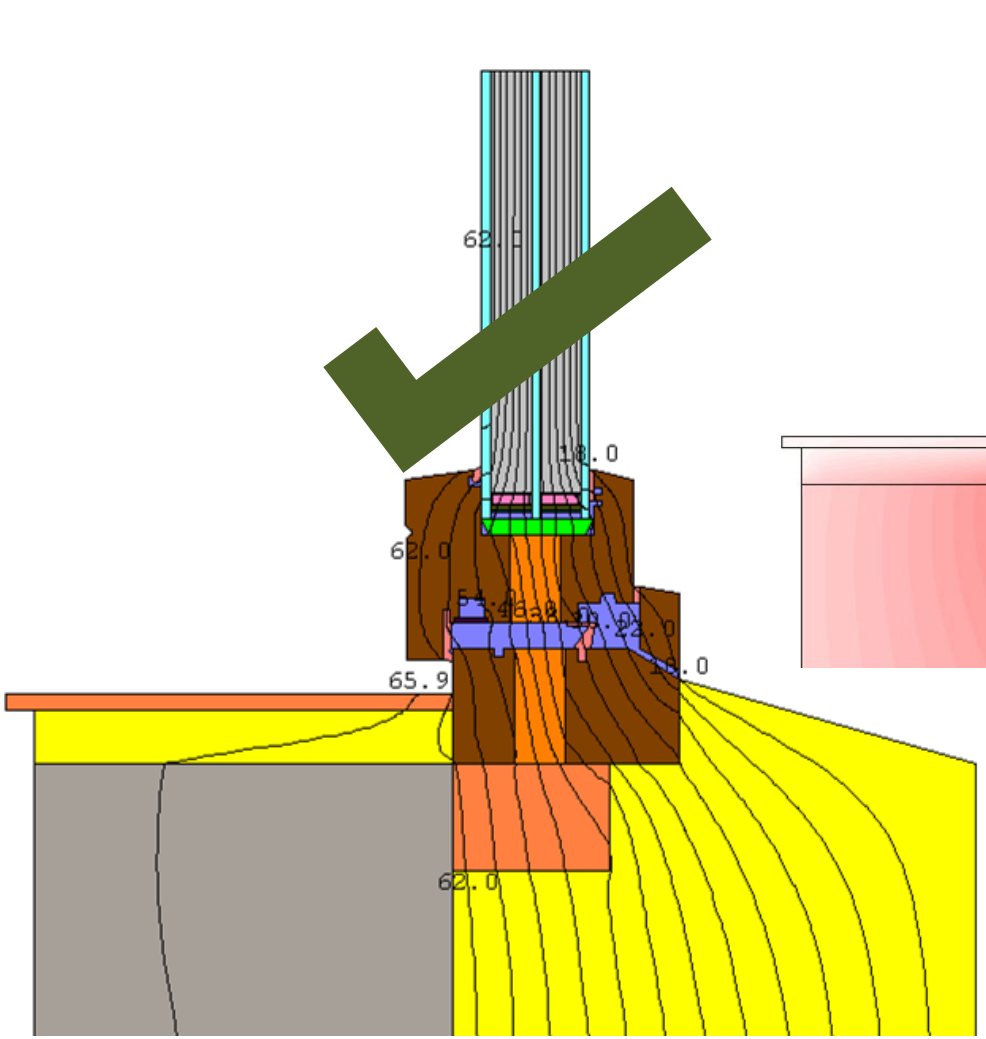
Window In Structural/Masonry Layer

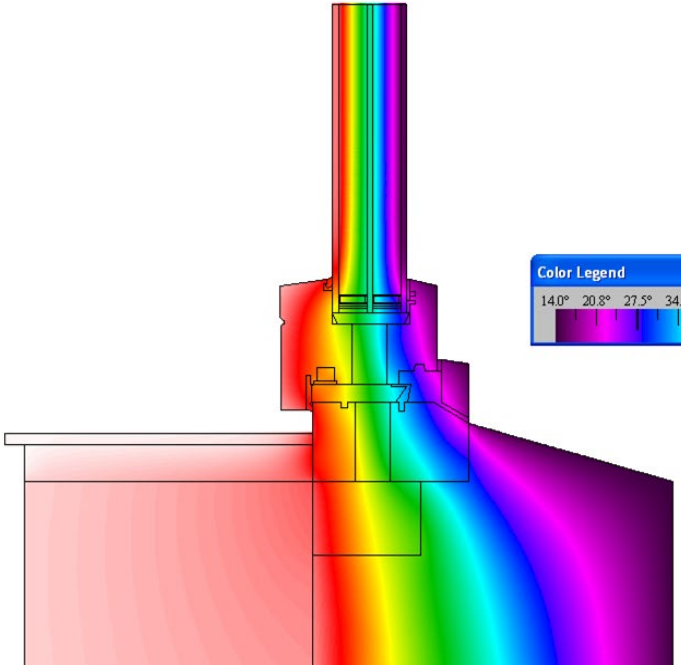


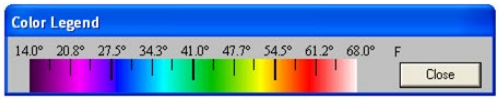


Ψ_e (for PHPP) **0.108** Btu/hr*f*F

Window External To Struct/Masonry Layer

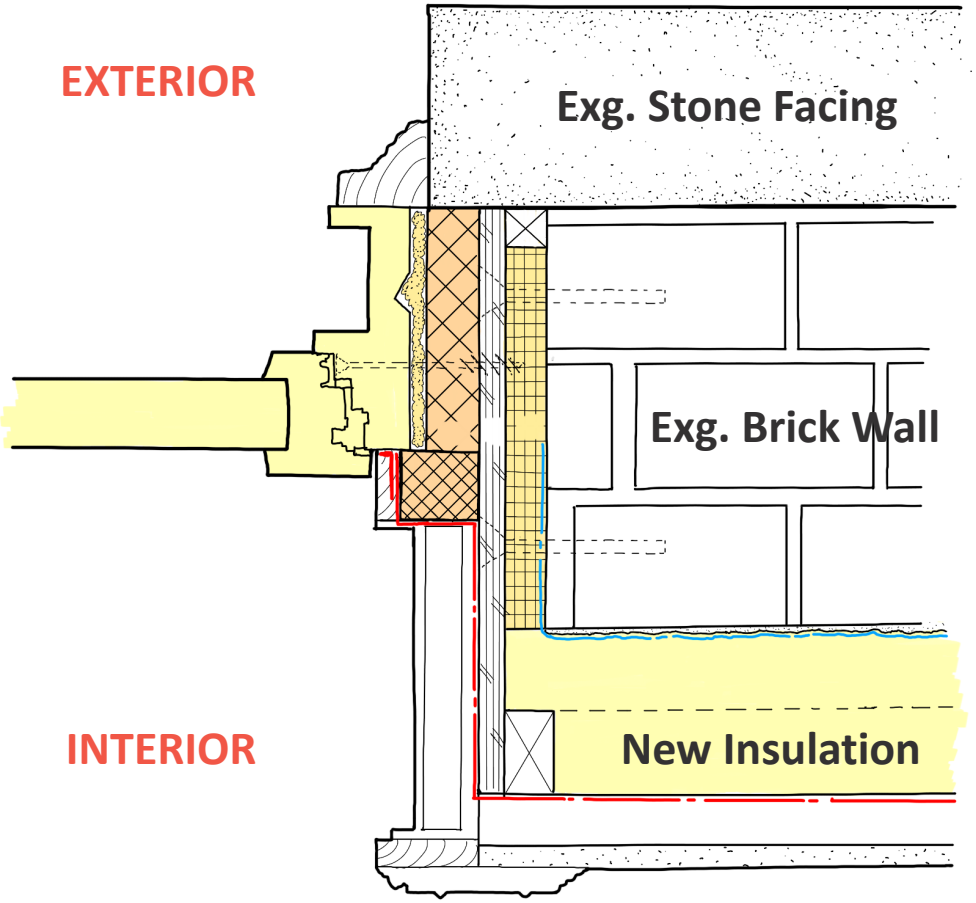






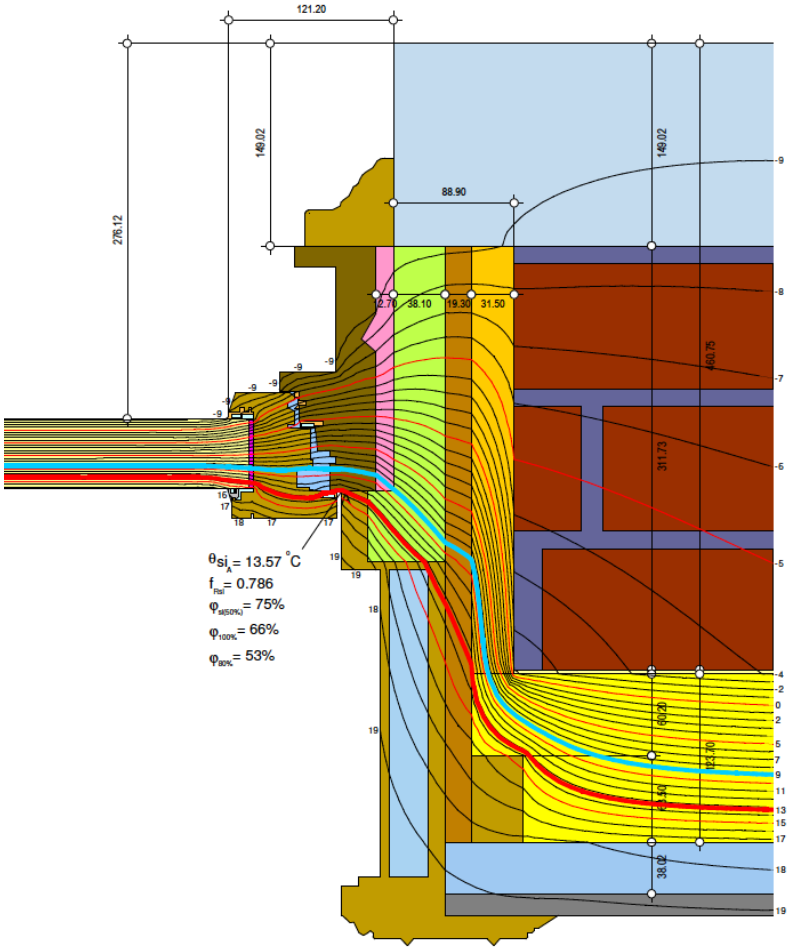
Ψ_e (for PHPP) **0.006** Btu/hr*f*F

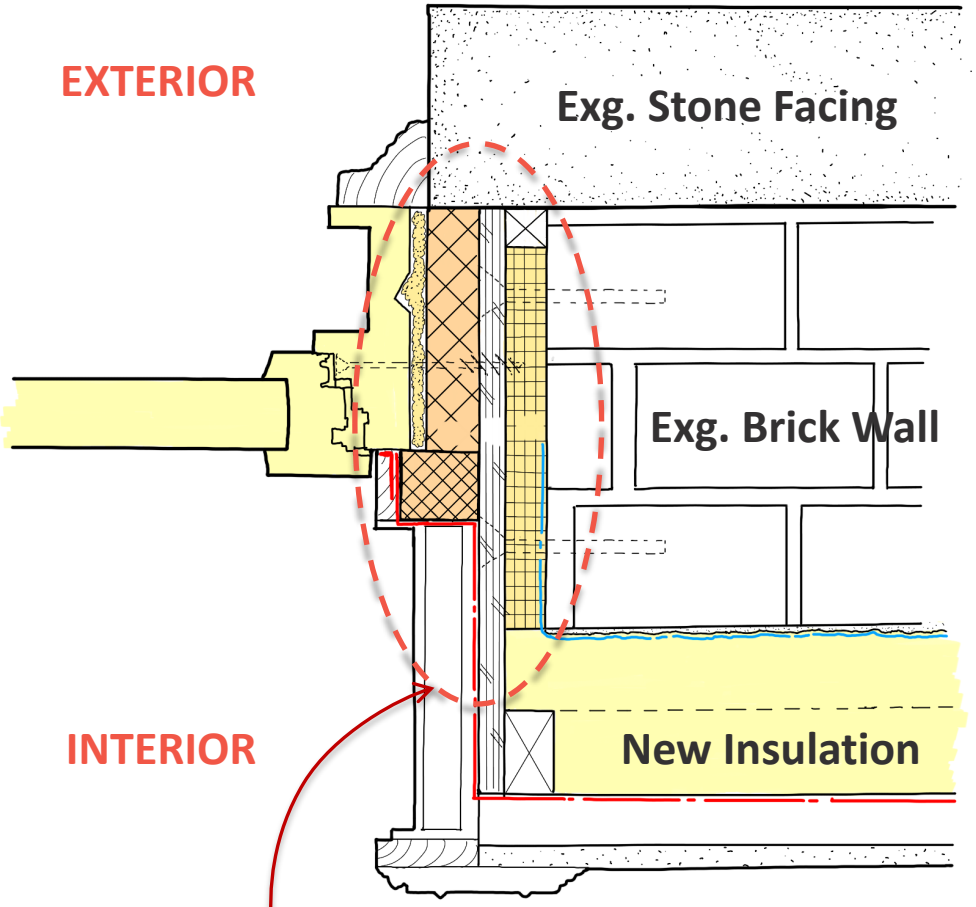
Example: Historic Masonry Retrofits [Jamb]



Source: BLDGtyp, llc

Example: Historic Masonry Retrofits [Jamb]





Insulating the RO is critical to connect the window to the insulation layer

Source: BLDGtyp, llc

Fresh Air Ventilation

Michigan, UNIVERSITY OF CHICAGO FIELD LABORATORY, GO Logic

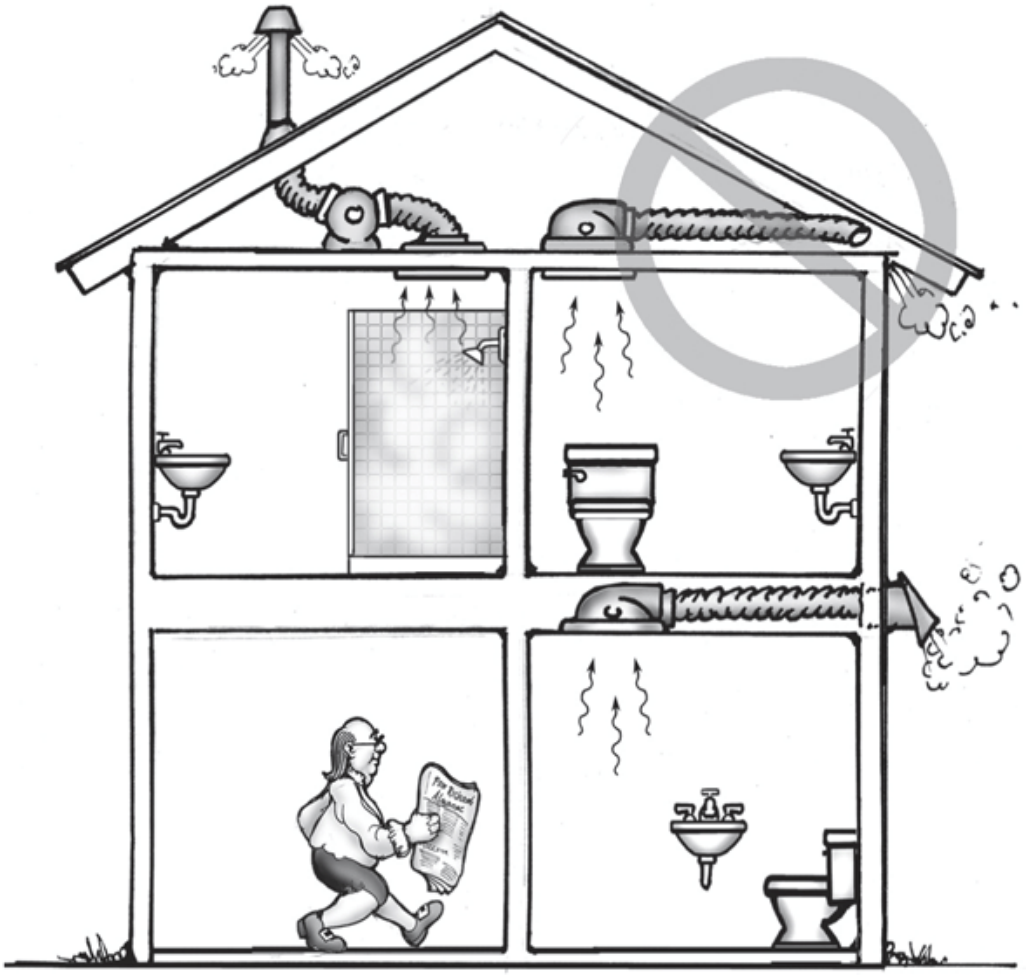
principle 4:
balanced ventilation + heat recovery

exhaust

supply

Fresh Air Ventilation

- **Exhaust stale 'dirty' air**
- **Bring in fresh 'clean' air**
  - Dilutes pollutants
    - CO_2
    - Water Vapor
    - VOCs
  - Can help to improve humidity (in humid or dry climates)
- **Mechanical ventilation systems can:**
  - Filter the air
  - Temper the air in heating & cooling seasons
  - Provide humidification and dehumidification
  - Take advantage of **heat recovery** between the outgoing exhaust air and incoming fresh air



Pollutants In Indoor Air

Pollutant	Effects
Water vapor	None at moderate levels (30-60% RH). If lower, can be uncomfortable for skin dryness. If too high, can be uncomfortable but also lead to mold/mildew growth.
Carbon Dioxide (CO_2)	Not harmful until concentrations over 5,000 ppm, but as an indicator of air quality it is generally accepted that 1,000 ppm or less should be maintained. (Atmospheric concentration is approximately 400 ppm).
Dust, pollen	Numerous sources, often an allergen or irritant, can be harmful for repeated or continual exposure to high levels.
Volatile Organic Compounds (VOCs)	Various natural and artificial chemicals found in paint, adhesives, cleaning products, “new car smell,” but also from plants and animals. Some are harmful after long-term exposure, others are harmless.
Carbon Monoxide (CO)	A product of combustion, this odourless toxic gas causes headaches around 100 ppm for many hours, above 800 ppm cause severe effects within 1 hour, over 1,600 ppm is fatal after 2 hours.
Radon	A natural but harmful product of the radioactive decay process of uranium, radon must be controlled at ground level with radon barrier and sub-slab exhaust system, if in regions with high levels.

