PASSIVE HOUSE 102:

Multi-Family Passive House Buildings & Design

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, are pleased to offer *Passive House 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
or email PassiveHouseTrainingCT@icf.com

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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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Passive House is a performance-based building certification standard that focuses on the dramatic reduction of energy use for space heating and cooling, while ensuring a comfortable, healthy, and low-carbon building

Passive House achieves:

- Dramatic reduction in overall energy use
- Dramatic reduction in carbon emissions
- Proven improvement in air quality, health, and occupant comfort
- Greater building durability
- Resilience to major weather events
- Lower operating costs
- Pathway to net-zero

Air Quality, Health, and Occupant Comfort

- Continuous ventilation of filtered air
- Increased use of non-toxic materials
- Consistent comfortable room temps
- Elimination of air drafts
- Increased natural lighting
- Quieter acoustic conditions

Durability & Resilience

- **Shelter in Place**
  Maintain consistent indoor temps during extreme weather and power outages

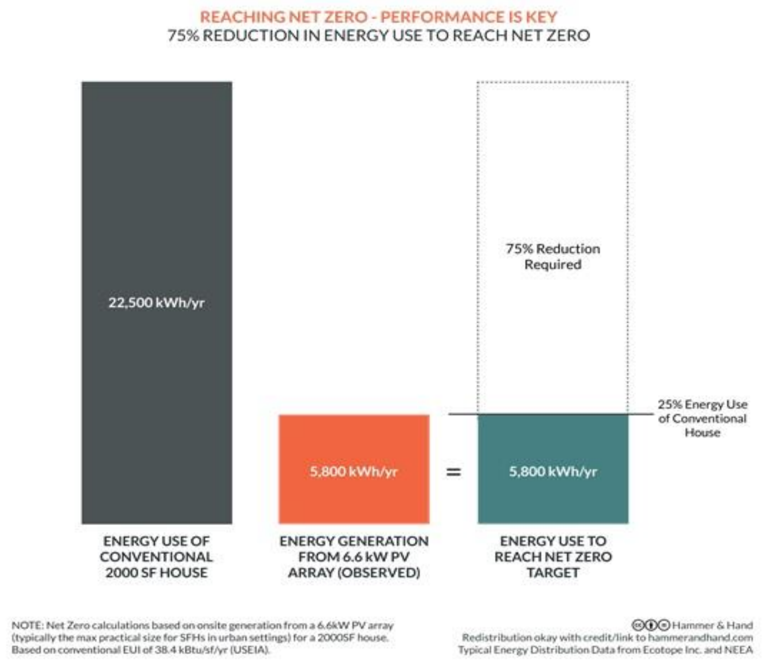
- **Durable & Long Lasting Construction**
  Resists mold, rot, pests & water intrusion

- **Passive Not Active**
  Lower reliance on mechanical systems

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.

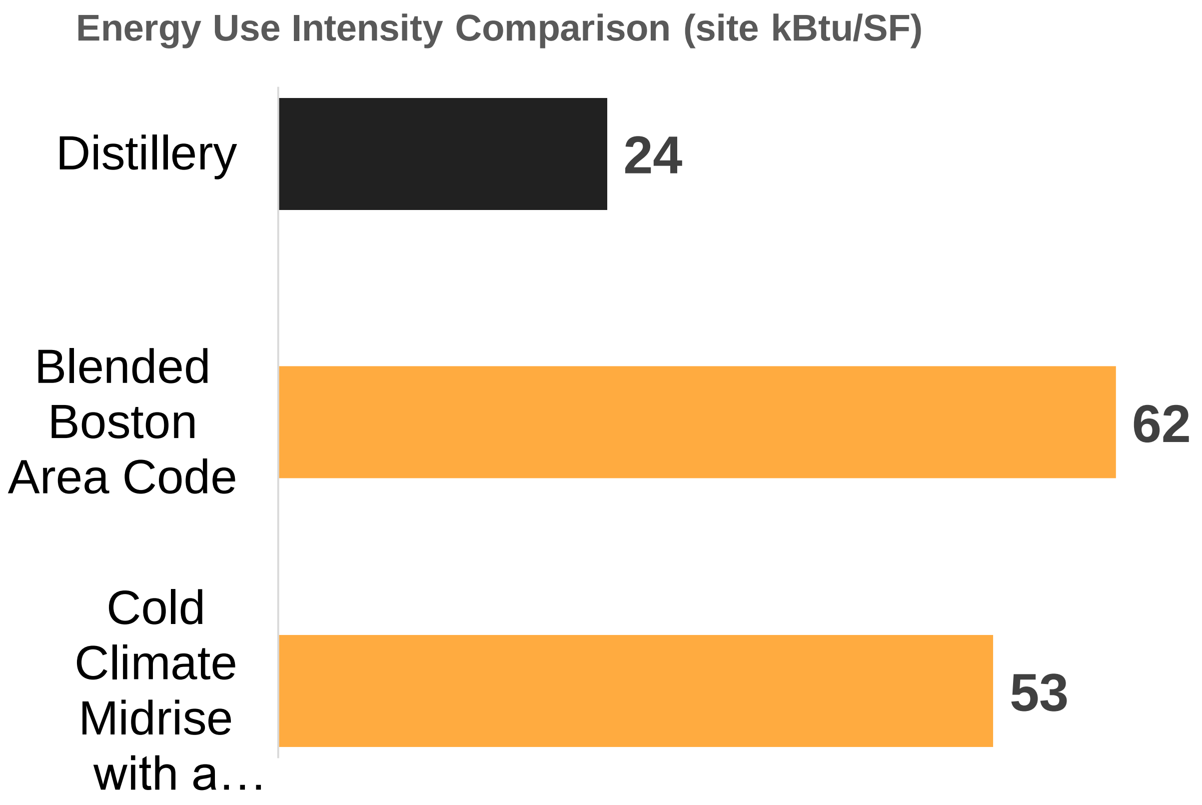


Energy Reduction

90% or greater reduction in heating and cooling loads comparted to a typical building

Performance Comparison

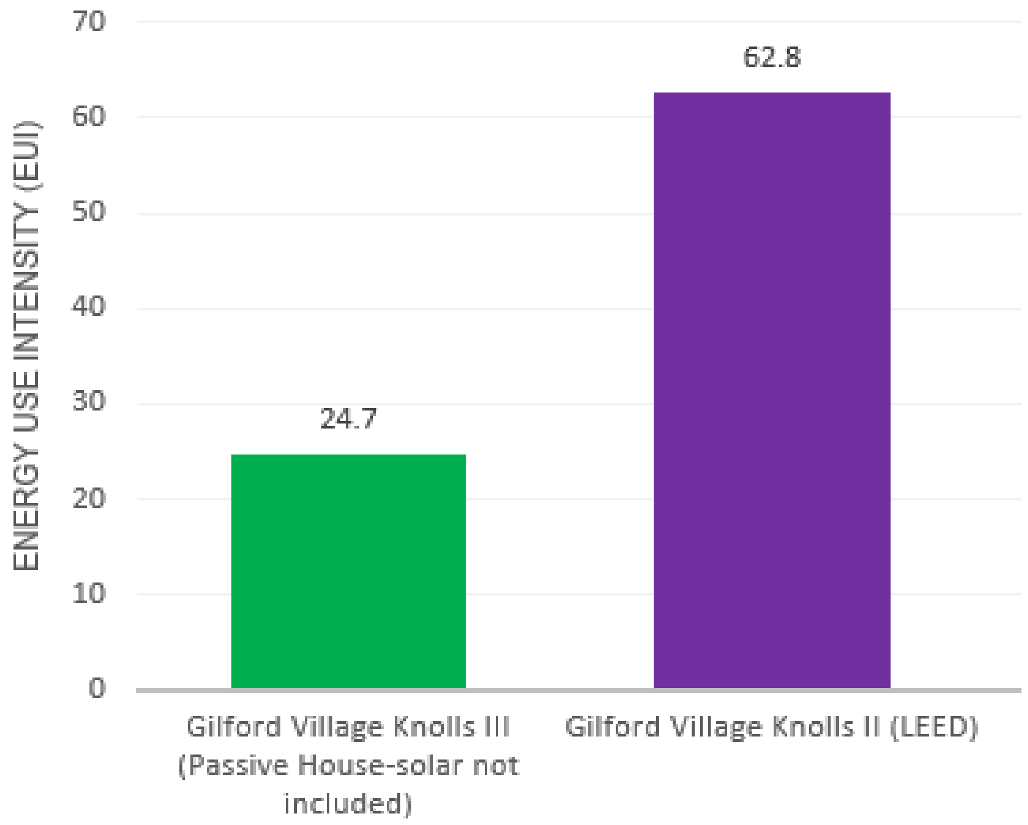
Distillery: Uses 60% less energy/sq. ft. than typical Boston Area Code Built



