PASSIVE HOUSE 201
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 or email PassiveHouseTrainingCT@icf.com
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)

<table>
<thead>
<tr>
<th>Incentive Timing</th>
<th>Activity</th>
<th>Incentive Amount</th>
<th>Max Incentive (Per Unit)</th>
<th>Max Incentive (Per Project)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Construction</td>
<td>Feasibility Study¹</td>
<td>Up to 100% of Feasibility Study Costs</td>
<td>N/A</td>
<td>$5,000.00</td>
</tr>
<tr>
<td></td>
<td>Energy Modeling²</td>
<td>75% of Energy Modeling Costs (Before 90% Design Drawings)</td>
<td>$500.00</td>
<td>$30,000.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>50% of Energy Modeling Costs (90% Design/50% Construction)</td>
<td>$250.00</td>
<td>$15,000.00</td>
</tr>
<tr>
<td>Post Construction</td>
<td>Certification³</td>
<td>Up to 100% of Certification Costs</td>
<td>$1,500.00</td>
<td>$60,000.00</td>
</tr>
</tbody>
</table>

---

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 through PHIUS, PHI, or EnerPHit certification offerings.

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

Go to [EnergizeCT.com](https:// EnergizeCT.com) or call 1-877-WISE USE for more details.
The future of high-performance, all-electric homes starts here.
<table>
<thead>
<tr>
<th>LEVEL 1</th>
<th>LEVEL 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total UA Alternative Compliance or HERS Index Score</strong> ¹</td>
<td><strong>Total UA ≥ 75% better than 2021 IECC or HERS Index Score ≤ 55</strong></td>
</tr>
<tr>
<td>Heat pump for space heating ²</td>
<td>Required</td>
</tr>
<tr>
<td>Space Conditioning Connectivity &amp; Controls ³</td>
<td>Optional</td>
</tr>
<tr>
<td>Heat pump for water heating</td>
<td>Required</td>
</tr>
<tr>
<td>Hot Water Distribution ⁴⁵⁶</td>
<td>Required</td>
</tr>
<tr>
<td><strong>Envelope Infiltration Rate (ACH)</strong></td>
<td><strong>Duct Leakage Rate (CFM)</strong></td>
</tr>
<tr>
<td>ACH50 ≤ 2.5</td>
<td>2021 IECC code minimum requirements</td>
</tr>
<tr>
<td>CFA &gt; 850H2: ACH50 &lt; 4.0</td>
<td>All ductwork must be located in conditioned space</td>
</tr>
<tr>
<td>CFA &gt; 850H2: ACH50 ≤ 5.0</td>
<td></td>
</tr>
<tr>
<td>CFA &gt; 850H2: ACH50 &lt; 3.0</td>
<td></td>
</tr>
<tr>
<td>CFA &lt; 850H2: ACH50 ≤ 4.0</td>
<td></td>
</tr>
</tbody>
</table>

### ALL-ELECTRIC HOME INCENTIVE STRUCTURE

<table>
<thead>
<tr>
<th></th>
<th>Level 1</th>
<th>Level 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Family</td>
<td>$7,500</td>
<td>$10,000</td>
</tr>
<tr>
<td>Single Family Attached</td>
<td>$3,000</td>
<td>$5,000</td>
</tr>
<tr>
<td>Multifamily</td>
<td>$1,500</td>
<td>$2,500</td>
</tr>
</tbody>
</table>

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

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

BROUGHT TO YOU BY

Proud sponsors of

Eversource

CNG

SCG

UI

energize CT™
Part of the AVANGRID Family
Thank You

For more information, please visit EnergizeCT.com/passive-house or email PassiveHouseTrainingCT@icf.com
PASSIVE HOUSE 201
Your local Passive House group

ctpassivehouse.org
What did we learn before?

PASSIVE HOUSE

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

What is Passive House?
- Passive House is a 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.

How do Passive House Buildings Perform?
- 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.