High Humidity Issues

Moist indoor air leaking out through cracks encounters cold surfaces, and the moisture condenses

Condensation may even occur on cold interior surfaces if the assembly is poorly insulated. (even if at just one point)

Ventilation System Configuration Options

SYSTEM TYPES

Exhaust Only:

Typical in most small buildings, air is extracted from the bathrooms, kitchens, etc, only. Tends to depressurize building and relies on infiltration through cracks / leaks for supply.

Supply Only:

Fresh air is supplied into living spaces, only. Not very common. Tends to pressurize building and increase exfiltration.

Balanced:

Equal amounts of supply & exhaust. Minimal effect on infiltration.

Balanced with Heat Recovery:

Best of all the above. Optimal for Passive House & Low-Energy Buildings in most climates.

OPERATION TYPES

Intermittent:

The fan (typically extract) is activated by the occupant for a specific event (e.g. cooking or showering), and may be based on a countdown timer.

Cycling:

The fan(s) cycle on and off based on a timer (e.g. 15 min on, 15 min off), typically without occupant input. Since a higher flow rate must be achieved to maintain the necessary average flow rate, larger ductwork is required. Not recommended for Passive House.

Oscillating:

The fans (typically in pairs) alternate air flow direction according to some time interval, optionally with regenerative heat recovery cores.

Continuous:

The fan(s) runs continuously, and have multiple speeds. Better for minimizing duct size. Optimal for Passive House.

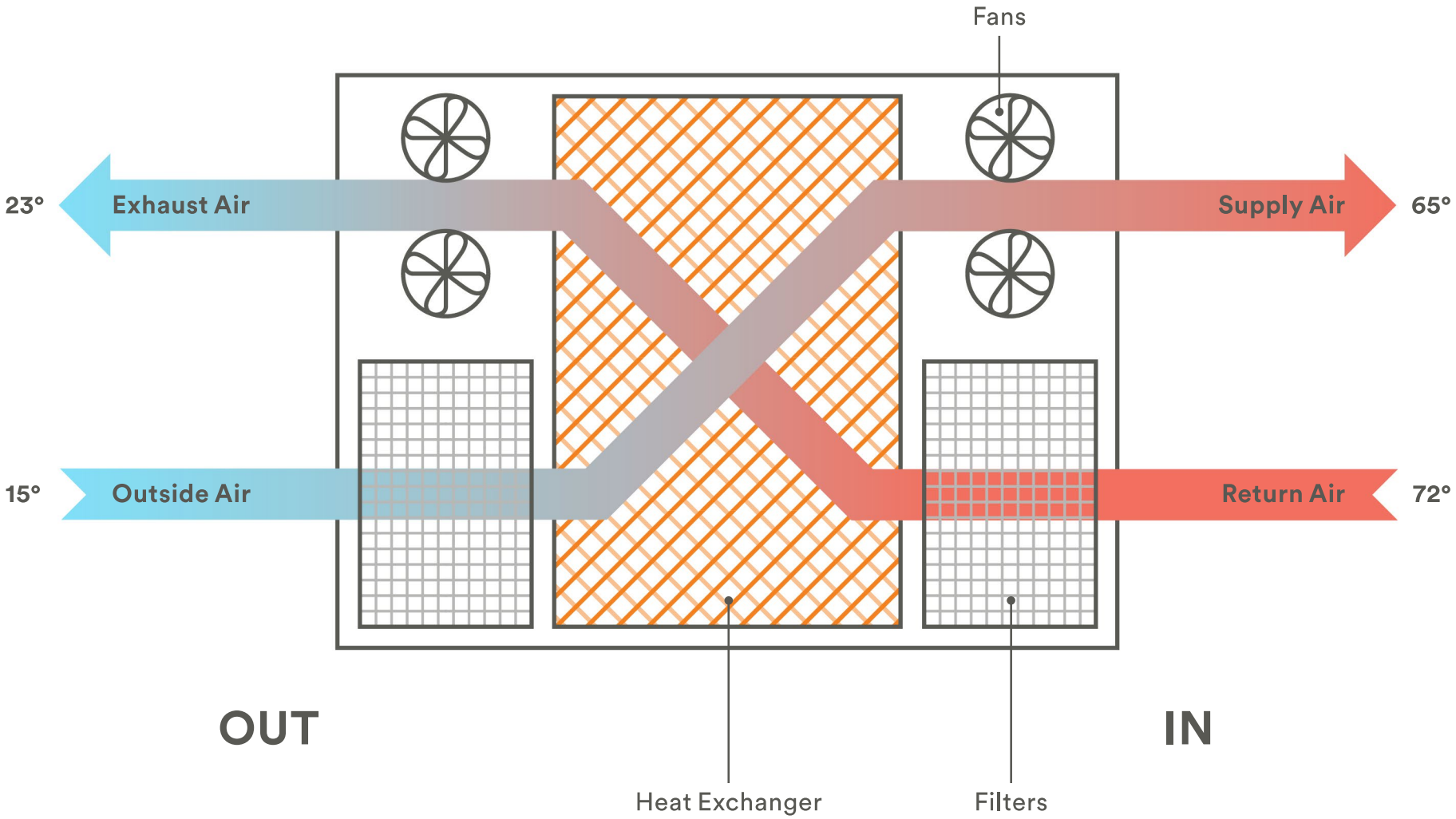
Balanced Ventilation: HRV And ERV

The H/ERV (heat/energy recovery ventilator) is the lungs of the Passive House ventilation system.

H/ERV's must be:

- Super-insulated
- Airtight
- Thermal bridge free
- Quiet
- Energy efficient
- Suitably located

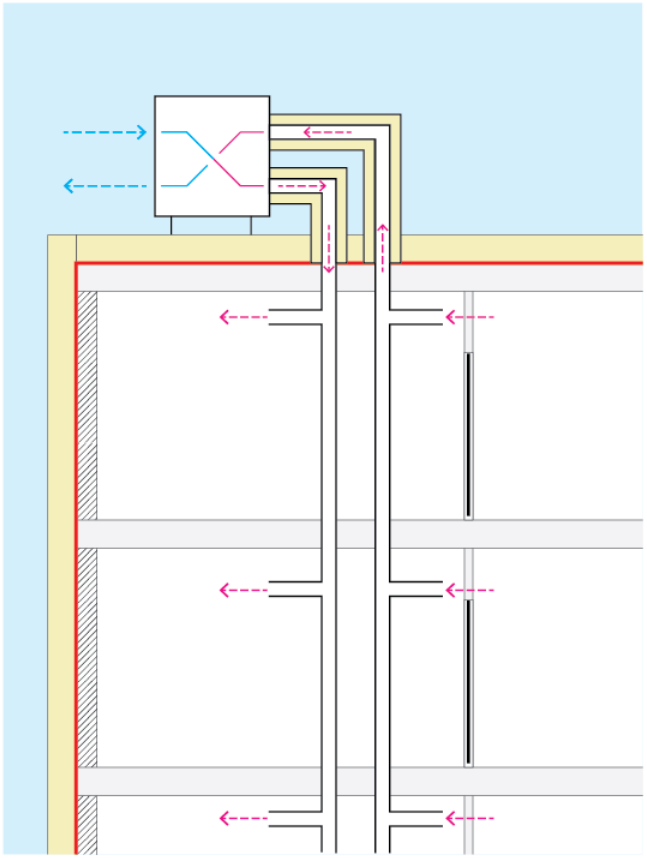
Heat / Energy Recovery Ventialtor



Balanced Ventilation System Options

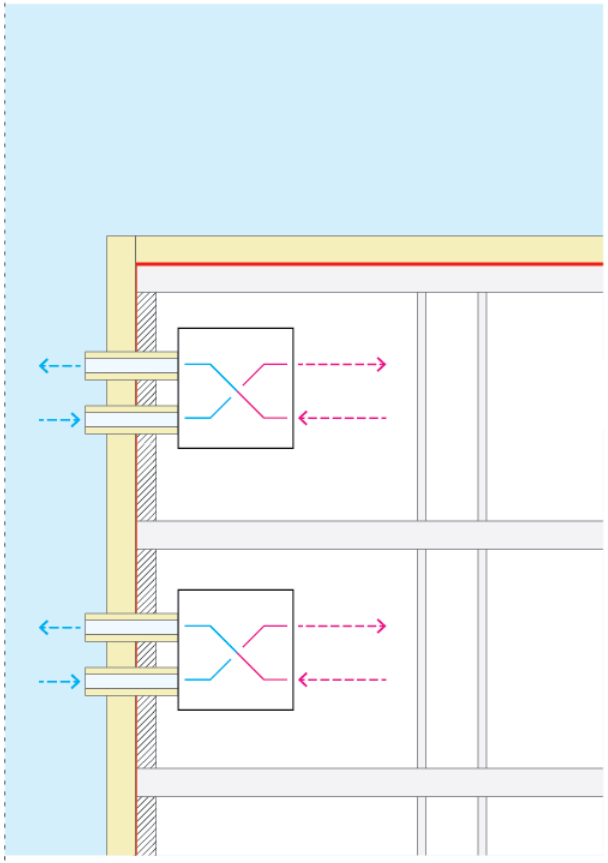
Centralized:

One main ventilator unit for the entire building



Decentralized:

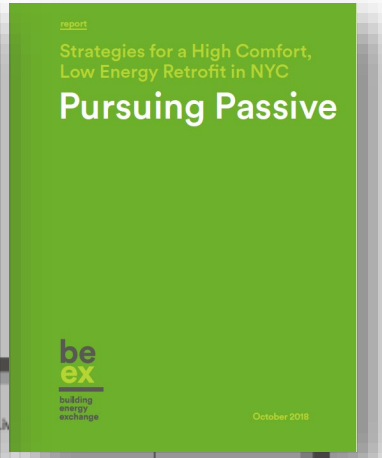
Multiple ventilators distributed throughout the building

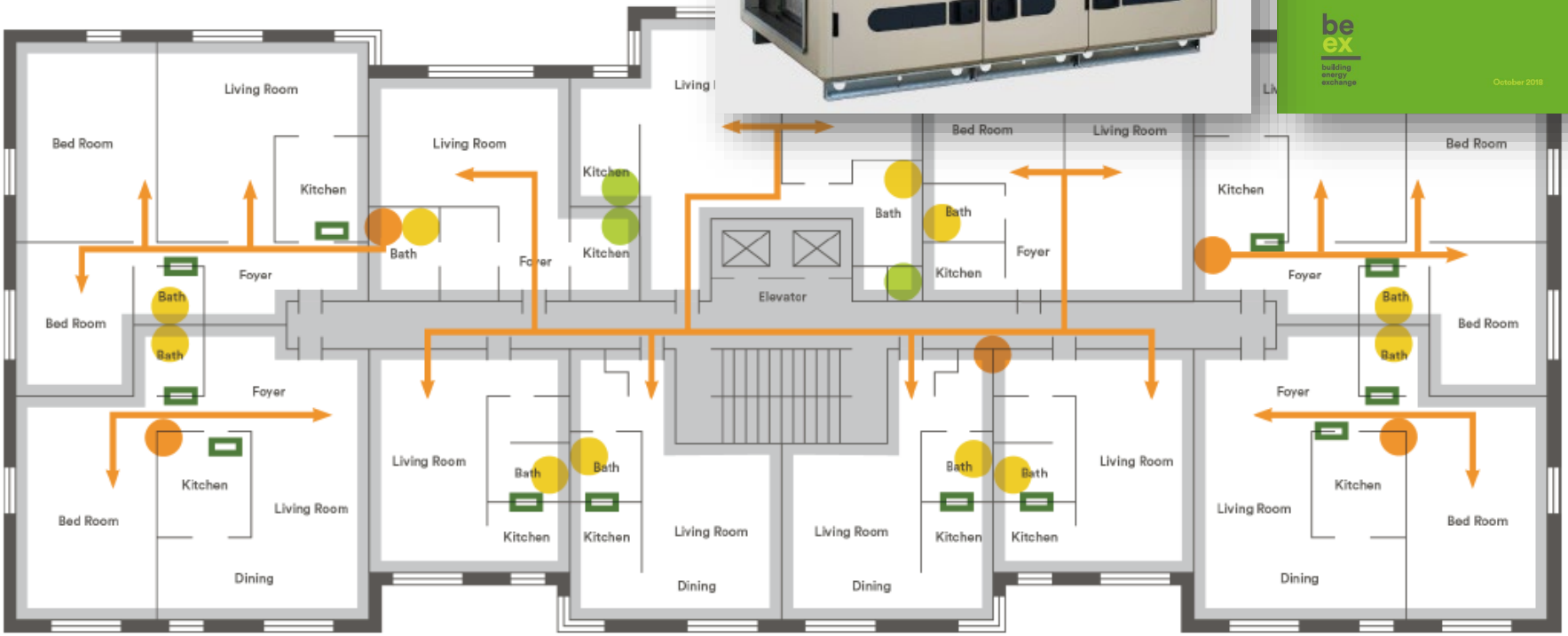


Source: BLDGtyp, llc, Candela Lofts

“Pursuing Passive” Ventilation

- Convert to a ‘balanced’ system
- Rooftop ERV (central)
- Transfer grills to connect spaces