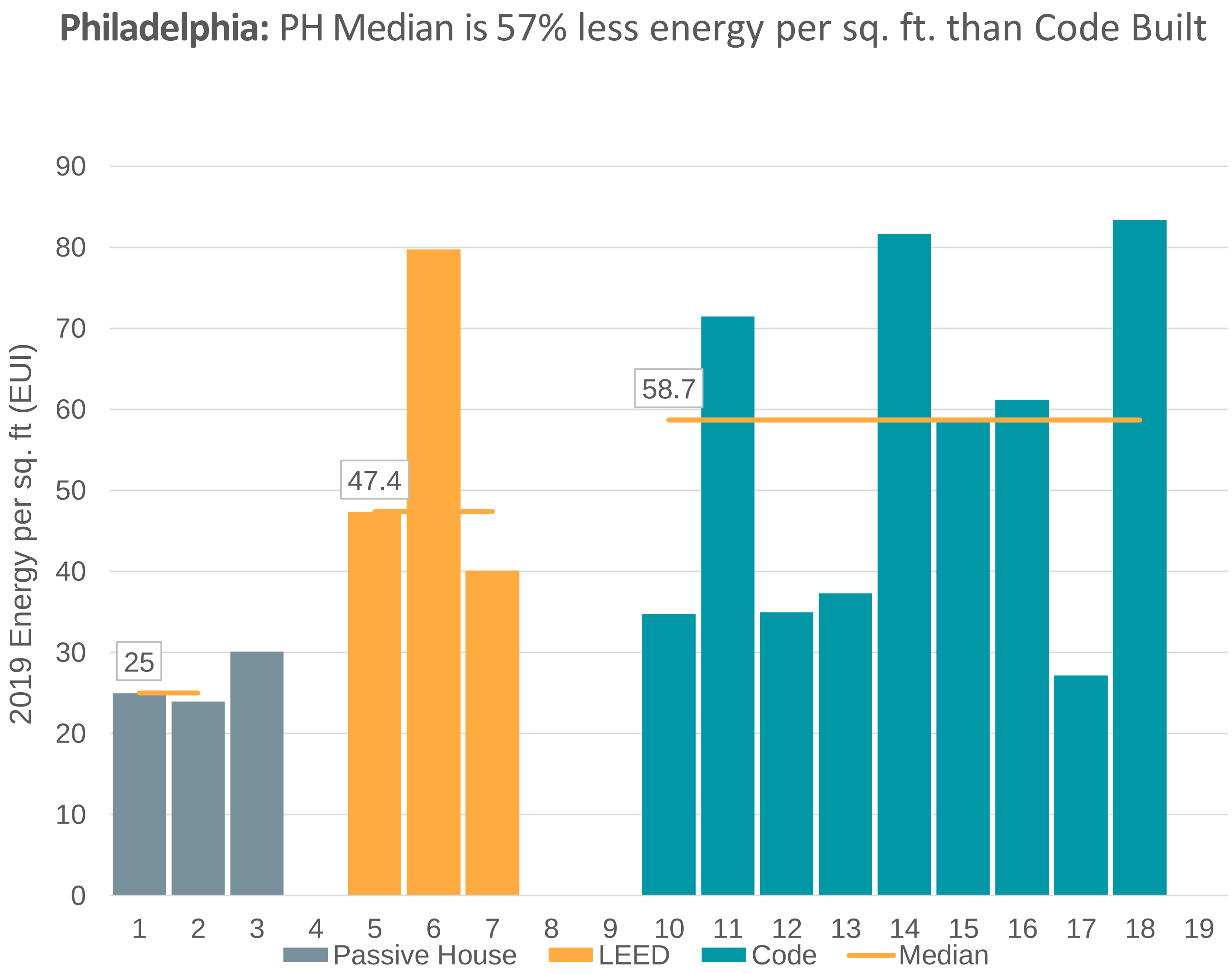
Distillery North, Boston

Performance Comparison

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



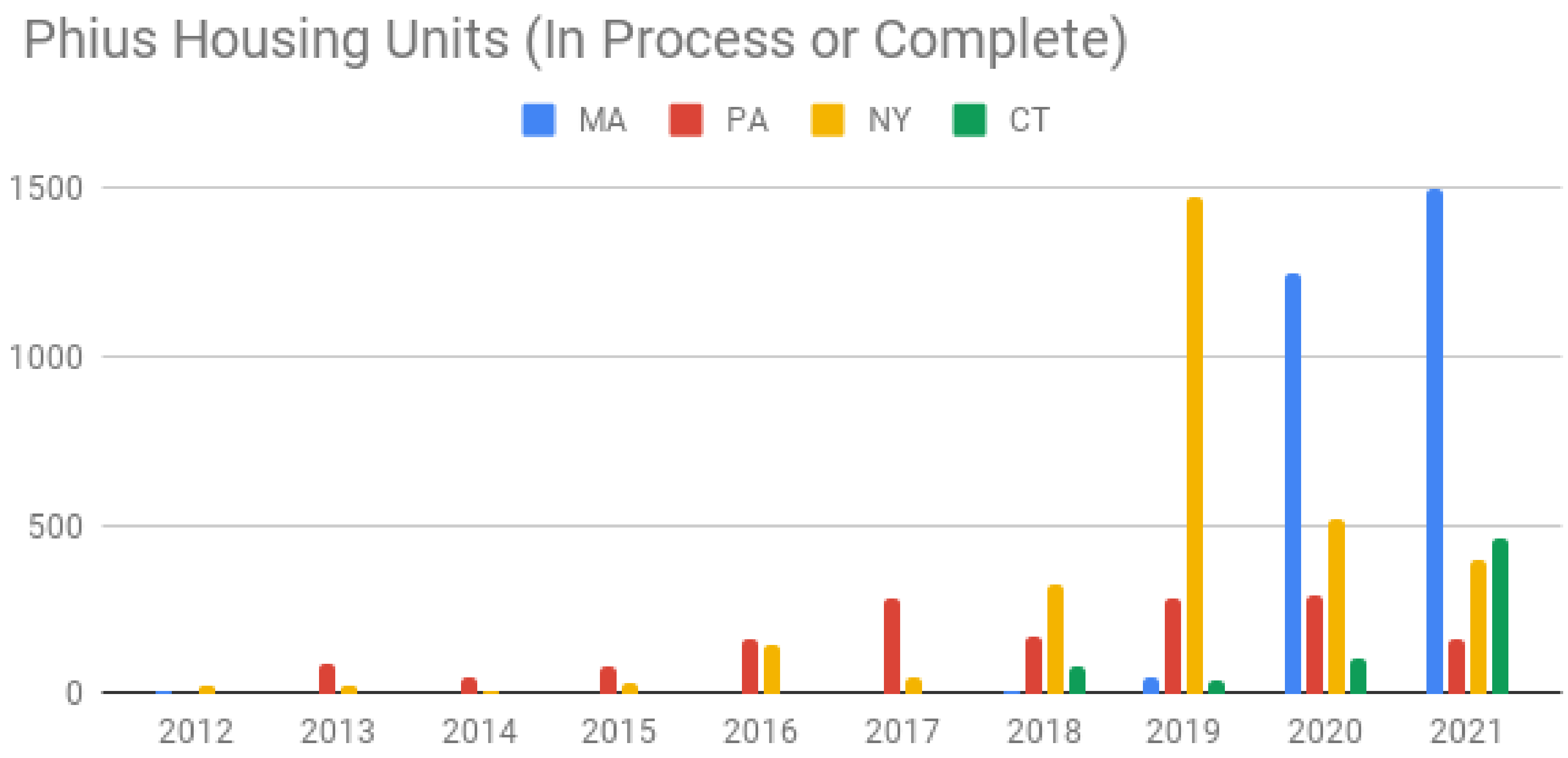
Performance Comparison



Stable Flats (Onion Flats)

