Emerging Heat Pump Technologies

FEBRUARY 2024

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Acknowledgements

About NEEP

NEEP was founded in 1996 as a nonprofit whose mission is to serve the Northeast and Mid-Atlantic to accelerate regional collaboration to promote advanced energy efficiency and related solutions in homes, buildings, industry, and communities. Our vision is that the region's homes, buildings, and communities are transformed into efficient, affordable, low-carbon, and resilient places to live, work, and play.

Disclaimer: NEEP verified the data used for this brief to the best of our ability. This paper reflects the opinion and judgments of the NEEP staff and does not necessarily reflect those of NEEP Board members, NEEP sponsors, or project participants and funders.

KEY TAKEAWAYS

- The Northeast/Mid-Atlantic region has aggressive emission reduction targets, including a focus on decarbonizing the building sector. Increased energy efficiency and electrification of key end uses, including space and water heating, provide critical pathways to building decarbonization.
- Electric heat pump solutions for space and water heating are readily available for single-family applications, with the market maturing quickly. Heat pump solutions for larger multifamily and commercial applications are less mature, and market awareness of these solutions is low.
- A series of emerging heat pump solutions are now available for larger multifamily and commercial applications, including technology suited for applications with low-temperature performance.
- Emerging categories explored in the brief include "micro" heat pumps, commercial packaged heat pumps (aka rooftop units), air-to-water heat pumps (space heating), central heat pump water heaters, 120-volt heat pump water heaters, and "combi" heat pumps.
- Energy efficiency program administrators and policymakers should be evaluating these new solutions for inclusion in promotional program offerings.
- Regional stakeholders should be collaborating on opportunities to develop these markets through coordinated market interventions.

Introduction

The Northeast and Mid-Atlantic region is home to some of the most aggressive carbon reduction commitments in the country.[1] Decarbonizing homes and buildings will require a combination of efficiency, electrification, and grid integration. Since space and water heating account for the majority of direct emissions in homes and buildings, low-carbon replacement solutions are needed across a range of sectors and building types.

Efficient electrification of homes and buildings has made progress in recent years through the adoption of heat pump technologies for space and water heating applications. There is now a robust slate of options for residential and commercial cold climate ducted and ductless heat pumps, as well as options for stand-alone 240-volt heat pump water heaters. However, other HVAC and hot water system applications in both the residential and commercial sectors still need readily available, affordable, efficient heat pump solutions.

For these applications where heat pumps and improved efficiency have yet to be routinely adapted, improved heat pump technology and model options are increasingly able to accommodate a variety of building types and HVAC needs. Newer generation equipment can combine heat pumps with ventilation, humidity controls, and other smart technology to offer efficient, creative, customizable, and coordinated combinations to manage a building's needs.[2] Units with low temperature performance (often referred to as "cold climate") can lead the way for gains in efficiency, but even buildings that incorporate heat pumps that do not have low temperature performance can realize significant energy and cost savings.[3]

Energy efficiency and decarbonization program administrators can begin to examine and incorporate emerging heat pump categories in their customer pilot programs. These categories represent a host of new HVAC measures that programs may eventually promote to achieve ambitious energy and carbon savings goals.

This brief discusses air source heat pump technologies that are up-and-coming in functionality and availability for applications in the Northeast and Mid-Atlantic region.[4] The emerging heat pump technology categories[5] are listed in Table 1 and provide detailed information about the existing status of the technology as well as advantages, challenges, and technology examples. Under each category, the "applications" section mentions which building type or situation may most readily benefit from that technology.

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[1] Center for Climate and Energy Solutions. "State Climate Policy Maps." https://www.c2es.org/content/state-climate-policy/.

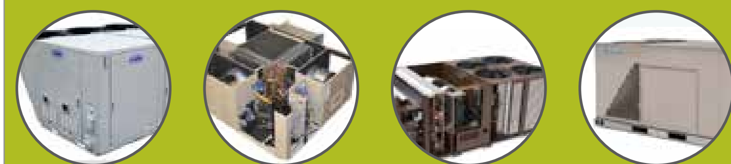
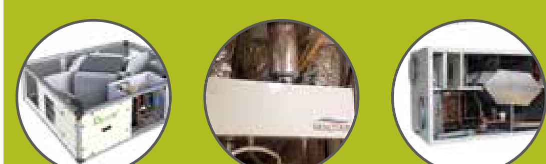
[2] For some categories discussed, ground-source or water-source systems may provide practical and economical solutions. Because these options often have extensive customization needs and site-specific variables, we did not include them in this brief. Other heating technologies such as solar or biomass, though they may be practical and economical, are outside the purview of this brief.

