Air-to-Water Heat Pumps

These advanced systems come with a steep learning curve

BY TED CUSHMAN

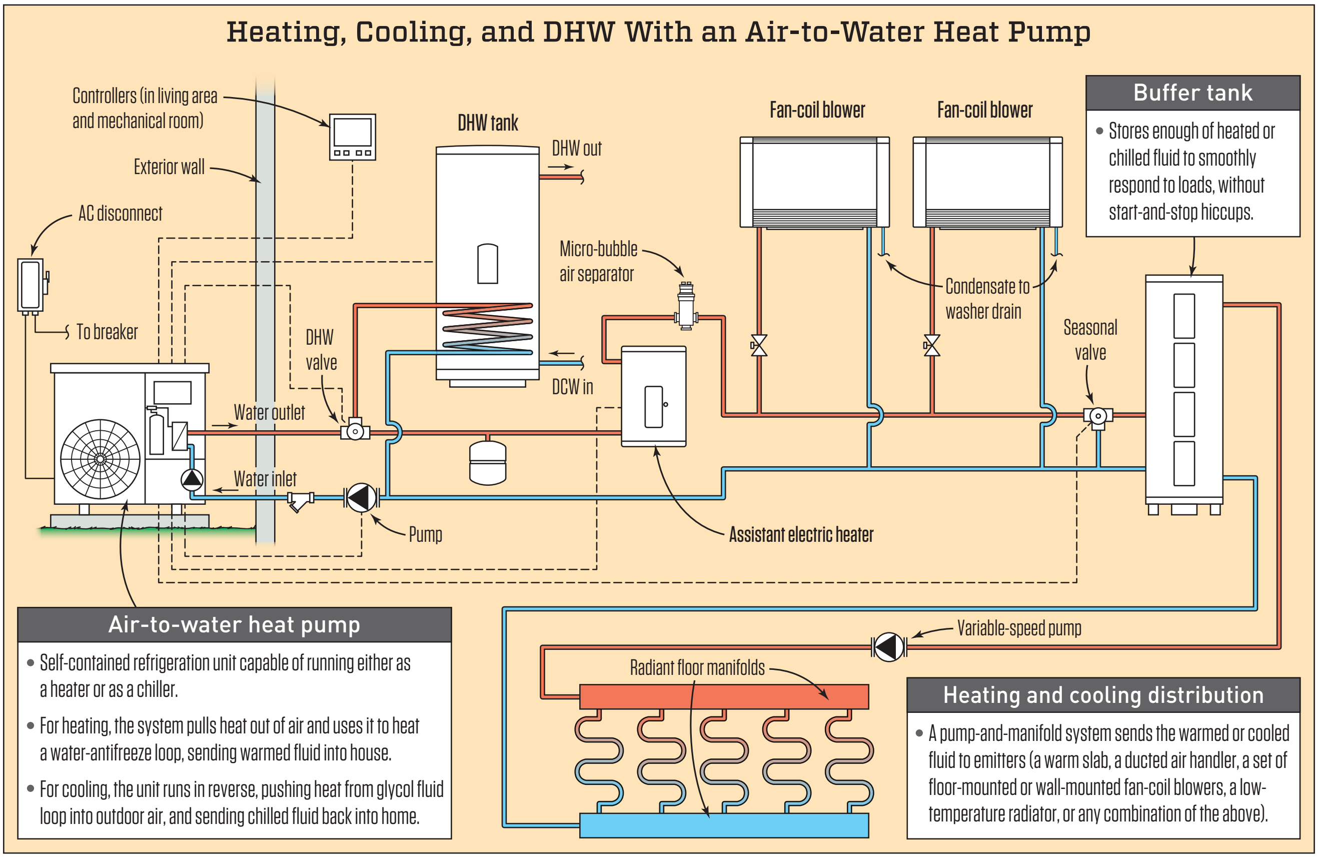
Heat pumps, like air conditioners, are a well-established and well-known technology. Most builders are familiar with some form of heat pump. As an alternative to gas furnaces, split-system heat pumps have been popular in mixed climates in the United States for years, where they do double duty, supplying heating in winter and cooling in summer. More recently, gains in efficiency and in cold-weather performance are helping mini-split heat pumps become a go-to solution for high-performance homes in the colder parts of the United States.

