PASSIVE HOUSE 101

An Introduction to the Passive House Building Standard

PASSIVEhouse MASSACHUSETTS

www.PHMass.org | Aaron@PassiveHouseMA.org | Twitter @PassiveHouseMA

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The Sponsors of Energize Connecticut, and in partnership with Connecticut Passive House and BuildGreenCT, are pleased to offer *Passive House & All-Electric Homes Initiative* to support workforce development and help transform the energy efficiency and building construction industries in Connecticut.

For more information, please visit EnergizeCT.com/passive-house
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Take energy efficiency to a new level

Residential New Construction Passive House Multi-family buildings with five units or more

PASSIVE HOUSE INCENTIVE STRUCTURE FOR MULTI-FAMILY (5 UNITS OR MORE)				
Incentive Timing	Activity	Incentive Amount	Max Incentive (Per Unit)	Max Incentive (Per Project)
Pre-Construction	Feasibility Study[1]	Up to 100% of Feasibility Study Costs	N/A	$5,000.00
	Energy Modeling[2]	75% of Energy Modeling Costs (Before 90% Design Drawings)	$500.00	$30,000.00
		50% of Energy Modeling Costs (90% Design/50% Construction)	$250.00	$15,000.00
Post Construction	Certification[3]	Up to 100% of Certification Costs	$1,500.00	$60,000.00

1. Feasibility Study will require documentation in the form of a Feasibility Study report and invoice from the Passive House Consultant
2. Incentives will only be awarded prior to 50% Construction Drawings for Passive House projects. No incentives will be granted after 50% Construction Drawing set.
3. Certification may be either through PHIUS, PHI, or EnerPHit certification offerings.

Next steps you can take...
Contact your Energy Efficiency Representative or

Go to EnergizeCT.com or call 1-877-WISE USE for more details.

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The future of high-performance, all-electric homes starts here.

	LEVEL 1		LEVEL 2	
	Single Family (Detached Dwellings)	Multifamily (Attached Dwellings)	Single Family (Detached Dwellings)	Multifamily (Attached Dwellings)
Total UA Alternative Compliance or HERS Index Score †	Total UA ≥ 7.5% better than 2021 IECC or HERS Index Score ≤ 55		Total UA ≥ 15% better than 2021 IECC or HERS Index Score ≤ 45	
Heat pump for space heating ††	Required		Required	
Space Conditioning Connectivity & Controls †††	Optional		Required	
Heat pump for water heating	Required	Optional	Required ††††	
Hot Water Distribution †††††	Required		Required	
Envelope Infiltration Rate (ACH)	ACH50 ≤ 2.5	CFA > 850ft2: ACH50 ≤ 4.0 CFA < 850ft2: ACH50 ≤ 5.0	ACH50 ≤ 2.0	CFA > 850ft2: ACH50 ≤ 3.0 CFA < 850FT2: ACH50 ≤ 4.0
Duct Leakage Rate (CFM)	2021 IECC code minimum requirements		All ductwork must be located in conditioned space	
Balanced Ventilation Systems	Optional		Required HRV/ERV (≥70% SRE / ≥40% TRE)	
Induction Cooking	Optional		Required ††††††	Optional
Electric Vehicle Readiness †††††††	Required		Required	

ALL-ELECTRIC HOME INCENTIVE STRUCTURE		
	Level 1	Level 2
Single Family	$7,500	$10,000
Single Family Attached	$3,000	$5,000
Multifamily	$1,500	$2,500

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www.PHMass.org | Aaron@PassiveHouseMA.org

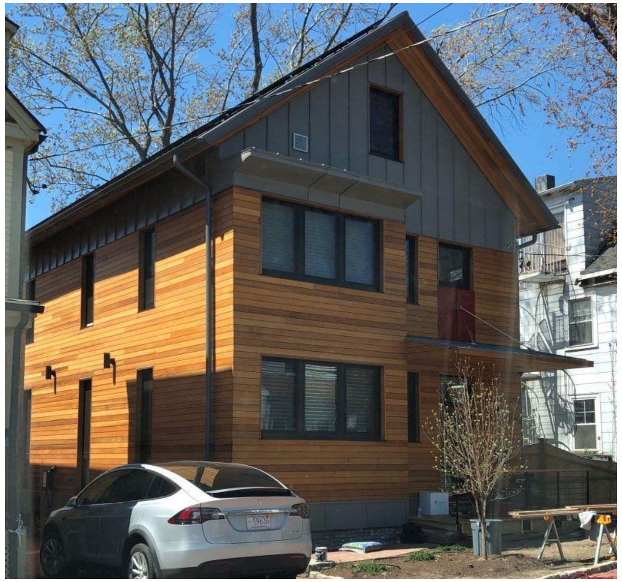
Your local Passive House group

ctpassivehouse.org

CTPH

CONNECTICUT PASSIVE HOUSE

Which of these buildings is a Passive House?



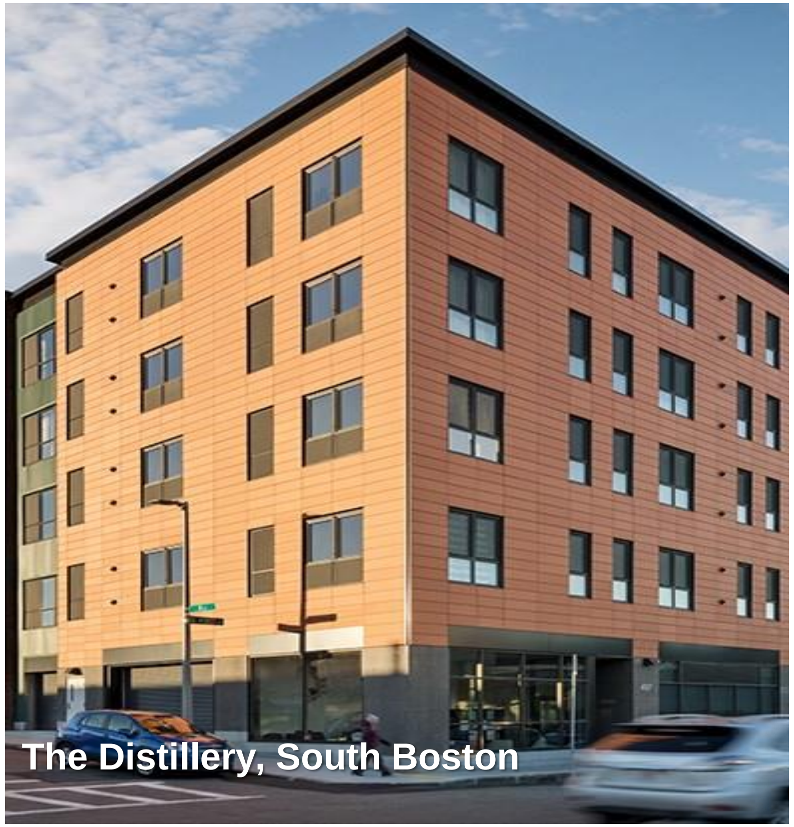
~~PASSIVE HOUSE~~

What have we learned?

1. Passive Houses are not all houses
2. Passive House are not all passive

What is Passive House?

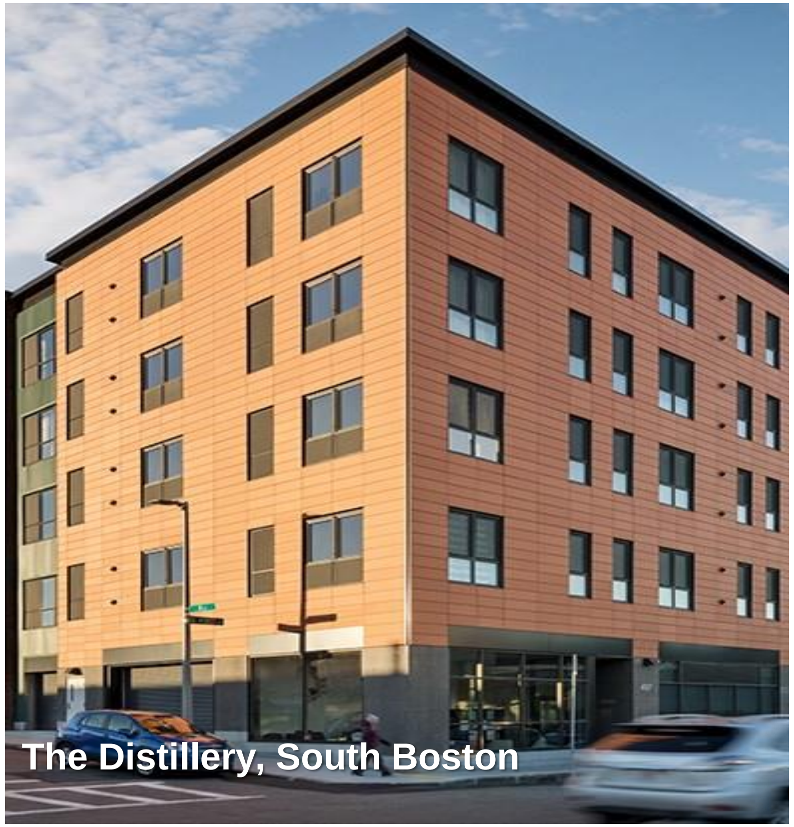
- Passive House is third party building verification program with two options for certification (PHIUS and PHI)
- These certification standards set energy performance and building envelope air-tightness requirements
- Passive House buildings are designed and constructed to meet these energy and air tightness metrics with any method or materials – there is no prescriptive list



The Distillery, South Boston

What Does Passive House Achieve?

