Guide To Sizing & Selecting Air-Source Heat Pumps in Cold Climates

A companion to NEEP's Guide to Installing Air-Source Heat Pumps in Cold Climates

Introduction

The use of air-source heat pumps (ASHPs) in cold climates is growing rapidly, but system sizing and selection practices have not always kept up with the wide range of applications commonly found in cold climates. System performance, comfort, and energy efficiency can be significantly impacted by poor sizing and system selection. The purpose of this guide is to assist installers in sizing and selecting ASHPs for cold climate applications, while maintaining high efficiency, performance, and customer satisfaction.

There are many types of equipment and a variety of common applications for ASHP installations in cold climates. Combinations of single and multi-zone, mini-split "ductless" and/or "compact-ducted" systems, and more conventional centrally ducted air-handler systems, may be installed in existing or new homes. When an ASHP is installed to reduce operating costs and/or emissions and existing heating equipment is left in place as a supplement, conventional approaches to sizing and selection don't always apply.

This guide is organized into four one-page application types so users can effectively match guidance to their specific installation. The applications are:

- Heating (or heating & cooling) displacement
- Full HVAC replacement
- Isolated zone
- New construction

Each category suggests the relevant information on sizing and equipment selection, system configurations, the use of pre-existing HVAC, and tips on key issues to look out for. Note: this guide assumes the appropriate application type has already been chosen, or is driven conclusively by customer needs. Also, there is no cooling-only application type. In almost any circumstance, even if the client is initially interested in cooling, a cold-climate heat pump can provide cost-effective heating for some part of the winter.

For cold-climate applications, this guide is focused on products that appear on the Cold Climate Air Source Heat Pump (ccASHP) Specification. Therefore, variable-speed systems are assumed in this guidance. Cold climates may be considered to be International Energy Conservation Code (IECC) climate zone 4 and higher, though interest in cold-weather performance may extend into some of the hottest climates in the U.S. The following section provides additional general guidance on building efficiency, load calculations, and equipment selection that apply to all the application types.

Note: Heat pumps should always be installed by licensed, trained professionals. Always follow manufacturer's specifications and installation instructions, and all applicable building codes and regulations.

Ensure Building Efficiency

In existing buildings, always try to ensure that any building enclosure issues (insulation, air leaks/bypasses, existing duct disconnects/leaks, etc.) are addressed before installing new equipment. This reduces heating & cooling costs, improves comfort and heat pump performance, and reduces the size of equipment required. Enlist the help of a home performance professional if needed to diagnose these issues. Many electric and gas utility companies offer resources to support home performance upgrades. U.S. DOE's Home Performance with ENERGY STAR program also provides useful resources.

Getting Load Calculations Right

Grossly oversizing equipment, whether individual zones or a whole house, can lead to excessive cycling, low efficiency and ineffective summer dehumidification. Right-sizing is important. ACCA Manual J[2] (or equivalent), when combined with the recommendations in this guide, is always an acceptable method for calculating heating and cooling loads for an ASHP installation. In some cases, contractors utilize simplified load calculation methods. Regardless of the method used, always follow these steps to help ensure accurate sizing of cold climate heat pumps.

- The load calculation method must account for:
    - surface areas and thermal properties of building enclosure (walls, roofs, windows, floors, foundations, etc.);
    - air leakage in the building, including latent load for cooling;
    - duct losses, only when ducts are to be used by the new equipment; and
    - solar gains from roof and windows, and internal sensible and latent gains for cooling.

- Load calculations have safety factors built in. Always follow the procedure accurately, without "padding" the estimates with additional safety factors. Always use approved outdoor design temperatures for the location, for load calculations and equipment capacity.

- Represent actual conditions accurately. For example, don't use duct loss factors for ductless systems, or for ducts that are internal to the conditioned space.

- Be cautious when applying infiltration estimates, which are often overstated. Blower door testing is recommended. Note that existing homes that have been reasonably weatherized tend to have natural air change rates at design conditions below 0.4. Efficient new homes are often well under 0.1 air change/hour. Heating infiltration loads occur mostly on lower floors, and cooling infiltration occurs mostly on upper floors of multi-story homes.

- Use the specified indoor and outdoor design conditions and other climate factors for the nearest location.

- Be especially attentive in these following situations, unique to many heat pump applications, where realistic equipment loads may be surprisingly small when:
    - calculating individual, small block loads (e.g. for a single zone ductless ASHP serving an individual room, or loads for individual heads of a multi-spilt system),
    - calculating loads for one or several rooms served by a compact-ducted system,
    - when an existing heating systems is left in place to supply backup to the heat pump, or when using balance-point sizing with a supplemental backup system, it's especially important to be conservative in load calculations. The risk of undersizing is mitigated when backup exists, and efficiency may be improved by sizing conservatively.