There's another flavor of heat pump you probably haven't heard as much about: "air-to-water" heat pumps, sometimes called "chillers." Large-scale versions of these systems are widely used in commercial construction, where they supply heated and chilled water to heat or cool living and working spaces in mid-rise and high-rise apartment and office buildings. Small, highly efficient systems sized for one-family homes are relative newcomers to the U.S. market, but these smaller systems have a growing toe-hold, especially among high-performance builders.

Air-to-water heat pumps aren't for the faint of heart. The concept is proven in large buildings, but miniaturizing the method for use in single-family homes has proven to be a challenge, even for big companies trying to develop the market niche. Contractors who have tried the systems report a variety of glitches, from software issues to component availability to difficulty finding qualified trade contractors to install and maintain the equipment. Still, the technology offers so much promise that early adopters have been working hard to master the learning curve and bring air-to-water heat pumps into the mainstream.

JLC talked this year with manufacturers, HVAC contractors, and builders who have tried out the air-to-water solution. Here's

Photos by Ted Cushman



Pieces of the puzzle. The schematic above shows the primary components of a typical air-to-water-heat-pump setup. There are many ways to configure a system, but in this example, the outdoor system provides heated or chilled water to satisfy three types of demand: domestic hot water, a radiant floor, and a pair of wall-mounted fan-coil units that can cool as well as heat.

what we learned about the technology's potential and about the practical complications you'll want to be ready for.

THE TECHNOLOGY

So what are air-to-water heat pumps, and how do they work? The principle is simple: A self-contained refrigeration unit capable of running either as a heater or as a chiller sits on a pad on the ground outside a building. When heating is called for, the system pulls heat out of the air and uses it to heat a water-antifreeze loop, sending the warmed fluid into the house. When the house calls for cooling, the unit runs in reverse, pushing heat from the glycol-fluid loop into the outdoor air and sending the chilled fluid back into the home.

Inside the house, a buffer tank stores enough of the heated or chilled fluid to smoothly respond to loads, without start-and-stop hiccups. A pump-and-manifold system sends the warmed or cooled fluid to emitters, which could be a warm slab, a ducted air handler, a set of floor-mounted or wall-mounted fan-coil blowers, a low-temperature radiator, or any combination of the above. In winter, the warm slab and the hydro-air blowers or radiators heat the house; in summer, the blowers and perhaps even a chilled slab cool the same spaces. Systems can also be configured to heat domestic water.

ARRANGING THE COMPONENTS

The muscle of an air-to-water-heat-pump system is the outdoor unit, a self-contained compressor, condenser, and evaporator that can produce either heated or chilled water. For builders, installers, or even do-it-yourselfers, one big advantage to this concept is that all the refrigerant for the system is contained inside the package unit. Installers just have to place the unit and hook up the hot and cold water-antifreeze loops, which, unlike handling refrigerant, requires no special license from the Environmental Protection Agency (EPA). Seattle-area builder Ted Clifton, who handles his own installations, comments, "With refrigerant, there's a little

Tight squeeze. Here, workers for ReVision Energy install a SpacePak air-to-water heat pump at a custom home in southern Maine. ReVision's Chris Blaisdell checks the unit's dimensions **(1)**, and then he checks the headroom **(2)** and support frame width **(3)**. All the refrigerant in the system is contained within the package unit, but planning and coordination are needed to make sure the pad is correctly sized and power hookups and shutoffs are appropriately located.

bit of a hazard. You don't want to let that leak out into the air; you have to be careful. But running just supply and return water lines, it's no big deal. You could even puncture one of those and it's not going to cause any big problem besides a leak."

In a typical installation, the fluid from the outdoor unit is pumped to a buffer tank inside the house. This simplifies the control system. The chiller on its pad outside senses the temperature in the buffer tank and keeps it constant. Loops drawn off the buffer tank serve the heating and cooling output devices in the living spaces; if the house calls for heat and those supply loops activate, the temperature in the buffer tank changes, which signals the heat pump to kick in and restore the balance.

Next in the chain are the emitters. In this regard, houses we looked at in researching this story turned out to be similar. Each well-insulated home had a radiant slab on the ground floor. Besides the heated slab, all these homes also had some sort of hydro-air point heat source to heat upstairs zones or to provide cooling in summer, or simply as a quick-response supplement for the main heated slab.