Heating And Cooling Systems

Vienna, Austria, DORMITORY/NEW BUILD, Baumschlager Eberle Architekten

Enerphit Criteria Mandatory For Path 1 & 2

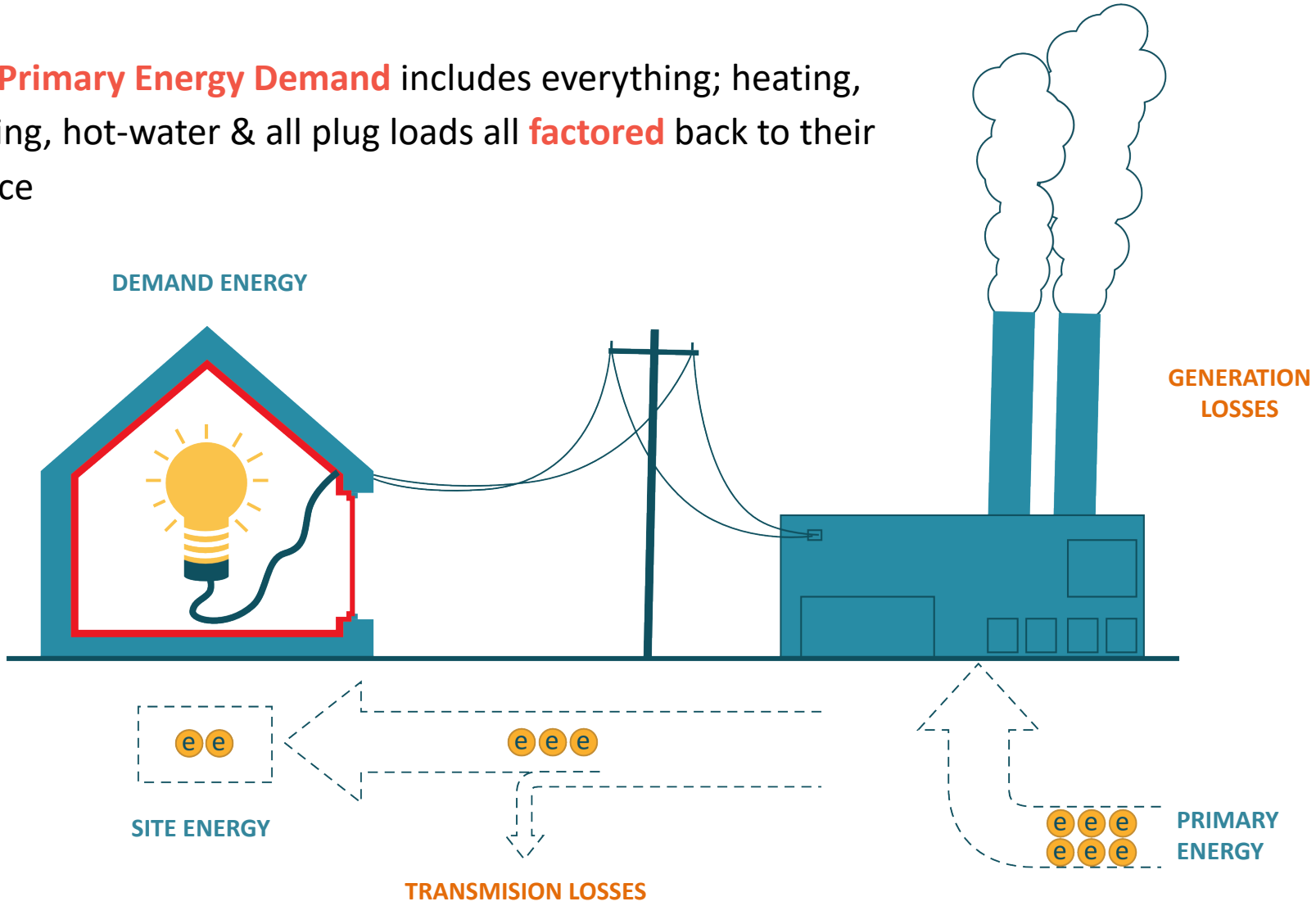
			Criteria[1]			Alternative Criteria[2]
Airtightness						
Pressurization test result n_{50}	[1/h]	≤	1.0			
Renewable Primary Energy (PER)[3]			Classic	Plus	Premium	
PER demand[4]	kBtu/ft².yr	≤	$19 + (Q_H - Q_{H,PH}) \cdot f_{ØPER,H} + (Q_C - Q_{C,PH}) \cdot 1/2$	$14.25 + (Q_H - Q_{H,PH}) + (Q_C - Q_{C,PH}) \cdot 1/2$	$9.5 + (Q_H - Q_{H,PH}) + (Q_C - Q_{C,PH}) \cdot 1/2$	± 4.75 kBtu/ft².yr deviation from criteria...
Renewable energy generation[5] (with reference to projected building footprint)	kBtu/ft².yr	≥	-	19	38	...with compensation of the above deviation by different amount of generation

Q_H: heating demand
$Q_{H,PH}$: Passive House criterion for the heating demand
$f_{ØPER,H}$: weighted mean of the PER factors of the heating system of the building
Q_C: cooling demand (incl. dehumidification)
$Q_{C,PH}$: Passive House criterion for the cooling demand
If the terms "$(Q_H - Q_{H,PH})$" and "$(Q_C - Q_{C,PH})$" are smaller than zero, zero will adopted as the value.

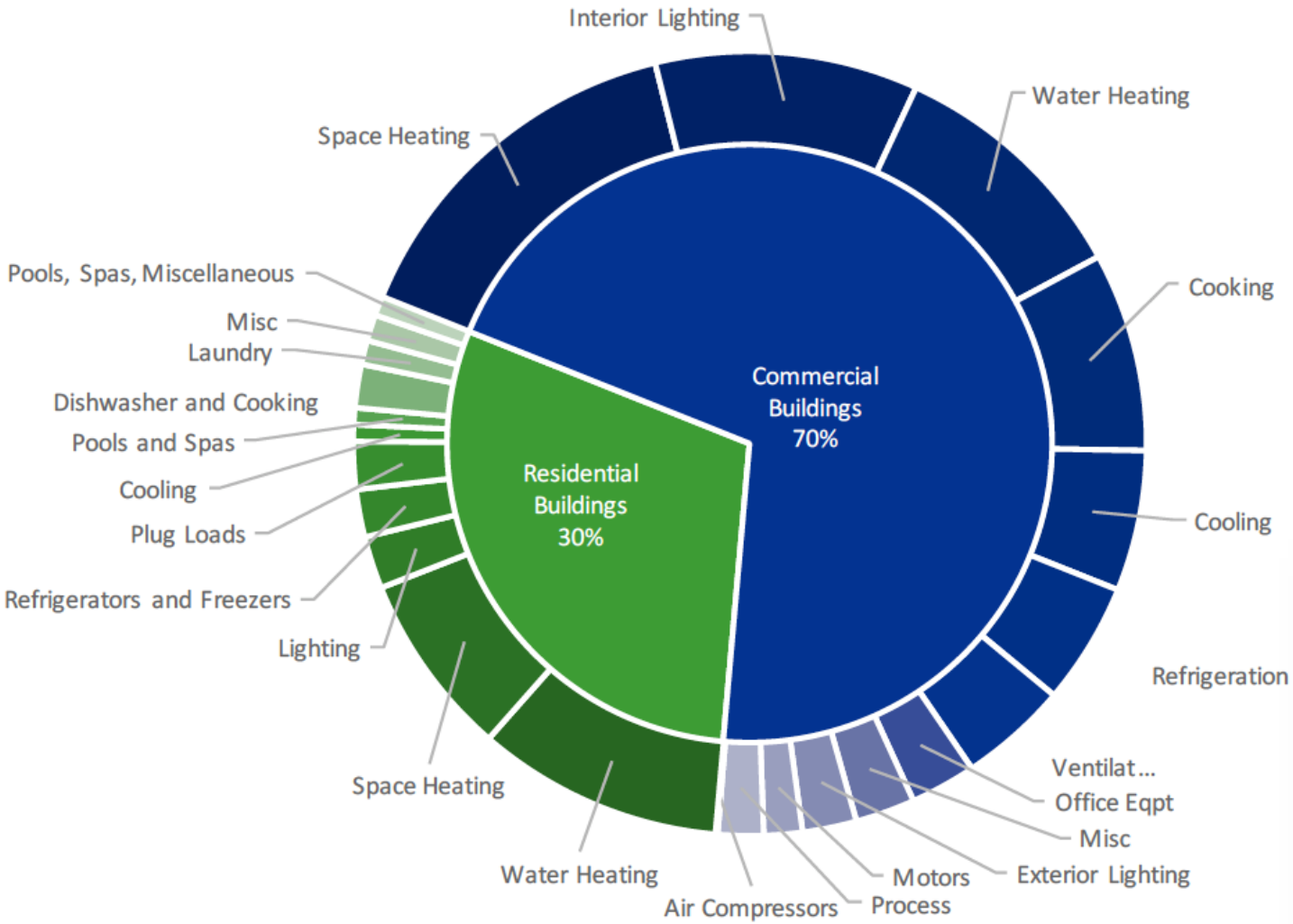
- PER demand thresholds lessen as you move from ‘Classic’ to ‘Plus’ to ‘Premium’
- Calculated using a baseline allowance plus additional demand to allow for challenges in dealing with retrofitting exiting buildings

‘Primary’ Energy?

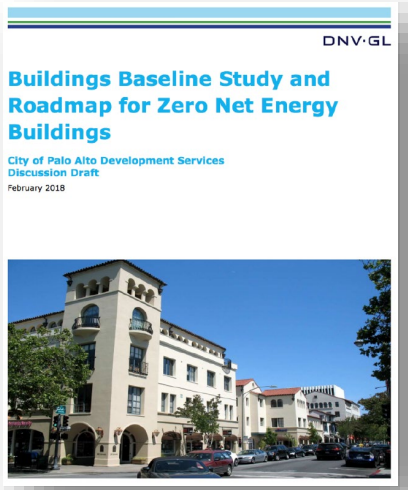
The Primary Energy Demand includes everything; heating, cooling, hot-water & all plug loads all **factored** back to their source



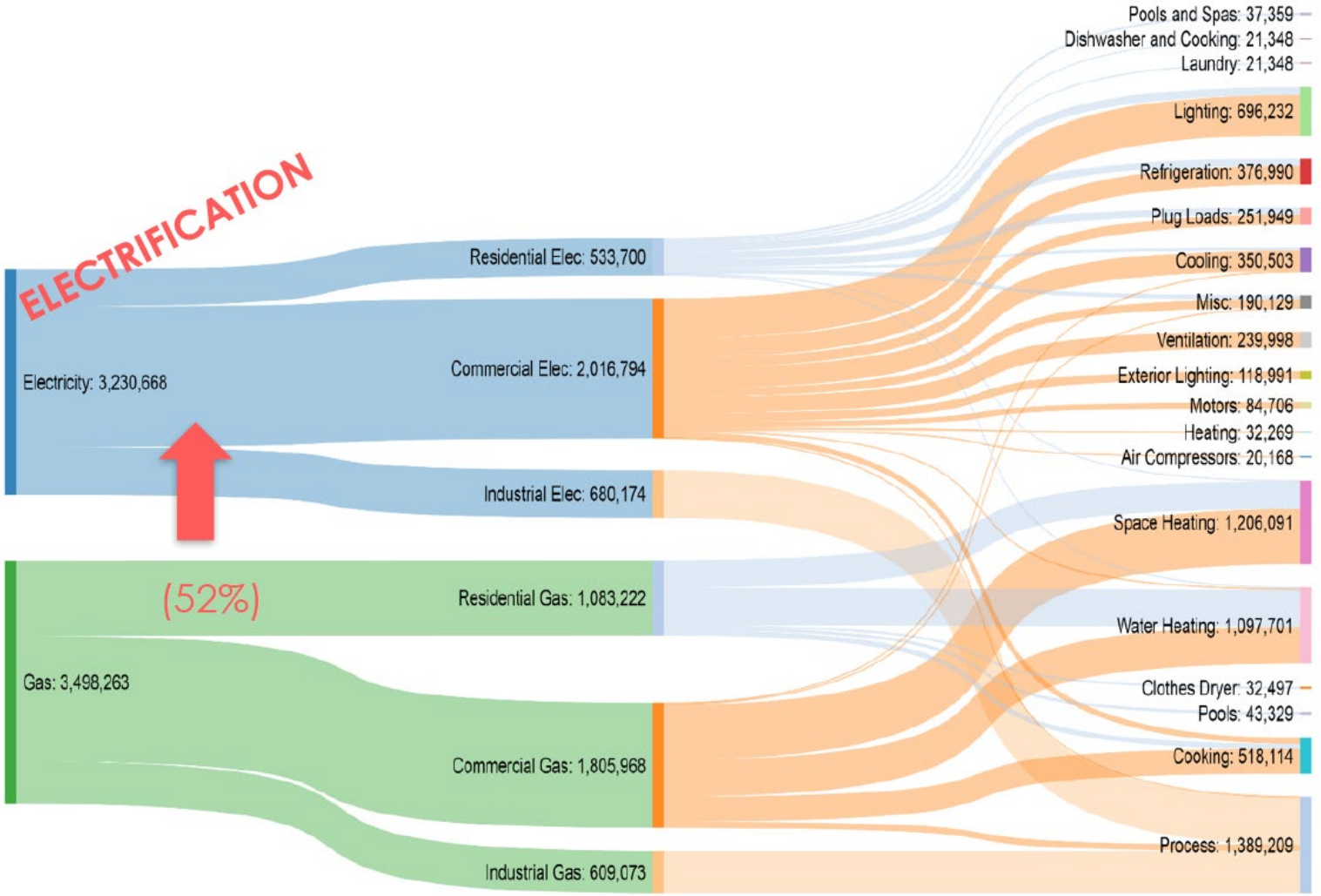
How Does Palo Alto Use Energy?



Source: https://www.cityofpaloalto.org/civicax/filebank/documents/63492



What Needs To Shift?



Source: https://www.cityofpaloalto.org/civicax/filebank/documents/63492

Two Sets of Primary Energy Factors

1. Non-Renewable Primary Energy (PE) Factors

This is the original basis used in the Passive House Planning Package (PHPP). The same generic PE factors were used all around the world, irrespective of how electricity is generated at any given location or the availability of renewable energy. PHI is phasing this rather crude system out, moving towards PER below.

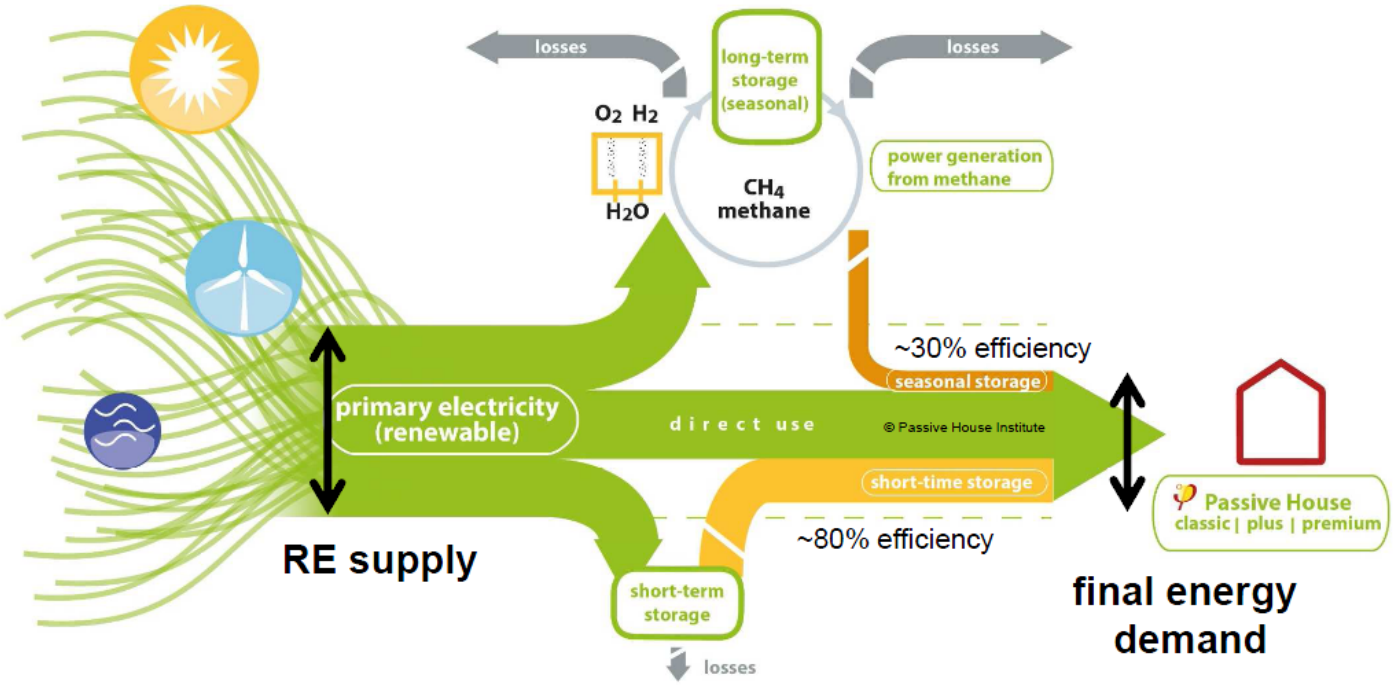
2. Primary Energy Renewable (PER) Factors

In 2015 PHI introduced the PER system into PHPP. In this case, localised factors are specified for different energy types and uses. This PER system will eventually take over from the PE system above.

