Cold Climate Ductless Heat Pump Specification and Recommendations

Guidance for Northwest IECC Climates Zones 5 and 6 (RTF Heating Zones 2 and 3)
Version 2.0 – September 2020

A relatively new class of inverter driven mini-split heat pump or ductless heat pumps (DHPs) are capable of providing comfortable heating for a home when outdoor temperatures are as low as -15°F. These units are well suited for cold climates with little or no need for supplemental or backup heating. This document provides learning gathered from HVAC and building science professionals regarding optimizing performance and comfort when installing mini-split heat pump systems (DHPs, low-head "short ducted" and multi-head) in climates where winter temperatures commonly drop below 20 degrees Fahrenheit.

This document is for utility program staff that can be leveraged for both contractor and homeowner facing materials. The primary focus is on existing homes where the DHP is used to add cooling and displace more expensive wood or electric resistance heating. These "displacement systems" are installed in homes with a pre-existing heating system (baseboard, forced air, etc.). Some or all of the pre-existing system remains in place and the DHP system is allowed to offset as much load as possible.

The document provides guidance how to get the best performance and longevity out of a cold climate DHP. It also includes discussion of unique design considerations for multi-level homes, very low load homes, and air distribution in rooms without a heat source.

CONTENTS

Disclaimer: This is not a design document, nor is it intended to replace professional design practices. Heat pumps should be installed by licensed, trained professionals. Always follow manufacturers' specifications and installation instructions and all applicable building codes and regulations.

COLD CLIMATE DUCTLESS HEAT PUMP DEFINITION & SPECIFICATION

The term "cold climate" is a general term used to describe any location that experiences extended periods of below freezing temperatures. For the purpose of this document, it is assumed to be in IECC-defined climate zones[1] 5 or higher or Regional Technical Forum (RTF) heating zones 2 or 3[2]. In the Northwest, this generally consists of locations east of the Cascade mountains and most of Montana and Idaho but may also include higher elevation areas west of the Cascade mountains. Homes in IECC climate zone 4 (RTF heating zone 1) should be treated as "cold climate" if historic local weather records show periods near or below 5°F.

A cold climate DHP (ccDHP) refers to those that meet the following minimum specifications:

1. Compressor must be variable capacity (inverter type)
2. Indoor and outdoor units must be part of an AHRI matched system
3. AHRI matched system must be rated ≥ 10.0 HSPF
4. AHRI matched system must have ≥1.75 COP at 5°F
5. Deliver ≥80% of rated[3] capacity at 5°F
6. If a drain pan heater is present, it may only run as part of the defrost cycle

Applying the Northwest Specifications to the NEEP Qualified Products List

The Northeast Energy Efficiency Partnerships (NEEP) maintains a list of cold climate air-source heat pumps. This list includes most variable capacity heat pumps (ducted and ductless) currently sold in North America with a COP at least 1.75 at 5°F as reported by the manufacturer. The NEEP List contains AHRI HSPF and SEER ratings and additional data on capacity and performance not typically found in general product literature. The additional 5°F data on the list is provided voluntarily by the manufacturers and is not part of the AHRI test procedure requirements. This list also includes air source heat pumps, central ducted, and ducted mini-split heat pumps.

For Northwest parties following the recommendations in this document and consulting the NEEP qualifying product list, NEEA recommends filtering the NEEP list for ductless products meeting the additional criteria of a minimum 80% rated capacity at 5°F

NEEA maintains a Northwest Specification-filtered version of the NEEP product list for Northwest utility access at Conduit.org. Members of the Alliance may also request their own log-in account to download the full, searchable NEEP list. To access either of these resources submit a request to info@neea.org.

HSPF and SEER as Proxies for Performance

NEEA, NEEP, Natural Resources Canada and California utilities lack confidence that the existing performance metrics for air-source heat pumps (HSPF and SEER) provide the necessary information to adequately characterize heating and cooling performance under all operating conditions. For example, the current HSPF performance metric does not include low temperature testing points below 17°F, assumes the use of electric resistance elements, and tests in steady-state operation (as opposed to allowing modulation). These deficiencies add up to measurements that do not accurately reflect real-world performance of the latest generation of air-source heat pumps, designed and optimized to provide heat efficiently. For this reason, the following recommendations have been developed to achieve greater certainty in low temperature performance.

