PASSIVE HOUSE 102: Multi-Family Passive House Buildings & Design

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

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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.

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

Go to [EnergizeCT.com](http://EnergizeCT.com) or call 1-877-WISE USE for more details.

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Part of the AVANGRID Family
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 compared to a typical building
Performance Comparison

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

<table>
<thead>
<tr>
<th></th>
<th>Energy Use Intensity Comparison (site kBTU/SF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distillery</td>
<td>24</td>
</tr>
<tr>
<td>Blended Boston Area Code</td>
<td>62</td>
</tr>
<tr>
<td>Cold Climate Midrise with a…</td>
<td>53</td>
</tr>
</tbody>
</table>
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

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

Phius Housing Units (In Process or Complete)

Data from PHIUS projects database
The Growth of Passive House

State incentives have helped fuel this growth in Massachusetts

Annual Passive House Units and Projects

Construction Completion Year

Data from Mass Save Incentive program
The Incremental Cost of Achieving Passive House

- Finch Cambridge 1.4%
- Harbor Village 1.5%
- Hanson Village 2.6%
- Old Colony 2.8%
- North Commons 2.6%
- Mattapan Station 2%

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 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) 34.8 kBtu/ft² (Commercial)</td>
<td>60 kWh/m² (all projects)</td>
</tr>
</tbody>
</table>

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

**Building Information**

<table>
<thead>
<tr>
<th>Category</th>
<th>Non-residential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Status</td>
<td>Under construction</td>
</tr>
<tr>
<td>Building type</td>
<td>Office</td>
</tr>
<tr>
<td>Year of construction</td>
<td>2016</td>
</tr>
<tr>
<td>Units</td>
<td>5 (Design)</td>
</tr>
<tr>
<td>Number of occupants</td>
<td>251 /Person</td>
</tr>
<tr>
<td>Occupant density</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Boundary conditions</th>
<th>Building geometry</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Climate</strong></td>
<td><strong>Volume</strong></td>
</tr>
<tr>
<td>BOSTON LOGAN INT APT</td>
<td>20,163 ft³</td>
</tr>
<tr>
<td><strong>Internal heat gain</strong></td>
<td>15 kWh/m²</td>
</tr>
<tr>
<td>1.5 Btu/ft²</td>
<td>10,052 ft³</td>
</tr>
<tr>
<td><strong>Interior temperatures</strong></td>
<td><strong>Area/Volume Ratios</strong></td>
</tr>
<tr>
<td>77 °F</td>
<td>Area/Volume</td>
</tr>
<tr>
<td></td>
<td>0.30</td>
</tr>
<tr>
<td><strong>Overheating temperatures</strong></td>
<td><strong>Floor area</strong></td>
</tr>
<tr>
<td>77 °F</td>
<td>1,255 ft²</td>
</tr>
<tr>
<td></td>
<td>Envelope area/SA</td>
</tr>
<tr>
<td></td>
<td>4.39</td>
</tr>
</tbody>
</table>

**Passive House Requirements**

<table>
<thead>
<tr>
<th>Certificate criteria: PHIUS+ 2019</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating demand specific:</td>
</tr>
<tr>
<td>target:</td>
</tr>
<tr>
<td>total:</td>
</tr>
<tr>
<td>Cooling demand specific:</td>
</tr>
<tr>
<td>target:</td>
</tr>
<tr>
<td>total:</td>
</tr>
<tr>
<td>Heating load specific:</td>
</tr>
<tr>
<td>target:</td>
</tr>
<tr>
<td>total:</td>
</tr>
<tr>
<td>Cooling load specific:</td>
</tr>
<tr>
<td>target:</td>
</tr>
<tr>
<td>total:</td>
</tr>
<tr>
<td>Source energy:</td>
</tr>
<tr>
<td>specific:</td>
</tr>
<tr>
<td>target:</td>
</tr>
<tr>
<td>total:</td>
</tr>
<tr>
<td>Site energy:</td>
</tr>
<tr>
<td>specific:</td>
</tr>
<tr>
<td>target:</td>
</tr>
<tr>
<td>total:</td>
</tr>
<tr>
<td>Air tightness:</td>
</tr>
<tr>
<td>CHF600 per envelope area:</td>
</tr>
<tr>
<td>target:</td>
</tr>
<tr>
<td>total:</td>
</tr>
</tbody>
</table>

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 Metrics

## Air Tightness Standard

<table>
<thead>
<tr>
<th>Building Energy Code</th>
<th>Passive House*</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 ACH50</td>
<td>0.6 ACH50</td>
</tr>
</tbody>
</table>

(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 form, 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 incorrect placement, can negatively impact solar heat gain
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
• $R \geq 40-50$
• Insulation 10-12”
Roof
• $R \geq 40-60$
• Insulation 12-16”
Floor (on-grade)
• $R \geq 25-30$
• Insulation 6-12”
Air Tightness

Main Principles:
- Continuous air barrier around building
- Eliminate air gaps, holes, etc. in barrier
- Taped seams, 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
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 (compared 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 sq 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.
Thank You

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