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>
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<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 either through PHIUS, PHI, or EnerPHit certification offerings.

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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Heat Pump Design and Installation Best Practices
Adam Romano C.E.M.
Principal Building Systems Consultant
aromano@swinter.com
212.564.5800 x1110
Since 1972, Steven Winter Associates, Inc. has been providing research, consulting, and advisory services to improve the built environment for private and public sector clients.

Our services include:

- Energy Conservation and Management
- Sustainability Consulting
- Green Building Certification
- Accessibility Consulting

We have over 125 staff across four office locations: New York, NY | Washington, DC | Norwalk, CT | Boston, MA

For more information, visit www.swinter.com
New Single Family

• Can control the loads with good air sealing and insulation
• Match that load with the right sized system
• Do a great job designing and installing to optimize performance
Existing Single Family

- Paybacks and ROI’s for HPs work well in retrofits
- Especially when the replace delivered fuels like oil or propane
Passive House MF

- Heat Pumps in high-performance (Passive House) perform very well when very small capacity equipment is used
Learning Objectives

Understand heat pump technology and its applications

Determine the most appropriate system configuration

Recognize the signs of a quality installation

Properly commission new installations
System Design: Sizing and Selection
As a first step, gather the information that is needed to determine what the most appropriate heat pump option is for a particular home.
Customer **Goals**

- Comfort
- Cost Savings
- Environment
Home Layout

- Open Floor Plan
- Compartmentalized
Proper Sizing is Key

**Too Small**
System will not keep the house warm on the coldest days
- Poor comfort, or need for backup heat
- Slow catch up if using thermostat setbacks

**Too Big**
System will cycle on and off
- Poor comfort
- Poor energy efficiency
- Poor durability
- More expensive

**Just Right**
- Comfort
- Efficiency
- Durability
Resources

1. Guide to Sizing & Selecting ASHPs in Cold Climates
   http://www.neep.org/sites/default/files/Sizing%20%26%20Selecting%20ASHPs%20In%20Cold%20Climates.pdf

2. Guide to Installing ASHPs in Cold Climates

ACCA

- ACCA Manual J: Residential Load Calculation
- ACCA Manual D: Residential Duct Design
- ACCA Manual T: Air Distribution Basics
- ACCA Manual S: Residential Equipment Selection
System Types **Mini-Split**

- Smaller decentralized air-source heat pump systems
  - Split and Mini Split <1.5 Tons

- Here are one-to-one systems where you'll have one outdoor unit coupled with one.

- Indoor units are typically small and that indoor unit can be either ductless or ducted.
System Types **Multi-Split**

• This is again one outdoor unit, but it's connected to multiple indoor units.

• We would have refrigerant piping going from the outdoor unit to a couple of indoor units
  • One outdoor unit
  • 2+ indoor units
  • Ducted, Ductless, or mix
  • 1.5 – 4 tons typ.
Multi-Zone, Multi-Split

- MA Study: More Fan Coils = Less Efficient!
- **Oversizing** one likely reason
- 1 ductless head/bedroom is oversized!
- At least one mfr acknowledges this:

  “The outdoor unit should not be selected based on how many indoor units are desired. If the outdoor unit is oversized just to provide a certain number of indoor units for each of the zones, overheating, humidity issues and **higher than expected energy usage** can occur.”

  “If an indoor unit nominal capacity is more than 50% higher than the maximum heating or cooling load in a space... humidity, overheating and higher than expected system **energy usage** can occur. This space should not have its own indoor unit.”

http://meus1.mylinkdrive.com/sfiles/M_Application_Note_1036_Applying_MXZ-C_Multi-Zone_Systems-20190530.pdf
**System Types** Central Split

- One outdoor unit, one central ducted air handler
- More conventional residential A/C system
  - Typ. 2 - 5 tons
  - “Fully ducted”
### American Standard / Mitsubishi Electric M-Series H2i

