Air-to-Water Heat Pumps - Technical Note

Audience: This document provides an overview of air-to-water heat pumps (AWHPs), which can be used in homes having hydronic heating systems. Some light-commercial buildings may also be good candidates for residential-scale systems of this type.

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Introduction

Air-to-water heat pumps (AWHPs) are most applicable to homes that have existing or new hydronic heat distribution systems, but no ducting. Like their more-common air-to-air cousins, AWHPs extract thermal energy from outdoor air and boost it (through a vapor-compression refrigeration system) to a temperature suitable for home heating.

While lesser-known in the U.S., AWHPs are common in other parts of the world. “Air-to-water heat pumps are not widely-available in the United States at this time, but there is growing interest in the technology.” [R1] “These air-to-water heat pumps—known as hydronic heat pumps—are widespread in Europe but uncommon in the United States. Now, new models are emerging, and the Department of Energy is giving the technology a vote of confidence by supporting new domestic production lines.” [R2]

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- Summarizes how AWHPs are becoming increasingly-common in the U.S. and that homes with hydronic distribution, about 26% of homes in Massachusetts, are potential candidates for AWHP retrofits
- Presents pros and cons of AWHPs vs. ductless air-source heat pumps, the usual alternative for retrofitting homes with hydronic heat distribution systems
- Explains the various configurations of AWHPs, the main ones being *Outdoor MonoBloc* and *Split* systems, and presents their relative pros and cons, as well as freeze-protection considerations for Outdoor MonoBloc systems
- Briefly discusses the expected future of AWHPs in the U.S.
- Summarizes several relevant case studies

$NOTE_1$: Information regarding various brands of AWHPs appears in this document, but the Alliance intends no brand endorsement by these references.
$NOTE_2$: All references cited are listed in a references table. Clicking on "[R7]", for example, will present the table which includes a brief description and an external link for each reference.

Homes with Hydronic Distribution: Candidates for AWHP Retrofits

A home's existing heating system, including the heat distribution method, determines which type(s) of heat pumps may be suitable. See [R3] to identify the type(s) of heat pump(s) to consider based on the existing heating equipment and distribution system. Ductless Air-Source Heat Pumps (ASHPs) are the most commonly-used approach to retrofitting homes that do not have central ducting that is suitable for both heating and cooling. Both AWHPs and ductless systems can be configured to contribute to Domestic Hot Water (DHW), but DHW support is rarely available in ductless systems. AWHPs can be considered as an alternative to ductless heat pumps in retrofits. General information regarding ASHPs is covered in [R4].

Data from EIA (U.S. Energy Information Administration) [R5] shows a total of about 9.3 million homes with hydronic heating systems that might be candidates for AWHPs. These include 6.5 million homes heated with natural gas, 1.6 million homes heated with fuel oil or kerosene, and 1.2 million homes heated with propane. Focusing more locally, [R6] shows that Massachusetts has 0.70 million households (26% of all households) with steam or hot water boilers as the main heat source, hence hydronic distribution. We understand that hydronic systems are more common in multi-family homes compared to single-family homes, so the percentage for single-family homes might be a bit lower. These Massachusetts-specific values show that there is a significant market for retrofitting with AWHPs. "Since boilers and chillers are particularly common in the Northeast …, air-to-water heat pumps are garnering increased interest as a practical and low-carbon replacement for existing fossil fuel-based systems." [R7]

"Until recently, the primary way to move toward decarbonizing these homes was to install multiple ductless mini-split heat pump units (or a ducted system) to provide warm air to each room. For many of these homes, a new option may prove most cost-effective. Owners could

install a heat pump that takes heat out of the outdoor air and concentrates it to produce hot water, which can then be sent through the existing radiators or baseboards". [R2]

AWHPs can tie into existing hydronic heat distribution systems (baseboards or radiant loops). Radiant loops are a great match, while baseboards may require system modifications and/or weatherization improvements to lower the demand for heat. The heat output of conventional hydronic baseboards drops by a factor of two when water temperature drops from 170°/180°F, as typical from a conventional boiler, to 120°/130°F, as typical from AWHPs. Radiant hydronic heating systems can be well-suited to AWHPs because they are typically designed for 120°F to 130°F supply water. The typical heated-water loop with baseboards or radiators in series around the home's perimeter can be modified to a *home-run* arrangement, wherein each heating element (or smaller groups) has its own loop to the AWHP. In some cases, it may be possible to increase the flow rate to compensate for the lower water temperature.