[1] https://basc.pnnl.gov/images/iecc-climate-zone-map
[2] https://nwcouncil.box.com/v/ClimateZoneCalculationWorkbook
[3] "Rated" refers to the capacity of the heat pump at 47°F

RECOMMENDED PRACTICES

Install a Cold Climate Heat Pump in Cold Climates

Any DHP used to provide displacement or primary heating for a space located in a cold climate should meet the cold climate DHP specification. Less expensive non-cold climate DHPs may work well when outdoor temperatures are above freezing, but they will have diminished capacity and will require secondary or supplemental heating systems when it gets cold. This significantly compromises the annual energy savings of the DHP. Secondary or supplemental heating should not be needed in the zone (space) a cold climate DHP is designed to serve.

Ensure Building Efficiency

Insulate and reduce air leaks in the house before upgrading your HVAC system. In existing buildings, the best practice is to address any building envelope and weatherization needs (insulation, air leaks/bypasses, existing duct disconnects/leaks, etc.) before installing new equipment. This provides multiple benefits: reducing heating & cooling costs, improving comfort and heat pump performance, reducing the required size and capacity of equipment required, and thus reducing the cost of the system install. Enlist the help of a home performance professional to diagnose and correct these issues. Many utilities offer resources to support home weatherization and performance upgrades.

Calculating Design Load

Establishing how much heating and cooling the space needs at design conditions is essential to keeping first cost low and maximizing the performance, comfort and longevity of a DHP system.

- Cold climate heat pumps should not be sized using “old-school” rules for heat pumps as they can deliver sufficient capacity even when it is very cold outside, and the best have 90% of rated capacity at very cold ambient temperatures.
- Size the cold climate heat pump to approximately 125% of the zone load at the local design temperature. This ensures the DHP has sufficient capacity to re-heat a cold house, without causing poor performance under mild conditions.
- Use a room-by-room load calculator to estimate the zone load when **any** of these are true:
    1. The zone has more than 25% window to floor area ratio.
    2. The zone has large unshaded south or west facing windows with potentially very high cooling loads.
    3. The zone is isolated from the rest of the home, such as a “peninsula” with only one or two shared walls.
- While a room-by-room heat loss calculator is the gold standard for proper sizing, a cold climate heat pump will generally perform well by estimating the design load using the table below.

Design Load Rough Estimator - Btuh/sq.ft.	Climate (design temperature F)			
House Description	below -10°F	-10°F to 5°F	5°F to 20°F	above 20F
No-wall Insulation	47	41	35	Not a Cold Climate
2x4 construction w/insulation	25	22	19	
2x6 construction w/insulation	18	15	13	
New Construction (post 2012)	16	14	12	

This applies to only area conditioned by DHP (e.g. living room + kitchen + dinning). The values include 125% oversizing

Example: Design load for 700 sq.ft of a 1950's ranch home with insulation in the walls: 700 x 22 = 15,347 Btuh

Model Selection

Once you know the zone load, use the following guidance and application-specific recommendations to select the appropriate size and model for the home:

- Identify a unit from the NEEP qualified cold climate heat pump products list[4].
- Verify that the unit retains at least 80% of its rated 47-degree capacity at 5°F. Capacity values at 47-degrees are provided on the NEEP list.
- If the manufacturer's extended performance tables do not provide the maximum capacity at colder temperatures, you can use the NEEP qualified products list[4]. The NEEP list provides turn-down ratios, along with minimum and maximum capacities at 47, 17 and 5 degrees for most qualifying products.
- Try to choose products that have low minimum output ratings as this minimizes short cycling under low load conditions. A good rule of thumb is to make sure that "turn down ratio" (the maximum capacity at 17°F divided by the minimum capacity at 47°F) is greater than 4.0.
- Use manufacturer's extended performance capacity tables for the system capacity values. (**DO NOT** use the nominal rated capacity of the DHP system as they are not the same as the heating and cooling performance for the specific climate).
- Be aware that the manufacturer-supplied performance tables may not take into account the amount of time per hour a system spends in the defrost mode in cold, humid conditions. Capacities may need to be de-rated for defrost cycle, especially in coastal areas. Consult with your distributor or equipment manufacturer as needed.
- A drain pan heater will use an acceptable amount of extra energy during defrost cycles, provided that it is integrated with the system and only runs as part of the defrost mode. Make sure the pan heater is designed to run only when the DHP is in defrost mode.