- **Singlezone Non-ducted Wall Placement**
- **AHRI Cert #: 202373691**
- **Outdoor Unit #: NAXSPB18A112AA**
- **Indoor Unit #: NAXWPH18A112AA**
  - Maximum Heating Capacity (Btu/hr) @5°F: 20,900
  - Rated Heating Capacity (Btu/hr) @47°F: 20,300
  - Rated Cooling Capacity (Btu/hr) @95°F: 17,200

### Performance Specs

<table>
<thead>
<tr>
<th>Heating / Cooling</th>
<th>Outdoor Dry Bulb</th>
<th>Indoor Dry Bulb</th>
<th>Unit</th>
<th>Min</th>
<th>Rated</th>
<th>Max</th>
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</thead>
<tbody>
<tr>
<td>Heating 5°F</td>
<td>70°F</td>
<td>Btu/h</td>
<td>2,696</td>
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<td></td>
<td></td>
<td>kW</td>
<td>0.21</td>
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<tr>
<td></td>
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<td>COP</td>
<td>3.76</td>
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<td>-</td>
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<tr>
<td>Heating 17°F</td>
<td>70°F</td>
<td>Btu/h</td>
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<td>11,500</td>
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<td>1.15</td>
<td>2.1</td>
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<tr>
<td></td>
<td></td>
<td>COP</td>
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<td></td>
<td>2.93</td>
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<tr>
<td>Heating 47°F</td>
<td>70°F</td>
<td>Btu/h</td>
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<td></td>
<td>18,000</td>
<td>20,000</td>
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<td></td>
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<td></td>
<td>1.28</td>
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<td></td>
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<td>COP</td>
<td>5.34</td>
<td></td>
<td>4.12</td>
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<tr>
<td>Cooling 82°F</td>
<td>80°F</td>
<td>Btu/h</td>
<td>3,367</td>
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<td>19,755</td>
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<td>-</td>
<td>1.4</td>
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<tr>
<td></td>
<td></td>
<td>COP</td>
<td>6.58</td>
<td></td>
<td>-</td>
<td>4.14</td>
</tr>
<tr>
<td>Cooling 95°F</td>
<td>80°F</td>
<td>Btu/h</td>
<td>3,070</td>
<td></td>
<td>18,015</td>
<td>18,015</td>
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<td></td>
<td></td>
<td>kW</td>
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<td></td>
<td>1.44</td>
<td>1.63</td>
</tr>
<tr>
<td></td>
<td></td>
<td>COP</td>
<td>5</td>
<td>3.67</td>
<td>3.24</td>
<td></td>
</tr>
</tbody>
</table>

---

**SEER**: 21  
**EER**: 12.5  
**HSPF Region IV**: 11  
**Energy Star**: ✔️  
**Variable Capacity**: ✔️  
**Maintenance Capacity (Max 5°F/Max 47°F)**: 68%  
**Maintenance Capacity (Max 5°F/Max 17°F)**: 86%  
**Maintenance Capacity (Max 5°F/Rated 47°F)**: 102%  

https://neep.org/ASHP-Specification
Comparing Performance

Two “one-ton” ductless heat pumps:

<table>
<thead>
<tr>
<th></th>
<th>Outdoor: 47°F</th>
<th></th>
<th>Outdoor: 5°F</th>
<th></th>
<th>Outdoor: -13°F</th>
</tr>
</thead>
<tbody>
<tr>
<td>HSPF</td>
<td>Max. Cap</td>
<td>COP</td>
<td>Max. Cap</td>
<td>COP</td>
<td>Max. Cap</td>
</tr>
<tr>
<td>HP A</td>
<td>12.5</td>
<td>18,000 Btu/h</td>
<td>4.15</td>
<td>8,051 Btu/h</td>
<td>2.81</td>
</tr>
<tr>
<td>HP B</td>
<td>12.5</td>
<td>21,000 Btu/h</td>
<td>2.68</td>
<td>13,600 Btu/h</td>
<td>2.21</td>
</tr>
</tbody>
</table>

https://neep.org/ASHP-Specification
Installation Considerations
Indoor Unit

• Placement of the indoor unit serves as a major driver for a system’s overall efficacy.
  • The ASHP head must be placed so it can circulate air through the entire conditioned space and can provide a uniform comfort level.
High Return Temp?