Primary Energy Renewable (PER) FACTOR

PASSIVE HOUSE INSTITUTE

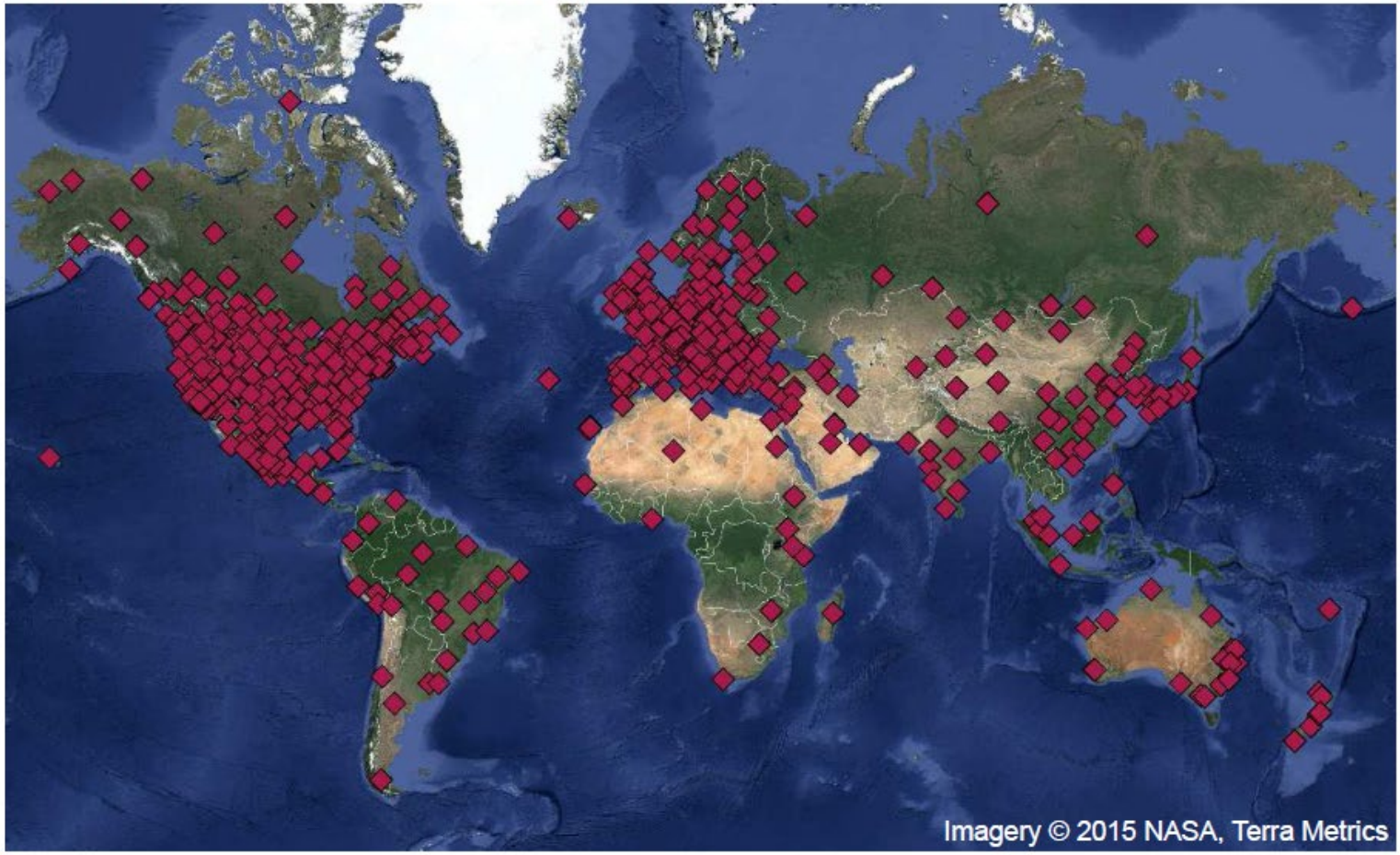
$$\text{PER-factor} = \frac{\textit{Energy supplied from RE sources}}{\textit{Final energy demand}}$$



PH meets Net-Zero – PER, Plus and Premium Passive - October 2015 – Vancouver

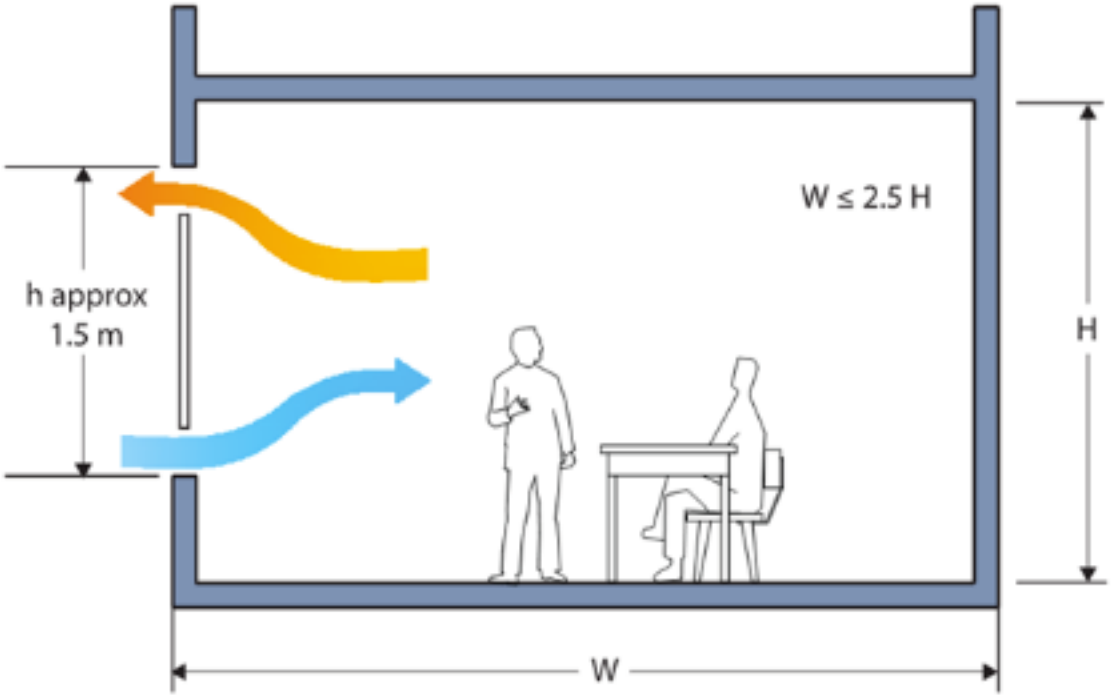
>700 Worldwide Calculations

Calculations for PER factors. March 2015



PH meets Net-Zero – PER, Plus and Premium Passive - October 2015 – Vancouver

Passive Cooling: Operable Ventilation



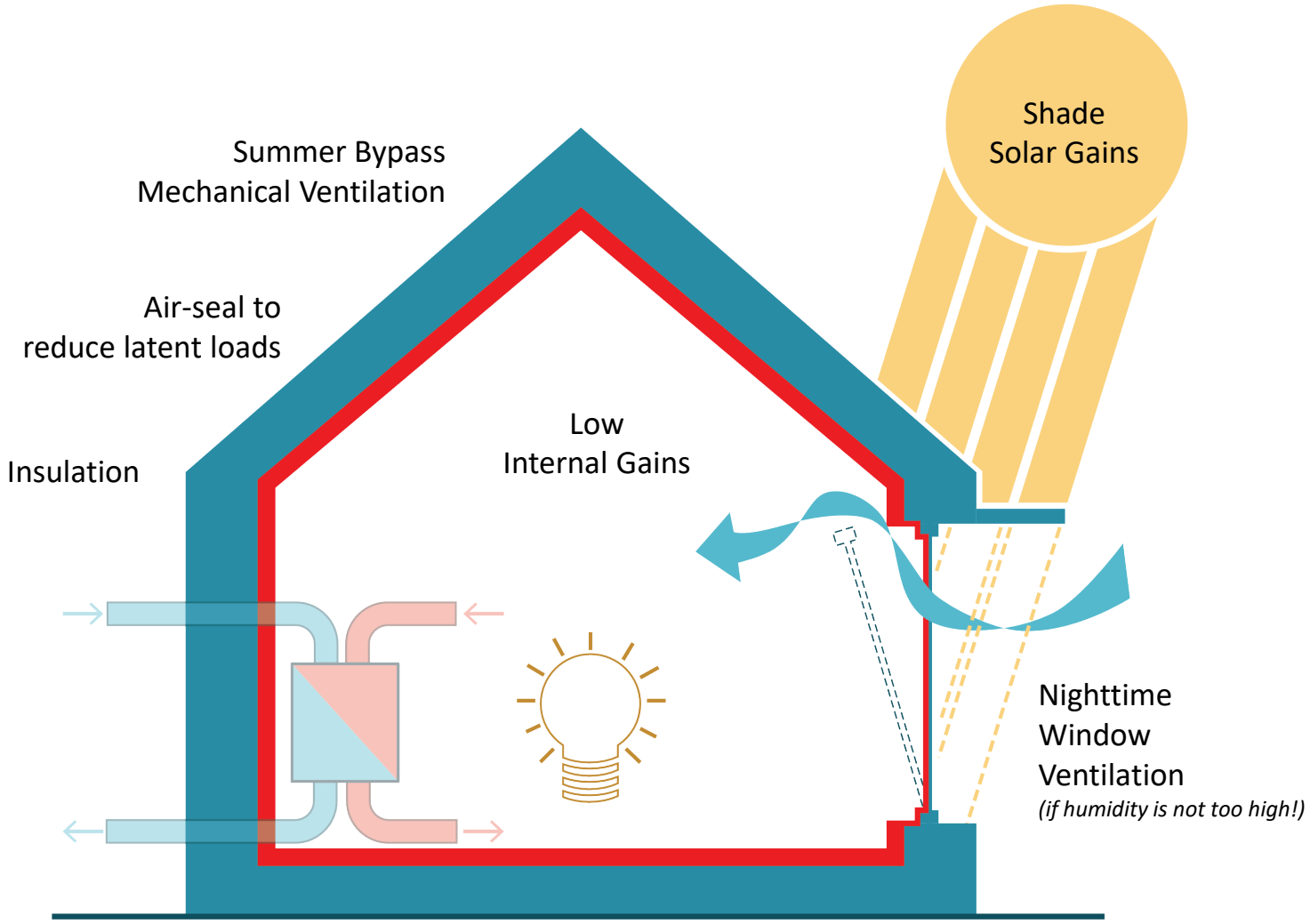
- Study stack effect potential
- Consider security, outdoor air quality, noise
- Ensure occupants will manage systems

Passive Cooling: Reduce Peak Load

For cooling, the design process is similar to that for heating, but with more focus on:

- Window size and orientation
- Shading requirements
- Operable window ventilation
- Humidity control

Peak Sensible & Latent Cooling Loads



Sensible Cooling ($P_{c\text{-}sensible}$)

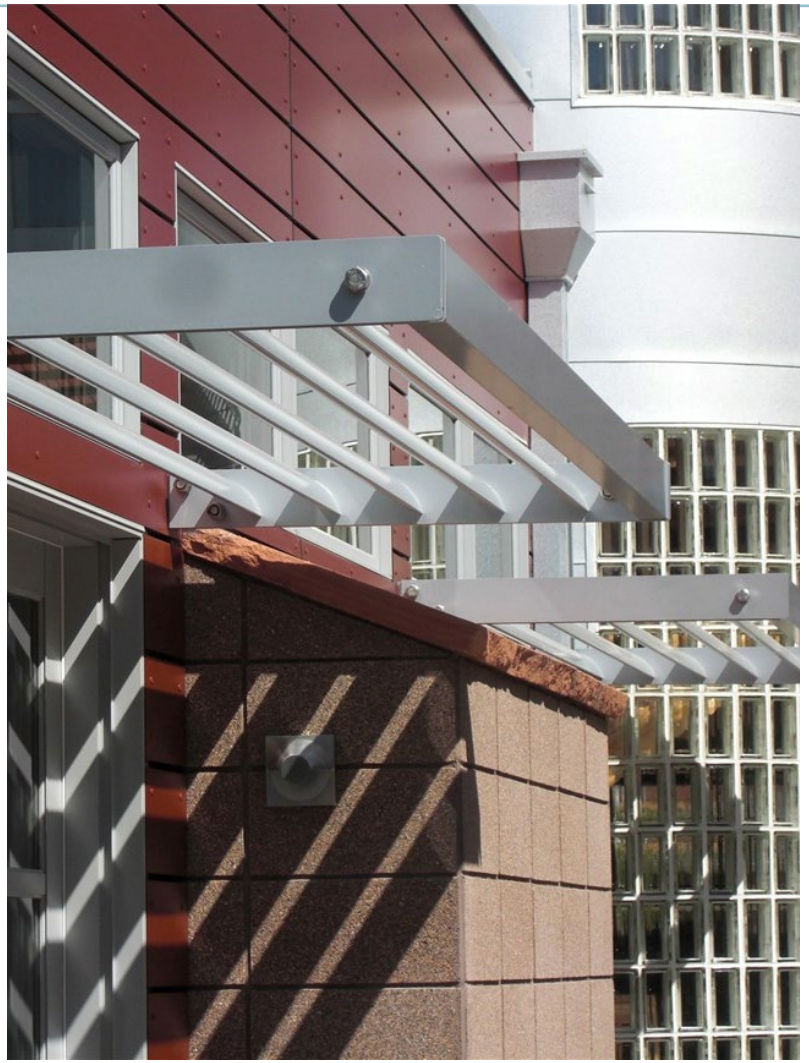
When possible, take advantage of passive cooling techniques:

Shading (outside of the glass is by far the best). May be movable, or fixed (but check influence on heating demand, too!)