- Heating loads are reduced by 90% or more compared to a typical building
- Overall energy demand can be reduced by 60% or more
- Significant improvement in Indoor Air Quality and Occupancy Comfort
- Verified performance and build quality



Passive House’s Can Be Any Building and Any Size

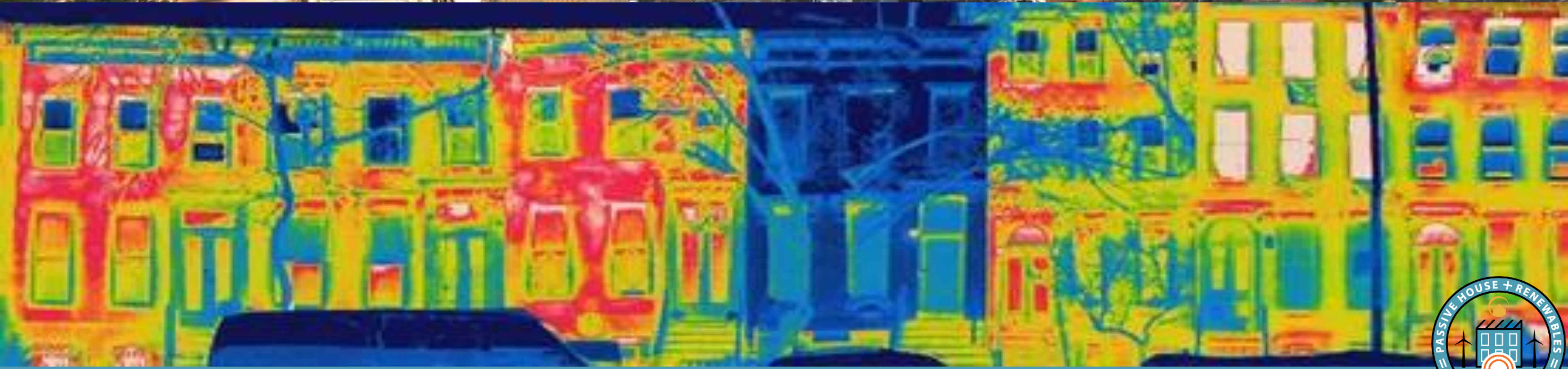
- Residential home, townhouse, multifamily building, commercial office, school, municipal building, hotel…


Waverly School, Beverly


Single-Family Home, Cambridge

Winthrop Center
Commercial Office, Boston

The Passive House Effect



Passive House Roles

Phius Certified Consultant or PHI Certified Designer/Consultant (CPHC and CPHD/C)

- Primary lead on Passive House process from design through certification
- May be in-house with design team or outside consultant

Energy Modeler

- Lead on running WUFI or PHPP

Phius Certified Builder or PHI Certified Tradesperson (CPHB or CPHT)

- Recommended for GC Project Manager, Site Supervisor, and/or Lead Carpenters

Phuis Passive House Rater/Verifier or PHI Passive House Certifier

- Provides third-party verification of built conditions and certification criteria
- Submits reports for final certification

Benefits of Passive House

Financial Benefits

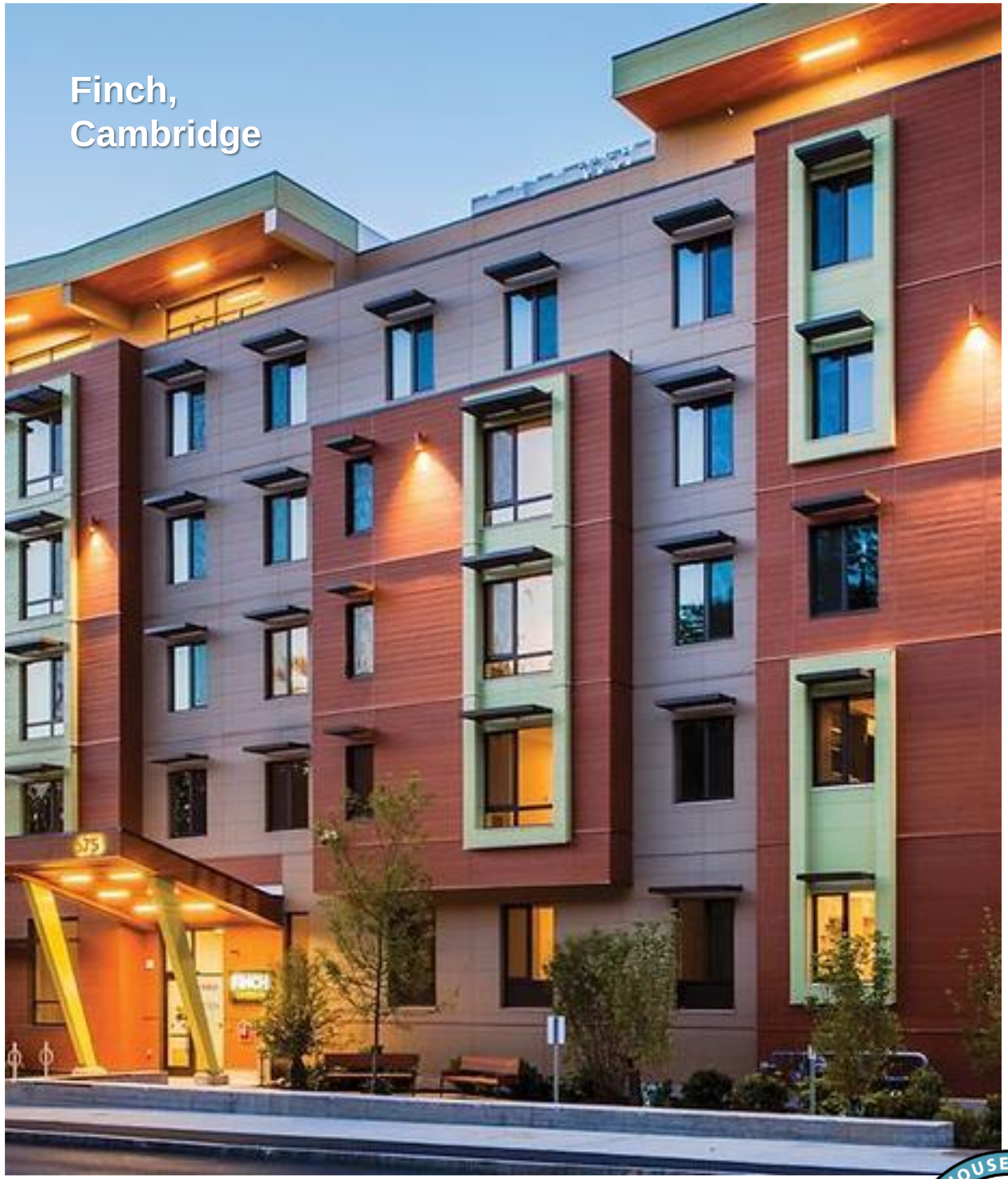
- Reduced energy utility costs
- Reduced equipment maintenance costs
- Longer lasting construction

Health & Comfort Benefits

- Improved indoor air quality
- Reduced air drafts
- Quieter acoustics

Environmental Benefits

- Reduced carbon emissions
- Climate resilient building
- Platform for electrification and net-zero



Benefits of Passive House

How A Texas Passive House Survived the 2021 Deep Freeze

Monday morning at 1:00 a.m., the power went out, and when they woke that morning, it was 9°F outside and 62°F inside.