[3] We use terminology such as "cold climate capable" here to refer to heat pumps that can operate with relative efficiency at temperatures below freezing. For this brief, we are not distinguishing what would qualify a heat pump for colder climate applications aside from efficiency in sub-freezing temperatures above that of electric resistance. Because many of the products mentioned herein lack thorough testing data, especially third-party data, we opt to mention promising manufacturers and models without stating in-depth capacities. Equipment specifications included are from manufacturers or AHRI if available. With newer technologies particularly, further testing and real-world performance may differ either positively or negatively from information currently available.

[4] Mentions of manufacturers and models in this brief do not construe endorsements but rather are examples of the technology category.

[5] Categories are defined here for convenience. Some technologies may bridge categories.

Table 1. ***Emerging Technology Heat Pump Categories Covered in Brief***

Cold Climate "Micro" Heat Pumps 	Smaller capacity heat pumps that are 120-volt and intended for "room" cooling and heating.
Commercial Packaged Heat Pumps (aka Rooftop Units) 	Units that replace/displace gas furnaces in commercial rooftop units. May include ventilation controls.
Air-to-Water Space Heating Heat Pumps 	Units able to provide water heated to 140°F or higher to provide hydronic heat for buildings. (Provides space heating but not water heating.)
Central Heat Pump Water Heaters 	Domestic hot water systems designed for commercial/multifamily applications.
120-Volt Heat Pump Water Heater 	Domestic hot water (DHW) heaters operating on a standard 120V outlet.
"Combi" Heat Pumps 	Integrated space heating/cooling, ventilation, and energy/heat recovery ventilators (ERV/HRVs). May include other building needs such as humidity control or DHW.

COLD CLIMATE "MICRO" HEAT PUMPS

What Are They:

"Micro" heat pumps are low-capacity heat pumps that can be easily installed and are designed to serve a single zone. Micro units could be installed in the following configurations: through-window, through-wall, portable, or a modified mini-split arrangement (see Figure 1). Given the popular through-window configuration option, these units are sometimes referred to as window heat pumps. The Northwest Energy Efficiency Alliance has offered the definition that they:

- Operate on shared 15A 120V circuit.
- Have an inverter driven compressor.
- Are factory charged: a packaged system does not require refrigerant evacuation/charging.
- Are easy to install.
- Are generally intended for one room or a smaller living space.

Variants have different form factors and configurations. Cold climate micro units are now entering the market. These have defrost cycles and operate well at temperatures significantly below 40°F. For the Northeast region, with older housing stock and significant multifamily housing, these may hold particular potential for scaled-up decarbonization efforts. Two models are expected to be available by the end of 2024, likely with more on the way should these prove commercially successful.

Figure 1. ***Examples of Through-Window and Through-Wall Applications***

Example of through-wall model.
Only air exhaust/intake to exterior. *Image from Mestek*

Example of window "saddle" unit. *Images from Gradient*

Micro vs. PTHP and SPVHP: Packaged terminal heat pumps (PTHP) are designed to be installed in a standard-sized hole in an exterior wall. Single package vertical units (SPVHP) are typically designed for installation in utility rooms or small vertical spaces. Both run on 240V and are intended as more permanent HVAC installations. They also typically rely on electric resistance heating below 40°F. Micro units differ in that they typically use an existing window opening or only use a small ducting through the wall. Currently, only a few PTHP and SPVHP models can operate well in cold climates. These are noted on the NEEP Cold Climate Air Source Air Source Heat Pump List: Ice Air RSXC Series (for PTHP), and Ice-Air SPXC series and Ephoca series (for SPVHP).

A particular challenge for cold climate micro units (and potentially any unit installed higher up) is managing defrost and condensate water if the location allows the drained water to freeze and become a potential ice risk to people and equipment below. Manufacturers are addressing this issue by developing solutions to manage the meltwater when required. Some solutions include nebulizing (misting) the water, draining water into existing indoor piping, or temporary storage.

APPLICATIONS: Single-family room heat/cool. Light commercial. Retrofit for multifamily.

Status:

Cold climate "micro" heat pumps are still new to the market, and heating season ratings do not yet exist. The New York City Housing Authority is conducting field performance testing of window units in multifamily housing in New York City. This project is testing Midea America and Gradient models. More models from other manufacturers are expected within a year or two. ENERGY STAR and Consortium for Energy Efficiency (CEE) are considering specifications for window heat pumps, and so we may expect listings and specifications in the next few years or sooner. These new models should generally be able to deliver efficient heating performance to 17°F or lower.

Rebates: There are no known prescriptive rebates yet stated specifically for these types of heat pumps. They may be incorporated into residential rebates once performance data is established. Most states in the Northeast region have custom rebate programs for demonstrable savings from equipment upgrades.

Advantages:

- Potential solution for residences without ground space available for standard outdoor condensers.
- Quieter, with a greater range of operation and improved control compared to conventional window AC units with a reverse cycle.
- Comparable capacity to a small ductless mini-split but lower cost.
- For homes/apartments with only 120V service, these units may allow heat pump benefits without the need for a potentially expensive panel upgrade or running new 240V lines.
- Potentially installed by owner/tenant/DIY with minimal set up.
- Pre-charged, contained systems reduce risks of leakage.
- Potential to mostly or fully address multifamily housing heating/cooling needs.
- Tenants may be able to purchase and take the units with them if they move.
- For window units, the saddle design allows for more of the original window view than other designs.
- For through-wall units, there may be only the need for an exhaust/intake vent.
- They may help with emergency cooling.