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

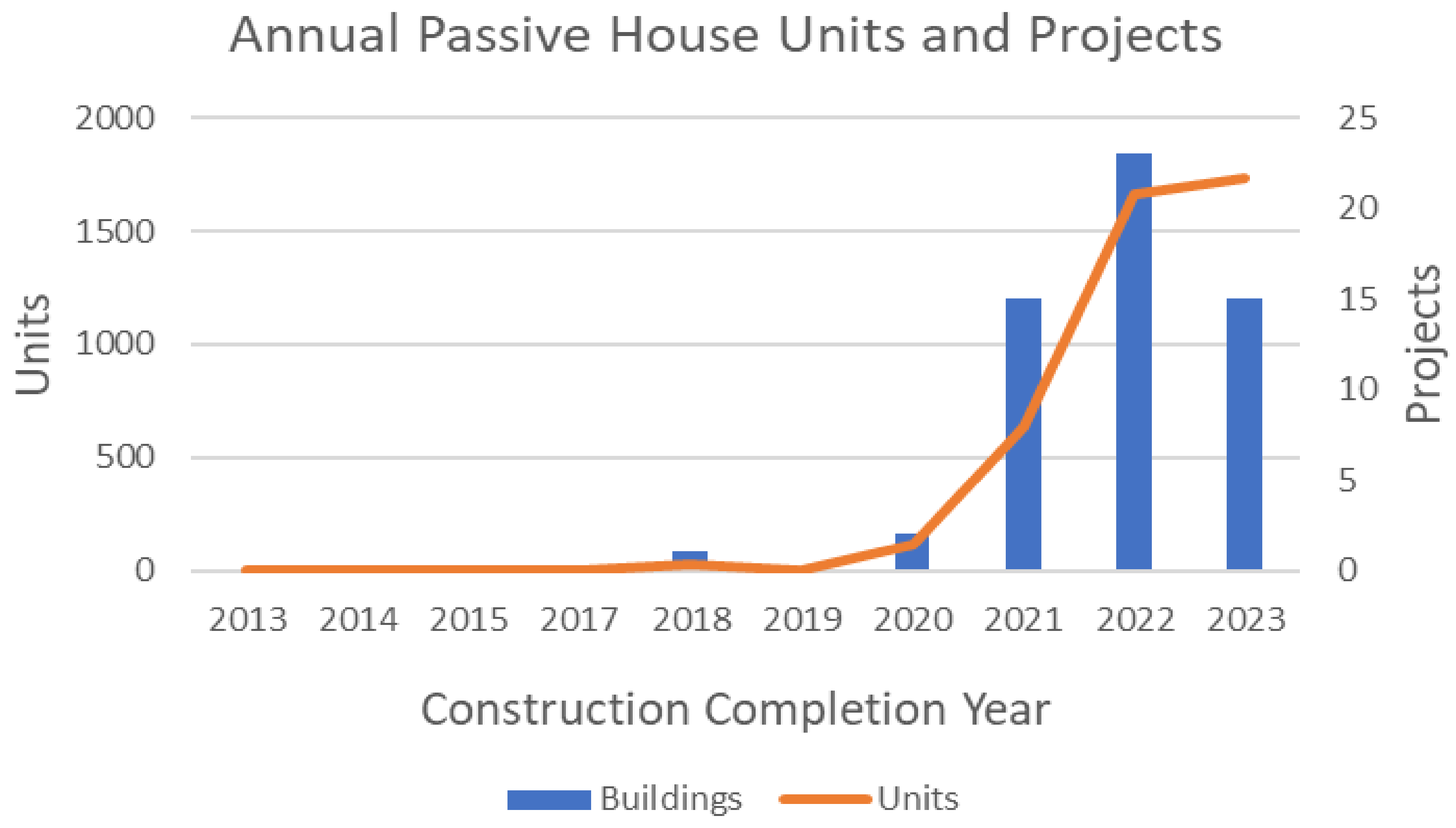
The Growth of Passive House



Data from PHIUS projects database

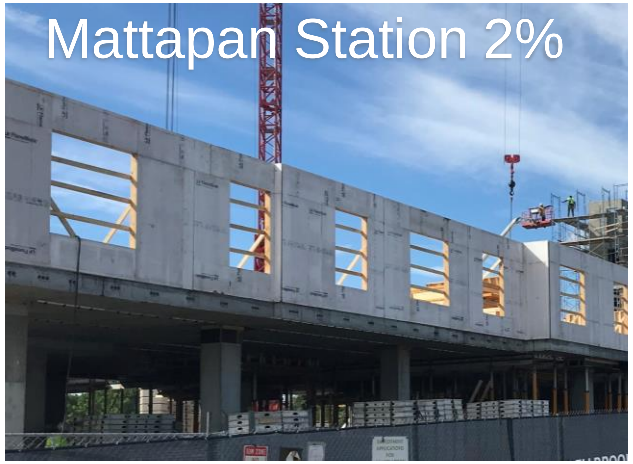
The Growth of Passive House

State incentives have helped fuel this growth in Massachusetts



Data from Mass Save Incentive program

The Incremental Cost of Achieving Passive House



MASSACHUSETTS CLEAN ENERGY CENTER

Data from MassCEC Passive House Design Challenge

Passive House Certification Requirements

Performance Criteria

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

Other Criteria

- Ventilation, Moisture Management, Quality Assurance

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 Metrics

	PHIUS	PHI
Annual Heating	5.3 kBtu/ft2	15 kWh/m2 (4.8 kbtu/ft2)
Peak Heating	4.4 Btu/ft2	10 watts/m2 (3.2 btu/ft2)
Annual Cooling	2.9 kBtu/ft2-yr	15 kWh/m2-yr (4.8 kbtu/ft2)
Peak Cooling	4.2 Btu/ft2	10 watts/m2 (3.2 btu/ft2)
Source Energy	3840 kWh/person (Residential) 34.8 kBtu/ft2 (Commercial)	60 kWh/m2 (all projects)

Passive House Institute

PHIUS
Passive House Institute US

*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

BUILDING INFORMATION

Category:	Non-residential
Status:	Under construction
Building type:	Retrofit
Year of construction:	
Units:	1
Number of occupants:	5 (Design)
Occupant density:	251 ft²/Person

Boundary conditions

Climate:	BOSTON LOGAN INT ARPT MA
Internal heat gains:	1.9 Btu/hr ft²
Interior temperature:	68 °F
Overheat temperature:	77 °F

Building geometry

Enclosed volume:	20,169 ft³
Net-volume:	10,092 ft³
Total area envelope:	5,509.7 ft²
Area/Volume Ratio:	0.3 1/ft
Floor area:	1,255 ft²
Envelope area/iCFA:	4.39

PASSIVEHOUSE REQUIREMENTS

Certificate criteria: PHIUS+ 2018

Heating demand	
specific:	2.24 kBtu/ft²yr
target:	5.3 kBtu/ft²yr
total:	2,808.17 kBtu/yr
Cooling demand	
sensible:	2.02 kBtu/ft²yr
latent:	0.15 kBtu/ft²yr
specific:	2.17 kBtu/ft²yr
target:	2.9 kBtu/ft²yr
total:	2,728.64 kBtu/yr
Heating load	
specific:	4.18 Btu/hr ft²
target:	4.4 Btu/hr ft²
total:	5,252.03 Btu/hr
Cooling load	
specific:	3.24 Btu/hr ft²
target:	4.2 Btu/hr ft²
total:	4,062.01 Btu/hr
Source energy	
total:	0 kWh/yr
specific:	0 kBtu/ft²yr
target:	34.8 kBtu/ft²yr
total:	0 kBtu/yr
specific:	0 kBtu/ft²yr
Site energy	
total:	-6,036.6 kBtu/yr
specific:	-4.81 kBtu/ft²yr
total:	-1,769.33 kWh/yr
specific:	-1.41 kWh/ft²
Air tightness	
ACH50:	0.99 1/hr
CFM50 per envelope area:	0.03 cfm/ft²
target:	1.97 1/hr
target CFM50:	0.06 cfm/ft²

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

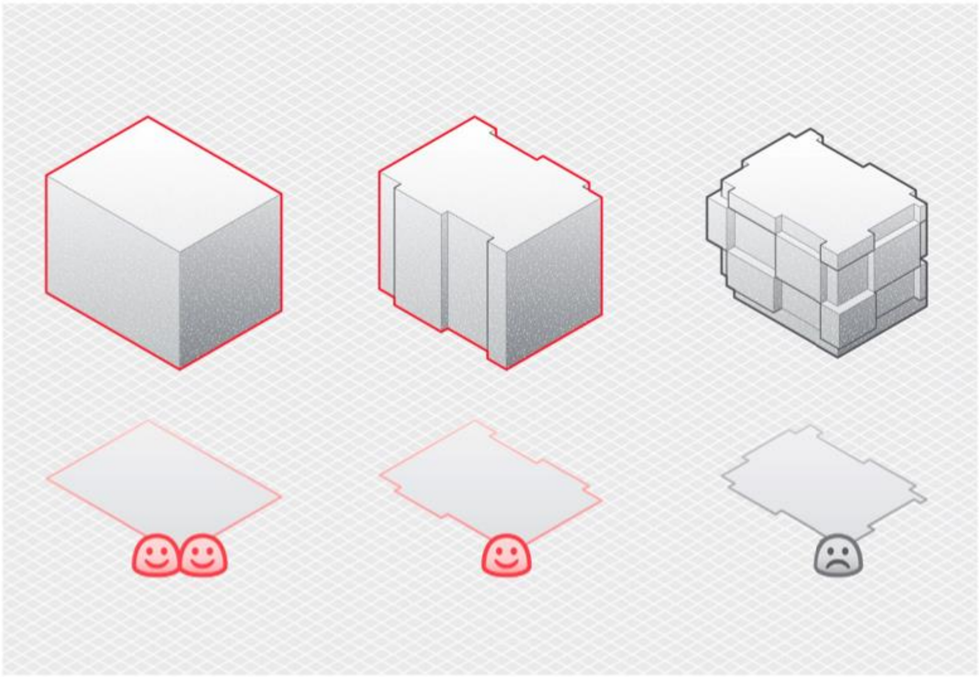
Features of Passive House Buildings:

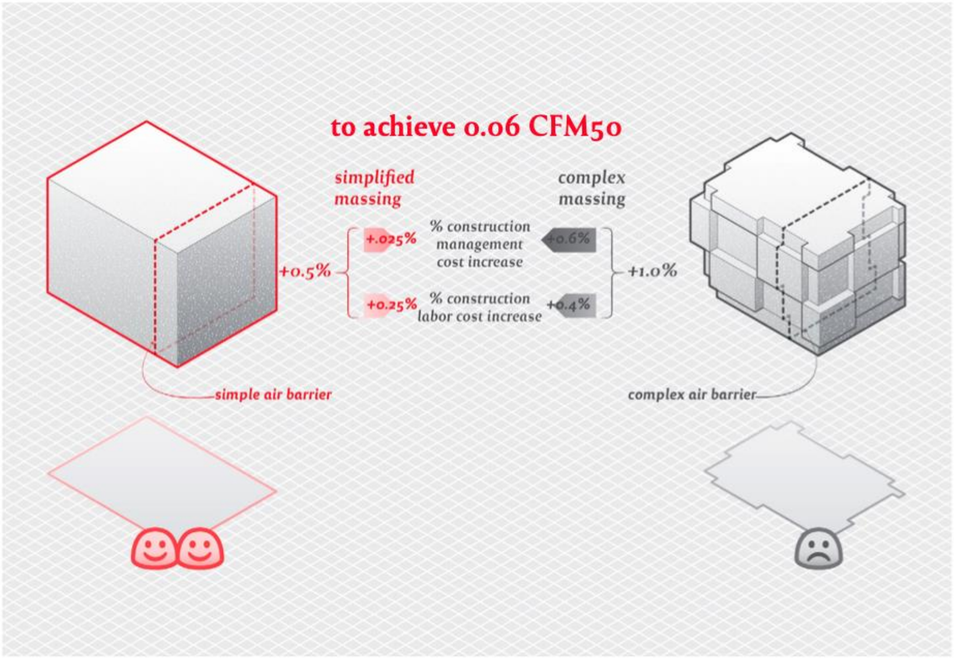
- Continuous Thermal Insulation
- Thermal Bridge Free Construction
- Airtight Envelope
- High-Performance Windows & Doors
- Optimized Solar Heat Gain
- Balanced Ventilation
- Efficient & Minimized Mechanical Systems (Heat/Cooling/Water)

Design Concepts

Massing and Form

- The more complicated the from, the more challenging it is to achieve air-tightness and thermal bridging reductions

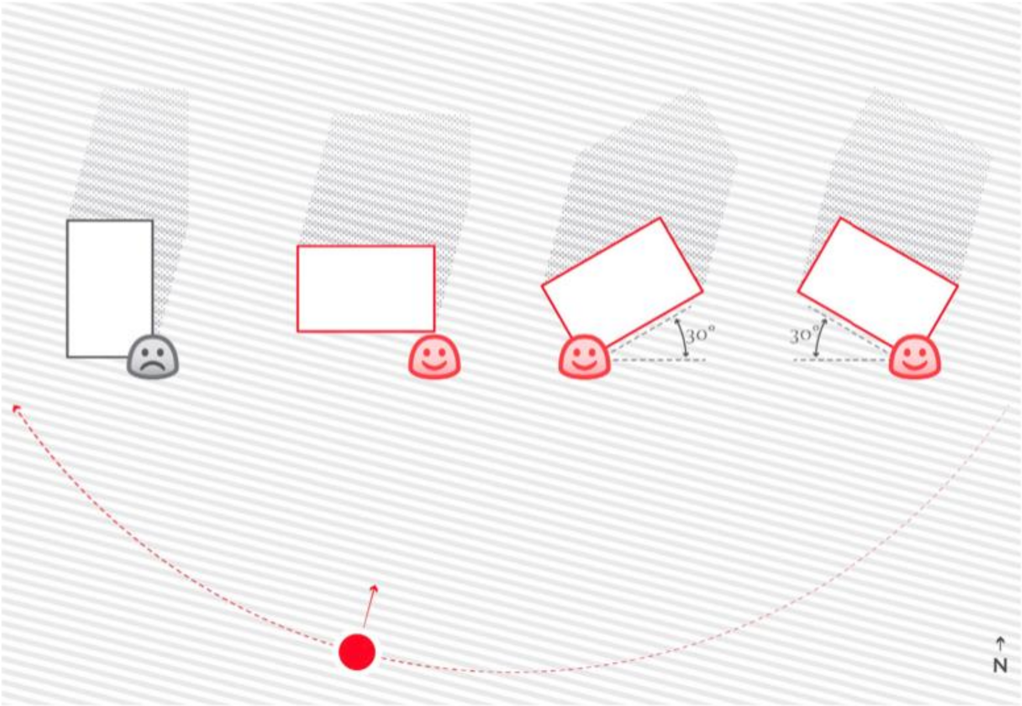


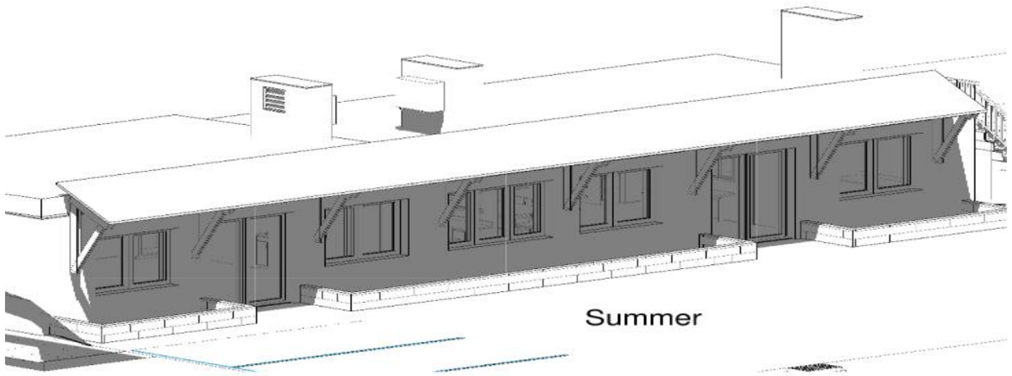


Design Concepts

Building Orientation and Siting

- Long face towards sun exposure
- Beware of trees and other buildings

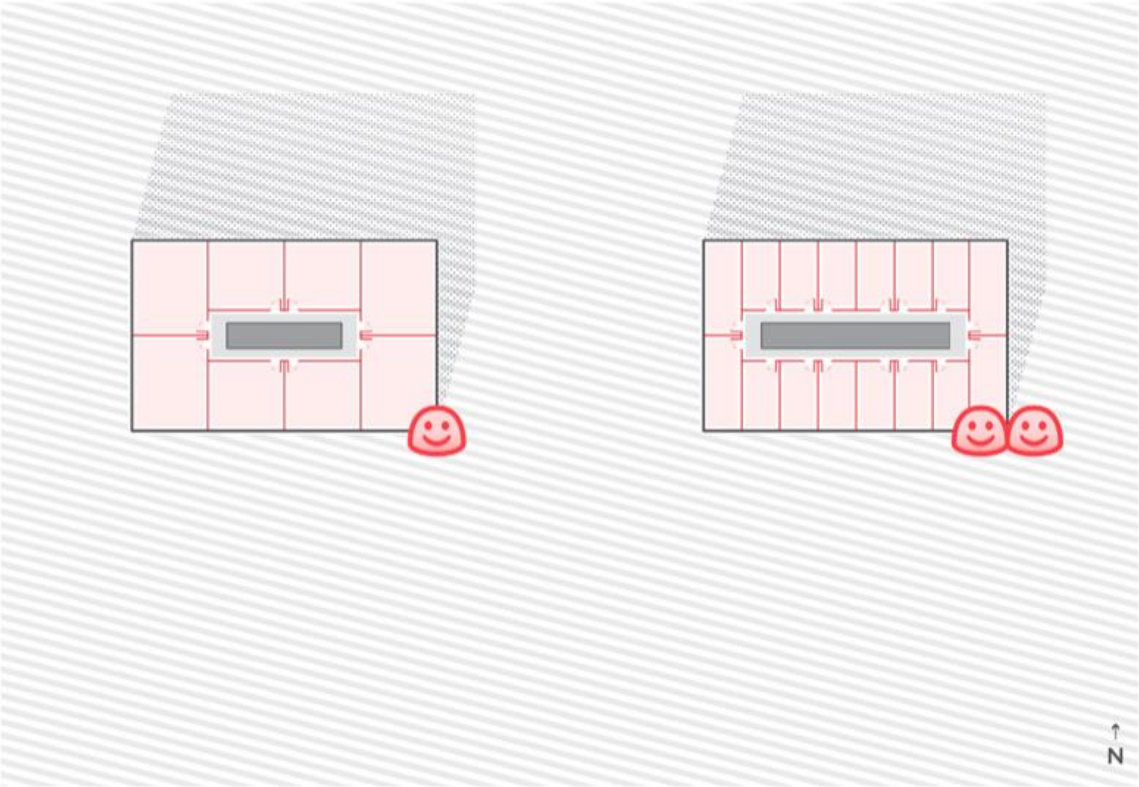




Design Concepts

Increased Density

- More heat sources inside (people, appliances, etc)