The Distillery, South Boston
Passive House Building Standards

Passive House’s can be any building and any size

- Residential home, townhouse, multifamily building, commercial office, school, municipal building
Which of these buildings is a Passive House?
Passive House Organizations

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

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

*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 Massachusetts | www.PHMass.org
### Input

**Building Type**
- Passive House Massachusetts

**Location**
- Massachusetts

**Size**
- Envelope Area (ft²): 3,750.0
- HVAC Area (ft²): 2,000.0
- Dwelling Units (Count): 1
- Total Bedrooms (Count): 4

**Density**

### Output

**Metrics**
- Annual Heating Demand: 5.2 kBtu/ft²yr
- Annual Cooling Demand: 5.7 kBtu/ft²yr
- Peak Heating Load: 3.9 Btu/ft²hr
- Peak Cooling Load: 2.7 Btu/ft²hr
- Phius CORE: 3725 kWh/person.yr
- Phius ZERO: 0 kWh/person.yr
Advanced Energy Modeling

**WUFI Passive or PHPP (Passive House Planning Package)**

- Model heating and cooling demand, peak load, and total energy demand
- Model hygrothermal interactions between the indoor air and the building envelope
- Calculate the required performance level of individual components such as wall insulation, windows, etc. and their influence on the energy balance
- Account for all building components and systems, local climate data, and building use
- Determine the size and required performance of mechanical systems
- Account for internal and external heat gain sources
Passive House Metrics

Air Tightness Standard

Building Energy Code  Passive House*

3 ACH50  0.6 ACH50

(air changes per hour at 50 Pascals)  (air changes per hour at 50 Pascals)

*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
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
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
General Design Strategies

Massing and Form
• The more complicated the form, the more challenging it is to achieve air-tightness and thermal bridging reductions
General Design Strategies

**Building Orientation and Siting**
- Long face towards sun exposure
- Beware of trees and other buildings
General Design Strategies

**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
Glazing Percentage and Placement

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

Main Goals:
• Reduce thermal bridging from wall studs, headers, etc.
• Create more space for cavity insulation
• Save on lumber costs

Focus Areas:
• Stud Spacing (24” on-center)
• Corners
• Headers
Advanced Framing

Corners

Typical Framing

Advanced Option 1

Advanced Option 2
Advanced Framing

Headers

- Double top plate
- Sheathing
- 2x framing member
- Rigid insulation
- GWB
- Stud wall beyond

Sheathing nailed to header

- 2" rigid foam
- If foam is not sealed properly, moisture can condense on cool inside face of 2-bys
- 1/2" air space between drywall and rigid foam

2-bys nailed together placed to the outside

2x6 wall

https://www.greenbuildingadvisor.com/article/better-energy-efficiency-with-insulated-headers

https://www.jlconline.com/how-to/insulation/insulated-headers
Cavity Insulation

- Fiberglass
- Mineral Wool
- Cellulose
- Spray-Foam
Proper installation is critical:

- Dense-packed insulation will settle if installed at a lower density than required
- Batts must be sized currently for the cavity to gaps at sides
- Looser insulation can get compressed during install, reducing performance
- Spray foam may not expand to desired thickness
Exterior Insulation

Mineral Wool Boards

Polyiso

Wood Fiber Boards

EPS/XPS Foam
Exterior Insulation

• Type of insulation will be driven by costs, familiarity, and project goals (such as reducing embodied carbon)

• Amount of insulation will be determined with energy modeling (WUFI or PHPP) and will take into account internal heat loads, thermal bridging, and other factors

Distillery
• 3” Mineral

Finch Cambridge
• 2” Mineral

Wheaton College
• 5” Mineral
Exterior Insulation

Before continuous insulation

After continuous insulation

Finch Cambridge
Thermal Bridging

Thermal Bridges

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

- Passive House requires focus on reducing the amount of, and mitigating the impact of, thermal bridges through the envelope
Thermal Bridges lead to:
• Heat loss
• Low surface temps
• Impaired thermal comfort
• Risk of condensation
• Risk of mold growth

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

Thermal Breaks

Without Thermal Break

With Thermal Break
Thermal Bridging

 Thermally Broken Steel Support
Thermal Bridging

The Tyler
Floor slab to exterior wall connections

Floor slab at exterior wall with conditioned apartments above and below. Insulation below slab near exterior edge raises temperature above the dewpoint of 49°F.
Thermal Bridging

Finch Cambridge
Building Envelope Layers

- **R-34 WHOLE WALL**
  - [R-38 CENTER OF CAVITY]
  - Drywall
  - 5.5” high density fiberglass
  - 2x6 stud wall
  - ZIP System Sheathing

**Air Management**
- ZIP Sheathing

**Heat Management**
- 3.5” of exterior mineral wool insulation (R-14)
- 5.5” of high density fiberglass insulation (R-23)

**Water Management**
- Primary barrier: Siding
- Secondary barrier: ROXUL mineral wool
- Final barrier: ZIP Sheathing
- Rain screen allows bulk water to drain away

**Vapor Management**
- 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.

Passive House Massachusetts | www.PHMass.org
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

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

- Taped Sheathing
- Membrane Sheet
- Fluid-applied
- Vaporized Sealant
Air Barrier