Challenges:

- Smaller capacities range from around 6,000 to 12,000 Btu/h.
- Efficiencies for cold climate capable models are expected to be slightly less than similar cold climate mini-splits.
- Pricier than non-cold climate capable window and portable heat pump models.
- For window units, the sash window opening needs to be weatherized and potentially locked in place.
- Not all windows, sills, interior walls, or exterior walls may be able to accommodate the units (e.g, the saddle-type units need a sash window for installation).
- The weight of the units, though not excessive, may be a problem because they are heavier than standard window AC units.
- During lower temperatures, the thawed water from condensers in certain locations may be more problematic because of refreezing on surfaces below (e.g., sidewalks). Solutions are being devised.
- Wall penetrations for ducting would still be needed for a wall-mount unit.
- Micro units are not necessarily a whole-house solution and may not support a complete transition off fossil fuels for a residence.
- Potential user misunderstanding of how they operate may result in them functioning as AC only, or adversely competing with other heating/cooling in the building.
- Units still need a primarily dedicated 120V circuit (no additional heavy electrical loads).
- Cost/energy savings estimates are still being assessed.

The potential for incorrect installation or building conditions has not been adequately assessed (e.g., primary HVAC function adversely affected, moisture issues).

Examples:

Window Or Through-Wall

Gradient Window heat pump (pre-ordering)
Midea (In development)
Gree (In development)

Through-Wall (Indoor Monoblock)

Designline (In development)
Ephoca AOI series Includes ERV.
Olimpia Splendid Maestro series

Portable (Not cold climate capable. Examples of note from Electrify Now. Separate intake/exhaust noted as most efficient design.)

Midea DUO MAP14HS1TBL Separate intake/exhaust. Noted as highest efficiency currently available.
Whynter ARC-14SH Separate intake/exhaust. Condensate drain pump included for lower capacity heating model. Higher capacity heating model has no drain pump.
Frigidaire FHPH142AC1 One intake/exhaust. Drain pump included.
LG LP1021BHSM One intake/exhaust. Drain pump included.

COMMERCIAL PACKAGED HEAT PUMPS (aka Rooftop Units)

What Are They:

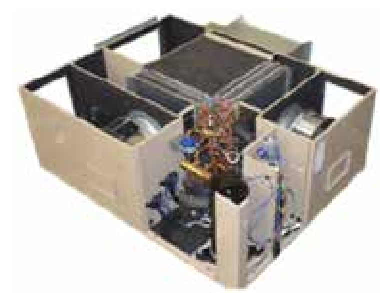
Commercial packaged HVAC systems or rooftop units (RTU) are a ubiquitous HVAC technology in the commercial building sector. (See RTU description below.) RTUs with some form of integrated heat pump are becoming increasingly available and popular nationwide. These may only have heat pumps for heating/cooling or may have a dual-fuel option for colder temperatures.

In our region, there are large opportunities for energy savings in the commercial realm through heating electrification. A 2020 report by the American Council for an Energy-Efficient Economy found that 27 percent of commercial floor space heated with fossil fuel systems could be electrified today with a simple payback of less than 10 years. Heat pump RTUs are already popular in southern states since heat pump performance can be especially effective through modest winters.

A variety of commercial-sized RTU replacement heat pump options along with newer refrigerants are expected within a few years. Many newer RTUs are also more efficient simply due to smarter energy-saving construction than their predecessors. Planning for RTU replacement is the best time to revisit actual building loads and needs to realize efficient options that result in savings. **Dual-fuel** RTUs can offer bridge technology for short-term improvements. (The Center for Energy and Environment (CEE) is investigating dual-fuel RTU performance.) **HRV/ERVs** (heat recovery/ energy recovery ventilators) incorporated into equipment also show high promise for significant energy savings. HRV/ERVs may be added into existing RTUs, but they often come as part of the package with newer RTU options.

Figure 2. ***Examples of Commercial Packaged Heat Pumps***

Aaon RN Series



Transom Topaz MHP Series HRV with heat pump

Daikin Maverick I

York Sun Choice Series

Configured to order (CTO) modularity and customization is a hallmark of RTU manufacturers. The combination of more efficient and flexible designs coming into the market along with state and utility incentives make electric options for commercial HVAC increasingly practical. Smaller capacity or fewer RTUs may be practical for a given building if one combines change-outs of existing RTUs to heat pump systems with weatherization and other efficiency measures.