- When a single zone system (typically ductless) is installed in an "open floor plan" house, it is acceptable to include "connected" open spaces in the load estimates for that zone. When rooms are open to each other, a single ductless unit may reasonably heat and cool that space — particularly if the home is weatherized. This may also include a significant part of second-floor heating loads, when an open stairway exists.

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General Equipment Selection Guidance

ACCA Manual S[3] (or equivalent), when combined with the recommendations in this guide, is an acceptable method to select equipment. The general guidance below may be combined with the application-specific recommendations to inform the selection process:

- Use manufacturer's extended performance tables to determine heating and cooling capacity as applicable, at the actual design conditions for the local climate. Some specific exceptions are noted in the application sections below.

- Extended performance tables are recommended for sizing equipment to heating loads (whether 100% of load, or based on some use of available backup heat source) but **be cautious** — not all published performance data is consistent, for example, tables may not show maximum capacity at colder temperatures. The information in the Cold Climate Air Source Heat Pump (ccASHP) Specification tables (maximum heating capacities reported at 5°F) may be used to corroborate extended performance tables near design conditions, and help ensure the right equipment selection.

- The step of adding the heating and cooling air flow needed for each room to estimate total system air flow applies to centrally ducted heat pump systems, and may be omitted for ductless distribution systems.

- The minimum capacity of the system selected is as important as the maximum. A good equipment selection for heating comfort and efficiency has adequate turn-down to perform well during mild weather, low-load conditions as well as design conditions. This is an important reason to not to overestimate or overstate design loads, and is particularly important for multi-zone equipment.

  When installing multi-zone systems, consider using separate single-zone systems, or increasing the number of outdoor units, each with lower capacity and with fewer zones. This will help allow the minimum capacity to be matched by a load for as many hours as possible, and typically has little impact on the system cost. In general, avoid situations were the minimum steady-state capacity of the outdoor unit (rated at 47F) is higher than the smallest indoor unit's heating capacity.

  (Note: it is important to use the steady-state minimum capacity of the outdoor unit, based on manufacturer's engineering data, that the outdoor unit can produce without cycling off; this is not always easy to find. Generally, it's not much less than 1/3 of the rated capacity. If you cannot get that information reliably, avoid selecting an outdoor unit with a rated capacity that is more than triple the capacity of the smallest indoor unit attached to it. Increasing the size of the indoor units is not the answer! Instead, install more, but smaller, outdoor units.)

References

[1] NEEP's 2013 Market Strategies Report, Aldrich, R. & Lis, D., (2014), Northeast/Mid-Atlantic Air-Source Heat Pump Market Strategies Report

[2] Rutkowski, Hank, Manual J Residential Load Calculation (8th Edition), January 1, 2016, Air Conditioning Contractors of America.

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[3] Air Conditioning Contractors of America, Manual S - Residential Equipment Selection (2nd Edition), 2015, Air Conditioning

Contractors of America. www.acca.org

Guide To Sizing & Selecting Air-Source Heat Pumps in Cold Climates

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Heating (or Heating & Cooling) Displacement

Application Description	Customer primarily desires to reduce heating (and/or cooling) cost for central area of home. Heating is supplemental when the existing heating equipment is not at or near the end of its service life. The main tradeoff is between initial cost vs. savings and comfort in remote zones.
Suggested ASHP System Configuration **(Single/Multi-Zone Ductless, Compact-Ducted, Centrally Ducted)**	For this application, typical configurations include 1-zone ductless, or 1-3 room compact-ducted located to serve central living space. Alternatively, a larger 2-5 zone system, ductless and/or compact-ducted, can be configured to serve home widely for better comfort and savings (at a higher installed cost). In some cases, a new single-zone central heat pump may be installed in a dual-fuel configuration with the existing (or new) central fossil-fired furnace.
Suggested Treatment of Existing HVAC System	Left in place, provides heat only as needed. A centrally ducted system may also provide mixing of house air for improved comfort provided the fan motor is electronically-commutated and can be set to run on low speed.
Sizing Strategy Overview	Place the first zone where heat will cover the most central living area. Establish any additional zones (as appropriate) to strategically cover key living areas per customer needs. Size each zone to heating load of area(s) to be served (block load): total will be undersized for whole-house design heating load.
Load Calculation	See “Getting Load Calculations Right” to ensure accurate load calculations.
Equipment Selection Considerations	Heating capacity of system at or near outdoor design temperature is a secondary concern. Undersizing somewhat for heating should improve efficiency and reduce overall heating costs, even though central system may be used slightly more in colder weather. High efficiency at predominant winter outdoor temperatures will reduce operating cost.
Oversizing Concerns / Tradeoffs	Cooling oversize is mitigated by variable-speed equipment; if minimum speed cooling capacity is over 115% of design cooling load, look for equipment with a higher ratio of heating to cooling capacity, or a wider turn-down ratio (a lower minimum capacity), or both.