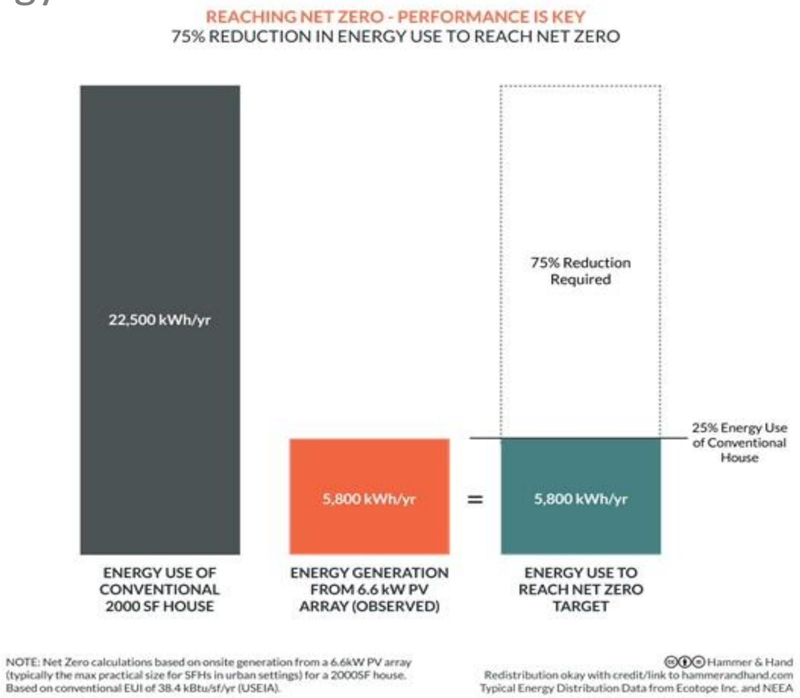
At our neighbor's house, which was identical to ours [before the Passive House retrofit], it was 36°F. They may as well have been living in a tent.

https://www.buildwithrise.com/stories/texas-passive-house-weathered-the-2021-storm

Pathway to Net Zero

Most buildings, even with those built to stretch or reach codes, still use too much energy to reach net zero. Passive House solves this

- First use Passive House measures to drastically reduce the amount of energy used.
- Then add renewables to meet the lower energy demand - getting to Net Zero Energy.



Affordable Housing & Passive House Are a Great Mix

Many state financing programs offer incentives for projects built to Passive House standards

Connecticut awards extra points in their Qualified Allocation Proposal (QAP)

Incremental Costs are Low for Multifamily Projects

MASSACHUSETTS CLEAN ENERGY CENTER

Data from MassCEC Passive House Design Challenge

The cost to build to the Passive House standard compared to stretch code construction is 1-4% for actual multifamily projects in Massachusetts

The projects to the left were part of the MassCEC's Passive House Design Challenge issued in 2018, and more recent projects are expected to have an even lower cost premium

Incremental Costs are Low for Multifamily Projects

PA was the first state to award extra consideration to Passive House projects in affordable housing financing applications.

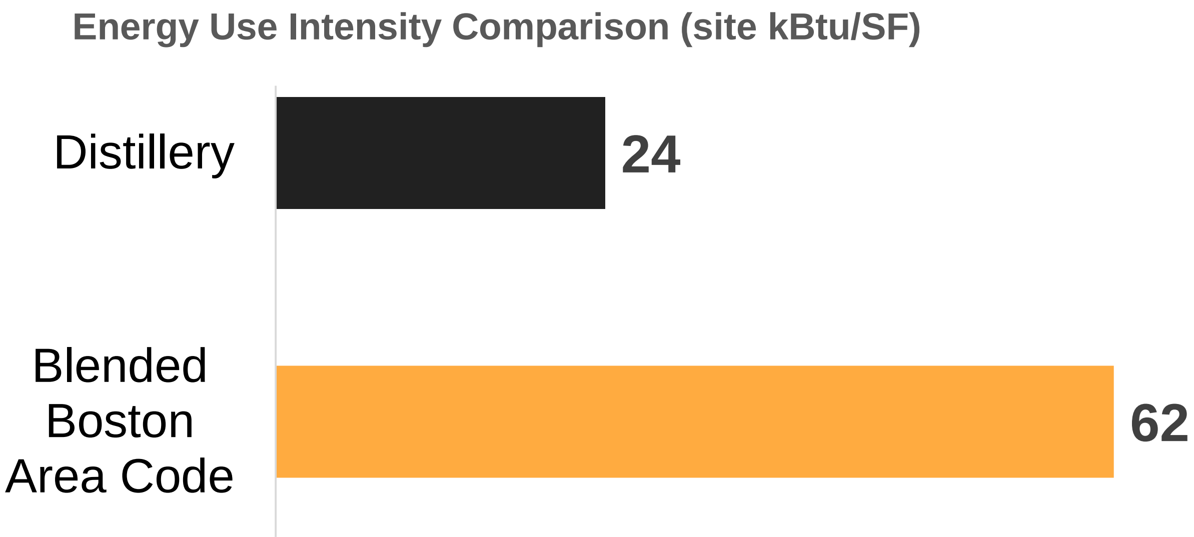
In the first year, the PH projects had 2% more costs compared to the non-PH projects.

By 2018, PH projects were 2% less on average.

Data from Pennsylvania Housing Finance Agency

Performance Comparison

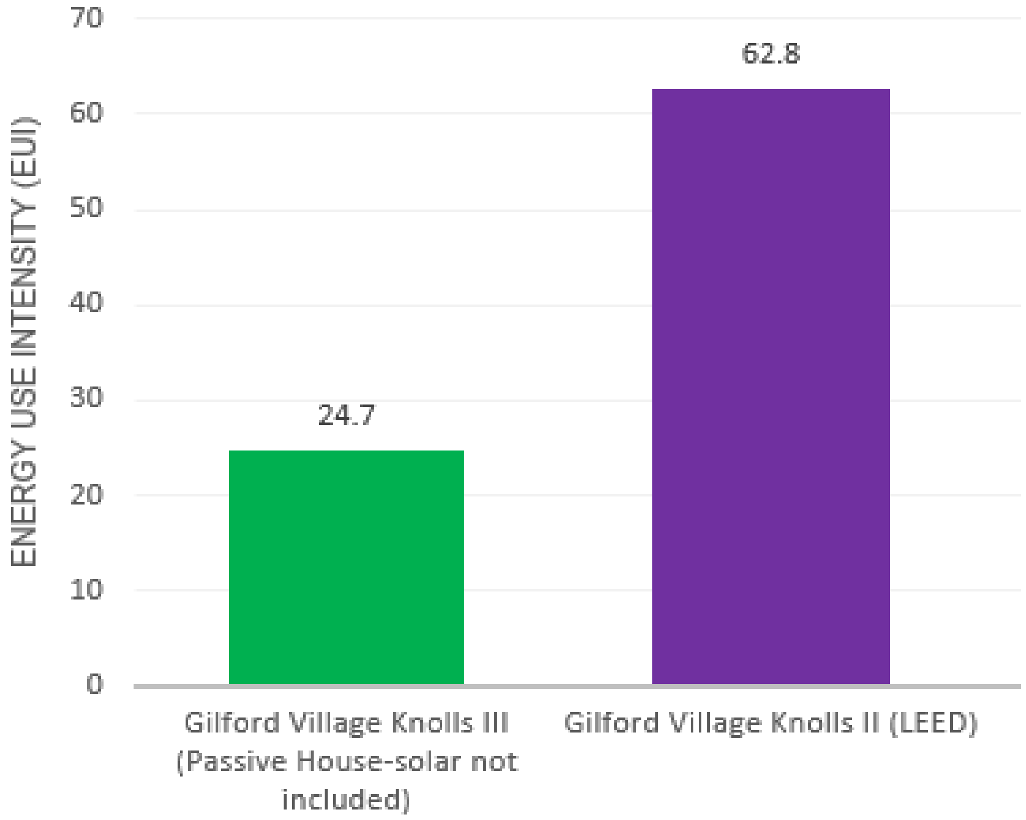
Distillery: Uses 60% less energy/sq. ft. than typical Boston Area Code Built