Air-to-air RTUs may incorporate adjustable ventilation and energy recovery ventilators and may act like the "combi" category later in this brief—the difference is that RTUs are installed outside the envelope and are typically intended for larger commercial scenarios, whereas the combi units are typically inside the building envelope and have a smaller capacity. Some commercial energy recovery ventilators coming on the market may serve as replacements for some RTUs when combined with other building shell and HVAC upgrades.

RTU and Heat Pump RTU Description: RTUs are packaged units that provide heated/cooled airflow or water directly from the unit into the building space or ductwork. They are typically found on flat commercial rooftops, thus the name, but could be installed elsewhere. Heat pump RTUs are distinct from other heat pump split systems in that the components are contained in one housing. There are now a multitude of larger-sized *split* heat pump options for providing heated/cooled refrigerant to heat exchangers in buildings, but options for commercial-sized *packaged* units are still emerging. (For this section, we focus on *air-to-air* RTUs. *Air-to-water* packaged heat pump units for rooftops exist and are discussed in the next section on air-to-water space heating.)

APPLICATIONS: Light/heavy commercial: New construction, retrofits.

Status: Several models mentioned below are now available in the United States and have been installed throughout the country. Independent field trials are beginning.

Rebates: Most states in the Northeast region have custom rebate programs for innovative and demonstrable savings from equipment upgrades. **Maine lists heat pump RTUs in Efficiency Maine's** commercial incentive program.

Advantages:

- High potential to offset fossil fuel and cost for larger commercial spaces, particularly during the more temperate months.
- Newer and more sophisticated RTUs are increasingly coupled with HRV/ERVs for more efficiency.
- Newer RTUs tend to be more modular, flexible, and capable of accommodating air quality sensors, humidifiers, UV lights, and other IAQ technologies.
- Heat pump RTUs are often designed to be adjustable for intake/exhaust air to meet the building's fresh air needs.
- RTUs are prefabricated and often easier to install than split units with refrigerant lines. The equipment housings are often more accessible for repair and adjustments.

Challenges:

- There are still not many cold climate capable "heat pump only" RTU models currently available in the United States. However, dual-fuel options can provide cost-effective solutions until more practical all-electric options are available.
- In general, RTUs need three-phase power, and their locations may be difficult to access.

Examples:

Because of flexible design options, manufacturers often offer heat pump options within an RTU series. Options may include dual-fuel integration. For dual-fuel options, fossil fuel may take over heating at a certain outdoor temperature or if the building interior space drops below a certain temperature, but some models are now able to offer fossil fuel heat concurrent with continued heat pump operation. Increasingly, RTUs also incorporate energy recovery options (ERV/HRV). Even though there are not many RTUs designed for efficient heat pump operation in very low temperatures, RTUs with heat pumps that provide heat in any capacity may still significantly offset costs and fuel.

York:	Sun Choice Series (12.5-25 ton)
Aaon:	RN and RQ Series Designed for sub-freezing climate.
Daikin:	Rebel (3-28 ton) HP-only or dual-fuel simultaneous.
	Maverick I (3-25 ton)
	DP14HM (3 ton)
Transom:	Topaz MHP Series
Lennox:	Enlight and Xion
Trane:	Impack (2-5 ton)
	Precedent (3-25 ton)

AIR-TO-WATER SPACE HEATING HEAT PUMPS

WHAT ARE THEY:

Air-to-water heat pump systems, also referred to as reverse cycle chillers, produce hot or cold water to be utilized in hydronic distribution systems and possibly domestic hot water as well. For this brief, we are focusing on those systems that hold more potential for space heating. Some emerging systems can produce water up to and over 180°F, making them a "drop in" solution for homes and buildings with existing hydronic distribution. Since boilers and chillers are particularly common in the Northeast and buildings have enduring pipework, air-to-water heat pumps are garnering increased interest as a practical and low-carbon replacement for existing fossil-fuel-based systems.

Figure 3. ***Examples of Air-to-Water Heat Pumps***

SpacePak Solstice series

Mitsubishi Ecodan CAHV Commercial ATW

LG THERMA V Monobloc

SanCO$_2$ Eco$_2$ residential install

Air-to-water heat pumps are available today in both split and "monobloc" configurations. Options are increasing for *both* residential and commercial applications. Some systems more extensively incorporate buffer tanks (storage tanks acting as thermal batteries for space heating or cooling).

Split systems operate much like standard air-to-air heat pump configurations with an outdoor compressor sending heated or cooled refrigerant into the building. A heat exchanger then heats or cools a water storage tank, and the water is sent where needed.

Monobloc systems consist of a singular outdoor unit that pipes heated or cooled water directly from the outdoor unit into the home or building. Thus, there is no need for refrigerant piping outside of the outdoor unit housing. They offer straightforward connections for water to connect to a separate water tank (or tanks) or to be used for heating/cooling directly.