Further Guidance

- Consider a floor mount unit to serve this first floor, especially when heating is the customer priority. Avoid oversizing ductless units for individual room loads. For effective distribution to individual rooms/bedrooms with low loads, use a single compact-ducted system when possible; avoid using the attic (or ensure duct connections are sealed with mastic and insulated to a minimum of R-8). Set ASHP heating thermostat to comfort level or slightly higher; set central or backup heating thermostat(s) approximately 4-10°F lower whenever possible to maximize heat pump utilization.

- Also note that when a heat pump satisfies a whole-house thermostat in very cold weather, pipes may freeze in basement or remote areas previously tempered by a central heating system. Mitigation strategies may include some combination of: supplemental heat; a backup thermostat connected in parallel to the central system located in affected areas; heat tape on pipes; and air sealing and insulation of exterior sill plates and/or foundation walls in basements, and crawlspaces where possible.

- Room-by-room load calculations may not be necessary for many retrofit applications where existing / alternate heating systems will remain in place.

- When installing systems with multiple zones, consider using separate single-zone systems or at least reducing the number of zones per outdoor unit. Avoid oversizing outdoor units, and avoid units with high minimum-speed capacity at 47°F (narrow turn-down ratios) whenever possible.

Guide To Sizing & Selecting Air-Source Heat Pumps in Cold Climates

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Full Heating System Replacement

Application Description	This approach is best suited for homes that have fairly small heating loads because they are small and/or relatively efficient. Planned weatherization work should be done first if possible, to reduce HVAC size and cost. Pre-existing system is decommissioned or possibly removed. (In some cases, existing ducts may be used when they are located in conditioned space, are adequately sized for required heat pump air flow, and a suitable indoor unit air handler can be selected).
Suggested ASHP System Configuration **(Single/Multi-Zone Ductless, Compact-Ducted, Centrally Ducted)**	For this application, a typical configuration would include multiple zones of ductless and/or compacted-ducted, configured to serve the entire home. In cases where existing ducts are suitable (see above), a central heat pump system may make sense.
Suggested Treatment of Existing HVAC System	Existing equipment is removed or disabled. Existing, non-viable distribution systems decommissioned or removed to the extent possible. Decommissioned ducts that are outside conditioned space are sealed and insulated at the registers (when registers are at insulated boundary of house). Decommissioned ducts that pass into conditioned space are cut off at the insulated boundary, which is then sealed (e.g. at duct chase into attic).
Sizing Strategy Overview	Size to meet both the estimated heating and cooling loads. Match system capacity at the design temperature with 100-115% of the estimated heating load, without the use of auxiliary heat. Or, design for auxiliary heat at a balance point of 20°F or below.
Load Calculation	Use full ACCA Manual J or equivalent.
Equipment Selection Considerations	Use manufacturer published performance at design conditions to identify systems with adequate heating and cooling capacity.
Oversizing Concerns / Tradeoffs	Potential cooling oversize is mitigated by variable-speed equipment; if minimum speed cooling capacity is over 115% of design cooling load, look for equipment with a higher ratio of heating to cooling capacity, or a wider turn-down ratio (a lower minimum capacity), or both.

Further Guidance

- Consider floor mount unit(s) to serve the first floor, especially when heating is the customer priority. Avoid oversizing ductless units for individual room loads. For effective distribution to individual rooms/bedrooms with low loads, use a single compact-ducted system when possible; avoid using the attic (or ensure duct connections are sealed with mastic and insulated to a minimum of R-8). Thermally isolated areas (such as bonus room over garage) may need separate zone(s) for comfort.
- If existing ducts are utilized, first ensure that the available indoor unit is matched well with the ducts for air flow and velocity. If there are pre-existing zone dampers, remove and seal any return bypass and ensure air flow modulates properly with zone thermostat calls.
- When sizing for existing, whole-house HVAC replacement, total heat pump capacity at design conditions shall not exceed (and in many cases will be smaller than) existing heating equipment capacity. Heating load may be further reduced because of shell improvements and any eliminated duct losses.
- Note that measurements of existing central equipment duty cycle at or near design conditions can also be used to estimate boundary of heating (and/or cooling) load.
- Ensure adequate primary or auxiliary heat in basement to prevent freezing pipes; air seal and insulate sill area and foundation walls in particular if possible.