Distillery North, Boston

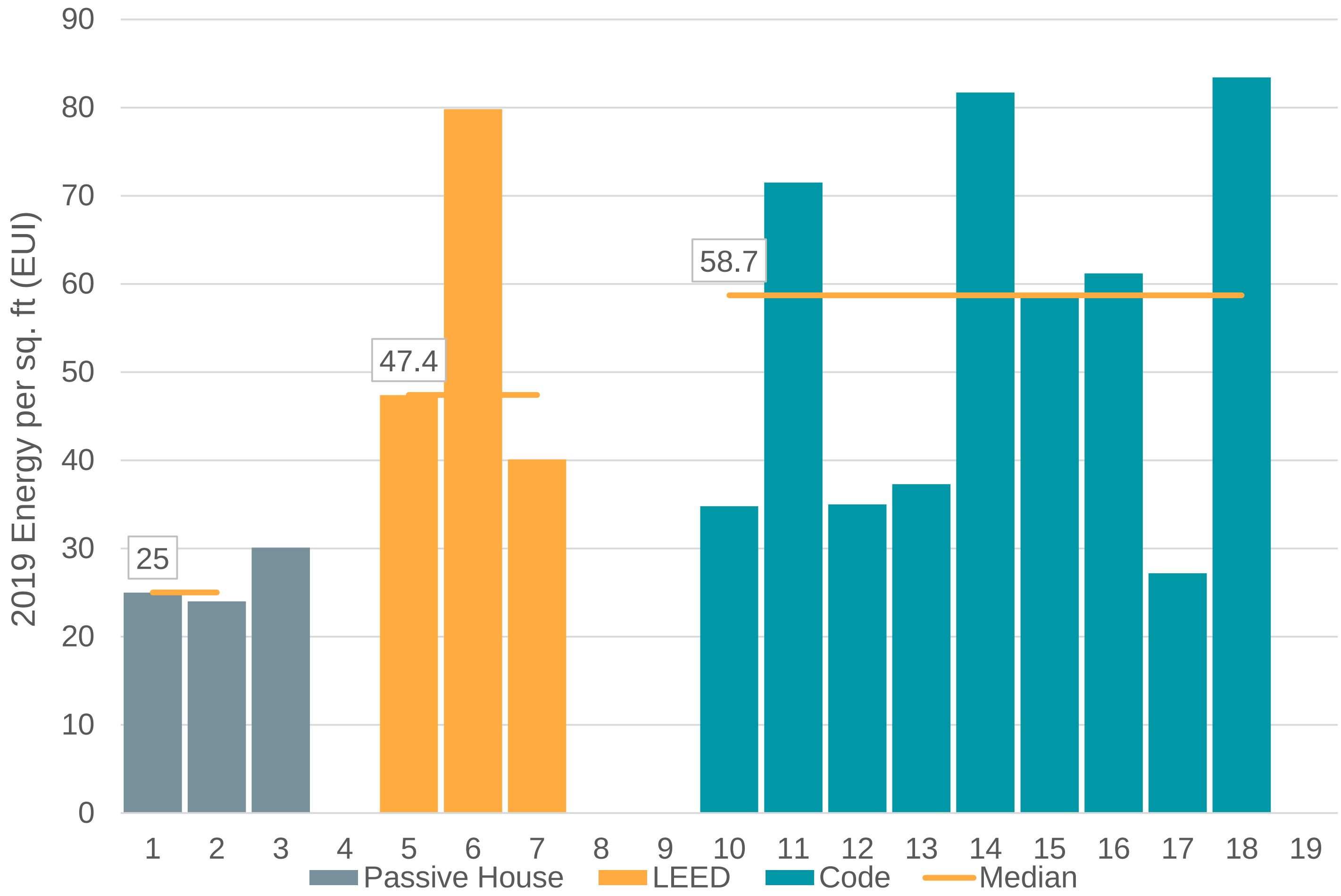
Performance Comparison

Gilford Village: PH uses 61% less energy than earlier LEED built (similar design otherwise)



Performance Comparison

Philadelphia: PH Median is 57% less energy per sq. ft. than Code Built



Stable Flats (Onion Flats)

Data from Philadelphia Energy Disclosure 2019 cross checked for LIHTC multifamily; Credit to Green Building United, Katie Bartolotta

Passive House Organizations

- Create and Manage the PH Standard
- Define Metrics and Criteria
- Provide Certification for Buildings
- Provide Accreditation for Professionals

Passive House Institute

PHIUS
Passive House Institute US

Passive House Timeline

Super-Insulated Homes

First PH concept building (Germany)

PHIUS

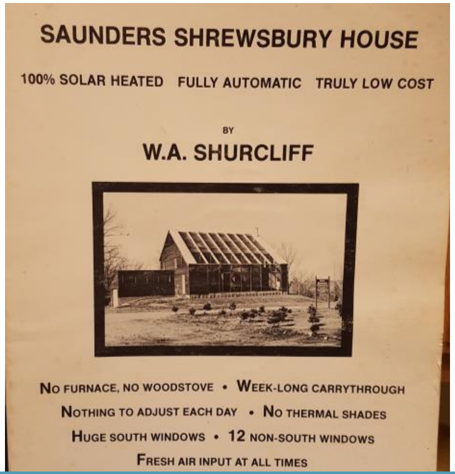
Passive House Institute US

PHIUS is founded

First MF PH in Mass

1970 | 1980 | 1990 | 2000 | 2010 | 2020

"passive house" in print



SAUNDERS SHREWSBURY HOUSE

100% SOLAR HEATED   FULLY AUTOMATIC   TRULY LOW COST

BY

W.A. SHURCLIFF

NO FURNACE, NO WOODSTOVE • WEEK-LONG CARRYTHROUGH
NOTHING TO ADJUST EACH DAY • NO THERMAL SHADES
HUGE SOUTH WINDOWS • 12 NON-SOUTH WINDOWS
FRESH AIR INPUT AT ALL TIMES