Heat pumps provide relatively low-temperature water. That's ideal for radiant slabs; 95°F hydronic fluid in the slab is typical. Depending on the setup, the small hydro-air fan-coil units that serve some rooms or zones can be supplied with 120°F to 130°F water if needed; the fan-coil units, however, are also designed to squeeze useful heat out of lower temperature water in a way that ordinary radiant baseboard can't. Higher water temperature allows higher heat output per hydro-air emitter, but lower-temperature water allows the emitters to operate more efficiently.

The choice depends on the situation. Builder Ted Clifton has installed the systems himself on about a dozen houses. Clifton explains: "I'm running 90°F water through my fan-coil units. I'm using the same water that I'm using in my radiant-floor loop, and I would rather have my floor loop be at 85°F or thereabouts. So I kind of compromise at around 90°F. To have the fan blowing by that makes it effective. If I can make water with the heat pump at 90°F, and use a tiny bit of electricity to blow that around with a fan, that is going to be more efficient and it's going to be less electricity than asking the heat pump to produce 120°F water."

But Mark Dwyer, who built a custom home in Bangor, Maine, last year, runs his fan-coil units straight off his heat pump at a higher water temperature than he draws off his buffer tank for his heated slab (for a look at Dwyer's house, see "Practical Net Zero," Feb/18). Dwyer notes that his fan-coil units can pump out 5,000 Btu/hr at 125°F, but less than 3,000 Btu/hr at 95°F. Dwyer's fan coils are mainly there for cooling during Bangor's 90°F-plus August weather; the warm slab by itself will probably handle his heating load. But if he does want a quick blast of extra heat in the winter, the hotter water in the fan-coil units can give him that.

EFFICIENCY AND CAPACITY

Heat pumps are rated for efficiency based on their "Coefficient of Performance," or COP. COP is the ratio of heat output to electric power input; so when an air-to-water heat pump is operating at a COP of 3, it's making three times the heat that the same amount of current would supply via a simple electric-resistance water heater. Air-to-water heat pumps on the market today have official COP ratings in the range of 4 to almost 6.

COP is a relative number, however, because it depends on outdoor ambient temperature. As temperatures outside drop, the heat pump has to work harder to pull heat out of the air, and its COP goes down. At the same time, the equipment's total output also drops. This means that as heating requirements increase, both the heat pump's capacity and its efficiency decline. At some point, the demand and supply curves cross, and the heat pump can't keep up with demand. And when that happens, the units are set up to fall back on backup heat, supplied by a simple resistance element in a backup water tank. As the resistance backup ramps up, shouldering a larger portion of the heating load, the COP drops sharply, bottoming out at 1, with the house relying on simple electric heat. So for houses heated with heat pumps (and this includes any kind of heat pump, not just the air-to-water variety), electric bills will be highest during the coldest part of the heating season.

In this regard, heat pumps have the opposite problem of conventional fossil-fuel equipment. Gas and oil heating equipment is sized to match peak heating loads, and it performs best during design conditions in the depth of winter. At lower loads, during the shoulder seasons of spring and fall, gas or oil heat cycles more, and tends to be relatively inefficient. Heat pumps, by contrast, shine during the shoulder seasons, when it's easy to make heat, but they fall off during the dead of winter when their heat source, the outdoor air, is cold. For that reason, when homeowners replace an existing furnace or boiler with a heat pump, they sometimes leave the original fossil-fuel equipment in place to serve as backup on the coldest days.

There are three factors that can cut the actual performance of a heat pump below its official rating, points out John Williams, the CEO of heat-pump manufacturer Chiltrix: a cycling penalty, a defrost penalty, and an altitude penalty. If units have to cycle on and off for part loads, if they have to warm up the coil to rid it of frost, or if they need to operate at high altitudes, performance will suffer slightly.

For colder-climate installations, Williams often recommends stacking two heat pumps together. In mild weather, Williams' Chiltrix, with its advanced variable-speed compressors and pumps, has a COP approaching 6; but even at its coldest operating temperature of -4°F, the unit's COP is about 2. "Don't confuse capacity with efficiency," advises Williams. While the unit's efficiency certainly drops in very cold weather, installing a second chiller can boost the setup's total capacity to the point where it can meet loads with very little reliance on electric resistance backup, even in deep winter months.