Guide To Sizing & Selecting Air-Source Heat Pumps in Cold Climates

A companion to NEEP's Guide to Installing Air-Source Heat Pumps in Cold Climates

Isolated Zone

Application Description	One room or zone that is otherwise thermally isolated from the rest of the home. This may be a newly finished basement room, build out above garage, an addition, or a room that previously had poor thermal comfort.
Suggested ASHP System Configuration **(Single/Multi-Zone Ductless, Compact-Ducted, Centrally Ducted)**	For this application, typical configuration is ductless, single zone. A compact-ducted system may be appropriate in larger spaces or where customer desires a low profile, provided there is space available to install the unit and ducts.
Suggested Treatment of Existing HVAC System	Left in place, provides primary heat for home; may not serve this zone well or at all. If existing distribution to isolated zone is ineffective, consider eliminating that branch (or branches).
Sizing Strategy Overview	Size to meet both the estimated heating and cooling loads of space served. May be sized solely for the heating load if client need is focused on heating only.
Load Calculation	See "Getting Load Calculations Right" to ensure accurate load calculations.
Equipment Selection Considerations	Use manufacturer published performance at design conditions to identify systems with adequate heating and cooling capacity.
Oversizing Concerns / Tradeoffs	Potential cooling oversize is mitigated by variable-speed equipment; if minimum speed cooling capacity is over 115% of design cooling load, look for equipment with a higher ratio of heating to cooling capacity, or a wider turn-down ratio (a lower minimum capacity), or both.

Further Guidance

- Note that an "isolated zone" in a house that is otherwise fully heated by an existing central system may have very small loads, especially heating loads; to improve operating efficiency and reduce installed cost, be careful not to size such a system larger than the actual room or calculated load of that space. If there is distribution from the central system, and the primary reason for the ASHP is to increase comfort, also account for the heat and/or cooling supply from that system before sizing the ASHP unit. It may be beneficial to reduce or completely remove central system distribution to the zone.
- If client need for new system is driven by an existing comfort issue, ensure that any building shell problems (insulation deficiency, air leaks/ bypasses, existing duct disconnects or leaks, etc.) are addressed before installing new equipment. Assessment by a building performance professional is strongly recommended.

Guide To Sizing & Selecting Air-Source Heat Pumps in Cold Climates

A companion to NEEP's Guide to Installing Air-Source Heat Pumps in Cold Climates

New Construction or Gut Rehab

Application Description	House is well insulated and relatively air tight (meets or exceeds current building energy codes).
Suggested ASHP System Configuration **(Single/Multi-Zone Ductless, Compact-Ducted, Centrally Ducted)**	For this application, typical configuration could include one, two or more zones, including ductless and/or compact-ducted, or a single central air handler. Ducts, when used, are contained entirely within the insulated boundary of the home. Smaller or very high performance homes may do well with only 1-2 ductless and/or compact-ducted zones. Large homes that meet current energy codes may require more zones and/or ducted systems.
Suggested Treatment of Existing HVAC System	Generally the ASHP will be the only heating source other than possible auxiliary heat.
Sizing Strategy Overview	Size to meet both the estimated heating and cooling loads. Match system capacity at the design temperature with 100-115% of the estimated heating load, generally without the use of auxiliary heat. Or, design for auxiliary heat at a balance point of 20°F or below.
Load Calculation	Follow ACCA Manual J or equivalent load calculations. See "Getting Load Calculations Right" to ensure accurate load calculations. Avoid oversizing, so that equipment can turn down and run a lower speed during a wide range of outdoor heating load conditions.
Equipment Selection Considerations	Use manufacturer published performance at design conditions to identify systems with adequate heating and cooling capacity.
Oversizing Concerns / Tradeoffs	Potential cooling oversize is mitigated by variable-speed equipment; if minimum speed cooling capacity is over 115% of design cooling load, look for equipment with a higher ratio of heating to cooling capacity, or a wider turn-down ratio (a lower minimum capacity), or both.

Further Guidance

- Consider floor mount unit(s) serving first floor, especially in open plan areas. To avoid oversizing ductless units for small individual room loads, and for effective air distribution to rooms with low loads (such as bedrooms) use a single compact-ducted system when possible; avoid using the attic (or ensure duct connections are sealed with mastic and insulated to a minimum of R-8). Thermally isolated areas (such as bonus room over garage) may need separate zone(s) for comfort.

- In very tight, low-load buildings be especially attentive not to oversize equipment. A strategically placed single-head ductless units may provide adequate comfort for an entire floor, or use compact-ducted systems to ensure distribution to smaller rooms. A centrally located, wall-mounted thermostat control is strongly recommended. **Do not choose outdoor multi-zone equipment sized at more that 115% of the heating load at design conditions, just to provide individual room zone control.**

References

[1] NEEP's 2013 Market Strategies Report, Aldrich, R. & Lis, D., (2014), Northeast/Mid-Atlantic Air-Source Heat Pump Market Strategies Report

[2] Rutkowski, Hank, Manual J Residential Load Calculation (8th Edition), January 1, 2016, Air Conditioning Contractors of America. www.acca.org

[3] Air Conditioning Contractors of America, Manual S - Residential Equipment Selection (2nd Edition), 2015, Air Conditioning Contractors of America. www.acca.org