PHI is founded

Passive House Institute

First certified PH in US

Passive House Certification Requirements

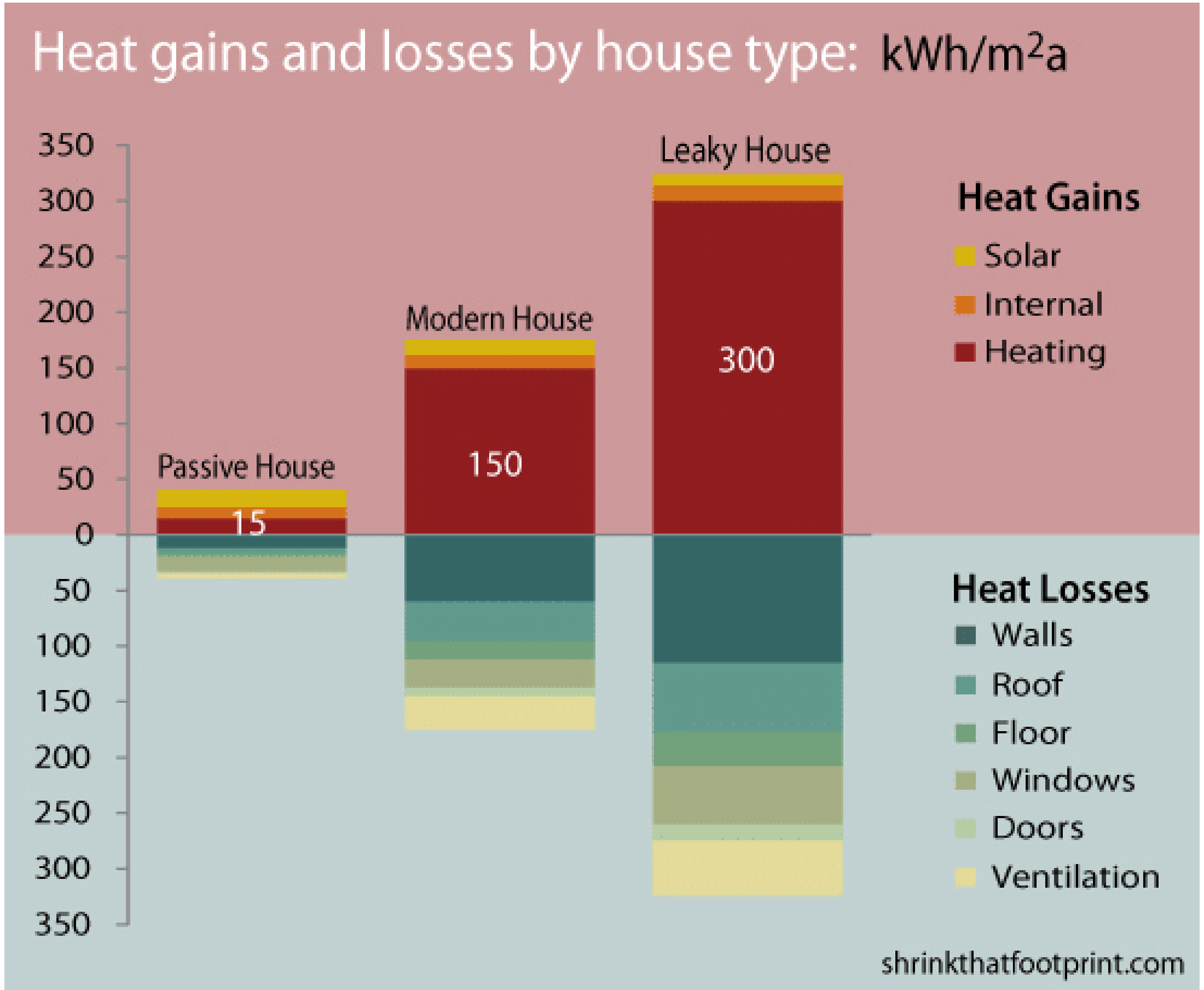
Performance Criteria

- Heating & Cooling Demand
- Whole Building Airtightness
- Source Energy Demand

Other Criteria

- Ventilation, Moisture Management, Quality Assurance

Passive House Metrics

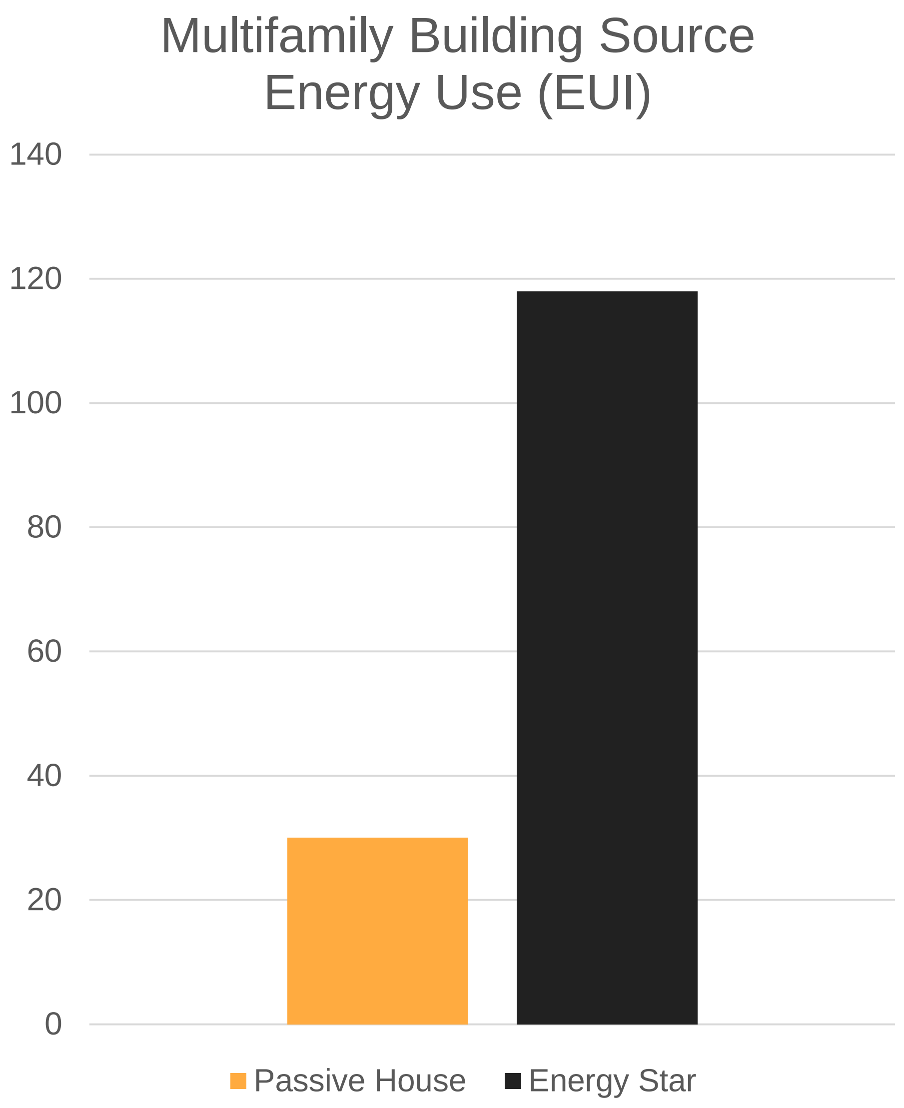


Passive House Metrics

Heating Demand
- 4.8 kbtu/sqft – 6.5 kbtu/sqft

Cooling Demand
- 2.5 kbtus/sqft – 4.8 kbtus/sqft

Source Energy Demand
- 25 kbtu/sqft - 35 kbtu/sqft



Passive House Metrics

Air Tightness Standard

Building Energy Code	Passive House*
3	**0.6**
ACH50	ACH50
(air changes per hour at 50 Pascals)	(air changes per hour at 50 Pascals)
	*Passive House International (PHI)

*above numbers are for general use only, consult PHIUS/PHI for specific project targets

PHIUS: phius.org/phius-certification-for-buildings-products/project-certification/
PHI: passiv.de/en/03_certification/02_certification_buildings/08_energy_standards/08_energy_standards.html

Passive House Process

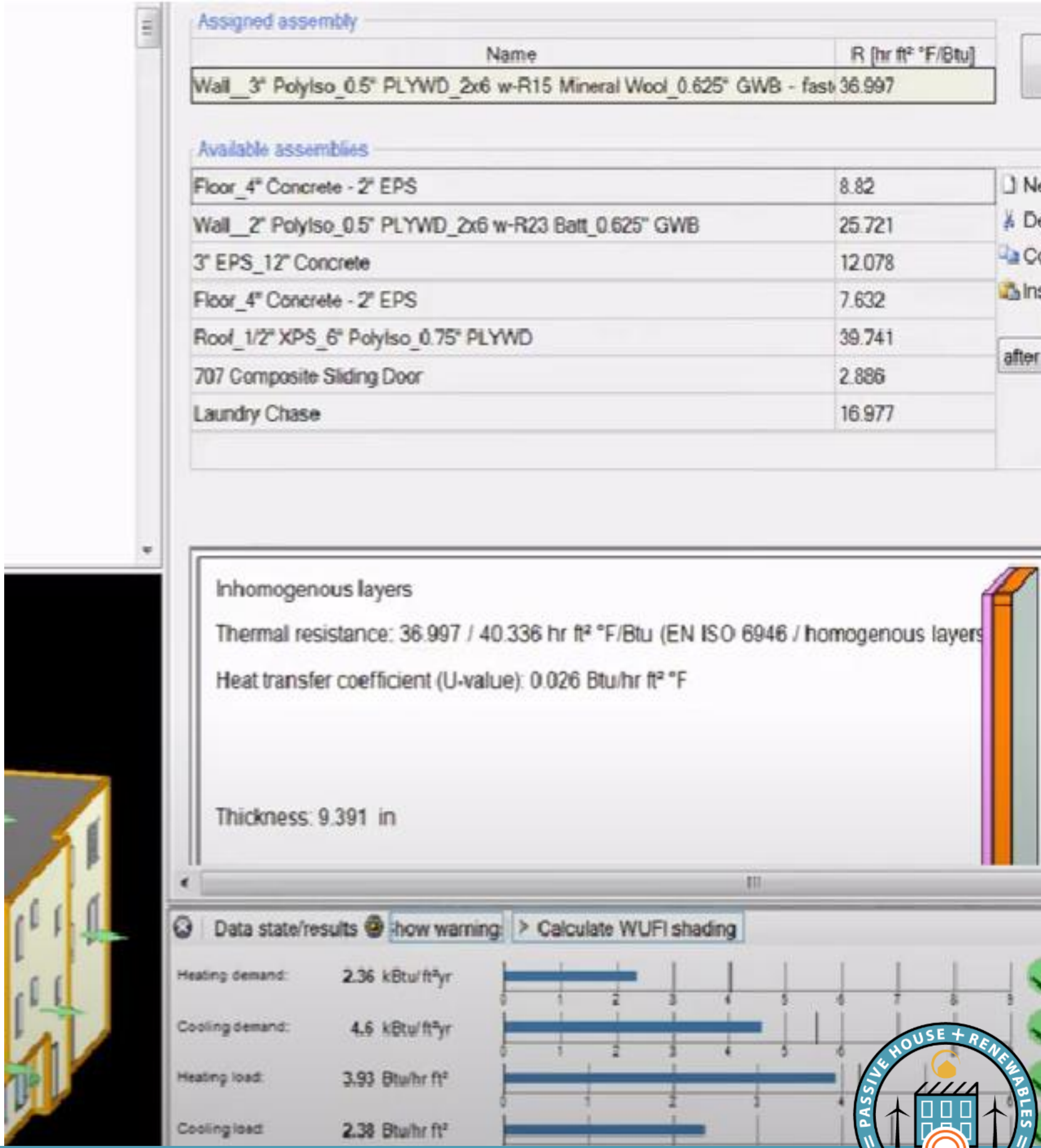
Pre-Design Phase

- Conduct Passive House Feasibility Study
- Choose Passive House certification standard
- Pre-register with Phius or PHI certifier
- Bring on a CPHC/D

Passive House Process

Design Phase

- Design team works with CPHC/D to meet PH requirements on project
- Energy Model is run (WUFI or PHPP)
- Mechanical system is chosen and sized
- Phius or PHI Certifier provide feedback



Passive House Process

Construction Phase

- Contractors and trades pay extra attention to PH details in construction
- On-site verification is conducted to ensure project is built to PH design
- Blower-door tests are run to check air-tightness

Passive House Process

Certification!