Most existing fossil fuel boiler systems are designed for temperatures around 160-180°F—aka "high temperature systems." Many of these hydronic heating systems are now considered oversized, especially when the building receives appropriate ventilation, weatherization, and fine-tunes the distribution. An updated heat pump system may be completely adequate without the same high temperature needs. There may also be the opportunity to now add cooling fan coils depending on the layout. (For newer, carefully designed buildings, low temperature hydronic heat under 140°F may be all that is needed. Heat pumps that can reach this lower temperature water without electric resistance heating are increasingly common and affordable.)

APPLICATIONS: Buildings with hydronic heating/cooling: Single-family, multifamily, light/heavy commercial: New construction, retrofits**.**

Status: Several models are available in the United States. Smaller capacity models are more available than larger capacity models at the moment. Air-to-water systems have gained considerable traction in European and Asian markets and some models may be adjusted to be sold in the United States. ENERGY STAR is exploring specifications for residential product standards.

Rebates: Most states in the Northeast region have custom rebate programs for innovative and demonstrable savings from equipment upgrades.

Advantages:

- Units can be installed anywhere practical outside—even several hundred feet away from storage or fan coils.
- Heat pump options are typically stackable, adding units to meet building needs.
- Models that reach higher temperatures offer a potentially straightforward replacement for conventional buildings with hydronic heating.
- For systems that may not reach desired temperatures (e.g., during cold spells), they are adaptable to including electric resistance or fossil fuel boosting.
- Many include the capacity to include a heating loop for DHW. No need for an additional DHW unit, though a storage tank would still be required.
- They can be combined with existing or third-party storage tanks and pipework.
- Good potential for houses with hydronic heat and separate ducted AC systems to incorporate a heat exchanger for cooling.
- Flexibility allows for potential furnace (air exchanger) heating and cooling as well.
- Well-insulated houses offer options for air-to-water systems at lower temperatures than 160°F.

- They may incorporate hydronic cooling as well for appropriately designed and humidity-controlled buildings (e.g., fan coils in a variety of options for walls, floors, or ceilings, chilled beams, in-floor cooling).

Challenges:

- Many air-to-water heat pumps rely on electric resistance boost to attain higher temps, reducing efficiency, though for a well-designed system, this may only be during particularly cold spells if at all.
- Commercial heat pump products to raise water to above 160°F with heat pump technology alone are available but are relatively recent. There is limited availability in the U.S. at the time of writing.
- Outdoor space may be limited in some circumstances.
- It can get complicated to add hydronic cooling options for retrofits that have only heating.

Examples:

>140°F

Transom: Hatch Hot Water Air Source Recip Heat Pump, Simcoe Air Source CO_2 Heat Pump CO_2 refrigerant.
LG: Therma V Monobloc and others anticipated within months.
SanCO_2: Eco2 Systems CO_2 refrigerant in mini-split configuration.
Intellihot: Electron series CO2 refrigerant, thermal battery for "tankless" function, commercial.

=<140°F

SpacePak: Solstice Inverter Extreme, Solstice Inverter Monoblock, Solstice Inverter Split, Solstice Commercial Inverter, , SpacePak | Hydronics | Solstice Air-to-Water Heat Pumps
Transom: Hatch Hot Water Air Source Heat Pump

Model examples outside of the U.S.

Daikin: Altherma 3 Cold climate capable. Can heat to 176°F. Currently sold overseas. Anticipated in the U.S. soon. Can produce hot or chilled water. Other large-scale models are undergoing in-field testing.
Nilan: DHW Air9
Tecalor: THZ 504 Has surface cooling function as well.
Mayekawa: Mayekawa Plus+HEAT Ammonia refrigerant, 185°F. Can include DHW.
Mitsubishi: Ecodan series Monobloc residential/light commercial to 160°F. Cold climate capable.
Ecodan CAHV Monobloc for commercial hot water. Cold climate capable.

Large Capacity Air to Water

There are many examples of reverse cycle chillers and larger commercial air to water heat pump systems. Most of these are not cold climate capable but may still offer opportunities to reduce costs and carbon load through efficient water heating during times with higher seasonal temperatures.
Mitsubishi: E-Series Air Cooled Modular Chillers Heat pump options.
Aermec: Aermec Air to Water HPs (2-231 tons)

CENTRAL HEAT PUMP WATER HEATERS

What Are They:

Central heat pump water heaters (CHPWH) have capacities much larger than what a standard household would use for domestic hot water. They are common in larger multifamily and commercial buildings; hotels, dormitories, hospitals, etc. where they supply most or all of the building's domestic hot water (DHW) needs. Central heat pump water heater systems offer opportunities to decarbonize buildings with fossil fuel central water heaters.[6] Temperature capacities can range from around 130°F to 170°F.