Installation of the Indoor Unit and Zone Temperature Sensing

- Place the indoor head in the main living space, with air flow directed to provide maximum circulation through the space and neighboring rooms.
- Install a wall-mounted thermostat in a location that most accurately measures the occupied room air temperature (generally away from the indoor head). Ensure that the system is programmed to sense temperature at the remote thermostat, not in the return air of the indoor unit. If the indoor head is located high (e.g., near the ceiling) it can only measure the temperature returning from high in the room, which may not reflect what the occupants feel down on the floor.

Installation of the Outdoor Unit

- Avoid placing units where any of these are true:
    1. they will be exposed to high wind,
    2. they are under the drip line of the roof or under other sources of water (like another DHP, or roof valleys, or roofs without gutters),
    3. drifting snow may accumulate (generally the leeward side of the house),
    4. heavy snow-melt or rain runoff may undermine the compressor pad,
    5. defrost cycle melt water may refreeze and become a slip hazard, or
    6. they would be in noise-sensitive areas, such as near bedroom windows.
- If mounting on an exterior wood wall, use anti vibration or sound dampening mounts/gaskets to reduce noise transfer due to vibration, or use mounts bolted to the foundation instead.
- If mounting on the ground, make sure soil is well drained and supportive of underlying pad, and use snow legs tall enough for the expected local snow accumulation.
- Add extra clearance if needed. Installation manual guidelines for clearances are minimums and often not adequate to provide enough space for proper maintenance, cleaning and removal of debris. Add extra space from dryer vents, fireplaces and locations with poor physical access.

[4] http://www.neep.org/initiatives/high-efficiency-products/emerging-technologies/ashp/cold-climate-air-source-heat-pump

Installation of Tubing and Line Set, Condensate Drain

- DO NOT REUSE manufacturer provided tubing flares or fittings. Only use flare fittings once. Cut refrigerant line and build a new flare fitting whenever the fitting is opened for service. Press type fittings or compression fittings are preferable as they have been proven far less prone to leaks.
- Apply refrigerant oil to the end of each flare and use a torque wrench to tighten to the manufacturer's torque specifications.
- Always purge the system lines with a vacuum and dry nitrogen prior to opening the system valves to fill the lines with refrigerant.
- Add or remove refrigerant charge ONLY IF NECESSARY. Many DHPs do not require adjustments from pre-charge levels for a standard line set. Consult the manufacturer's current installation manual to verify refrigerant charge adjustments as needed. When needed, use a digital scale to weigh in/out refrigerant.
- Install insulation over the entire line set length (both pipes) and protect the outdoor portion of the line set with a rigid cover to avoid insulation damage. UV resistant insulation or covering should protect the entire exposed line set. Note: some jurisdictions no longer allow UV resistant tape.
- Air-seal the penetrations through the exterior and through the drywall to the interior of the new DHP head.
- Ensure exposed air sealing materials on the exterior of the home are covered with line set hide or a UV safe product
- Ensure the condensate drain is sloped down and away from the building.
- Avoid using a condensate pump unless absolutely necessary to minimize failure risk and maintenance costs.

Maintenance Tips

All mini-splits require regular service and maintenance. System life can be extended by following a few simple guidelines.

- Instruct homeowners to clean the filter(s) on the indoor head/cassette every 3-4 months
- Avoid the use of condensate pumps whenever possible. Condensate pumps and pump filters need regular cleaning and the pumps commonly cause noise complaints.
- Use appropriate covers on all outside piping. Covers protect the line set from physical damage including degradation from UV rays as well as damage from pets or rodents.
- Inspect and clean condensate terminations to check for debris and blockages.