11 Crown Street

Location: Meriden, CT

Completed: 2020

Type: multifamily and townhouses

Size: 3 buildings, 63 units and 18 townhomes

Developer: The Michaels Development Co

Architect: Kenneth Boroson Architects

PH Consultant: Steven Winter Associates

Oak Tree Village

Location: Griswold, CT

Completed: 2021

Type: affordable multifamily

Size: 72 units, 2 buildings

Developer: Dakota Partners

Architect: Kaplan Thompson Architects

PH Consultant: Steven Winter

Associates

https://dakotapartners.net/news-item/oak-tree-village-transforms-griswold/

Rocky Neck Village

Location: East Lime, CT

Completed: 2021

Type: townhouses

Size: 50 three bedrooms & 6 ADA

Architect: Wallace Architects

Construction: LaRosa Building Group

https://dakotapartners.net/news-item/oak-tree-village-transforms-griswold/

The Tyler

Location: East Haven, CT

Completed: 2020

Type: Senior housing – retrofit

Size: 104,971 sg ft, 70 units

Developer: WinnDevelopment

Architect: The Architectural Team (TAT)

PH Consultant: Steven Winter Associates

Notes: adapted retrofit of high school building (EnerPhit)

Finch Cambridge

Location: Cambridge, MA

Completion: 2020

Building Type: Affordable multi-family

Size: 98 units, 101,024 sg ft floor area

Architect: ICON Architecture

GC: NEI General Contracting

Developer: Homeowner’s Rehab

CPHC: Linnean Solutions

MEP: Petersen Engineering

PH Consultant: New Ecology

PHIUS Passive House Institute US

Tracy Community Housing

Location: West Lebanon, NH

Completed: 2020

Type: Multifamily housing (50/50 affordable/m

Size: 29 units, 3 stories

Developer: Twin Pines Housing

Architect: Maclay Architects

GC: Estes & Gallup

MEP: Engineering Services of Vermont

PH Modeling: Eco Houses of Vermont

PH Rater: Karen Bushy

PHIUS
Passive House Institute US

Wheaton College Pine Hall

Location: Norton, MA

Completion: 2019

Type: University resident hall

Size: 45,000 ft2, 178 beds

Architect: SGA

GC: Commodore Builders

CPHC/Modeling: Thornton Tomasetti,

Winthrop Center

Location: Downtown Boston

Completed: 2023

Type: Commercial

Size: 812,000 sg ft

Developer: MP Boston

Architect: Handel Architects

GC: Suffolk Construction

PH Consultant: Steven Winter Associates

Northland Development

Newton, MA

Completion: TBA
Size: 500+ units (8 buildings)
Architect: SGA/Cube3/Stantec
Developer: Northland Investment Corporation
PH Feasibility: Steven Winter Associates
Consultant: Lambert Sustainability

Building Type: Market-rate/Affordable/Mixed-use

Carnegie Library

Pittsburgh, PA

Completed: 2018
Size 8,000 s.f.
Architect: Thoughtful Balance & NK Architects
Special Notes: First certified PH library in NA
Uses 40% of the energy of the previous library building despite being 2-3 times the size

Image: thoughtfulbalance.com/projects/CLPCarrick

Passive House Institute

Scott Subaru Dealership – Red Deer, Alberta

- Architecture: Cover Architectural Collaborative
- Engineering: 908 Engineering
- PH Consulting: Peel PH
- Size: 1,542 m2 (16,598 ft2)
- Air Tightness: 0.2 ACH50
- Heating Demand: 14 kWh/m2
- Primary Energy: 84 kWh/m2

Passive House Institute

Warren Woods Field Station – Three Oaks, Michigan (U of Chicago facility)

Project Details

- Type: Ecological Laboratory
- Architect: GO Logic
- Size: 2,131 ft2
- Air Tightness: 0.48 ACH50
- Heating Demand: 12 kWh/m2
- Primary Energy: 64 kWh/m2

- Frankfurt Hospital

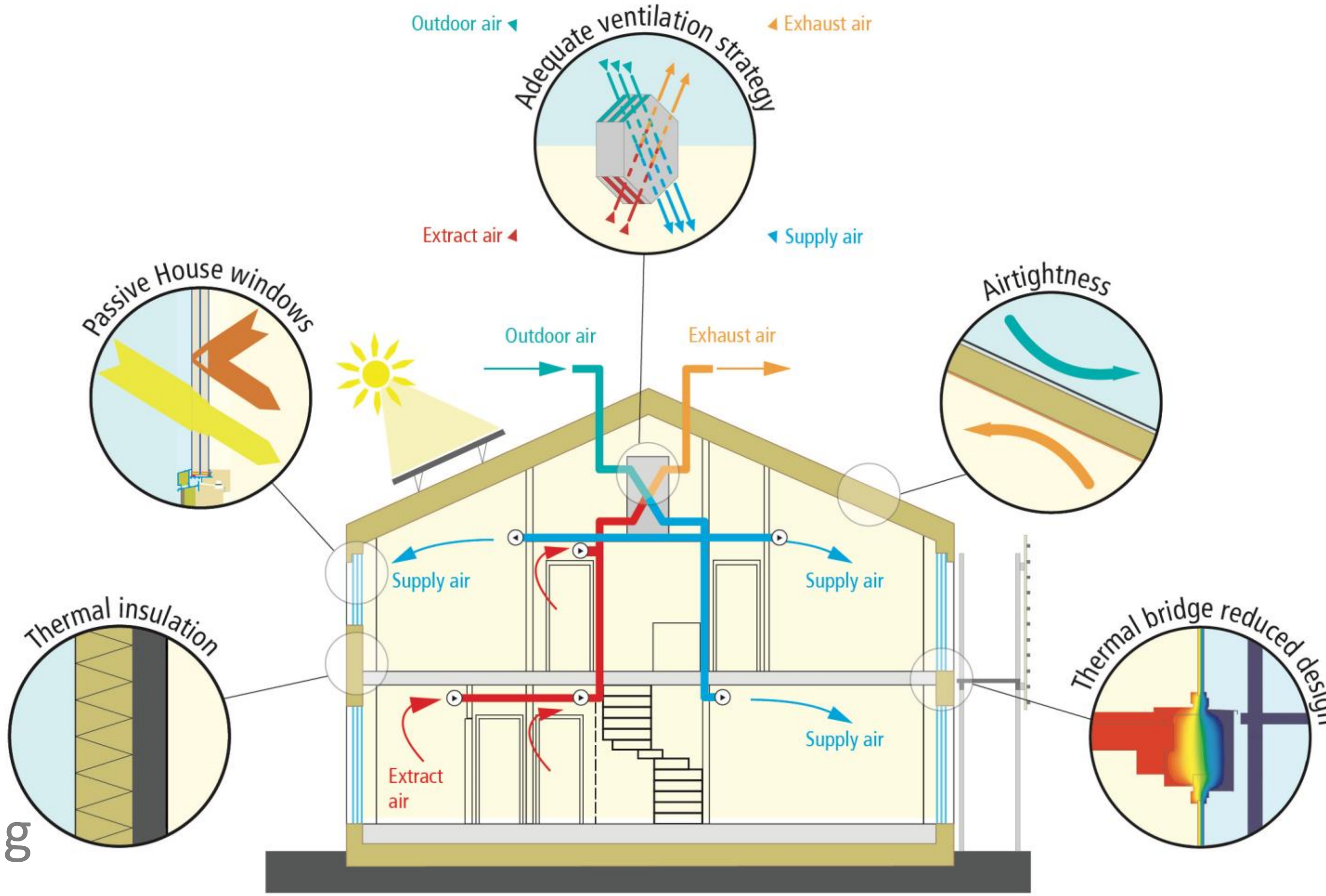
Features of Passive House Buildings

Building Envelope:

- Continuous Thermal Insulation
- Air-Tight Building Envelope
- Thermal Bridge Mitigation
- High-Performance Windows & Doors
- Optimized Solar Heat Gain

Mechanical Systems:

- Balanced & Continuous Ventilation with Heat Recovery
- Efficient & Minimized Heating & Cooling
- Efficient Water Heating & Distribution