Natural ventilation – including night-flush ventilation

Internal heat gain reduction (esp. lights)

Thermal mass



Moisture Sources

Moisture Sources considered in Peak Cooling Load Calculation:

Unintentional Infiltration:

- Air leaks in the building envelope
- Window and door operation

Intentional Ventilation:

- HRV / ERV / Enthalpy wheel
- Natural ventilation

Internally Generated:

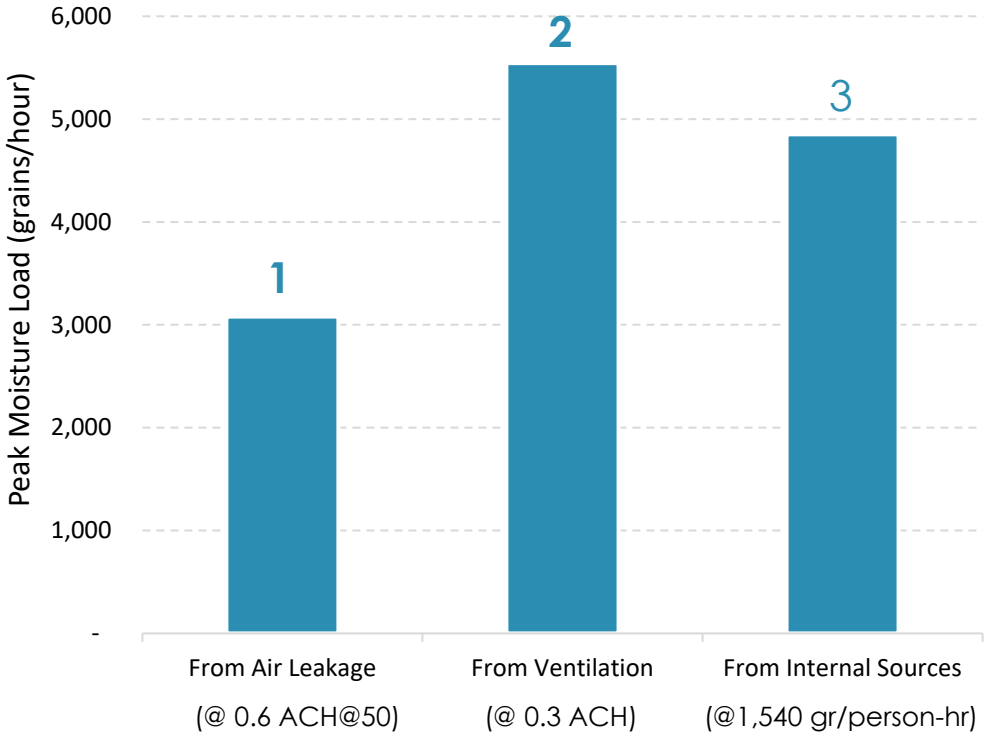
- Cooking
- Showering/bathing
- House plants
- Human activity
- Clothes washing/drying
- Dishwashing

Managing Moisture Loads

Mitigation strategies

1. Make building more airtight
2. ERV with high efficiency recovery
3. Simply must accommodate

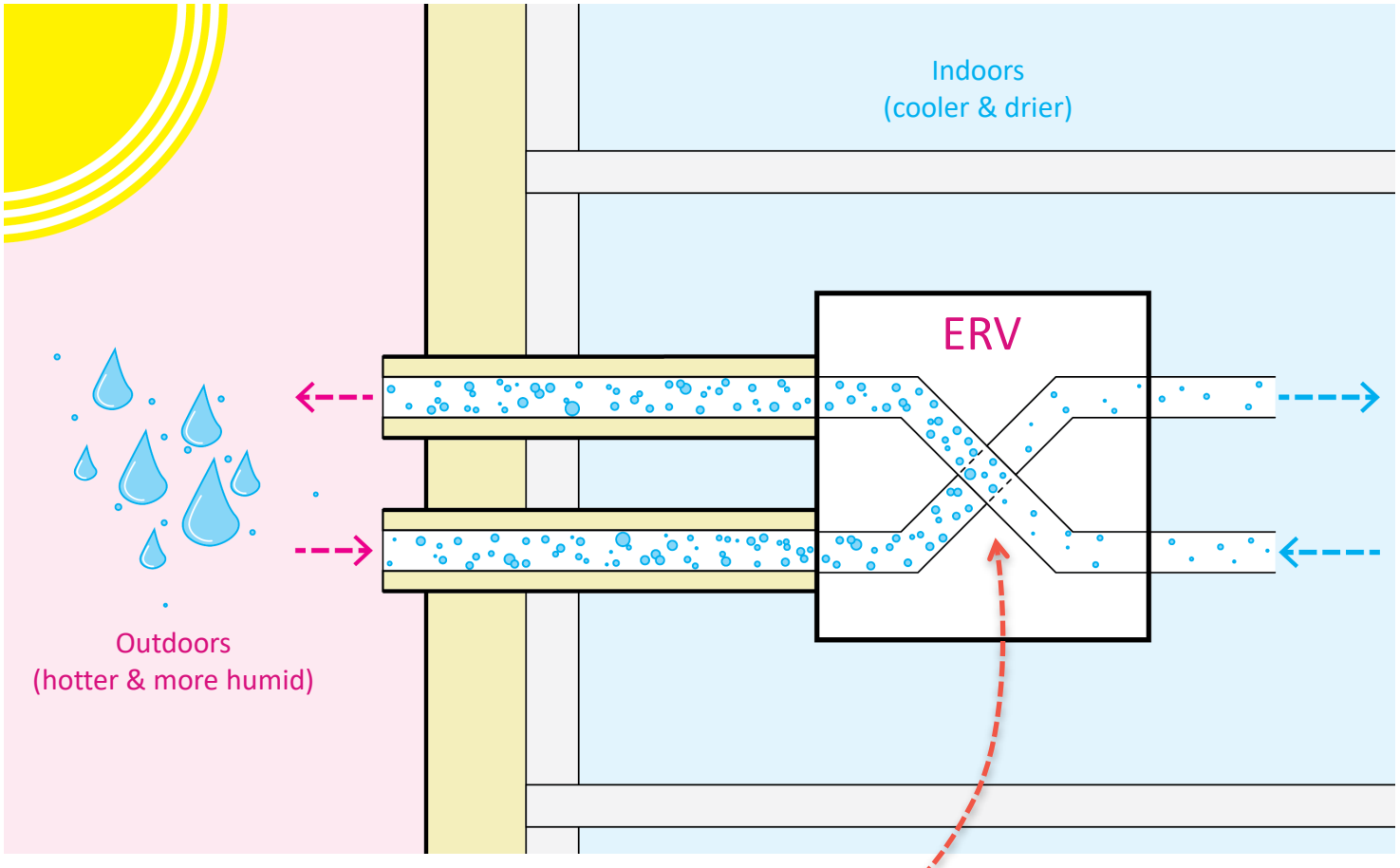
- Climate determines moisture
- Efficient cooling equipment critical
- Proper sizing critical! (Oversized cooling eq. poor at removing humidity)



Source: BLDGtyp llc, Mayers House. 2016

ERV & Humidity Control

Note: the reverse of this process is also true which is why in winter an ERV can help to maintain higher indoor RH levels even when the outdoor air is low RH.



In an ERV, when the relatively humid outdoor air passes by the relatively dry indoor air, the moisture moves from wetter to drier (higher vapor pressure to lower vapor pressure). The efficiency of this process will vary by ERV model.

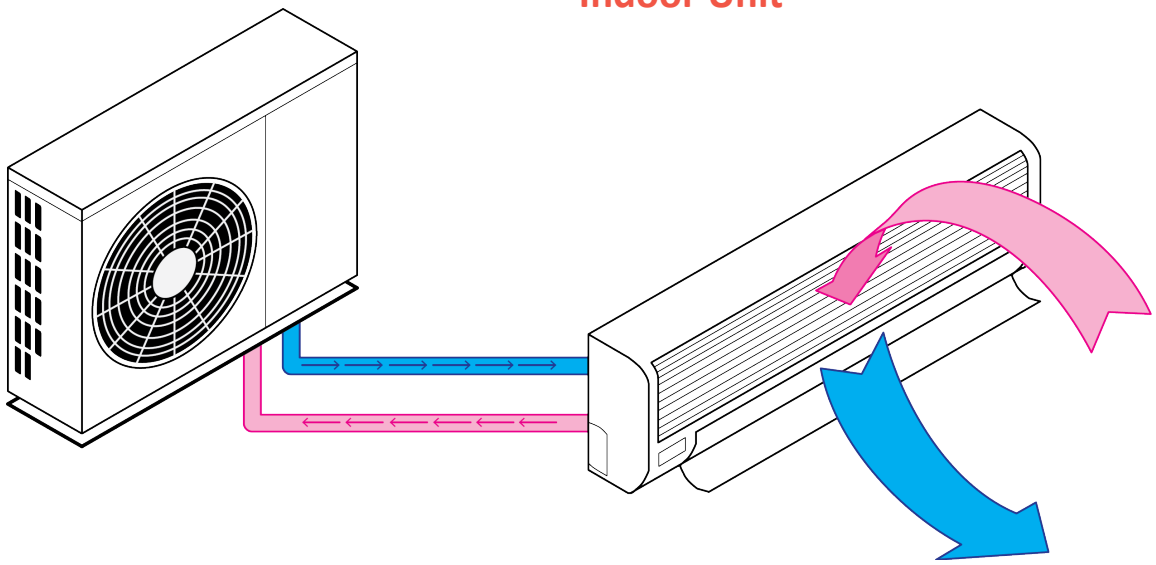
Heat Pump Heating + Cooling

Can be used for **heating and cooling**, for many types of buildings. They do not GENERATE heat, but instead use the refrigeration cycle to MOVE (pump) heat.

- Very efficient
- Multiple /Variable capacities
- Single and multi-zone
- Can dehumidify in summer
- Usually run on electricity

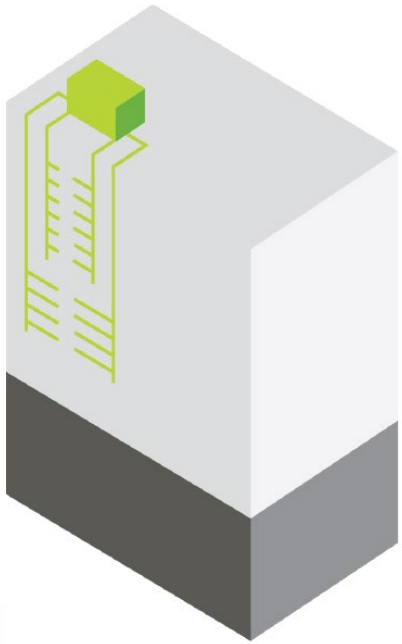
Outdoor Unit

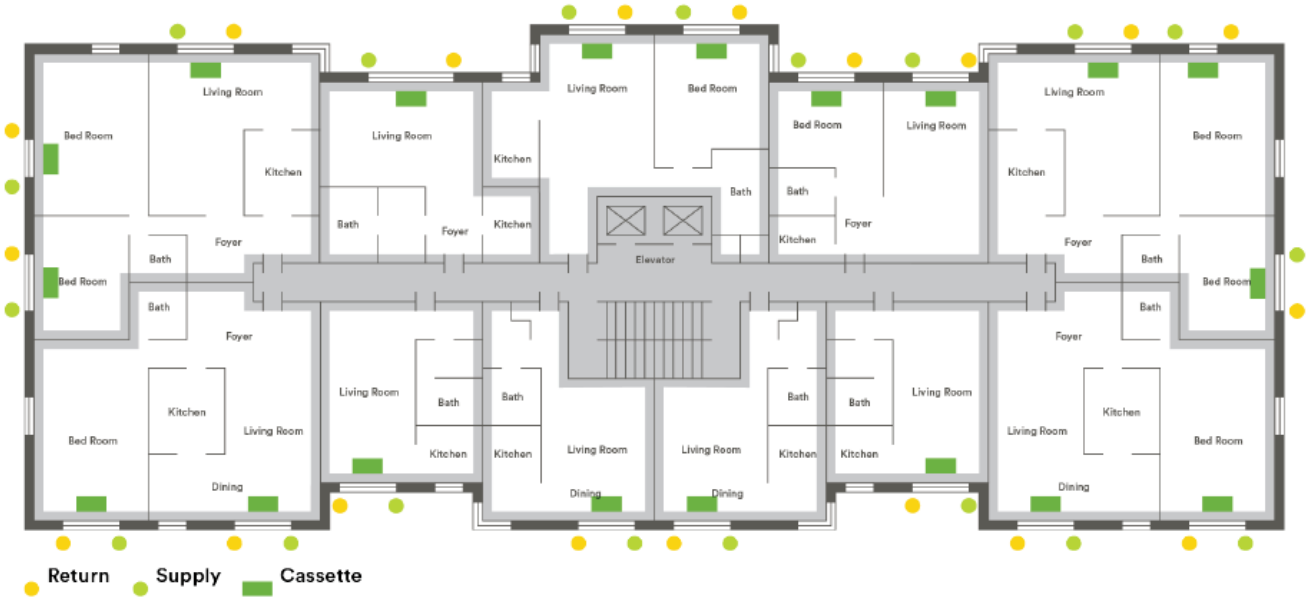
Indoor Unit

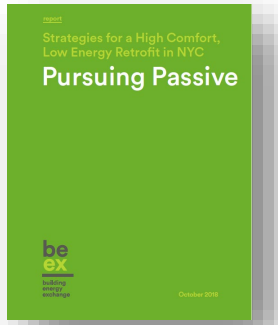


VRF - Rooftop Units + Exterior Risers

- Rooftop condensing units + risers on exterior facade
- Covered by EIFS / rainscreen risers serve stacks of floors (1 thru 7, 8 thru 15)
- No crossovers (to avoid increases in depth)
- Supply one side of each stack, return on the other feeds rooftop condensing units



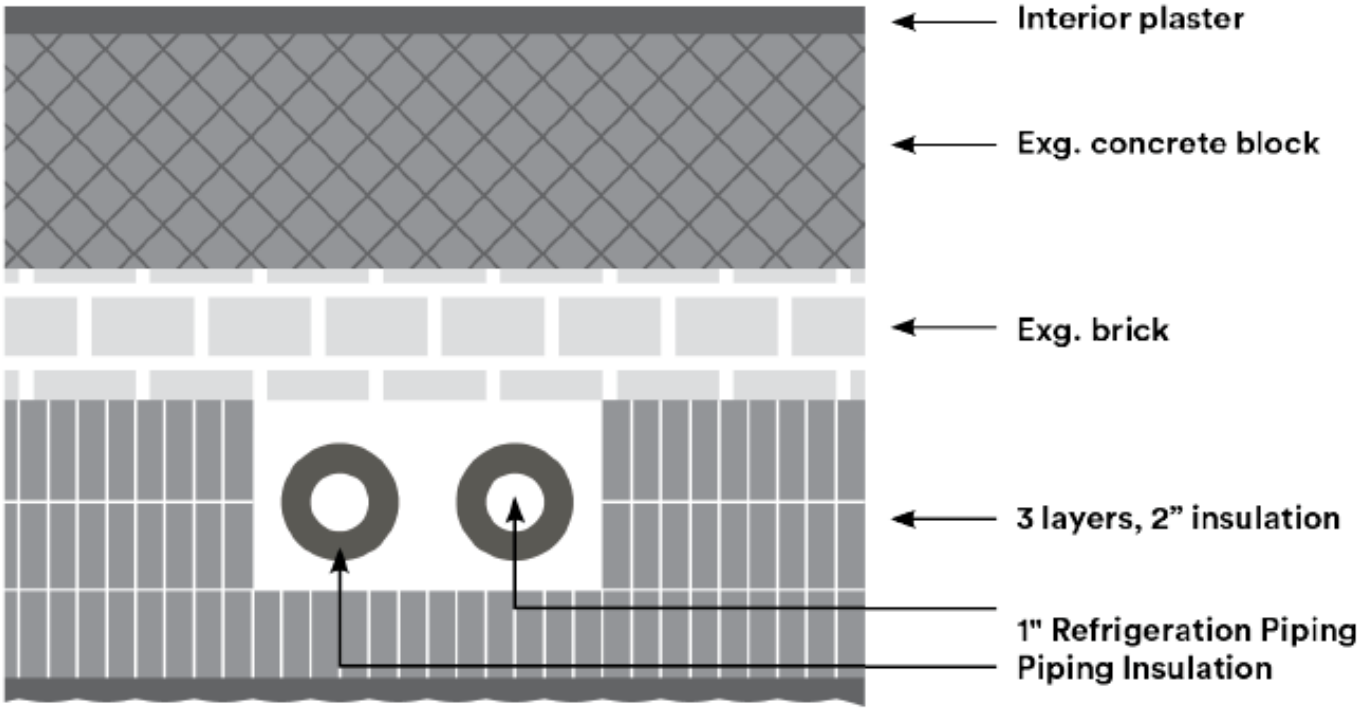


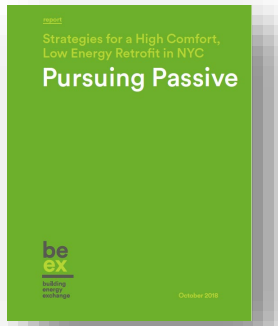


be-exchange.org

VRF - Rooftop Units + Exterior Risers

- Cassettes replace radiators
- Less tenant disruption
- Simpler phasing
- Increases exterior insulation





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Modeling And Design Evaluation

Vermont, GUILFORD SOUND ARTISTS' RESIDENCE, Ryall Sheridan Architects

Certification: Energy Model Based

Windows

Hollis Montessori School / Climate: Hollis, NH / TFA: 9058 ft² / Heating: 0.91 kWh/(ft²yr) / Cooling: 0.8 kWh/(ft²yr) / PER: 12.55 kWh/(ft²yr)

Window area orientation	Global radiation (main orientations)	Shading	Dirt	Non-vertical radiation incidence	Glazing fraction	SHGC	Solar irradiation reduction factor
Standard values →	kWh/(ft²yr)	0.75	0.95	0.85			
North	14	0.56	0.95	0.85	0.58	0.50	0.26
East	33	0.79	0.95	0.85	0.63	0.50	0.40
South	62	0.81	0.95	0.85	0.74	0.50	0.49
West	34	0.81	0.95	0.85	0.63	0.50	0.41
Horizontal	53	1.00	0.95	0.85	0.00	0.00	0.00
Total or average value for all windows.						0.50	0.43