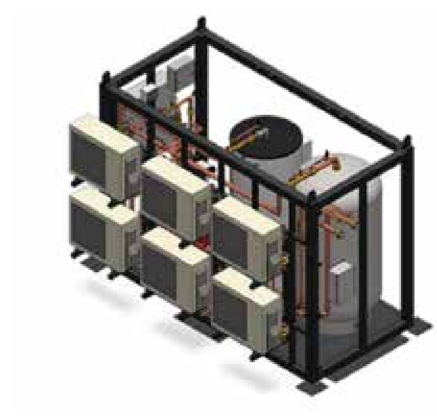
CHPWHs can provide a "drop in" solution for some buildings, particularly if there is not a high daily peak use spike. As heat pumps will typically recharge slower than a conventional unit, there are several methods for maintaining temperature during peak use: more and larger storage tanks, better water distribution within/between tanks to avoid thermal mixing, advanced mixing valves, and stacked condenser units are some methods. As with all larger-scale heat pump technology, careful planning and analysis are *essential* to meet needs and avoid oversizing (e.g., the hot water need assessment should take into account low-flow fixtures, pipe insulation, and correct building loads). Properly designed CHPWHs have the potential to reduce energy used by a factor of approximately three.[7] CO_2 refrigerant models are emerging in the U.S. as well.

NEEA maintains a qualified product list for commercial multifamily heat pump water heaters divided by general climate zone. Considerations for configuring a CHPWH system are discussed in this report from the Association for Energy Affordability.

Figure 4. ***Examples of Central Hot Water Heater Heat Pumps***

Nyle E360

Mitsubishi Heat2O



WaterDrop System customizable module example with $SanCO_2$ compressors

[6] There may be efficient options to incorporate large scale ground- or water-source domestic water heating especially in conjunction with any ground- or water-source building heating/cooling project. Ground- or water-source will have specific opportunities or constraints at a given location and are outside the purview of this brief.

[7] Ecosizer (Ecotope) is a free educational third-party tool for sizing CHPWHs in multifamily and commercial buildings. The tool is designed to support the building industry to adopt CHPWHs and assist and educate other building decarbonization stakeholders. Many manufacturers will also offer sizing guidance.

Residential heat pump water heaters that reach temperatures around 130-140°F are now relatively available (e.g., A.O. Smith or DHW hybrid systems for residential use). This brief does not discuss these smaller capacity units that are increasingly popular. NEEA maintains a qualified product list for residential HPWHs—both unitary and split systems.

APPLICATIONS: Multifamily, light/heavy commercial: New construction, retrofits.

Status: CHPWHs are available in the United States. Some installation case studies are available on manufacturer websites. As examples, the Mitsubishi Heat2o System is installed at Hotel Marcel in New Haven, CT, and Eco2 Systems in a multifamily retrofit in Seattle, WA. Third-party field validation studies are anticipated for 2024.

Rebates: Most states in the Northeast region have custom rebate programs for innovative and demonstrable savings from equipment upgrades. Those planning projects should contact their utility/state program.

Advantages:

- Replacement of central fossil fuel water heaters for commercial applications such as hotels, food processing plants, commercial buildings, malls, etc.
- Replacement of larger multifamily central DHW systems.
- Sizing and modular options can accommodate most needs and be prefabricated for easy installation (e.g., packaged skid mounted units that can be dropped in place at the outdoor location).
- Condenser placement location is relatively flexible.
- They can be used as pre-heaters for higher temperature needs.
- Most provide cooled water if needed as well as hot water.

Challenges:

- Potentially high upfront and operating costs.
- Heat pump systems are more complex than fossil fuel systems.
- Market availability is modest (but growing).
- Contractor education/certification is still limited for installations and maintenance.
- Space/location constraints. Exterior space or ample access to exterior air is necessary.
- Slower recharge needs to be considered in design (not a drop-in replacement for "instant" DHW).
- There may be a need for extra storage capacity, especially for usage spikes.
- Cold climate applications are in development and testing. Some models may need adjustments.

Examples:

In addition to these air-to-water systems below, many of these manufacturers also provide heat pump options for water-to-water.

Transom: Simcoe Up to 190°F. CO_2 refrigerant. Modular capable.

Mitsubishi: Heat2O 170°F. CO_2 refrigerant. 2 GPM for slow/steady generation.
Ecodan CAHV Anticipated in the U.S. market soon.

Daikin: MEGA-Q Up to 194°F. Anticipated in U.S. market soon.

Nyle: E360 160°F. 360,000 Btu/h heating. Operational to 10°F. R-513a refrigerant.
C-Series Air Source units 25,000 to 250,00 Btu/h heating. R-513a refrigerant. COP to 5.

A.O. Smith: CHP-120 For light commercial. COP 4.2. 119-gallon tank. To 150°F in heat pump mode.
Emerge™-x Several models available 66,688 Btu/h – 339,450 Btu/h heating capacity. R-513A refrigerant. To 160°F.

Mayekawa: unimo AW Others in the series combine air and water sources and provide simultaneous cold/hot water.

Lync: Aegis A To 160°F. CO_2 refrigerant. Operational to -4°F.