Passive House Institute, *principles of passive house*

Building Envelope

Provide a *thermal barrier* around the entire building

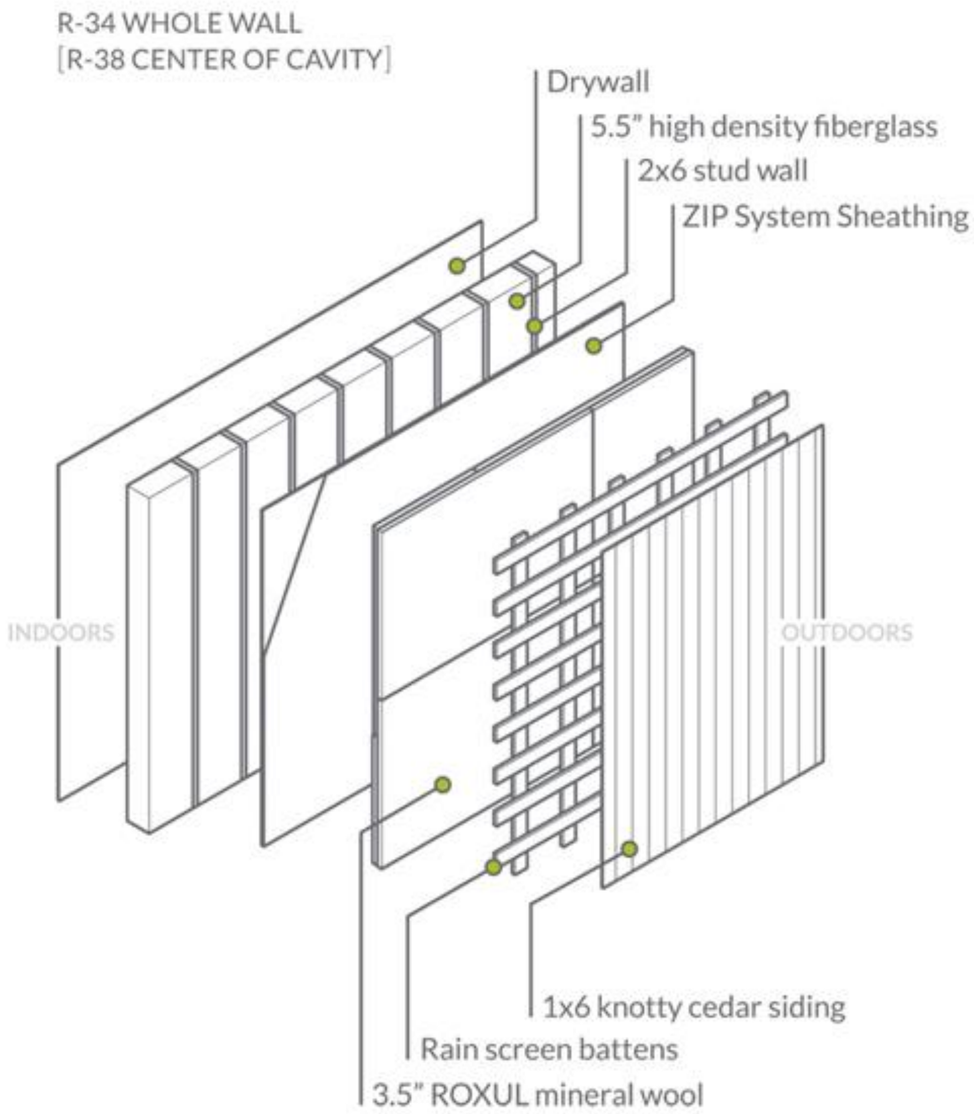
- Dense-packed frame cavity insulation
- Continuous insulation layer
- Reduction of thermal bridging

Create an *air-tight barrier* around the entire building

- Continuous air-barrier system
- Taped and sealed penetrations
- Elimination of air gaps

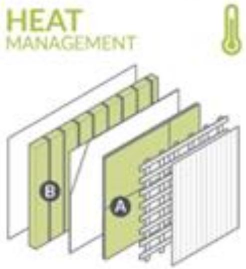
The Distillery

Building Envelope



Source: Hammer and Hand

Ⓐ ZIP Sheathing



Ⓐ 3.5" of exterior mineral wool insulation (R-14)

Ⓑ 5.5" of high density fiberglass insulation (R-23)

Ⓐ Primary barrier: Siding

Ⓑ Secondary barrier: ROXUL mineral wool

Ⓒ Final barrier: ZIP Sheathing

Ⓓ Rain screen allows bulk water to drain away

Ⓐ Rain screen dries cladding and the assembly

Ⓑ The assembly is vapor open in both directions; though the ZIP Sheathing is a vapor retarder, slowing vapor movement from interior into assembly. Mineral wool also warms sheathing, which encourages vapor diffusion.

Building Envelope

The Kenzi at Lot D (DREAM Collaborative)

Source: Hammer and Hand

Building Envelope

Finch Cambridge (ICON Architecture)

Building Envelope

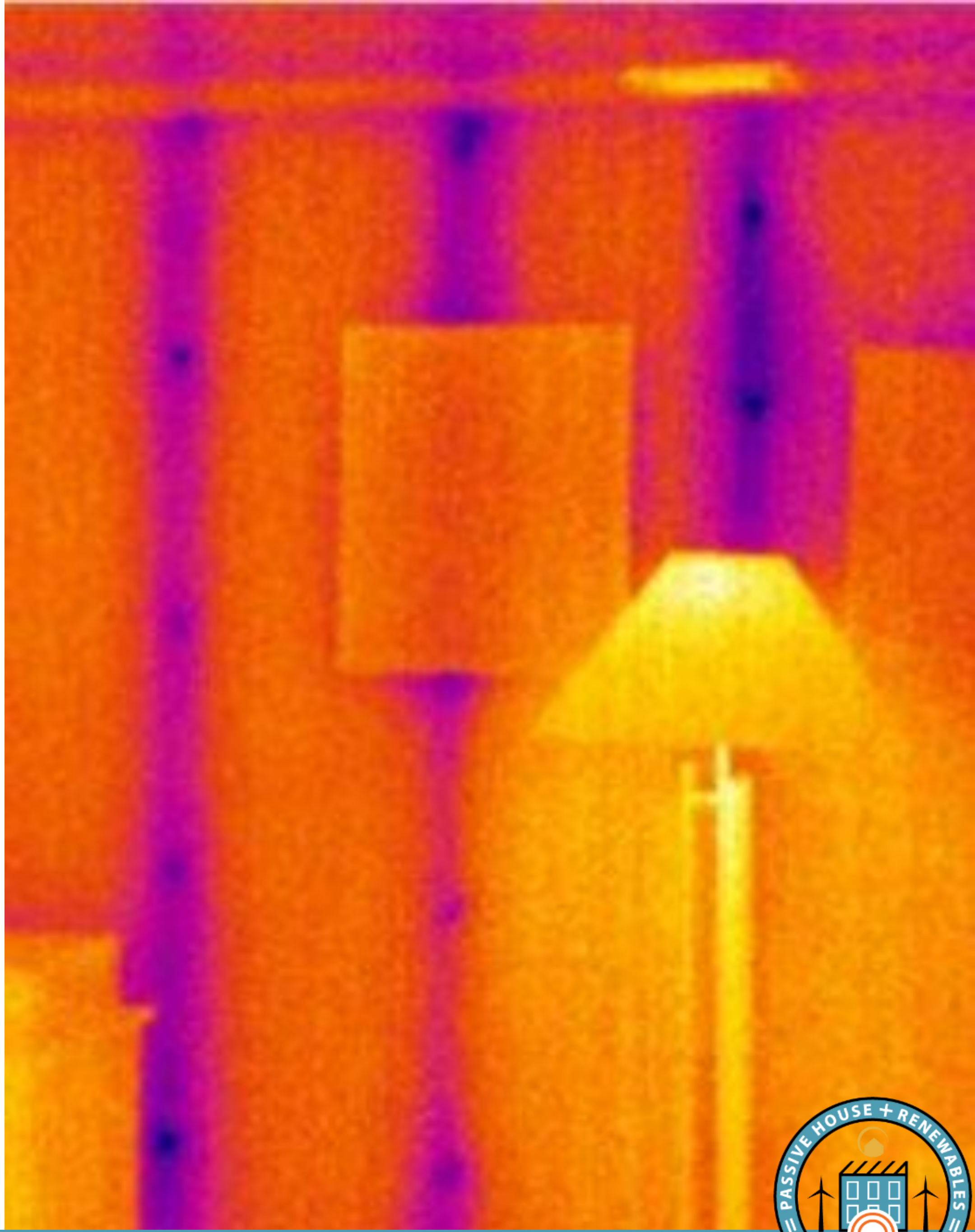
Wheaton College Pine Hall (SGA)

Building Envelope

Thermal Bridges

- Heat transfers through materials with higher thermal conductivity (wood , metal, concreate, etc.)