Distillery, 2017
- 28 units
- Wood framed
- 3" Mineral Wool

Finch, 2021
- 98 units
- Wood framed
- 2" Mineral Wool

Design Concepts

Glazing Percentage and Placement

- More than 25% glazing to wall ratio can present more challenges
- Too little glazing, or incurrent placement, can negatively impact solar heat gain

Finch Cambridge

Building Envelope

Main Principles:

- Thermal barrier around building
- Continuous insulation outside of frame
- Dense-packed cavity insulation
- Larger the building, lower the R-value
- Air-tight with dedicated air barrier system
- Reduction of thermal bridging through envelope

Typical Values (for climate zone 5b):

Walls
- R ≥ 40-50
- Insulation 10-12”

Roof
- R ≥ 40-60
- Insulation 12-16”

Floor (on-grade)
- R ≥ 25-30
- Insulation 6-12”

Air Tightness

Main Principles:

- Continuous air barrier around building
- Eliminate air gaps, holes, etc. in barrier
- Taped seems, penetrations, etc
- Target metric is measured with blower door test

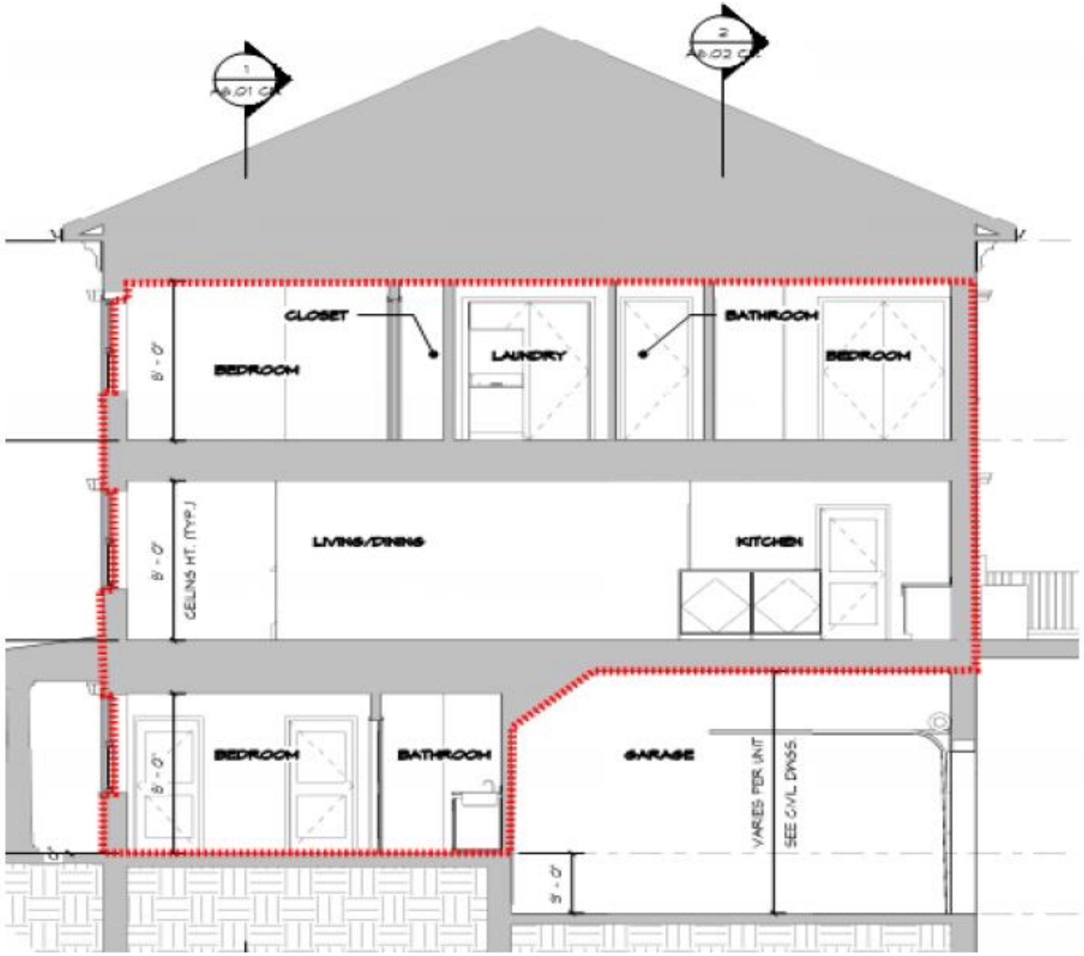
Elm Place
Huber Zip System sheathing (green) and tape (black)

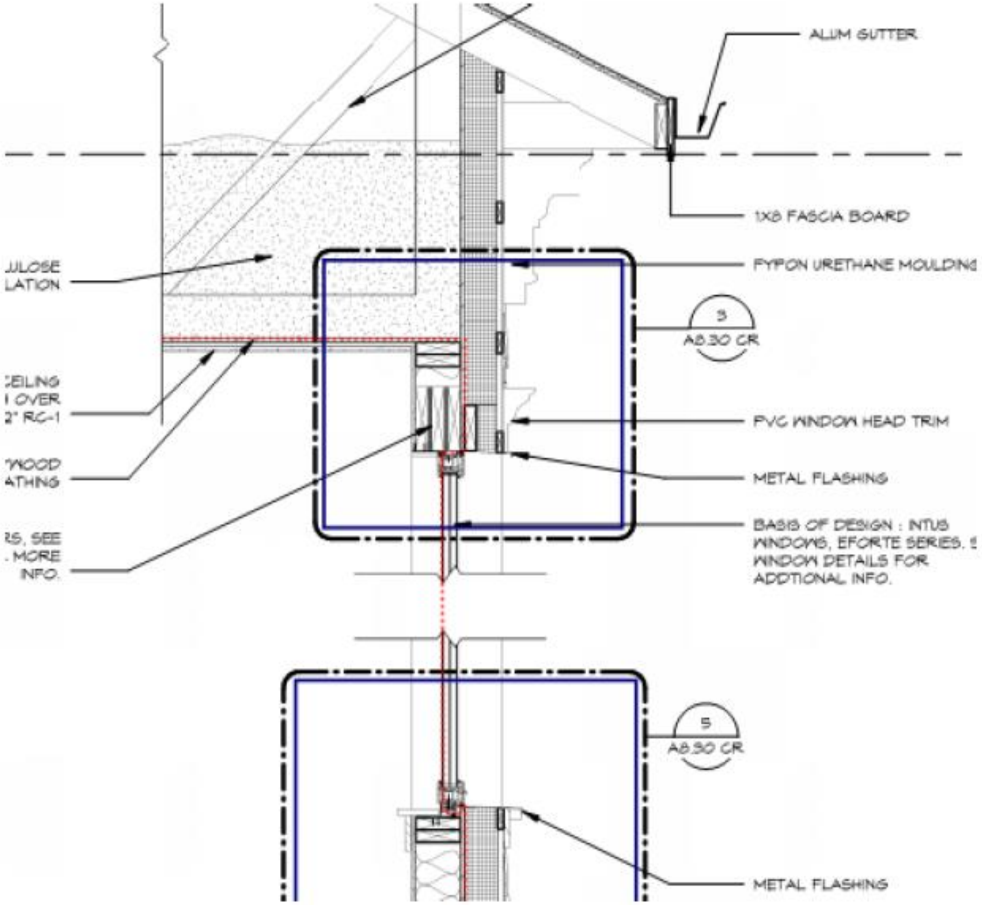
Bellis Circle
Pro Clima Intello (white) and tape (blue)

Finch Cambridge
Siga Majvest 500 (blue) and tape (white)