Nevertheless, there are cases in New England where AWHPs were successfully used with the existing baseboard systems for heating. Examples appear in the Case Studies section of this Tech Note. An experienced AWHP installer can evaluate your existing distribution system to determine whether it is suited to an AWHP retrofit, and to what extent home weatherization and/or distribution system modifications might be needed to accommodate it.

Advantages and Disadvantages of AWHPs vs. Ductless ASHPs

Table 1 lists the pros and cons of AWHPs relative to ductless ASHPs.

Table 1. Pros and Cons of AWHPs Relative to Ductless ASHPs

Advantages of AWHPs Relative to Ductless ASHPs	Disadvantages of AWHPs Relative to Ductless ASHPs
• **Domestic hot water.** Can also preheat water for domestic use (e.g. laundry, dishwashing, showers, etc.) • **Flexible equipment location.** Some AWHPs can have the compressor and heat exchanger inside the building envelope, which makes service in winter much easier	• **Expensive to configure for cooling.** AWHPs can also be used for cooling, but require air-tight insulation of the distribution piping and new radiators (able to heat and cool, and drain condensate) which is costly for retrofits. See [R14] starting at 45:30. "It can get complicated to add hydronic cooling options for retrofits that have only heating." [R7] In newly constructed buildings, such measures can be more easily accommodated. Some homeowners shut off their AWHP during summer and rely on ductless ASHPs in some rooms just for cooling • **Higher first cost**, even without cooling • **Fewer installers.** As of 2022, only a handful of installers in Massachusetts had experience installing AWHPs. 2023 has improved the installer pool. Spacepak said 39 contractors on their certified list have taken training as of 2024 • **Noise & Vibration.** AWHPs that are entirely indoors can send noise via copper pipes. Vibration dampers or plastic tubing can solve this noise transfer, as discussed in the [R3] HPWH User Guide, section C2. Noise Concerns • **Fewer Analytical Tools.** Northeast Energy Efficiency Partnership (NEEP) provides a very useful ASHP sizing tool [R9], but we are not aware of any such publicly available tool for AWHPs.

AWHP Configurations

AWHPs are available in several different configurations [R1]. Outdoor MonoBloc and Split configurations are the most common in the U.S. Figure 1 shows that the main difference between Outdoor MonoBloc and Split configurations is what flows between OUTSIDE and INSIDE.