- Passive House requires focus on reducing the amount of, and mitigating the impact of , thermal bridges through the envelope



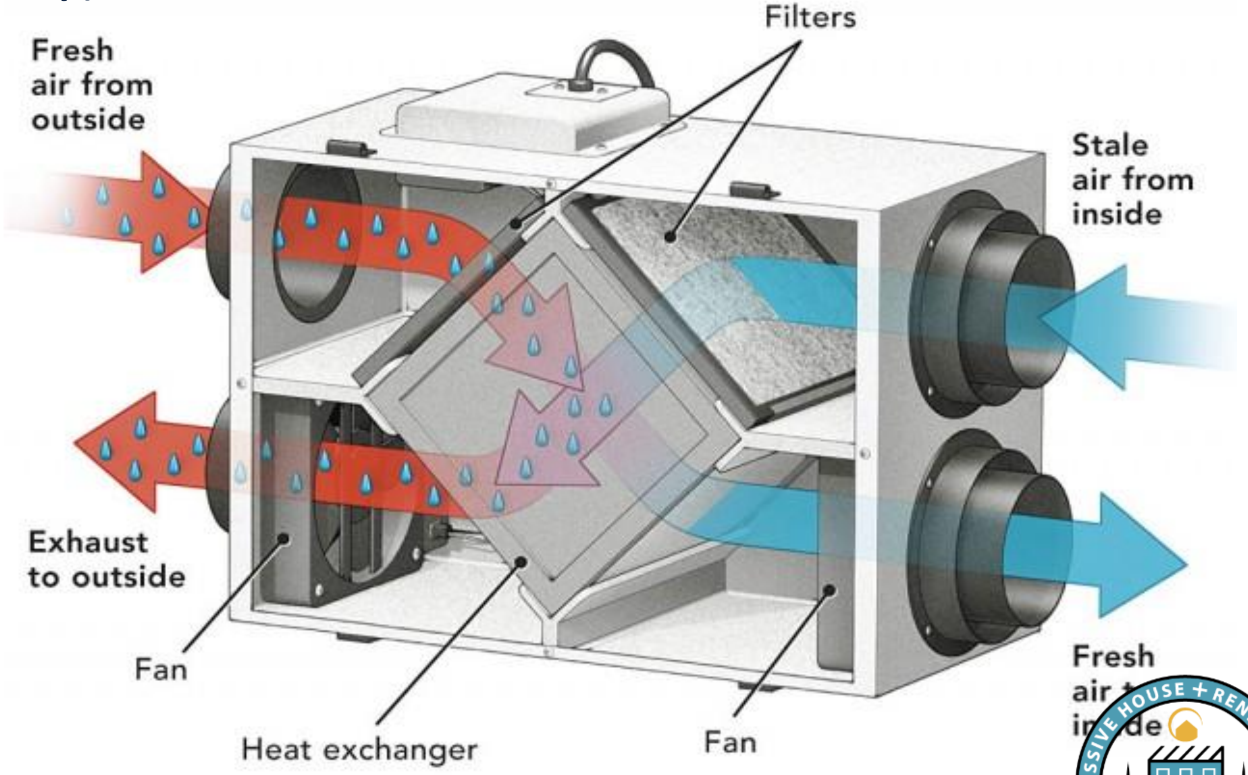
Mechanical Systems

Provide heating, cooling, ventilation, and hot water

- Balanced & Continuous Ventilation with Heat Recovery
- Efficient & Minimized Heating & Cooling
- Efficient Water Heating & Distribution

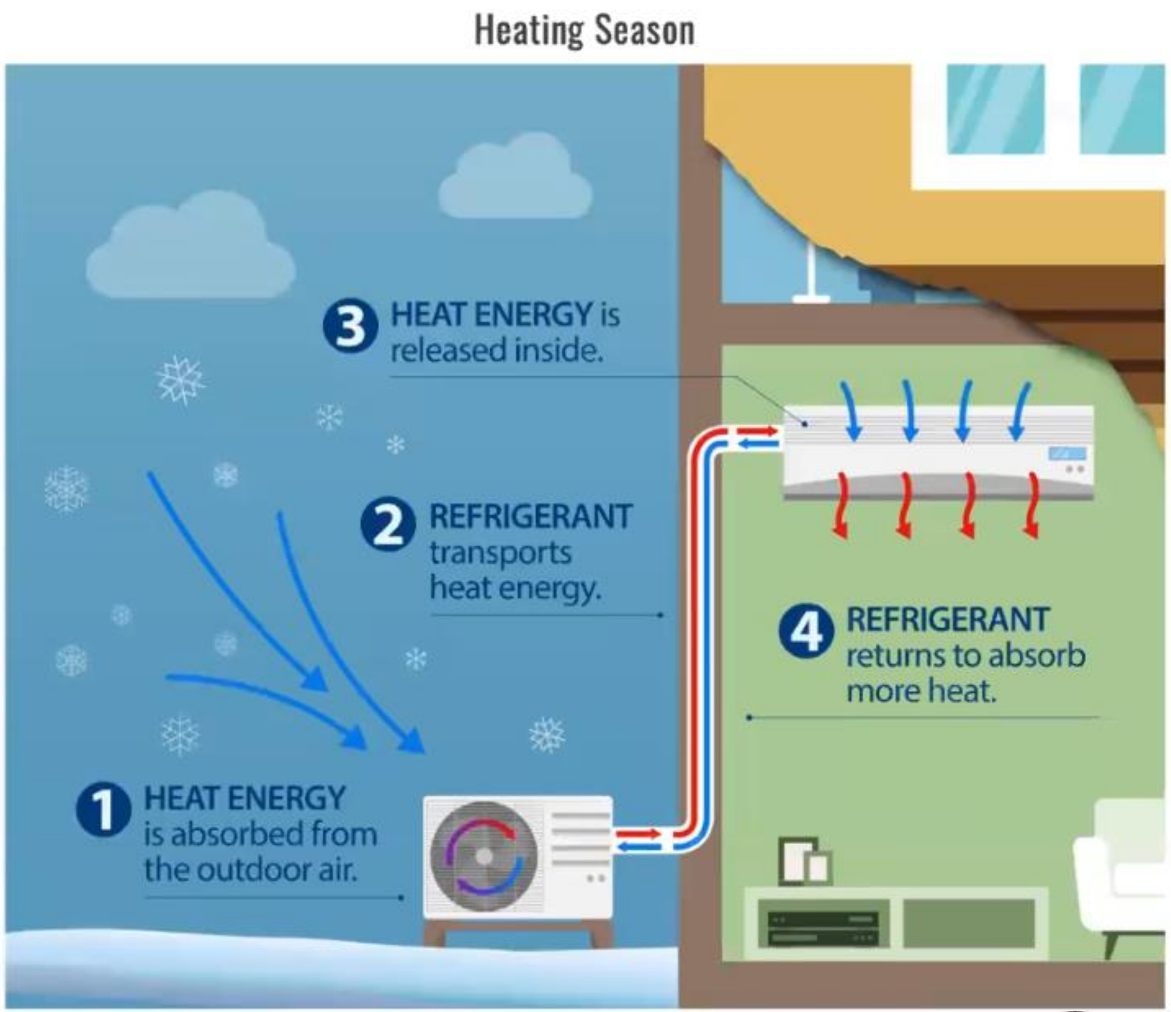
Energy Recovery Ventilators (ERV and HRV)

- Continuously running ventilation system (with variable fan speeds)
- Provides fresh ***filtered*** air into building while completely exhausting dirty air
- Recovers heat from outgoing air (~80% efficiency)
- Does not mix incoming and outgoing air
- ERVs also provide (some) humidity control



Air-Sourced Heat Pumps and VRF Systems

- All-Electric system
- Provide both heating and cooling
- Operate at 200%-400% efficiency (comparted to 100% for electric baseboard and 98% for new gas furnace)
- Can be undocked (aka mini-split system) or use tradition (but better sealed) air ducts
- Cold climate models remain effective in below zero temperatures



Lessons Learned: Design Phase

- Bring together your ***integrated team*** early and often to coordinate the project
  - Get your PH Rater/Verifier/Certifier on-board early as well as the CPHC/D
- Continuity of ***critical barriers*** is essential – air, thermal, water, vapor
  - Schematic/shop drawings should all highlight where these are – use color!
- Work with a ***mechanical engineer*** experience with low-energy buildings
  - You do not want to oversize equipment
- Consult with ***GC and trades*** during the design process
  - Focus on constructability and sequencing
- Plan for ***apartment compartmentalization*** from the beginning
  - This is required for Energy Star within Phius+2021
- Pay attention to ***solar heat gain*** and overheating in summer months
  - Shade systems are important on south facing sides (and some east/west)


Source: Ballston Mourningkill Associates

Lessons Learned: Construction Phase

- Hold ***kickoff meetings*** onsite with associated trades
  - Helpful to make sure everyone is on the same page with PH details
- Build ***mock-ups*** onsite that show installation details and provide training opportunities
- Invite ***manufacture reps*** to answer questions and demonstrate recommendations
- Know your ***air barrier*** and clearly label it everywhere
  - Assign an onsite air barrier manger to double-check
- Conduct ***blower door tests*** early and often
  - At minimum:
    1. Full envelope test once windows and doors are in
    2. After sheetrock is up and walls are closed
    3. Pre-occupancy for final numbers

Questions?

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Home Energy Rating System (HERS)

- Score of 100 is a standard “Reference Home”
- Score of 65 is 35% more efficient
- Score of 0 is a Net-Zero home

HERS Rater scores:

- All exterior walls (both above and below grade)
- Floors over unconditioned spaces (like garages or cellars)
- Ceilings and roofs
- Attics, foundations and crawlspaces
- Windows and doors, vents and ductwork
- HVAC systems, water heating system, and your thermostat