Air Tightness

Red Line Test





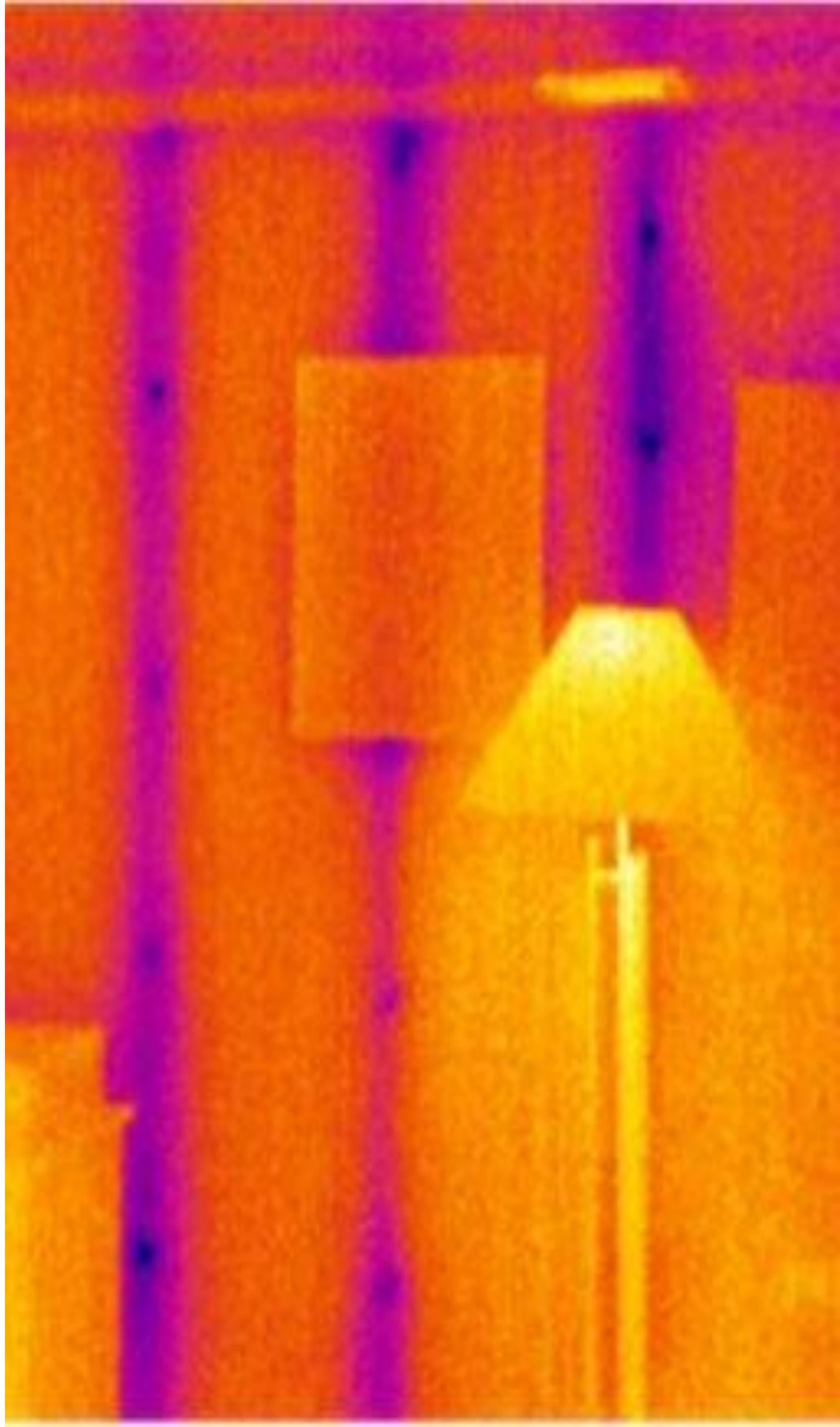
Thermal Bridging

Heat transfers through materials with higher thermal conductivity (wood studs, steel, metal fasteners, plumbing lines, etc)

Thermal Bridges lead to:
- Heat loss
- Low surface temps
- Impaired thermal comfort
- Risk of condensation
- Risk of mold growth

Thermal brides need to be mitigated or removed
- Insulation outside frame
- Thermal breaks
- Advanced framing to reduce frame use

Areas of Concern:
- Weak points in insulation (studs)
- Wall penetrations (plumbing, electrical)
- Beams that meet or pass through a wall
- Outside features attached to wall (balcony, awning)
- Corners
- Window frames



Thermal Bridging

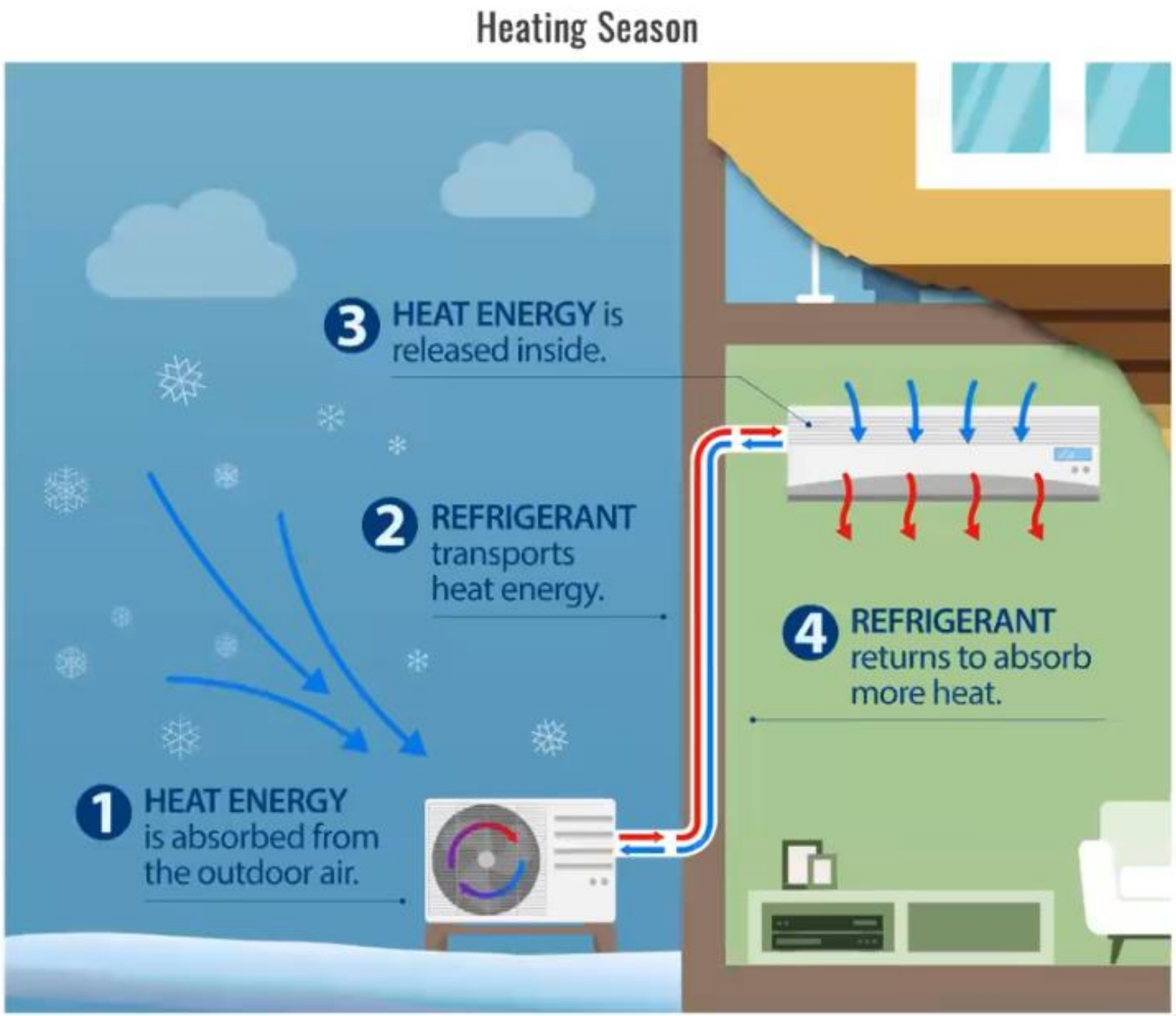
Finch Cambridge
Plastic clips as thermal breaks to attach exterior insulation

Elm Place
Insulation layer added between steel pillar and beams

Heating & Cooling

Air-Sourced Heat Pumps (and VRF Heat Pump)

- Provides efficient electric heating and cooling
- Can be centralized or unitized, ducted or ductless
- Operate at 200%-400% efficiency (comparted to 100% for electric baseboard and 98% for new gas furnace



Heating & Cooling

Finch Cambridge

- VRF condensers on roof connect to heat pump heads in each unit
- 13 rooftop condensers supply 149 indoor units