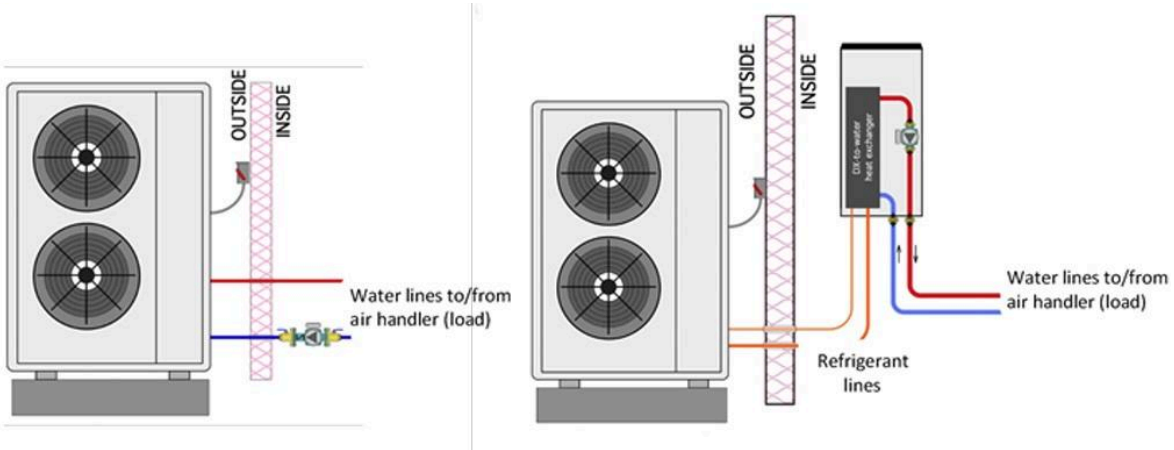

Figure 1: Monoblock vs. Split Configurations of AWHPs, from [R7] which credits this diagram to John Siegenthaler.

Outdoor MonoBloc AWHPs

Outdoor MonoBloc AWHPs have all components in one cabinet, installed outdoors, and may also include a 'buffer' water storage tank inside. See [R14] starting at 49:00. The refrigerant is contained within the cabinet, so the refrigeration system can be factory-sealed. Water (or water + antifreeze) lines connect the outdoor unit to the indoor hydronic distribution system.

Freeze Protection for Outdoor MonoBloc AWHPs

This configuration requires circulating water outdoors, thus freeze protection is needed for the water pipes and the outdoor heat exchanger:

> "All systems designed around monobloc air-to-water heat pump systems need to consider freeze protection. Even systems in southern states could experience a situation in which a prolonged power outage accompanied by subfreezing temperatures could allow water to freeze within the exterior piping and heat exchanger. Another possibility [of freezing] is when the heat pump is not operating due to a service issue while subfreezing temperatures occur" [R1].

Approaches to freeze protection include:

- **Antifreeze.** One of the simplest methods is to fill the entire system with a mixture of water and antifreeze. See [R1] for details
- **Insulation.** Outdoor pipes are wrapped with insulation, providing some protection during brief freezing periods
- **Heat Tapes.** Outdoor pipes are wrapped with electrically-powered heat tapes that are activated when the outdoor temperature falls below a threshold, providing protection as long as power is available
- **Freeze-Protection Valves.** These are not known to be currently available for AWHPs, but are used with MonoBloc SANCO$_2$ heat-pump water heaters that circulate potable water outdoors. In a private communication, the manufacturer told us that the approach could be employed with AWHPs. A pair of valves provide protection even under power outages by dumping the water when the system's all-mechanical, thermostatically-controlled valves sense potential freezing [R10] and [R11]. Other brands of freeze-protection valves, e.g Caleffi, are available as well.

Indoor MonoBloc AWHPs

Indoor MonoBloc systems require two or more fairly-large air ducts for supply and return of outdoor air. In [R1], there is an entire chapter on "INTERIOR AIR-TO-WATER HEAT PUMPS", which includes advantages and disadvantages, complete with illustrations and photos. The section concludes: "Interior air-to-water heat pumps are currently offered in Europe, but as of this writing [2020], are not available in North America."

Split AWHPs

Split systems have a refrigerant-to-air heat exchanger, a fan, and an expansion device located outdoors and a refrigerant-to-water heat exchanger indoors. The compressor is usually outdoors. Refrigerant lines connect the outdoor heat exchanger to the indoor heat exchanger. An indoor 'buffer' water storage tank may be included.

Advantages/Disadvantages of Outdoor MonoBloc vs. Split Configurations

The Mass Save® Qualified Product List, [R12], includes 51 AWHP products as of September 2024, including both MonoBloc and Split configurations. The list also includes other useful information like Model, Capacity, and COP (Coefficient of Performance). Based on this Mass Save® list, MonoBloc and Split AWHPs offer similar performance specifications, on average, as is evident in Table 2.