That choice depends on a case-by-case calculation. For many homeowners, a few hundred dollars in winter electric bills for resistance heating may be an acceptable price to pay for year-round total efficiency. But in other cases, the avoided cost of that backup electricity could be worth the investment in a second unit. "What I see," says Williams, "is that people who see a two-year or four-year payback on adding a second chiller will do it. That's a no-brainer. An eight-year payback? Half will, half won't. A 12- or 15- or 20-year payback? No one's going to do that. Because they'd rather have the money in their bank."

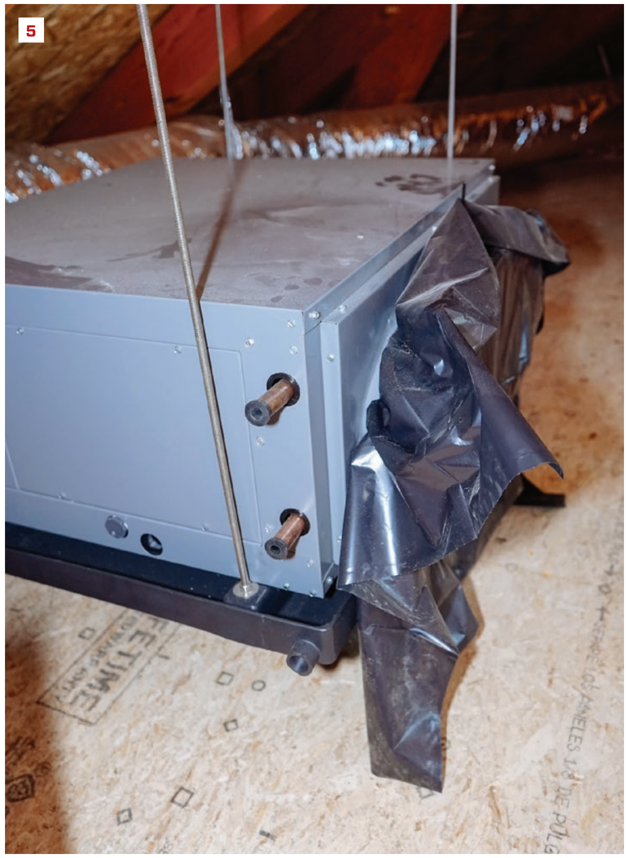
THE MARKET

So who's going to buy heat-pump hydronics for their home? John Williams, the Chiltrix CEO, says, "One of the sweet spots that we are seeing for this system is net-zero homes, Passive House homes, and in general, all-electric homes. Particularly in California, all-electric is becoming really important, because they have this net zero mandate. You can't get to net zero with gas or oil heat; there are no panels that you can install on your roof or out in the yard that will fill the oil tank up or make gas."

SpacePak's Jim Bashford says air-to-water systems have an edge over mini-split systems in larger homes. During his career as a contractor, says Bashford, he installed a lot of the systems in big spec houses where "it was best for them to use the heat pumps with water for the cooling, for microzoning, or just to cope with the sheer size of the house, where you wouldn't want to run high-pressure refrigerant lines and stuff through the wet walls."

Fortunat Mueller, an executive with solar and heating contractor ReVision Energy, says: "It's people who want hydronic distribution, because of the comfort advantage of warm floors and the zoning advantage of hydronic distribution, but who don't want fossil fuels. If those are your two goals, then air-source-to-hydronic heat pump is the answer. And many, many of our customers don't want any fossil fuels in their house—because of cost, and because of the environment, and because they can make electricity off the roof. But even those who can't make electricity off the roof, they can imagine electricity being made somewhere in a responsible way, in a way that they can't imagine oil or gas being made."

For Seattle-area builder Ted Clifton, the pairing of solar panels and air-to-water heat pumps is a no-brainer formula. The solar panels on Clifton's own house, on a net annual basis, do more than



Radiant floors team with hydro-air. ReVision Energy's Chris Blaisdell works on the hydronic tubing for a radiant slab in a custom house **(4)**. Behind Blaisdell is the hydronic buffer tank for the system. On the second floor of this home, a SpacePak high-velocity hydro-air unit **(5)** will supply heated or cooled air using fluid supplied by the same outdoor-mounted heat pump.