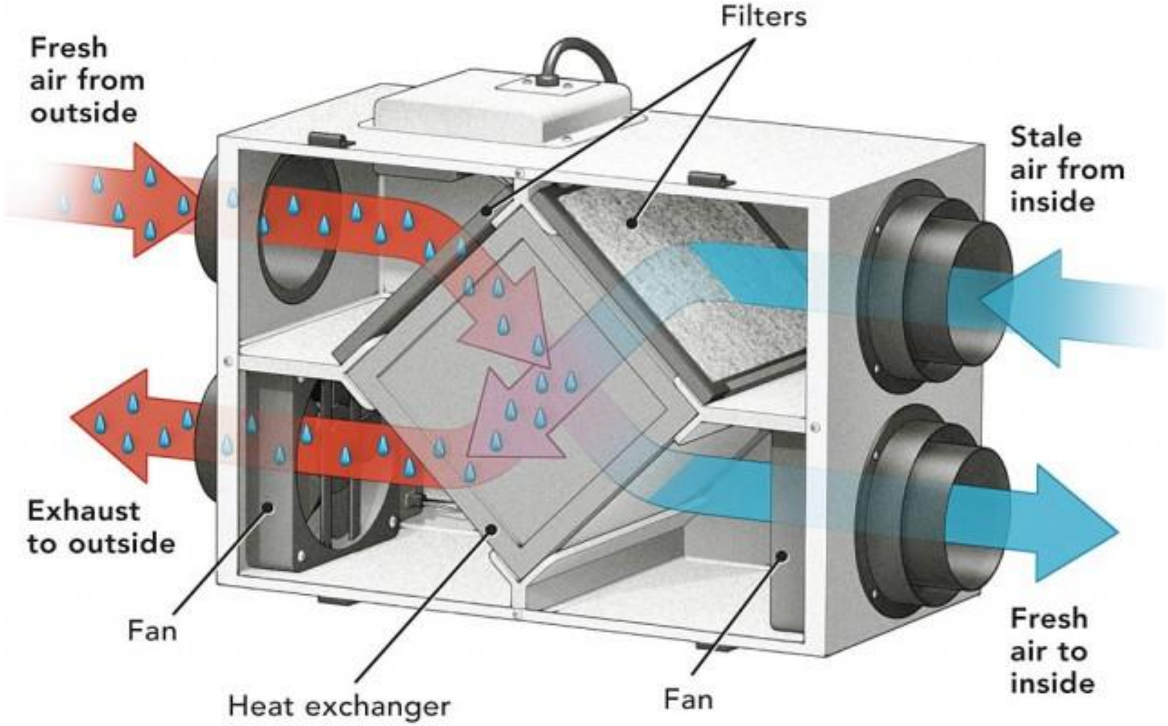
Distillery

- Individual heat pump systems for each unit
- One heat pump head per unit ducted to rooms

Ventilation

Heat/Energy Recovery Ventilators (HRVs and ERVs)

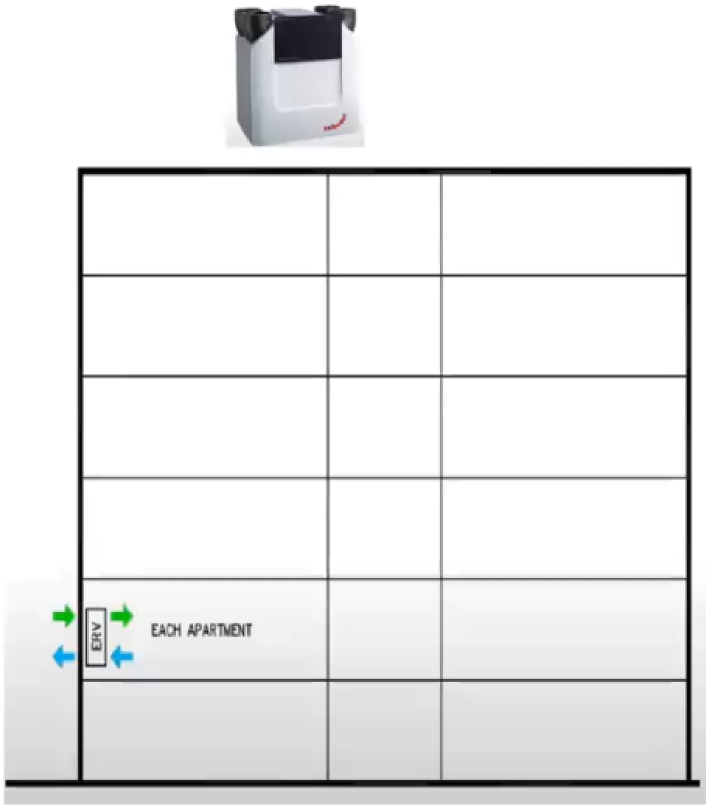
- Continuously running (variable speeds)
- Provides fresh filtered air into building
- Recovers heat from outgoing air
- Does not mix incoming/outgoing air
- ERVs also provide (some) humidity control



Ventilation

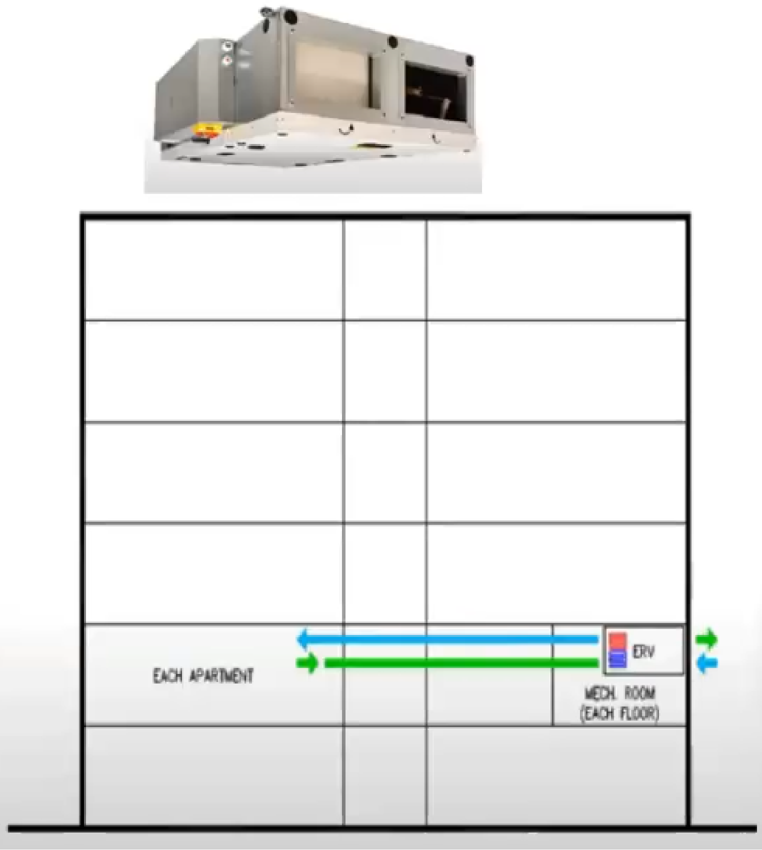
Unitized/Local

Ex: Distillery



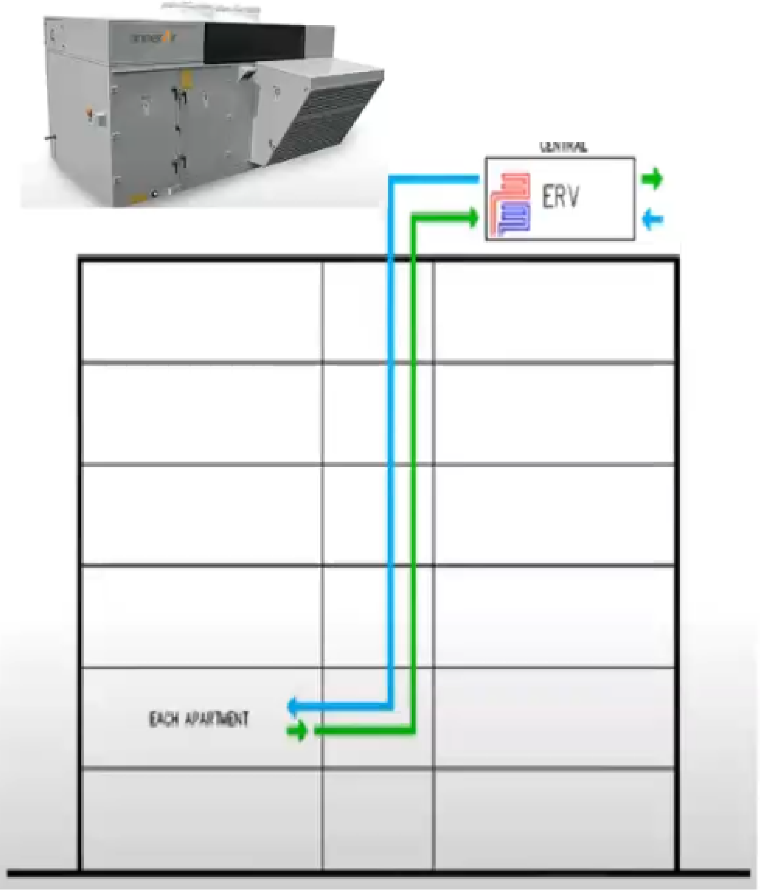
Hybrid/Floor

Ex: Mattapan Station



Centralized

Ex: Finch



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

PH Verifier: JSR Adaptive Energy Solutions

MEP: Petersen Engineering

PH Consultant: New Ecology

Finch Cambridge

Walls: 2x6 wood studs, dense packed fiberglass

Continuous Insulation: 2” mineral wool boards

Air Barrier: Siga Majvest 500

Roof: tapered polyiso over 1/2” plywood over 3.5”