Homeowner Education

- Provide a copy of the manufacturer's owner's manual (or installation manual) to the homeowner.
- Provide guidance on the importance of keeping snow and debris away from the outdoor unit.
- Instruct homeowners to use "heat" or "cool" settings (rather than "auto"), and generally turn off the unit when neither is needed. Using "auto heat/cool" settings to maintain a specific comfort setting can significantly increase energy use and cause the system to interact poorly with other heating systems.
- Instruct homeowners to use "automatic" fan speed setting to allow the fan speed to respond the compressor speed and allow the fan speed to operate as quietly as possible.
- Instruct homeowners not to set the thermostat with more than four degrees (4°F) of nighttime setback, as this forces the unit to operate at high power mode in the morning to bring temperature back up. A DHP provides best efficiency and comfort with a steady temperature setpoint and a small night setback.
- Instruct the homeowner to set the backup heating thermostat 3-4 degrees lower than the DHP thermostat. This ensures that the DHP provides the majority of the heating.

APPLICATION SPECIFIC CONSIDERATIONS

This section covers some of the unique considerations mini-split heats.

Multi-Head Mini-Splits

Multi-head mini-splits can have indoor units that are either ductless (DHPs) wall or floor mount or ceiling cassettes or fan coils with low-pressure distribution ducts (aka short-ducted). These systems enable the installation to consist of just one outdoor compressor/evaporator system with multiple refrigerant lines to indoor units. Make sure wiring and refrigerant lines are well marked to avoid the common mistake of having wiring and refrigerant lines connected to the wrong indoor unit. Avoid using multi-head system to serve multiple floors as to reduce the risk of over heating or cooling problems.

Short Ducted Mini-Splits

One type of mini-split heat pump system uses small indoor low-pressure fan coils that have short (typically less than 10ft) ducts serving multiple small rooms. These systems can save the cost of having multiple indoor units and refrigerant lines and conceal the HVAC system in the ceiling. They are particularly useful for serving several small rooms (e.g. bedrooms) to avoid over sizing and short cycling problems, which are common when a single indoor unit is placed in each room. A wise configuration for short-ducted mini-splits is to have the indoor unit placed in a soffit located in a hallway serving several rooms, with short ducts delivering air to each room. When installing short-ducted mini-splits be sure there is a reasonable return air path from the room back to the indoor unit to ensure good air circulation.

Homes with Electric Forced Air Furnaces

Homes with Electric Forced Air Furnaces (EFAFs) can be good candidates for DHPs. However, if the existing EFAF duct work is in good condition and is either insulated or located inside the conditioned space, it is generally cheaper, more effective and more efficient to use a cold climate unitary heat pump to heat and cool the entire home rather than installing a multi-head DHP solution.

A single head DHP is a better solution however in small homes (single-story or manufactured homes) when the EFAF is connected to ductwork that is old, leaky and/or located in the crawlspace under the house. In such cases a DHP provides low-cost heating and cooling without air from the leaky ducts drawing dirty air from the crawlspace or adding to the house heating and cooling loads. Properly installed, a cold climate DHP will cost one-third as much to operate as the EFAF system. The following will make sure you get the most out of your DHP:

1. Install the DHP in the main living area of the house.
2. Set the DHP to operate in “heat” or “cool” setting, never the “auto” setting, and adjust the temperature setpoint for heating and cooling separately, rather than at a single temperature.
3. Set the EFAF thermostat 3-4 degrees lower (in heating mode) than the DHP. This will make sure the DHP does most of the heating.
4. Inform the homeowner that it is okay for both the DHP and EFAF to run at the same time providing they rely on the expensive EFAF heating as little as possible. This is best accomplished by restricting airflow to registers (e.g. closing floor registers) in the same room as the DHP.
5. Seal any leaks in the EFAF ducting located outside the conditioned space.
6. If possible, install the DHP thermostat at the same location where the EFAF thermostat is located (typically in the hallway). This helps ensure the DHP will do most of the work and minimize operation cost.

New Homes

The lower heating and cooling needs (per square foot) of new homes increases the risk of oversizing DHP solutions (especially multi-head systems). Make sure the system’s minimum output is less than 1/4th the system’s rated output. This will help avoid short cycling and poor performance when outdoor air temperatures rise above 40 degrees. Installing an indoor unit in every room can easily result in a significantly oversized system. Using short-ducted mini-split systems for bedrooms and office spaces,

and a separate single head DHP in the main living area provides better comfort and performance than installing a multi-head system with a head in every room.

"Tiny" Homes

Homes less than 700 square feet and a design load less than 12,000 Btu/h are very good candidates for use of single-head DHPs or ducted mini-split systems. In these homes, the DHP should be placed in the primary living space with small backup heaters (typically electric resistance) in smaller rooms.