Listed Performance of FE18 vs. Return Temperature

- Capacity @ 5°F
- COP @ 5°F
Indoor Unit

• Overflow switch is designed to shut off the equipment served in the event that the primary drain becomes restricted.
Outdoor Unit

- Placement of the outdoor unit is just as critical as the placement of the indoor unit.
  - The ASHP must be placed to allow for unimpeded airflow through the unit (follow manufacturers recommendations)
  - The ASHP must be attached to the bracket and vibration dampers installed.
The outdoor unit, whether its being installed on a pad or a wall bracket, needs to be installed level from side to side and back to front.

If installing a pad be sure to dig down and compress the soil to prevent settling.
Stacked Outdoor Units

- The defrost function is designed to remove ice build up on the outdoor unit heat exchanger.

- If installing outdoor units in a stacked configuration, ensure the runoff produced from defrost does not drip down on the units below.
Outdoor Unit Placement

- Do not install outdoor units directly under any drip line from the roof or other overhang that would subject the outdoor unit to falling snowmelt or concentrated rain runoff.

Source: Steven Winter Associates
Snow is a Design Consideration

Wrong installation

Unit may become buried in snow due to heavy snowfall, snow sliding off the roof or snowdrift.
Line Set Installation

• ACR tubing can be bent easily, preventing the need for additional fittings.
  • Reduce likelihood of refrigerant leaks
• A variety of tubing benders are available.
  • Smaller diameter tubing is easier to bend without a tubing bender.
Improper heating is the primary reason for poorly made joints. The method of heating the joint must get both pieces, the pipe and the fitting to proper temperature before the filler material is applied.
Proper Brazing Techniques

- Purging nitrogen through the copper tubing during brazing.
- Oxygen in the air combines with copper at high temperature to form a heavy scale (copper oxide).
Proper Flaring Techniques

- Flare joints are the primary mechanical connection between the refrigerant line set and the indoor and outdoors units.
- Ensure the flare is made properly and that the flare nut is not overtightened
Pressure Testing

- Once you have the refrigerant line set properly installed, we need to make sure there are no leaks.
- A pressure test with nitrogen can be performed following manufacturers recommendations.
Line Set Insulation

- Line set insulation must cover the entire line set to avoid condensation and energy loss.
  - Once insulated the outdoor portion of the line set shall be protected to avoid insulation damage and UV degradation.

Source: Bruce Harley Energy Consulting, LLC
Line Set Insulation

- Once insulated the outdoor portion of the line set shall be protected to avoid insulation damage and UV degradation.
Line Set Installation

- Once the line set is installed, seal the openings with an approved sealant to prevent air movement and pest intrusion.
- A line set cover can be installed to protect the line set and help improve aesthetics.
Evacuation

- Micron Scale
- Confirm no leaks
- Confirm no moisture

---

### Evacuate and Charge

<table>
<thead>
<tr>
<th>LotBlock</th>
<th>N-101</th>
<th>Chk</th>
<th>NA</th>
<th>Iss</th>
</tr>
</thead>
</table>

**Evac and Charge**

- Confirm test pressure at 95 -100 PSI: 
  - ✔
- Confirm CU connected to the correct Apt: 
  - ✔
- Evacuate to 30" hg and Charge by weight: 
  - ✔
- 0-15F1: 0 lbs-0 ozs
  - ✔

---

### Triple Evacuation

**Triple Evacuation**

- DON'T Cut Corners!

- **Pressure/Leak Testing**
  - Pressure to the system to 600 PSIG
  - System must hold a pressure of 600 PSIG for a minimum of 24 hours

- **Confirm**
  - Micron Scale
  - Confirm no leaks
  - Confirm no moisture

- **Chk**
  - ✔

---

**Triple evacuation**

- Evacuate the system to 4,000 microns from both service valves where available. System manifold gauges must not be used to measure vacuum. A micrometer must be used at all times.