Heating degree hours [°F.day/yr]: 7440

Go to glazing list

Qua n- tity	Description	Deviation from north	Angle of inclination from the horizontal	Orien- tation	Window rough ope Width	Window rough ope Height	Installed in Selection from 'Areas' worksheet	Glazing Selection from 'Components'								
		°	°		ft	ft		1-Sorting: LIKE LIST								
1	W104	90	90	East	3.00	4.86	4-Wall_9351_E	01ud-Triple-insulated-Kr08								
1	W107	90	90	East	3.00	4.85	4-Wall_9351_E	01ud-Triple-insulated-Kr08								
1	W106	90	90	East	3.00	4.85	4-Wall_9351_E	01ud-Triple-insulated-Kr08								
1	W105	90	90	East	3.00	4.85	4-Wall_9351_E	01ud-Triple-insulated-Kr08								
1	D125	90	90	East	3.00	6.67	4-Wall_9351_E	01ud-Triple-insulated-Kr08								
1	W155	90	90	East	3.00	4.06	4-Wall_9351_E	01ud-Triple-insulated-Kr08								
1	W135	270	90	West	2.33	3.50	5-Wall_9544_W	01ud-Triple-insulated-Kr08								
1	W134	270	90	West	3.00	4.85	5-Wall_9544_W	01ud-Triple-insulated-Kr08								
1	W133	270	90	West	3.00	4.85	5-Wall_9544_W	01ud-Triple-insulated-Kr08								
1	W132	270	90	West	3.00	4.85	5-Wall_9544_W	01ud-Triple-insulated-Kr08								
1	W156	270	90	West	3.00	4.06	5-Wall_9544_W	01ud-Triple-insulated-Kr08								
1	W140	0	90	North	2.33	2.33	6-Wall_9368_N	01ud-Triple-insulated-Kr08	02ud Si82+Operable	0.50	0.11	0.19	0.018	1	1	1
1	W139	0	90	North	2.33	3.50	6-Wall_9368_N	01ud-Triple-insulated-Kr08	02ud Si82+Operable	0.50	0.11	0.19	0.018	1	1	1
1	W138	0	90	North	2.33	3.50	6-Wall_9368_N	01ud-Triple-insulated-Kr08	02ud Si82+Operable	0.50	0.11	0.19	0.018	1	1	1
1	W137	0	90	North	2.33	2.33	6-Wall_9368_N	01ud-Triple-insulated-Kr08	02ud Si82+Operable	0.50	0.11	0.19	0.018	1	1	1
1	W136	0	90	North	2.33	2.33	6-Wall_9368_N	01ud-Triple-insulated-Kr08	02ud Si82+Operable	0.50	0.11	0.19	0.018	1	1	1
1	D101L	360	90	North	3.00	6.67	7-Wall_9493_N	01ud-Triple-insulated-Kr08	06ud ADS75 Door mull:S	0.50	0.11	0.32	0.029	1	0	1
1	D101R	360	90	North	3.00	6.67	7-Wall_9493_N	01ud-Triple-insulated-Kr08	06ud ADS75 Door mull:S	0.50	0.11	0.32	0.029	0	1	1
1	W142L	360	90	North	2.67	4.50	7-Wall_9493_N	01ud-Triple-insulated-Kr08	04ud Si82+Operable mull:S	0.50	0.11	0.19	0.018	1	0	1
1	W153	360	90	North	3.52	3.52	7-Wall_9493_N	01ud-Triple-insulated-Kr08	01ud Si82+Fixed	0.50	0.11	0.19	0.018	1	1	1
1	W152	360	90	North	3.75	1.28	7-Wall_9493_N	01ud-Triple-insulated-Kr08	01ud Si82+Fixed	0.50	0.11	0.19	0.018	1	1	1
1	W154	360	90	North	3.75	1.28	7-Wall_9493_N	01ud-Triple-insulated-Kr08	01ud Si82+Fixed	0.50	0.11	0.19	0.018	1	1	1
1	W142M	360	90	North	2.67	4.50	7-Wall_9493_N	01ud-Triple-insulated-Kr08	09ud Si82+Operable mull:2S	0.50	0.11	0.19	0.018	0	0	1
1	W142R	360	90	North	2.67	4.50	7-Wall_9493_N	01ud-Triple-insulated-Kr08	04ud Si82+Operable mull:S	0.50	0.11	0.19	0.018	0	1	1
1	W103	0	90	North	2.33	2.00	8-Wall_9360_N	01ud-Triple-insulated-Kr08	02ud Si82+Operable	0.50	0.11	0.19	0.018	1	1	1
1	W102	0	90	North	2.33	2.00	8-Wall_9360_N	01ud-Triple-insulated-Kr08	02ud Si82+Operable	0.50	0.11	0.19	0.018	1	1	1
1	W101	0	90	North	2.33	2.00	8-Wall_9360_N	01ud-Triple-insulated-Kr08	02ud Si82+Operable	0.50	0.11	0.19	0.018	1	1	1
1	W127La	180	90	South	3.00	2.71	11-Wall_9432_S	01ud-Triple-insulated-Kr08	07ud Si82+Fixed mull:S,B	0.50	0.11	0.19	0.018	1	0	0
1	W127Lb	180	90	South	3.00	3.84	11-Wall_9432_S	01ud-Triple-insulated-Kr08	05ud Si82+Operable mull:S,T	0.50	0.11	0.19	0.018	1	0	1
1	W127M	180	90	South	6.00	6.54	11-Wall_9432_S	01ud-Triple-insulated-Kr08	06ud Si82+Fixed mull:2S	0.50	0.11	0.19	0.018	0	0	1
1	W127Ra	180	90	South	3.00	2.71	11-Wall_9432_S	01ud-Triple-insulated-Kr08	07ud Si82+Fixed mull:S,B	0.50	0.11	0.19	0.018	0	1	0
1	W127Rb	180	90	South	3.00	3.84	11-Wall_9432_S	01ud-Triple-insulated-Kr08	05ud Si82+Operable mull:S,T	0.50	0.11	0.19	0.018	0	1	1
1	W121La	180	90	South	3.00	2.71	12-Wall_9384_S	01ud-Triple-insulated-Kr08	07ud Si82+Fixed mull:S,B	0.50	0.11	0.19	0.018	1	0	0
1	W121Lb	180	90	South	3.00	3.84	12-Wall_9384_S	01ud-Triple-insulated-Kr08	05ud Si82+Operable mull:S,T	0.50	0.11	0.19	0.018	1	0	1
1	W121M	180	90	South	6.00	6.54	12-Wall_9384_S	01ud-Triple-insulated-Kr08	06ud Si82+Fixed mull:2S	0.50	0.11	0.19	0.018	0	0	1

© Passive House Institute

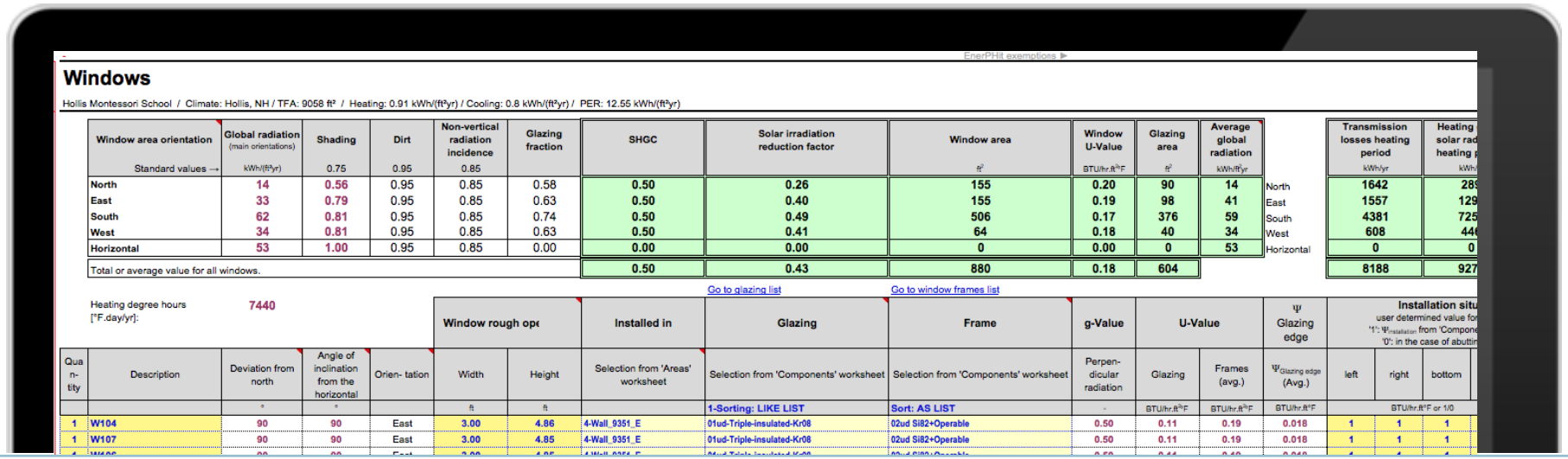
Energy balance and Passive House Design Tool

for quality approved Passive Houses and EnerPHit retrofits

Certification: Energy Model Based

What is PHPP?

- A numerical steady-state energy modeling spreadsheet
- Uses monthly climate data to quickly calculate detailed gains and losses for low-energy buildings
- Purpose built for low-energy buildings and Passive-House style buildings
- Excel spreadsheet based and low-cost



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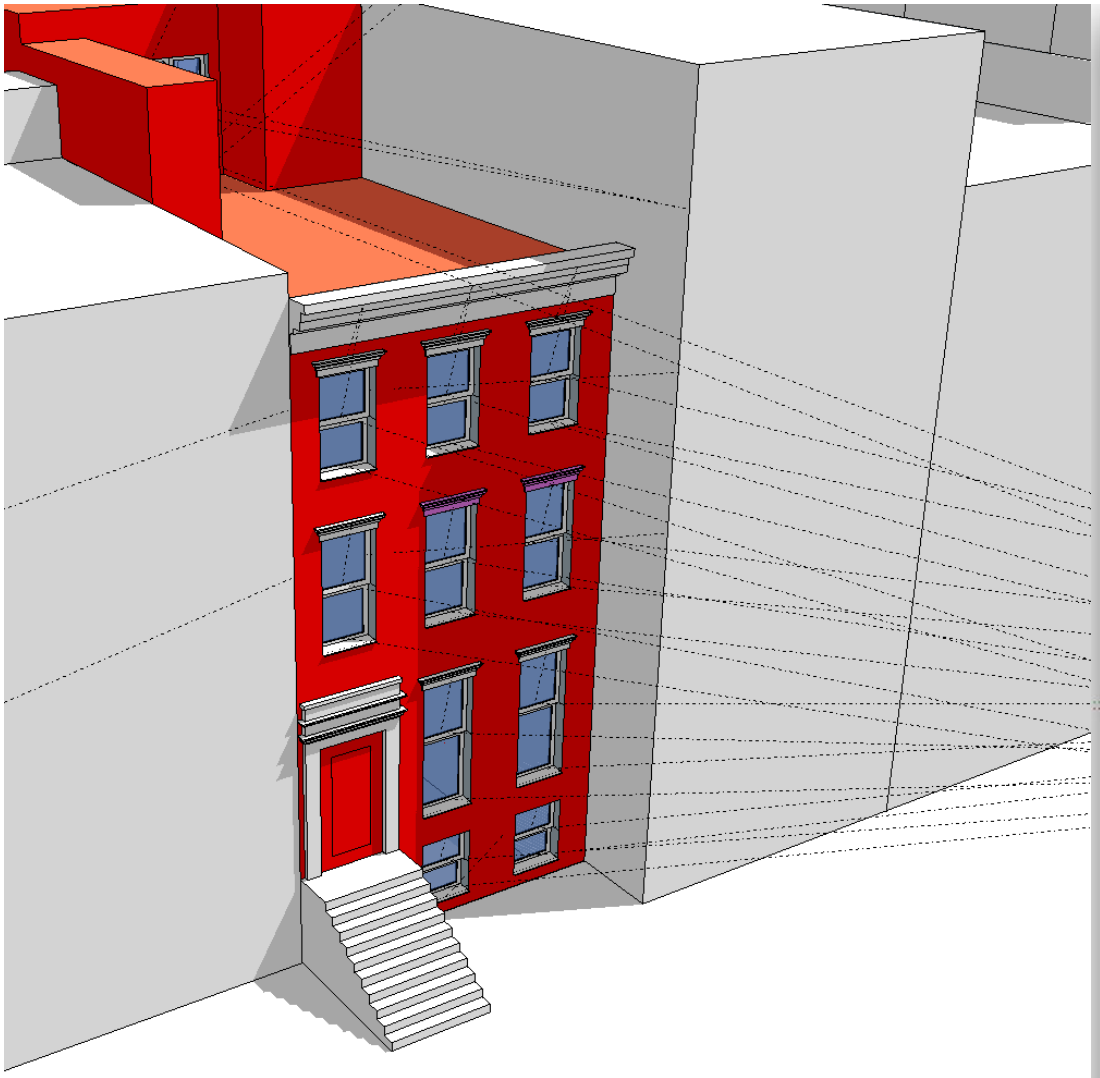
Window area orientation	Global radiation (main orientations)	Shading	Dirt	Non-vertical radiation incidence	Glazing fraction	SHGC	Solar irradiation reduction factor	Window area	Window U-Value	Glazing area	Average global radiation		Transmission losses heating period	Heating solar rad heating
Standard values →	kWh/(ft²yr)	0.75	0.95	0.85				ft²	BTU/hr.ft².°F	ft²	kWh/ft²yr		kWh/yr	kWh/
North	14	0.56	0.95	0.85	0.58	0.50	0.26	155	0.20	90	14	North	1642	28
East	33	0.79	0.95	0.85	0.63	0.50	0.40	155	0.19	98	41	East	1557	129
South	62	0.81	0.95	0.85	0.74	0.50	0.49	506	0.17	376	59	South	4381	725
West	34	0.81	0.95	0.85	0.63	0.50	0.41	64	0.18	40	34	West	608	44
Horizontal	53	1.00	0.95	0.85	0.00	0.00	0.00	0	0.00	0	53	Horizontal	0	0
Total or average value for all windows.						0.50	0.43	880	0.18	604			8188	927

Heating degree hours [°F.day/yr]: 7440

Go to glazing list | Go to window frames list

Qua-ntity	Description	Deviation from north	Angle of inclination from the horizontal	Orien- tation	Window rough ope Width	Height	Installed in Selection from 'Areas' worksheet	Glazing Selection from 'Components' worksheet	Frame Selection from 'Components' worksheet	g-Value Perpen-dicular radiation	U-Value Glazing	Frames (avg.)	Ψ Glazing edge ($\Psi_{Glazing\ edge}$ (Avg.))	Installation situ left	right	bottom
		°	°		ft	ft		1-Sorting: LIKE LIST	Sort: AS LIST	-	BTU/hr.ft².°F	BTU/hr.ft².°F	BTU/hr.ft.°F	BTU/hr.ft².°F or 1/0		
1	W104	90	90	East	3.00	4.86	4-Wall_9351_E	01ud-Triple-insulated-Kr08	02ud Si82+Operable	0.50	0.11	0.19	0.018	1	1	1
1	W107	90	90	East	3.00	4.85	4-Wall_9351_E	01ud-Triple-insulated-Kr08	02ud Si82+Operable	0.50	0.11	0.19	0.018	1	1	1

Geometry Input With Designph (Sketchup)



designPH main

designPH 1.0, registered to: edwinmay [Unregister]

Update window options | Redraw windows

Heat Balance | Areas | U-value

editor | Assemblies | Components | Climate

Annual Heat Demand

▼ Annual Heat Demand

Total heat losses (kWh/a)	Total free heat gains (kWh/a)	Utilisation factor	Treated Floor Area (m²)	Ann. Heat Demand (kWh/a)	Specific Ann. Heat Demand, Q_h (kWh/m²a)
12753.67	6634.95	0.98	250.48	6242.48	24.92

▼ Transmission heat losses

Total Heat Loss Area (m²)	Area Weighted U-value (W/m²K)	Av. Temp. Factor	Ann. Htg. Degree Hours (kKh)	Transmission Heat Loss (kWh/a)	Q_t (kWh/m²a)
833.41	0.20	0.88	70.10	10754.61	42.94

▼ Ventilation heat loss

Treated Floor Area (m²)	Ventilation volume (m³)	Eff. air exchange rate	Heat capacity of air	Ann. Htg. Degree Hours (kKh)	Ventilation heat loss (kWh/a)	Q_v (kWh/m²a)
250.48	626.20	0.14	0.33	70.10	1999.06	7.98