1. If the house is well air-sealed, consider adding active ventilation (bath fan, or a small heat recovery ventilator (HRV) system.
2. Keep room doors open when possible to encourage passive conditioning and ventilation.
3. Set backup (perimeter) heater thermostats 2-3°F cooler than the DHP thermostat.

Ultra-Low Load Homes

Ultra-low-load homes, like those certified to meet the Passive House standard, have loads too low to justify having a DHP indoor unit in every room. Small central forced air system or short-ducted mini-split systems that are independent of the home's heat recovery ventilation system are better suited for these homes. With a high efficiency heat recovery ventilator, minimal supplemental heating or cooling is needed when outdoor temperatures are above 50 or lower than 80 degrees Fahrenheit for heating and cooling, respectively.

Poorly Insulated Houses

The first step in a poorly insulated home is to insulate and air seal as much as reasonable before upgrading the HVAC system. Homes (typically older ones) that have electric baseboard, boilers, or radiant electric heated ceilings are excellent candidates for multi-head cold climate DHPs. Such systems can provide heating and cooling without the need to heat and cool the entire house. If the house has existing ductwork that is in good shape and/or located inside conditioned space (e.g. basement), it may be better to install a central cold climate heat pump.

Hot Houses (Cooling Dominated)

New homes and homes with lots of south or west facing windows will likely have higher cooling loads than heating loads. In these types of homes, a cold climate heat pump is likely the best option. Many cold climate heat pumps have excellent cooling capacity because of their larger sized heat exchangers and compressors. Cold climate heat pumps are well suited for climates with both cold winters and warm summertime conditions, providing additional attention is paid to proper room by room load calculations, zoning and controls.

Two Story Homes

Two story (or multi-story) homes present a unique challenge in that heating and cooling needs differ between the floors at different times of the day or year. Avoid using multi-head system with a single outdoor unit to serve both floors to avoid over heating or over cooling a floor. Multi-head mini-split systems cannot reduce heating (or cooling) to zero in other rooms when at least one room is calling for heating (or cooling). For example, if the main living area calls for heat in a multi-head system, some heat will continue to be added to one or more upstairs zones even if there is no call for heating there. This can result in imbalanced systems and uncomfortable conditions. The better approach is to choose two or more separate systems to operate the upstairs and downstairs.

As products continue to evolve, it is possible that this challenge will be resolved, so consult with the installer to inquire about this before using a multi-head solution that serves both upstairs and downstairs.

Moisture Condensation Risk Areas

Installing a single head DHPs can exacerbate moisture condensation risks, especially in older homes with limited wall insulation. The added risk occurs when the DHP is installed in one part of the home and other rooms or locations are no longer heated as much. The areas of highest risk in back bedrooms and closets that get very little air circulation. These spaces are difficult to heat regardless of the type of

heating system being used. If the surface gets cool enough, moisture from the air will condense and cause mold or mildew to grow, which is a health risk.

The best way to avoid this is to ensure all areas have some air flow and avoid placing boxes or stacks of clothing against poorly insulated walls. In addition, make sure that supplemental heating (like a cadet or baseboard heater) is not turned off, but rather just set at a lower than the DHP so that the DHP can do most of the work, but when it gets very cold, the backup heating prevents condensation on exterior wall surfaces.

ADDITIONAL RESOURCES

Cold Climate Heat Pump List

- Northwest Specifications and Recommendations-filtered list https://conduitnw.org/Pages/File.aspx?rid=4884
- NEEP http://www.neep.org/initiatives/high-efficiency-products/emerging-technologies/ashp/cold-climate-air-source-heat-pump

Webinars and Trainings

- NEEA https://goingductless.com/partners/training-events/
- NEEA Best Practices Installation Guide https://goingductless.com/assets/documents/uploads/DHP_BP-Guide.pdf

Contractor and Consumer Information

- www.GoingDuctless.com/partners
- www.GoingDuctless.com

Design Load Calculators and Sizing Tools

- HVAC Sizing Tool www.hvac/betterbuiltNW.com
- Wrightsoft http://www.wrightsoft.com/
- eComfort mini-split sizing wizard
- Elitesoft www.elitesoft.com/web/hvacr/elite_rhvacw_info.html
- CoolCalc https://www.coolcalc.com/