Air Barrier needs to be continuous!
• Red Line Test – can you follow the air barrier without lifting your pencil?
Continuous Air Barrier --- Watch the critical connections (floor to wall, etc.)
Air Barrier

Continuous Air Barrier

• Watch the critical connections
Air Barrier

Continuous Air Barrier
• Watch for penetrations, tapping details, etc
Air Barrier

Continuous Air Barrier

• Use recommended products including tapes and seals
Air Barrier

Continuous Air Barrier

• Pay attention to install sequencing and proper layering of the air barrier
Air Barrier

Continuous Air Barrier

• Pay attention location of penetrations and sealing methods

Pipe location does not leave enough room for seal
Blower Door Test Times (Minimum Recommendation)

1. Full envelope test once windows and doors are installed – ideally after mechanicals are installed and sealed off)

2. After sheetrock, test individual apartments/units for compartmentalization

3. Pre-occupancy whole building test

Tips
• Isolate the trouble zones (for Harbor Village this was the lobby)
• Use smoke testing to “follow the leaks”
• Have contractor there for as many tests as possible
Air Tightness Testing

Blower Door Tests – Early and Often - Harbor Village example

Midpoint Test 1

Midpoint Test 2

Photos from New Ecology, Inc
A *rainscreen* is a system that creates a gap *between the siding and the water-resistive barrier* (or exterior insulation) and promotes *drainage* and *airflow* within the wall assembly.

Rainscreen with vertical strapping and coravent at top and bottom of wall
Water Control Layers

Water needs a path to follow - and plan for it to fail:

1. Flow off the shingles and siding and gutters

2. Drip out weeps and off sills

3. Dry out from the inside
**Water Control Layers**

**Drainage Mats**

Homeslicker by Benjamin Obdyke provides ¼” gap for water to drain

**Vertical or Horizontal Battens**

Rainscreen w/ 1x3 strapping provides ¾” drainage and ventilation gap

Passive House Massachusetts | www.PHMass.org
Finch Cambridge - Cascadia Clips
The Loop – Knight Wall System
Both provide rainscreen and thermally broken siding connections
Building Envelope Layers

- **AIR MANAGEMENT**
  - ZIP Sheathing

- **HEAT MANAGEMENT**
  - 3.5" of exterior mineral wool insulation (R-14)
  - 5.5" of high density fiberglass insulation (R-23)

- **WATER MANAGEMENT**
  - Primary barrier: Siding
  - Secondary barrier: ROXUL mineral wool
  - Final barrier: ZIP Sheathing
  - Rain screen allows bulk water to drain away

- **VAPOR MANAGEMENT**
  - 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.

---

Drywall
- 5.5" high density fiberglass
- 2x6 stud wall
- ZIP System Sheathing

1x6 knotty cedar siding
- Rain screen battens
- 3.5" ROXUL mineral wool
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

Can be undocked (aka mini-split system) or use tradition (but better sealed) air ducts

- Cold climate models remain effective in below zero temperatures
Air-Sourced Heat Pumps and VRF Systems

Variable Refrigerant Flow (VRF)

• All-electric solution for larger buildings
• Heat-Recovery versions can provide heating and cooling within the same zone at the same time
• Non-Heat Recovery versions are in either heat or cool mode

- Central VRF

Outdoors

• Inverter (variable speed) scroll compressors
• Central controller monitors and reacts to all indoor unit expansion valves, and throttles inverter compressor

Air-Sourced Heat Pumps and VRF Systems

Passive House Massachusetts | www.PHMass.org
Mechanical System Sizing and Selection

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
Mechanical System Sizing and Selection

Unitized/Local
Ex: Distillery

Hybrid/Floor
Ex: Mattapan Station

Centralized
Ex: Finch

Passive House Massachusetts | www.PHMass.org
Mechanical System Sizing and Selection

Wall Penetrations

Central vs. Unitized: Wall penetrations from in-unit ERVs

Roof Space
Mechanical Systems (on not!?)

Rocky Mountain Institute Innovation Center

- No central heating or cooling system
- Relies on solar heat gain, thermal mass (concrete floors), and interior heat sources (i.e. people)
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)
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 manager 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
Lessons Learned: Project Management

- Communication is key!
- Highlight PH details on all schedules – in color!
- Review details and sequencing with GC/trades/subs
- Post *Airtight Building* signs for the duration of project
- Assign responsibility for air barrier to specific people
- Plan schedule for multiple blower door tests and walkthroughs
Questions?
Thank You

For more information, please visit EnergizeCT.com/passive-house or email PassiveHouseTrainingCT@icf.com