▼ Solar heat gains

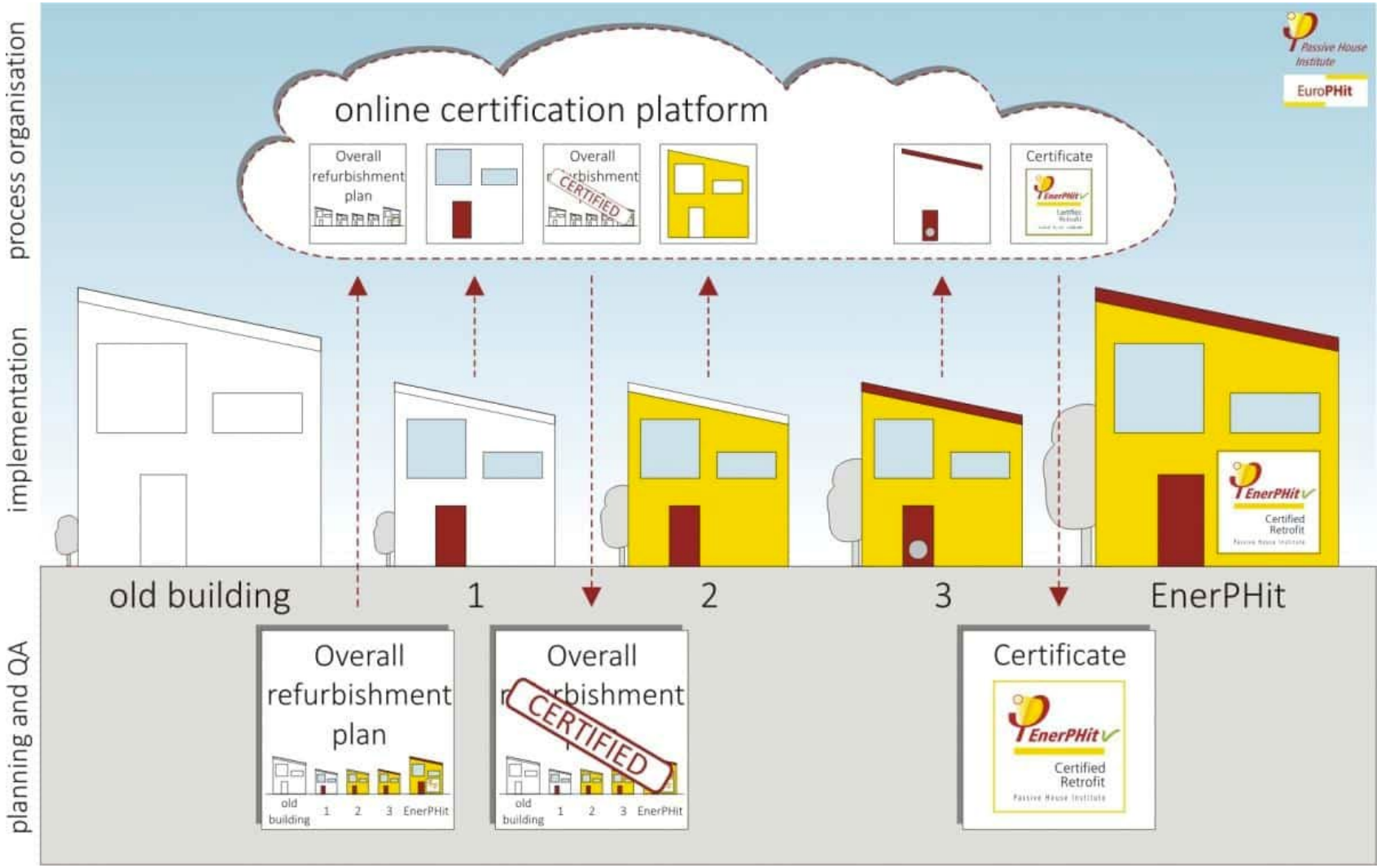
Group nr.	Area Group	Win. area (m²)	Glazing area (m²)	g-value	Reduction factor	Radiation, G_s	Solar heat gain (kWh/a)	Q_s (kWh/m²a)
2	North Windows	30.68	20.44	0.50	0.40	106.70	660.46	2.64
3	East Windows	9.62	5.31	0.50	0.33	279.40	449.64	1.80
4	South Windows	17.79	11.60	0.50	0.39	557.60	1958.43	7.82
5	West Windows	23.65	14.93	0.50	0.38	290.90	1315.51	5.25
6	Horizontal Windows	0.00	0.00				0.00	0.00
		81.75	52.29				4384.05	17.50

▼ Internal heat gain

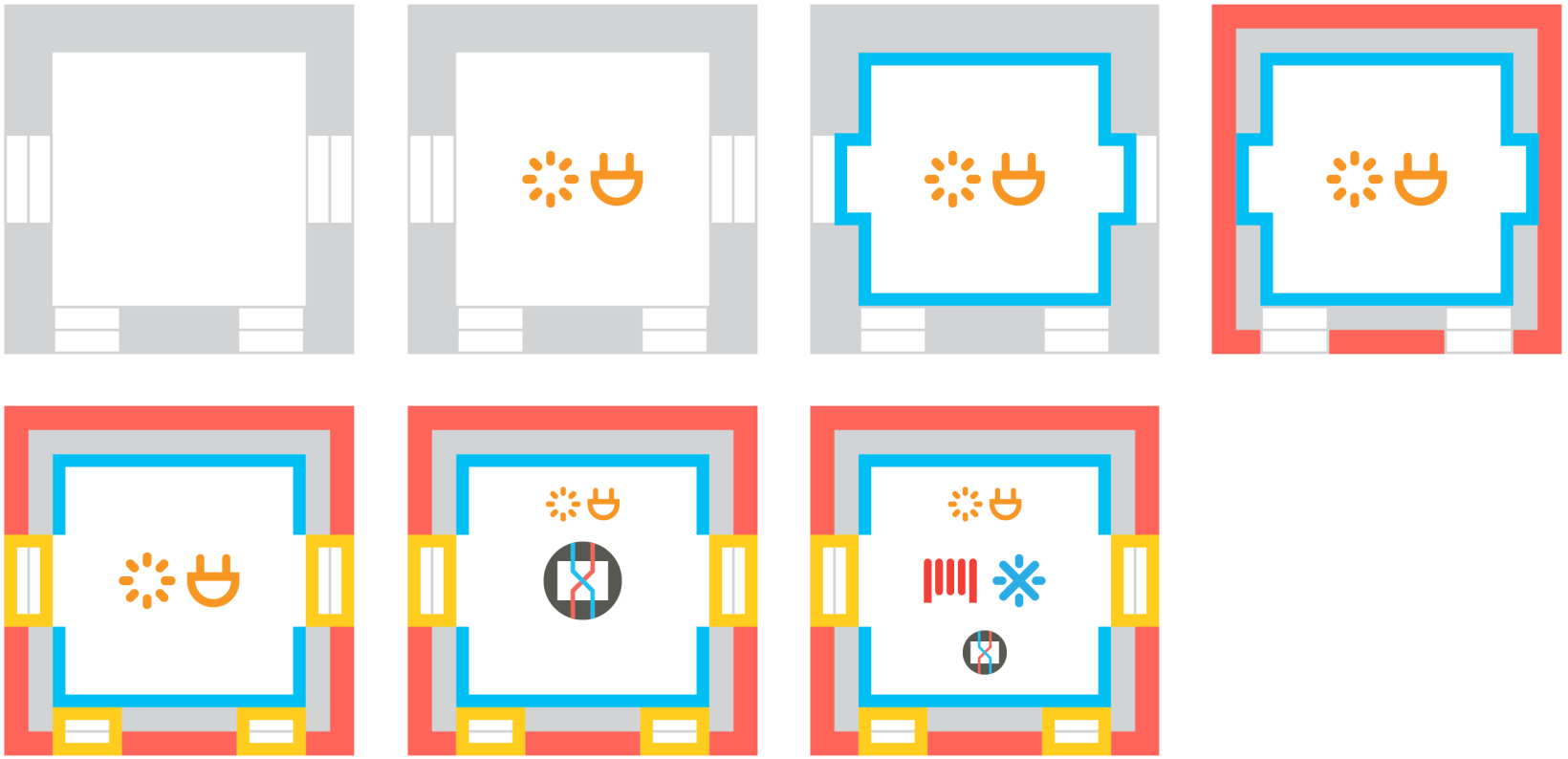
Treated Floor Area (m²)	Internal heat gain rate (W/m²)	Heating period (days/a)	Heating period (kh/a)	Internal heat gain (kWh/a)	Q_i (kWh/m²a)
250.48	2.10	178.30	4.28	2250.90	8.99

Source: BLDGtyp llc, NYC Townhouse. 2017

Phasing Retrofits And Certification

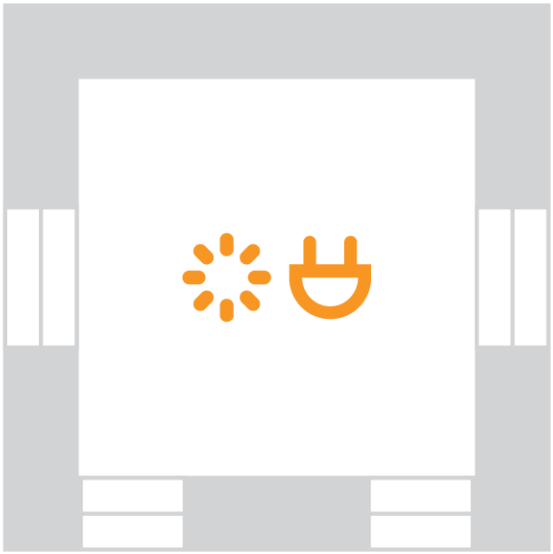


Retrofit Staging / Phasing



Source: BEEx, Deep Energy Retrofit Training, 2019

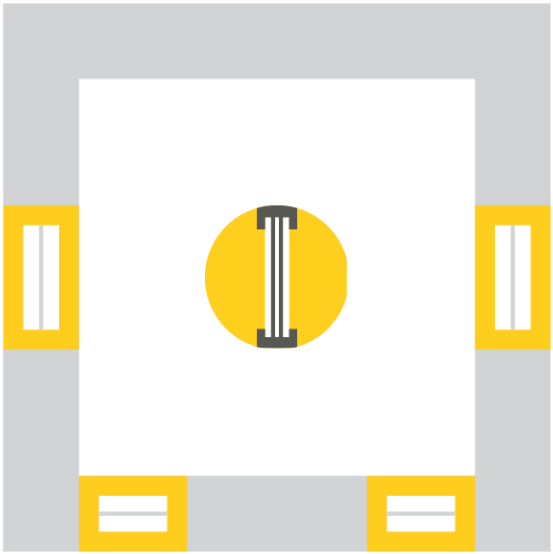
Phasing: Plug Loads



- Very few phasing issues and
- Provides many benefits if conducted early in the retrofit process.
- Cooling demands and loads will be reduced immediately.
- Any cooling equipment can be decreased in size.
- There is the potential for increased short cycling of the cooling equipment which could result in less humidity control

Source: BEEx, Deep Energy Retrofit Training, 2019

Phasing: Windows



High performance windows not compatible with window AC units

High performance windows significantly improve the air tightness

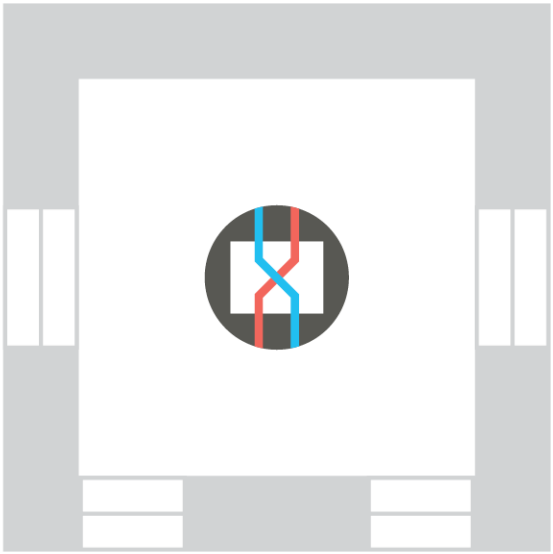
- Exhaust only systems may not provide adequate fresh air
- Evaluate ventilation strategy against window upgrade impacts

Overheating?

- Common in steam heating buildings (typically already oversized)
- Mitigation strategies affording better occupant control may be needed

Source: BEEx, Deep Energy Retrofit Training, 2019

Phasing: Ventilation



Typically, the earlier the upgrade the better.

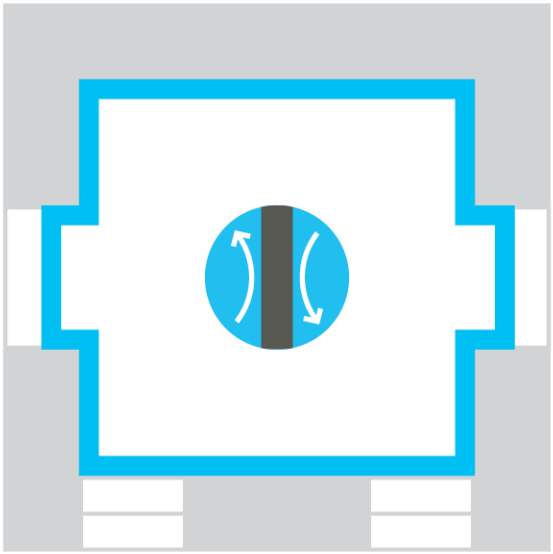
- Can reduce both heating and cooling loads and
- Provides better indoor air quality

Central ERV coupled with a dX coil for dehumidification improves humidity control

Changes require extensive interior construction, often very disruptive

Source: BEEx, Deep Energy Retrofit Training, 2019

Phasing: Air Sealing



Improvements will reduce fresh air infiltration

- Challenge for exhaust only systems
- Challenge for poorly balanced systems

Pair ventilation improvements with air sealing where possible

Improves comfort and acoustic environment

Improves air quality, reduces particulates

Reduces potential for condensation inside

Source: BEEx, Deep Energy Retrofit Training, 2019

Phasing: Insulation

Exterior repairs ideal time to increase insulation

Ideal to replace windows along with insulation improvements

- Even if windows not at end of life
- Far easier coordination of drainage, air tightness and vapor control
- Capital costs greatly reduced

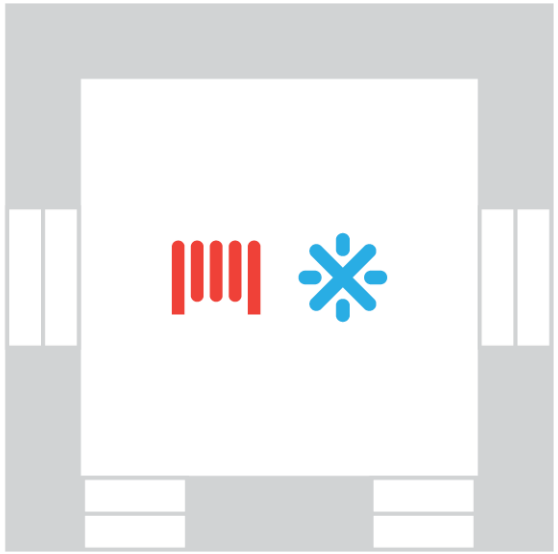
Interior insulation improvements can be disruptive

Roofs:

- Not typically subject to phasing
- Special conditions critical (door thresholds, parapet heights)
- Context often limits options

Source: BEEx, Deep Energy Retrofit Training, 2019

Phasing: Heating/Cooling



H/C system replacement after envelope improvements

- Allows proper sizing of equipment
- Increased temperature and humidity control results in greater comfort
- Reduced potential for moisture problems