Table 2. Key Specifications from the Mass Save® Qualified Product List, [R12]

AWHP Configuration (from 2024 Mass Save® QPL)	Average Capacity (tons)	Average Rated Efficiency (COP) A5W110-COP (at an outdoor temperature of 5°F, the unit can provide 110°F water)
Split	3.96	2.01
MonoBloc	3.56	2.19
All Types	3.65	2.15

"If we look at comparable MonoBlock and split heat pump models from the same manufacturer, there is barely any difference in efficiency…When deciding to purchase a heat pump, building owners can choose between a single appliance (monoblock) or a two-part split version. Both systems have their benefits and drawbacks, particularly with respect to difficulty of installation and space requirements. The question of whether to go with a monoblock or split heat pump is a complex one that should be considered on a case-by-case basis depending on the conditions at hand. We will show you what is important when making this decision." [R13]

Table 3 compares Outdoor MonoBloc vs. Split configurations.

Table 3. Comparison of Outdoor MonoBloc vs. Split ASHPs

Advantages of Outdoor MonoBloc*	Advantages of Split*
● **Factory sealed** ○ They are "factory charged so there is less risk of refrigerant leakage or improper charging" [R1] ○ They use less refrigerant than split heat pumps [R13] ○ They may not need an annual refrigerant inspection [R13] ● **Easier installation** ○ They can be installed without HVAC tools and skills, e.g., by a plumber, resulting in lower installation costs [R13] ○ "Monoblock systems often include a pump as well as components normally required in hydronic systems, which simplifies and speeds installation" [R7] ○ Smaller than comparable split heat pumps, therefore may be easier to place [R13] ● **More selection** ○ There are about 4 times as many MonoBloc as Split configurations in the MassSave® HPQPL product list ○ Of 14 manufacturers, 3 offer only Split, 1 (Spacepak) offers both, and 10 offer only monobloc [R12]	● **No risk of freezing** ○ Because "no water or water-based antifreeze solutions are used in the outdoor portions of the system, there is nothing in the outdoor portion of the system that can freeze" [R1] ○ "No danger of system freezing" [R13] ○ No anti-freeze maintenance ○ Less energy for pumping ○ No heat tape power use and vulnerability to outages

* Advantages of one configuration are disadvantages of the other**.** The table excludes indoor Monoblocks because they are currently not available in North America.

Future of AWHPs

AWHPs are evolving rapidly, with new products coming on the market [R15] and [R16]. For instance, AWHPs that produce higher-temperature output are starting to become available in the U.S. which will make it much easier to re-use existing baseboards, albeit at a cost of lower efficiency. High-temperature AWHPs could greatly expand the retrofit market for AWHPs. One source [R7] includes examples from Transom, LG, SanCO$_2$, and Intellihot that are available in the U.S. Also included are some products not yet offered in the U.S. Examples include:

- Daikin Altherma 3 which is cold-climate capable and can output water over 170°F.
- Mitsubishi Ecodan series mono-bloc, residential/light-commercial, cold-climate capable, can output water over 160°F.

Best practices for AWHP installation are improving as well. For example, water tubing with less resistance to flow and built-in insulating properties makes a system more efficient, provided the installer is willing to buy special tools and be trained.

Case Studies

The following case studies provide three examples of residential AWHP installations. In each case, the AWHP did not provide cooling, but the home ended up fossil-fuel-free.

In a Green Building Alliance article [R17], the homeowner describes his AWHP retrofit in Vermont. The homeowner opted not to include air conditioning, which allowed him to use lower-cost panel radiators to distribute heat (as opposed to fan-coil units) and also, presumably, eliminated the need to fully insulate his plumbing lines. He eliminated the use of propane from the home. [R17]

In a YouTube video [R18] (from 23:40 through 31:40), the homeowner describes the split AWHP retrofitted in his North Andover, Massachusetts home for heating only. He used room-by-room Manual J heat loads to determine that the existing baseboards would be sufficient with the ~120°F output of a 5-ton Spacepak split AWHP with storage tank. One large room needed wood-burning backup or additional weatherization, but natural gas was eliminated from the home, which is fully solar powered now.