CCSPF w/ 16/5” deep trusses

Floor: Floor over garage, concrete with 6” XPS

Air Tightness: 0.0562 cfm50

Harbor Village

Location: Gloucester, MA

Completed: 2021

Type: Multifamily Affordable Housing

Size: 30 units

Developer: North Shore CDC

Architect: ICON Architecture

GC: Groom Construction

MEP: Petersen Engineering

Struct Eng: Lim Consultants

PH Modeling/Verifier: New Ecology, Inc

Harbor Village

Walls: 2x6 wood studs, dense packed cellulose

Continuous Insulation: 2: rigid foam boards

Air Barrier: Siga Majvest 500

Tracy Community Housing

Location: West Lebanon, NH

Completed: 2020

Type: Multifamily housing (50/50 affordable/market-rate)

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

Tracy Community Housing

Wall: 2x6 wood studs, dense packed cellulose

Continuous Insulation: 4” polyiso (R40)

Air Barrier: Zip System

Roof: 11” polyiso (R62)

Floor: 5” rigid (R20)

Air Tightness: 0.044 cfm50

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,

Walls: Steel Frame, mineral wool in cavities

Continuous Insulation: 5” mineral wool

Air Barrier: Siga Majvest vapor permeable air barrier

Wheaton College Pine Hall

Walls: Steel Frame, mineral wool in cavities

Continuous Insulation: 5” mineral wool

Air Barrier: Siga Majvest vapor permeable air barrier

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

Townhomes

Walls: 2x6 wood frame with fiberglass batts

Continuous Insulation: 4” rigid

Roof: 8” closed cell foam

Floor: 4” ccf under slab on grade

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

Townhomes

Walls: 2x6 wood frame, dense packed cellulose

Continuous Insulation: 2” polyiso

Air Barrier: Zip System

Floor: 4” concrete slab with 8” sub-slab insulation

Roof: vented attic w/24" loose fill cellulose, flat roof w/8" polyiso, lobby roof w/6" polyiso

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)

Columbus Commons

Location: New Britain, CT

Completed: 2020 (Phase 1)

Type: affordable housing & mix-use

Size: 80 units

Developer: Xenolith Partners/Dakota Partners

Architect: Paul B. Bailey Architect

PH Consultant: Steven Winter Associates

Columbus Commons

Location: New Britain, CT

Completed: 2020 (Phase 1)

Type: affordable housing & mix-use

Size: 80 units

Developer: Xenolith Partners/Dakota Partners

Architect: Paul B. Bailey Architect

PH Consultant: Steven Winter Associates

https://www.courant.com/community/new-britain/hc-news-new-britain-columbus-commons-20190724-hog6eo5k7rdu3me7ky7nd4yeui-story.html

LESSONS LEARNED: DESIGN PHASE

- Bring together your **integrated team** early and often! All the aspects of the project need to be coordinated together from the beginning. Know your PH Rater/Certifier and take advantage of their expertise.
- **Continuity of critical barriers** - air barrier, WRB, thermal barrier, vapor barrier- and show those lines in the design drawings.
- Work with a **mechanical engineer** with experience in low energy buildings. Most engineers will oversize equipment.
- Consult your trades during the design process to identify any issues related to **constructability**.
- In cold climates using heat pumps, pay attention to **location of compressors** and keeping them out of snow.
- Pay attention to shading - south- and west-facing apartments can have **excessive solar heat gain**.
- Design for **energy monitoring** from the beginning. This may mean designing how circuits are installed/organized.
- Plan for **apartment compartmentalization** (unit to unit air tightness). This is required for EnergyStar (with PHIUS+).
- Design for **easy maintenance** - changing filters in minisplit heads, ERVs, etc. Consider how to educate tenants on building operations.

LESSONS LEARNED: CONSTRUCTION PHASE

Kickoff Meetings

At each stage in the construction process, convene a **kickoff meeting** on site with all the associated trades. Make sure everyone knows what they are responsible for, especially in the area of air sealing.

Build mock-ups showing installation techniques.

Invite **manufacturer reps** to answer questions about specific products.

LESSONS LEARNED: CONSTRUCTION PHASE

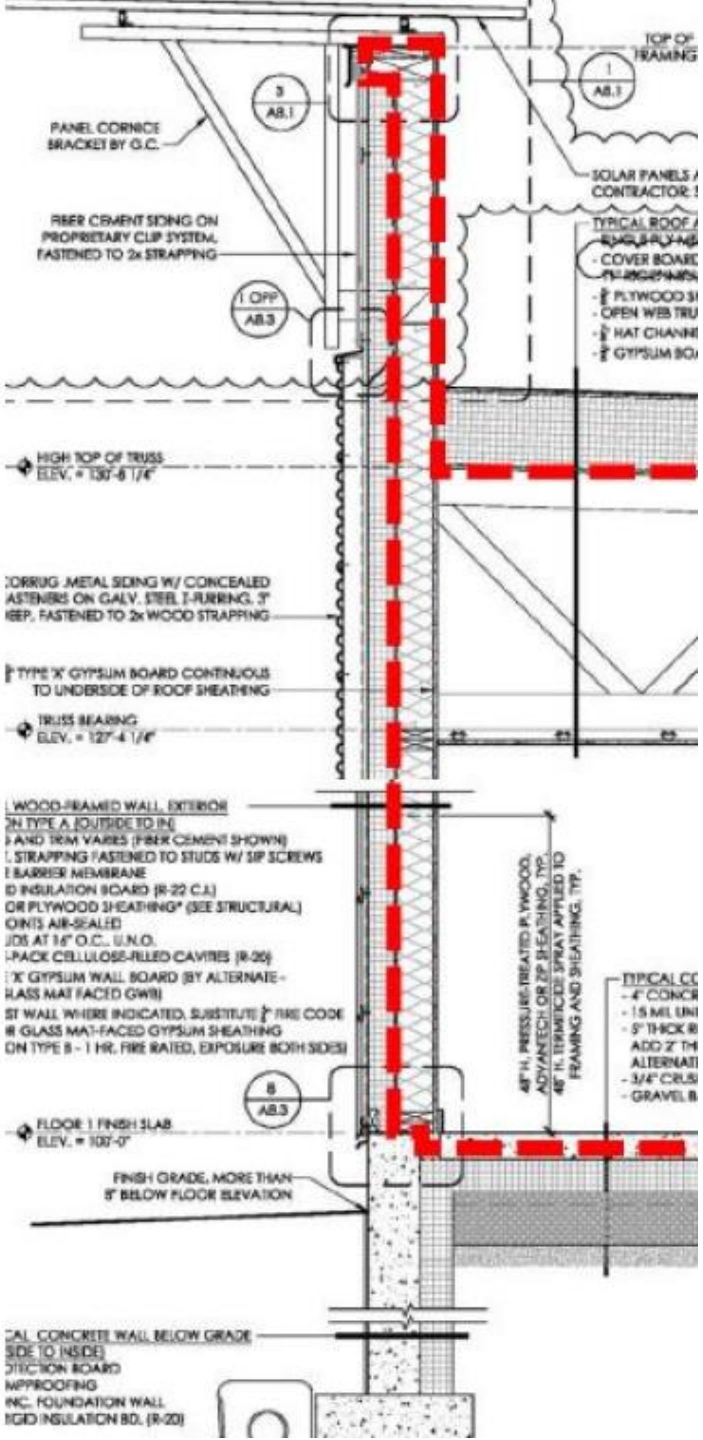
Know Your Air Barrier

Everyone on your team should know exactly where the air barrier lies in your assemblies.

Clearly label the air barrier on plan sets.

Identify who is responsible for maintaining the air barrier.

Signage can help remind your trade partners of their responsibility to inform the site supervisor to any unanticipated penetrations in the air barrier.



Source: Maclay Architects

LESSONS LEARNED: CONSTRUCTION PHASE

Blower Door Testing

Test early and often.

At minimum:
1. Full envelope test once windows and doors are installed (ideally after mechanicals are installed and sealed off)

2. After sheetrock, test individual apartments for compartmentalization

3. Pre-occupancy for final numbers

Smoke testing can be useful at preliminary stages to identify leaks in the envelope.

Source: Black Mountain Architecture

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Thank You

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