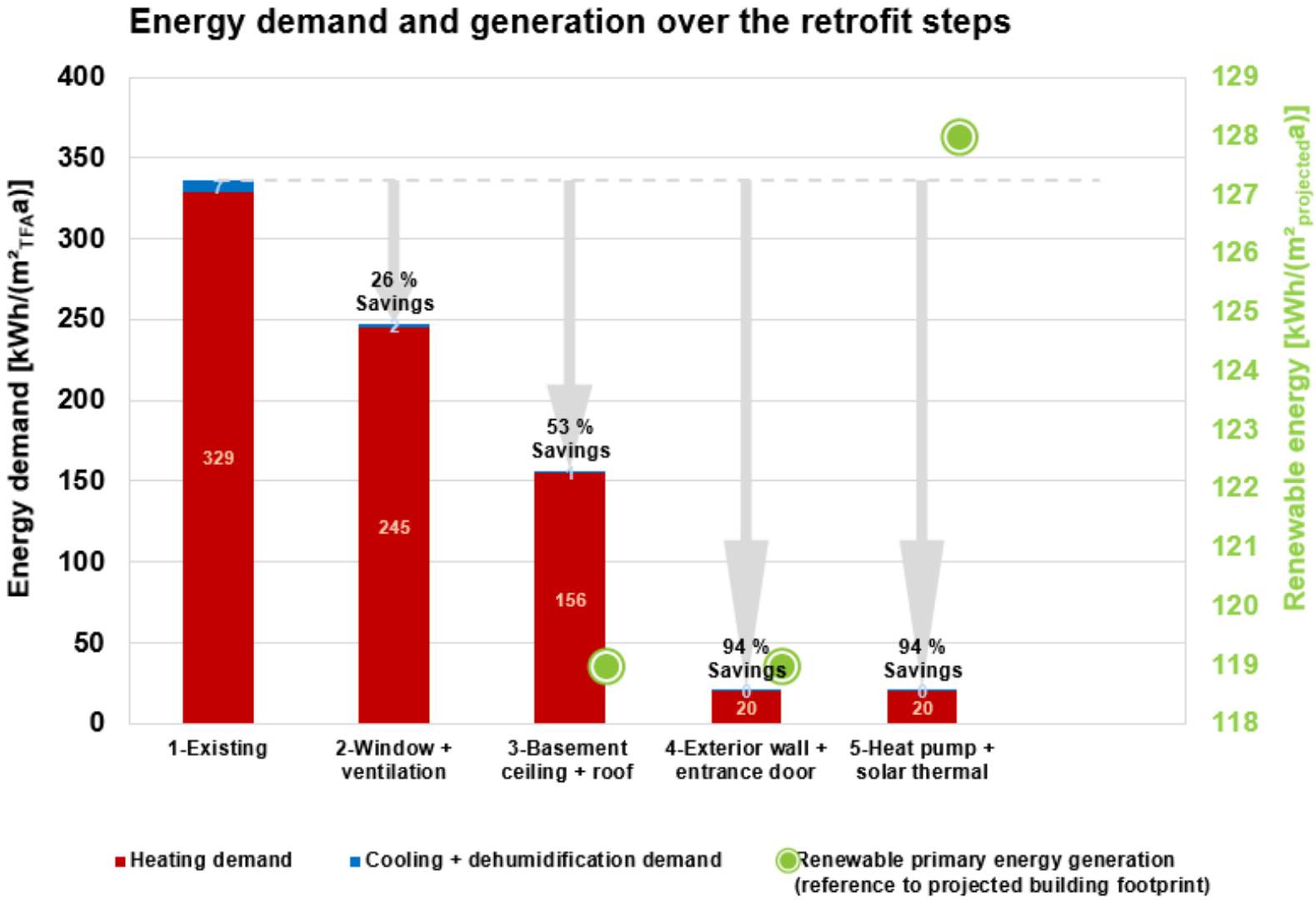
Consider exterior supply & return lines when applying exterior insulation

PTAC openings can often be used for new units

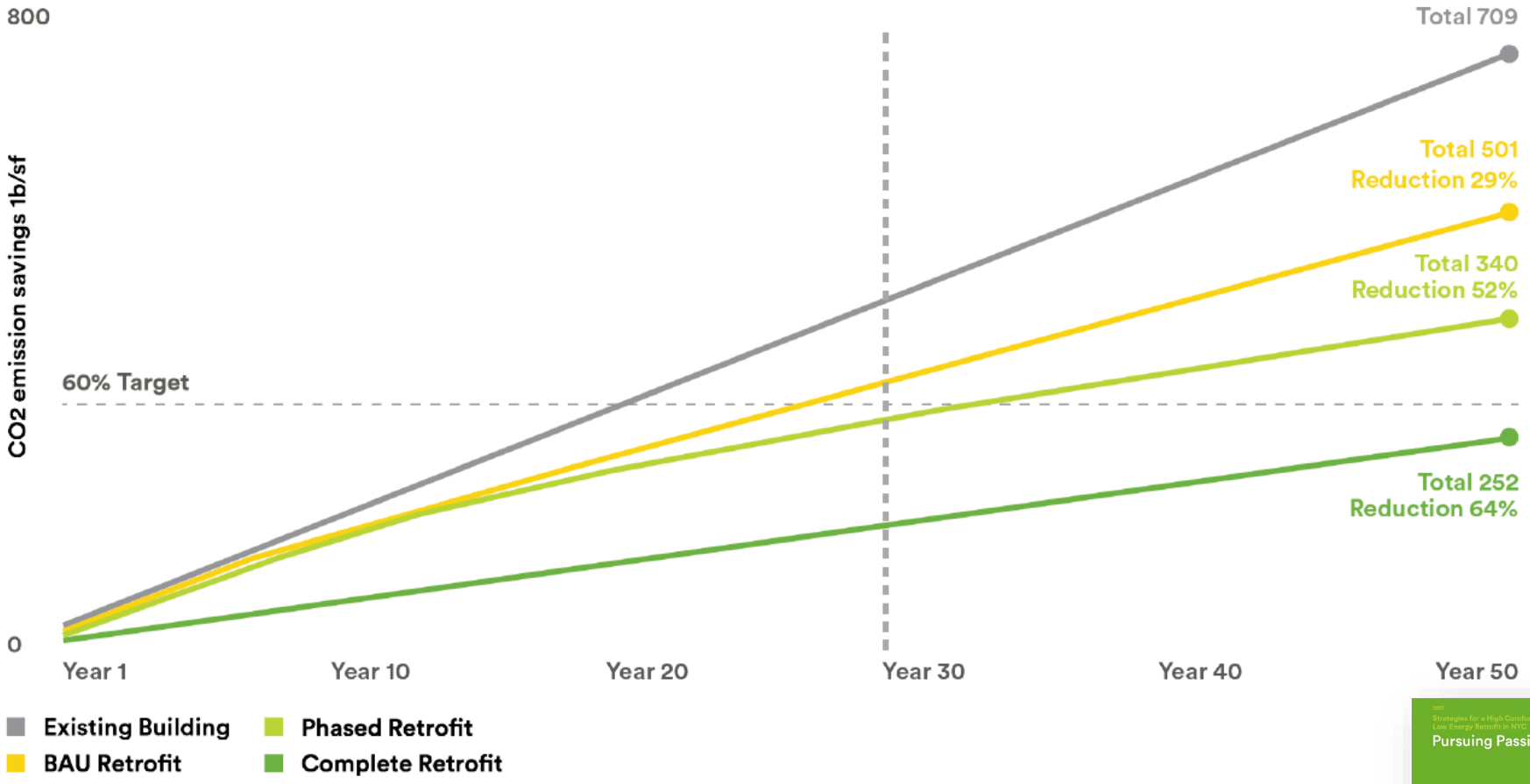
Identify chases for interior runs of supply & return lines

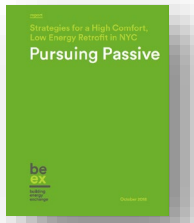
Source: BEEx, Deep Energy Retrofit Training, 2019

Phasing Retrofits And Energy Savings



”Pursuing Passive” Scenario Comparisons



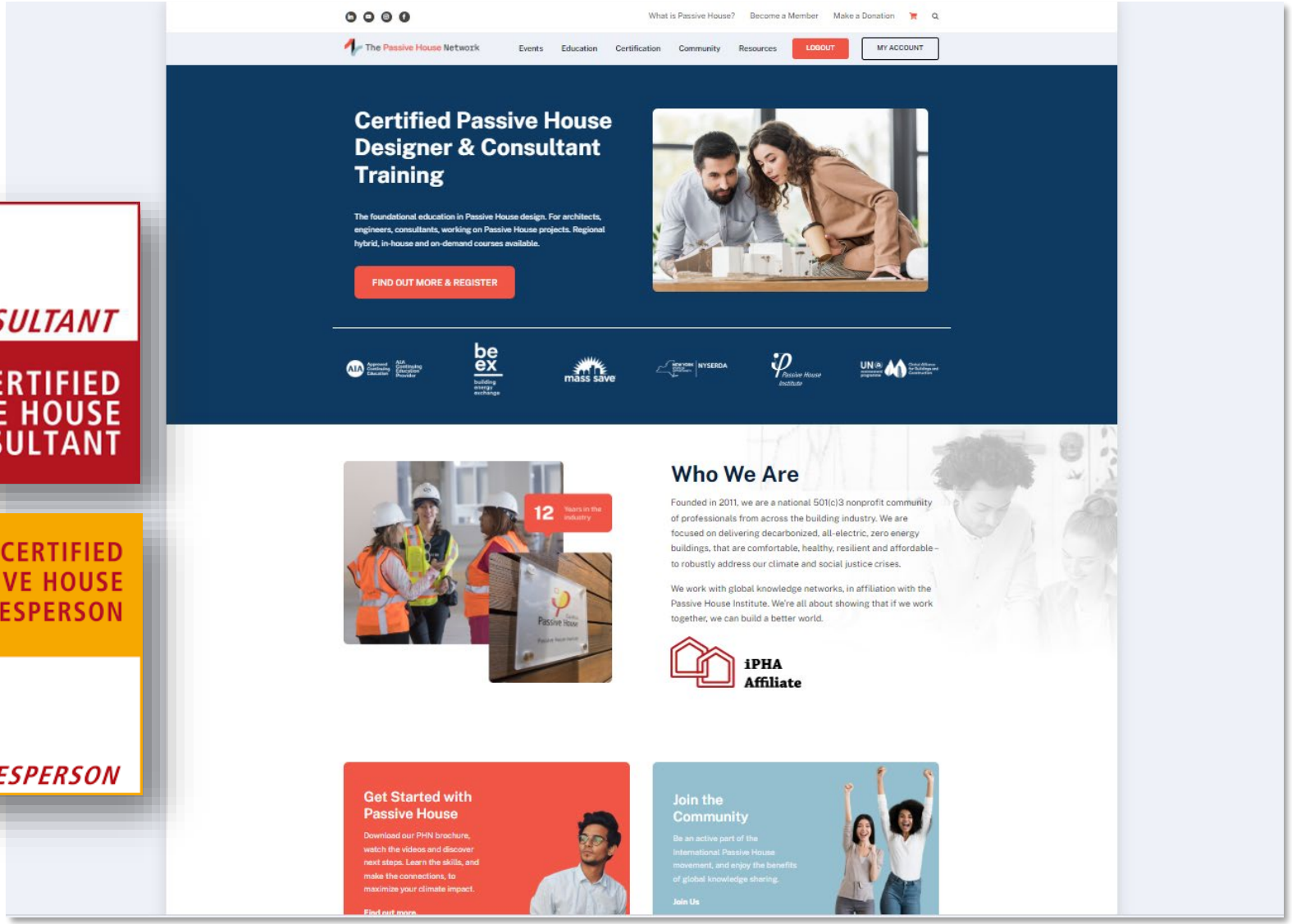


be-exchange.org

Where To Learn More?

Tirol, Austria - SUPERMARKET/NEW BUILD - Raimond Rainer Architect

PHN [passivehousenetwork.org]



Passive House International [passiv.de]

http://www.passivhausprojekte.de/

Summary

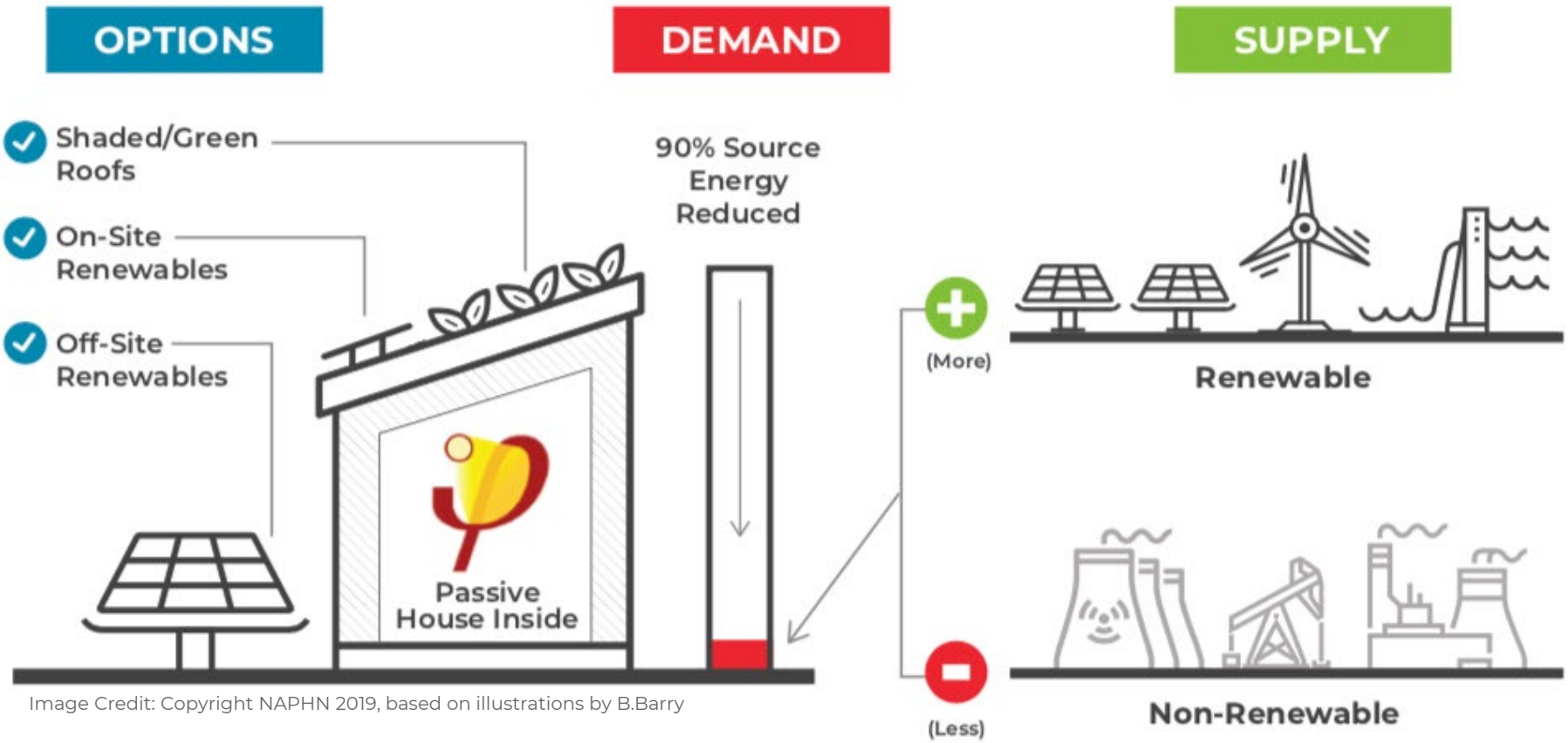


Image Credit: Copyright NAPHN 2019, based on illustrations by B.Barry

Closing

- Continuing Education Units Available
  - Contact shuskey@co.slo.ca.us for AIA HSW Learning Units
- Coming to Your Inbox Soon!
  - Slides, Recording, & Survey – Please Take It and Help Us Out!
- Upcoming Courses:
  - September 13 - Installing Heat Pumps: Lessons from the Field
  - September 19 - Regenerative Design in Practice: Zero Net Carbon Design Series
  - September 21 - Energy Code Compliance for All-Electric ADUs
  - September 27 - Ventilation 101
  - October 24 - Modeling All-Electric Homes in the 2022 Energy Code
  - October 30 – November 3 - Passive Design/Build Boot Camp with Emu Passive - Hands On Training and Exam (FREE!)
  - November 8 - Carbon Free Homes: Features, Benefits, Valuation

Calendar of Events and Trainings - 3C-REN

Thank you!

For more info:
3c-ren.org

For questions:
info@3c-ren.org

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TRI-COUNTY REGIONAL ENERGY NETWORK

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Closing Remarks

Hudson Valley, New York, HOME/NEW BUILD, Barlis Wedlick Architects