Rheem: Commercial models 60K btu/h & 135k Btu/h heating capacity models available. R134a refrigerant. To 150°F

SanCO2: Eco2 Systems CO_2 refrigerant. Residential model stackable for commercial uses. Operational to -25°F. Paired as commercial packaged units with WaterDrop System.

WaterDrop: Modular drop-in heat pump plants CO_2 refrigerant. Uses SanCO2.

120-VOLT HEAT PUMP WATER HEATERS

WHAT ARE THEY:

Plug-in 120V heat pump water heaters (HPWHs) can transform the water heating market by addressing some of the barriers that 240V heat pump water heaters face. The most significant barriers are higher upfront and installation costs, as well as the high cost of electrical panel upgrades. The 120V HPWHs are designed to reduce the cost and complexity that customers may incur, by plugging into a standard 120V outlet and not requiring a new 240V electrical line in a fuel-switch retrofit. According to consumer reports, an estimated 90 percent of water heater replacements occur on an emergency basis. Without an easy, affordable, and fast heat pump water heater replacement solution, homeowners are more inclined to like-for-like replacements.

Emerging best practice recommendations from installers and manufacturers recommend upsizing two tank sizes when replacing a unit with a 120V HPWH since the units have longer recharge times (e.g., an 85-gallon tank to replace a 55-gallon former tank). All 120V HPWHs also have an *integrated mixing valve,* or the ancillary tank can be outfitted with one, so that the HPWH can heat water to higher temperatures, providing up to one-third more hot water by mixing cold water into the water line to maintain the desired temperature.

Future Focus Initiative provided a 2022 study on the efficacy of 120-volt water heaters in a research project for Midwest states. New Buildings Institute also recently completed a field study with findings and market commercialization recommendations for the California area.

APPLICATIONS: Single-family, multifamily: Retrofits**.**

Status: Rheem and A.O. Smith manufacture integrated units. Nyle manufactures a split unit.

Figure 5. ***Examples of 120-Volt Water Heater Heat Pumps***

Rheem ProTerra 120V Plug-in

A.O. Smith Voltex® 120V Plug-In

Nyle C6 (no storage tank)

Rebates: Several of the models are ENERGY STAR certified and so should qualify for federal tax credits as well as most utility rebates. There are no known rebates associated with these units currently. As more information and performance specs are known, states/utilities may incorporate these units into standard residential/light commercial rebate programs.

Avantages:

- Relatively fast and easy low-cost installation.
- No electrical panel upgrade is required if 240V is not available or practical.
- They are relatively quiet (~45 dBA).
- They offer ancillary dehumidification (and cooling) for the installed room.
- Potential for stop-gap emergency replacement of a failed DHW system.
- They can potentially use existing storage tanks or more compact tanks for the separated condenser design.

Challenges:

- The ordering process can be difficult but is expected to improve. National retail sites now have some available.
- They are not intended for households with more than five people (depending on tank size).
- Not enough information/awareness among contractors.
- Slower recharge time than people may expect from their previous system.
- They may cool a smaller room several degrees in cold seasons as well.
- As with other HPWHs, installation is intended for interior or semi-conditioned spaces. Location matters for efficiency in heating-dominant regions.
- Heat pump water heaters have a minimum cubic foot space requirement depending on model (i.e., 750 cubic feet or more depending on the room's heat capacity).

Examples:

Rheem: ProTerra 120V Plug-in 40-, 50-, 65- and 80-gallon hybrid electric heat pump. R134A refrigerant.

A.O. Smith: Voltex®- 120V Plug-In 66- and 80-gallon hybrid electric heat pump. R-513a refrigerant.

Nyle: C6 R-513a refrigerant. 6,000 Btu/h capacity. Heat to 145ºF. Recovery rate of approx. 10 GPH. Compressor sends hot water to storage tank(s). R8A 8,000 Btu/h. Recovery rate of approx. 13 GPH. Anticipated to be available mid-2024.

As another example of an emerging technology, A.O. Smith micro heat pump water heaters are small 15- to 20-gallon units that can be wall or ceiling mounted. These are not cold climate capable and are not yet sold in the U.S., but as technology improvements and creativity push the envelope, we can expect more such niche applications.

Figure 6. ***Example of a Mounted Lower Voltage Water Heater Heat Pump*** (not yet sold in U.S.)

A.O. Smith HPW-60A

"COMBI" HEAT PUMPS

WHAT ARE THEY:

For this brief, we consider "combi" units as integrated HVAC systems providing several services including heating, cooling, dehumidification, and ventilation. Typically, these are designed for buildings with lower-than-normal heat/cool loads and are increasingly being installed in small, very efficient new homes (e.g., Passive House standard construction). These units use a small heat pump, often incorporate HRV/ERV plates, and use the building's ventilation system to provide heat/cool. They may also include dehumidification, air filtration, UV sanitation, and may even have potential to augment hot water production with extra summer month heat. Some have built-in or optional pollutant sensors that monitor CO2 or VOC levels or particulates as situations dictate. Most appear to be designed for a central distribution system though they could be adaptable to shorter ducted runs. Lastly, these combi units are intended to be installed *inside* the building envelope with just an air exhaust/ intake to the outside.