In this YouTube video [R19] (from 1:50 through 6:17), the homeowner conducts a tour of his now carbon-free home in Acton, Massachusetts. A 4-ton Spacepak MonoBloc AWHP provides heat by circulating a water-and-antifreeze mixture through existing baseboards. The system includes a ‘buffer’ tank. A separate 1.5-ton ductless mini-split heat pump provides cooling for most of the home’s first floor. The homeowner eliminated natural gas from the home.

References

[R_]	Brief Description	External Link
1	Article from idronics™ No. 27, written by hydronics experts	https://idronics.caleffi.com/article/air-water-heat-pump-configurations
2	Recent ACEE Blog Post	https://www.aceee.org/blog-post/2024/10/heat-pumps-homes-heated-hot-water-are-here
3	HeatSmart Alliance Tech Note: Quick Reference on Residential Heat Pump Retrofit Options	https://heatsmartalliance.org/homeowners/recommended-resources/
4	Information about air source heat pumps is helpful in general	https://goclean.masscec.com/clean-energy-solutions/air-source-heat-pumps/
5	EIA Table HC6.1 Space heating in U.S. homes, by housing unit type, 2020	https://drive.google.com/file/d/1ZLBOsvPdTBqtfjxtG8qPc1ZaH8ysofWe/view
6	Table from the 2020 EIA Residential Energy Consumption Survey (RECS), which has a wealth of data on U.S. housing characteristics and energy consumption	https://www.eia.gov/consumption/residential/data/2020/state/pdf/State%20Space%20Heating.pd
7	NEEP (Northeast Energy Efficiency Partnership) report Feb 2024, pages 12-14	Emerging Heat Pump Technologies
8	Air-to Water Heat Pump Design and Installation Guide	AWHP Design & Inst guide
9	NEEP (Northeast Energy Efficiency Partnership) Cold Climate ASHP Specification & Product List	https://neep.org/heating-electrification/ccashp-specification-product-list
10	SANCO2 Freeze Protection Valves for sale	https://skipthewarehouse.com/sanco2-eco-fpvkt3540-freeze-protection-valve-kit?srsltid=AfmBOoofYU2IcdhkHi1nk1awPFcfaK4RzW-zpSimubodl-K7oRpkE1TT
11	SANCO2 Freeze Protection Manual	https://manuals.plus/sanco2/gs4-45hpc-freeze-protection-manual#google_vignette
12	The Mass Save® equipment list. Under “First select an equipment type”, click on “AIR TO WATER HEAT PUMP”	https://www.masssave.com/heat-pump-qualified-list
13	Factors to consider regarding MonoBloc vs split	https://www.wolf.eu/en-de/advisor/heat-pump-monoblock-or-split
14	YouTube video “Air to Water Heat Pumps – Demystified” from Efficiency Vermont; 1:28 total; Good details on Hydronics and AWHP	https://www.youtube.com/watch?v=W3IoF2vVNBo
15	New ‘Ambient’ AWHP product from USBoiler	https://www.usboiler.net/electric-products/heat-pump.html
16	New Air To Water Heat Pump from China uses propane (R290) refrigerant and includes five models with a nominal capacity ranging from 6 kW [1.7 ton] to 17 kW [4.8 ton]	https://www.pv-magazine.com/2024/11/08/phnix-presents-new-residential-air-to-water-heat-pumps/
17	Article by a homeowner giving a narrative description of his AWHP retrofit in Vermont	https://www.greenbuildingadvisor.com/article/air-to-water-heat-pump-retrofit
18	NorthAndoverCAM YouTube video 23:40 through 31:40 only	https://www.youtube.com/watch?v=9SMxaOMX-oY
19	Acton Open House YouTube video 1:50 through 6:17 only	https://www.youtube.com/watch?v=zXa8MiDVsRA