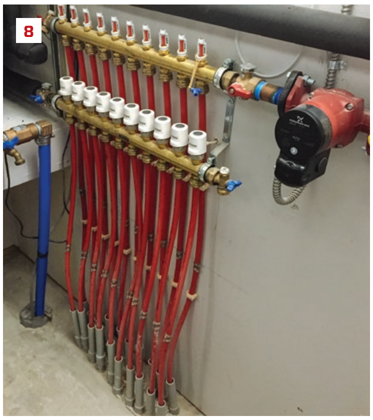
power the heat pump and radiant slab to heat his own dwelling; they also provide all the power Clifton needs to drive his Tesla Model S sedan. After building about a dozen net-positive-energy homes that include heat-pump hydronic radiant slabs, Clifton said, "I feel like every house should have one. Gas boilers, electric furnaces, that stuff has to go the way of the dinosaur. There is no reason to even sell or install any of that stuff anymore."

GROWING PAINS—AND POTENTIAL

It's an attractive dream. But in the real world, air-to-water heat pumps make up a very small fraction of the market. That means that the industry's knowledge base is small, and anyone who dips a toe in the water needs to be ready for a steep learning curve. Even Ted Clifton, an enthusiastic booster of the technology, has to admit that finding a reliable supplier has been tough. Clifton has been through several brands of heat pumps, he says. "The first three—the Unichiller, the Thermo Matrix, and the Daikin Altherma—the supplier that I got them from stopped carrying each one for various reasons. The first two because of issues, but the Daikin, because they stopped shipping them to North America." More recently, Clifton has been installing the Chiltrix.

Clifton is hoping that broader adoption of the technology will boost its reliability. "If more people were installing them, we could put a lot more R&D into these air-and-water heat pumps," he says. "Because so far, it has been tough just getting them to run correctly. And if they were the most popular system, obviously we would be working the bugs out of these things. It's kind of like electric cars, you know; someone has to start buying them before they are really mainstream."

Jim Bashford, the Northeast regional sales manager for SpacePak, downplays the complexity of the technology. "Our unit is essentially a high-efficiency electric boiler that sits outside. It makes really efficient hot water and chilled water. For any contractor that is used to heating with low-temperature water, there is nothing really different. The only thing different is the unit that is making the water."



Moving parts. The heat pump itself is easy to place and connect, but a full heating and cooling system can be complex to understand and install. Above are components of a Chiltrix installation in Bangor, Maine: the outdoor heat pump unit **(6)**, the buffer tank **(7)**, a hydronic manifold for the heated floor **(8)**, and a wall-mounted hydro-air emitter **(9)**.

Chiltrix executive John Williams tempers his optimism with realism. "If an installer has everything done correctly, it takes over an hour to commission," he says. "Because we have hundreds of parameters in there. There's all the installer settings, which are on a hidden menu. Then there's factory settings, which are on a hidden menu. And then you have all the customer-facing settings. So it takes a good minimum of an hour."

"And then what happens is, as we go through some of the diagnostics, we see if there are flow problems, we see if there is any air in the system, and the system starts telling us if it was installed correctly," continues Williams. "It's pretty straightforward, but I'd say our average installer is going to be on the phone for a couple of hours with us, commissioning the system, every time."

"Some people when they have a sale, they go out searching for dumb customers," says Williams. "That's not how it works with this product. We never sell this to a dumb customer. You have to be pretty smart to buy this from us, because otherwise you wouldn't understand how it works and why you should do it."

Fortunat Mueller's company, ReVision Energy, is no stranger to high tech. And some of the company's offerings, such as its integrated photovoltaic and mini-split setups, are fully dialed in (see "Teaming Heat Pumps With Rooftop Solar Power," Jun/14). What about air-to-water? ReVision installed a half-dozen Daikin Altherma units before Daikin pulled the plug on the product, and Mueller says, "They're finicky." And he says ReVision is still working out some kinks with its first few SpacePak air-to-water projects.

But Mueller says ReVision is up front with customers when the company is cutting its teeth with an unfamiliar technology. "With any new product," Mueller says, "we are transparent with our customers about where we are on our learning curve. And we try to match a customer for the place in the product life cycle where we are. Because some customers are excited about being early adopters, and others want nothing to do with that. So we try to be plain about that with people."

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