- Evacuate the system to 1,500 microns from the suction service valve. The suction service valve must be closed. The suction service valve must have a vacuum of 2 PSIG (or less) before proceeding. System must hold a pressure of 600 PSIG for a minimum of 24 hours.

- Evacuate the system to 20 microns. System must hold the vacuum at 500 microns for a minimum of 1 hour.
Charging

• We need to determine the volume of refrigerant that needs to be added.

• Measure twice charge once
Wiring

• Ensure that the overcurrent protection device is labeled, and the correct size based on the manufacture’s requirements
• Ensure the conductors are the correct size and compatible with the terminals.
Wiring

- A disconnect switch needs to be installed at the outdoor unit to allow for service, and the ability to deenergize the unit in the event of an issue.
- The disconnect switch should be located within arms reach of the service panel of the outdoor unit.
Wiring

- Install the input power and indoor unit wiring at the terminal block.
  - Firmly tighten the terminal screws and ensure the connections are tightly fastened.
- Ensure the system is properly grounded.
Wiring

- The power and communication cable is then connected to the indoor unit(s).
- Ensure that the correct wire is attached to the correct terminal at the terminal block.

<table>
<thead>
<tr>
<th>Unit</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>Ground</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outdoor Unit</td>
<td>Black</td>
<td>Red</td>
<td>White</td>
<td>Green</td>
</tr>
<tr>
<td>Indoor Unit</td>
<td>Black</td>
<td>Red</td>
<td>White</td>
<td>Green</td>
</tr>
</tbody>
</table>
Wiring

• Install 3-pole disconnect switch, in order to deenergize the indoor unit for service or repair.
Controls

- Wall-mounted thermostats preferred
  - Instead of remote controls
- Prioritize use of Heat Pump for heating
  - Manually adjust systems
  - Two(+) stage thermostats
  - [https://nyserda.ny.gov/qualified-integrated-controls](https://nyserda.ny.gov/qualified-integrated-controls)
- Dual-fuel systems typ. have built-in controls
Start-Up

• Verify proper voltage at outdoor and indoor units.
• Perform heating and cooling mode check.
• Record return and supply temperatures at indoor unit(s)
• Test condensate drains
Additional Considerations: Challenges and Solutions
Challenges & Solutions

Challenge: ASHP Capacity at Cold Temperatures

Possible Solutions:
- Lower the load
- Use multiple ASHPs
- Use ASHPs to meet part of the load
- Some combination
Challenges & Solutions

Challenge: **Comfort** Supply Air Temperature
- ASHP supply temp ~90-125°F

Possible Solutions:
- Lower the load
- Assess room-by-room loads & comfort concerns
- Use ASHPs to meet part of the load
- Some combination
Challenge: **Air Volume**, Duct Size (Meeting Load)

<table>
<thead>
<tr>
<th>Air Flow</th>
<th>Supply Temperature</th>
<th>Heat Delivered</th>
</tr>
</thead>
<tbody>
<tr>
<td>60 cfm</td>
<td>150°F</td>
<td>4,800 Btu/h</td>
</tr>
<tr>
<td>60 cfm</td>
<td>110°F</td>
<td>2,400 Btu/h</td>
</tr>
</tbody>
</table>

Possible Solutions:
- Lower the load
- Measure pressure/flows before, modify ducts as needed
- Use ASHP for part of the load
Central Ducted Challenges & Solutions

Challenge: **Duct Leakage** and Insulation

Solution:
- Insulate and seal ducts!
Challenges & Solutions

**Challenge:** Electrical Capacity

Solution:
- Upgrade the electrical service
- Install a sub-panel
In Summary

- Reducing building loads reduces the size of the heat pump, which improved cost effectiveness, performance, and capacity.
- Reduce refrigerant line lengths and make sure piping is protected from damage.
- Ensure units are installed at a height that will ensure performance.
- Stay up-to-date with new alternatives.
Questions?

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

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