Figure 7. ***Examples of "Combi" Heat Pumps***

Dpurat ERV with heat pump

Minotair Heat Pump/Ventilation unit

Genvex Premium Preheat 250 CL A

This type of bundled technology has also been referred to as: compact air treatment unit, compact HVAC, multifunction air exchanger, heat recovery ventilator with heat pump, extended compact heat pump system, conditioned energy recovery ventilations, or compact ventilation unit. Some experts in Passive House construction practices wrap the concept into the simpler terms “combined system” or “magic box.” For essentially *all* buildings with a contained envelope, there is increasing awareness of the benefits of incorporating energy recovery systems into the mix—capturing “free” heating or cooling while mechanical ventilation is ongoing.

These combi units are different than dedicated outdoor air systems (DOAS) in that they include heat pump cooling and heating. DOAS are specifically for outdoor air exchange and can be greatly enhanced by active or passive heat exchange between incoming/outgoing air, but DOAS units are not intended to be the main source of heating/cooling. A separate heating/cooling system and a DOAS may be most practical for most applications at this point, particularly for commercial buildings.

APPLICATIONS: Single-family, multifamily, light commercial: New construction, retrofit.

Status: Popular overseas. Several options in the United States. Expect more options available in U.S. within the next few years.

Rebates: These units are not yet specifically mentioned in regional rebate programs. However, most states in the Northeast region offer custom rebate programs for innovative and demonstrable savings from equipment upgrades. Multifunctional units such as these would likely require a thorough building energy model to quantify savings.

Advantages:

- They can deliver fresh air in a conditioned state to reduce ventilation impact on comfort.
- ERV/HRV components add to high efficiency.
- Fewer building shell penetrations (potentially just one). Ideal for small, well insulated buildings.
- One duct system to manage heat/cool, fresh air, humidity control, and air filtration/sanitation.
- Potential for easier, comprehensive multifamily applications and retrofits.
- With more sophisticated systems, summer waste heat may be designed to aid DHW.
- Some have no operating temperature limit and do not require frost prevention heaters.

Challenges:

- Most currently available are around 2-ton size or smaller, so for a retrofit, comprehensive weatherization may be needed to allow them to be effective.
- Appropriate ductwork may not be in place for retrofits.
- Cost may be prohibitive (of course, cost should be considered alongside the total offset costs of separate components and systems addressed by the combi units).
- Not many U.S. models are available as of this writing.
- Many efficient European options do not offer cooling.

Examples:

Build Equinox: CERV
Nilan: Nine models noted: Combi203 Polar, Combi 302 Polar Top series, VPR series, and VPL series.
Minotair: Minotair

The Passive House Portal Component Database: Heat Pumps notes several combined systems. The majority are from China, Germany, and Denmark with limited availability in the U.S. at the moment.

Brands include:

Stiebel	**Zehnder**	**Lv Wu Environmental Technology**
Panasonic	**Tecalor**	**Aerosmart M**
Zimmerman	**Genvex**	**Drexel und Weiss**

Conclusion

The Northeast U.S. has made strides toward building decarbonization. Residential single-family and small business heat pump options are becoming robust and can address most fossil fuel replacements. (Hydronic heating is an exception, but more options are now appearing.) Solutions for both small-scale and very large-scale heating/cooling needs are also making their way onto the market for commercial and multifamily applications.

- **More options:** For many of these more niche HVAC needs, cost/benefit analyses can show clear financial advantages for heat pump options. More definitive trials and testing are now underway. Popular overseas product lines are preparing for U.S. sales. Expect to have an increasing number of heat pump options across the board.
- **Combined systems:** Emerging technologies have opportunities to combine several previously separate systems into single managed units. Ventilation, moisture control, air quality filters and sensors, and domestic hot water are increasingly options or are included in a variety of choices.
- **Modular systems:** Particularly for commercial needs, modular (stacked) heat pump systems allow for high levels of customization, flexibility, and efficiency.
- **Dual-fuel:** For larger commercial applications and in the shorter term, dual-fuel options for colder climates may be practical to install if full electrification is not feasible.
- **Full electrification:** For commercial needs in colder climates, full efficient electric heating options, although currently limited, *are* available and are increasing. Heat pump upgrades, particularly in conjunction with building improvements and "smart" use technology may make electrification very feasible.

Emerging technology markets in heat pumps and highly efficient electrification are evolving quickly. Efficient and electrified HVAC paired with other building efficiency measures can significantly reduce energy use, operational costs, and overall environmental impact. We appear to be on the cusp of a large expansion of available technology on the U.S. market in the next few years. NEEP will continue to track and report on market, program, and policy changes for our partners so the region can be prepared to drive adoption of these new HVAC solutions.