Heat Pump Water Heaters Bring Them Upstairs?

by **IAN M. SHAPIRO**

Heat pump water heaters are seeing increasing use in homes. They go well with solar PV and so support strategic electrification to reduce carbon emissions. And they are more efficient than electric-resistance water heaters. Several major water heater manufacturers are now making them. They are clearly here to stay.

But there's some confusion about where to put them, and some installers worry about putting them upstairs in conditioned areas of a building. They'll just steal heat in winter, no? An energy expert friend of mine calls this robbing Peter to pay Paul. DOE's website says, "Install them in a space with excess heat, such as a furnace room," implying a typical basement.

But in new high-performance homes, and in apartment buildings, we often simply do not have a basement in which to put a heat pump water heater. Is it terrible to put it upstairs? Is it so terrible that we should avoid doing it altogether? Should we belly up and pay the (significant) extra cost required for a split-system heat pump water heater? Or just go back to using an electric-resistance water heater?

A heat pump water heater is typically installed in the basement. What if there is no basement?

Why It's Okay

Heat pump basics show that putting the water heater upstairs is really not so bad, specifically if the space heating is also done with heat pumps. Given the increased use of heat pumps nationwide, including in cold climates, let's compare a heat pump water heater installed in the basement with one installed in the heated space upstairs.

For a heat pump water heater in the basement, the annual average efficiency (COP) might be around 2. This means that two parts of heat are being put into the water for each one part of energy that is consumed by the heat pump as electricity, and the remaining one part of heat comes from the space around the water heater. See Figure 1.

Now let's move that same heat pump water heater upstairs. Again, one part of heat from the air in the house combines with one

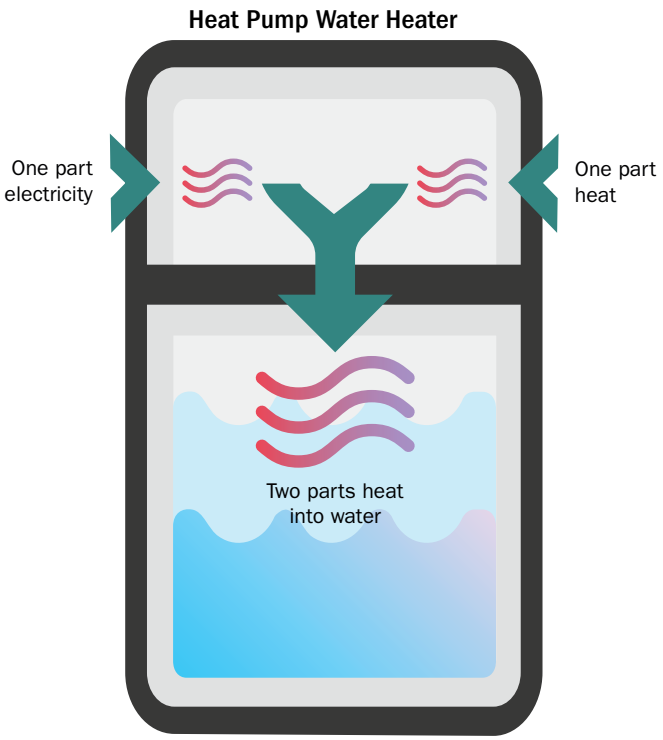


Figure 1. Two parts of heat are being put into the water for each one part of energy that is consumed by the heat pump as electricity. The remaining one part of heat comes from the space around the water heater.

part of electricity consumed by the heat pump water heater to make two parts of heat put into the water. But what about the electricity used by the space-heating heat pump? The space-heating heat pump is contributing that one part of heat that the water heater draws from the upstairs space. That one part of heat might be provided at a COP of 3: One part of electricity combines with two parts of heat from the outdoors to deliver the three parts indoors. See Figure 2. But we only need one part of heat placed into the indoor space for the water heater, not three. Remember: The water heater is using one part of heat from the space and one part from the electricity to the heat pump to get its two parts of heat into the water. So for the one part of heat that is used indoors for the water heater, we need only one-third part of electricity from the space-heating heat pump to get those two parts of heat right into the water heater. So the two parts of heat in the water heater are obtained by using one part of electricity for the water heater itself, and an additional one-third part of electricity for the space-heating heat pump. Overall, the effective COP for water heating is 2 divided by (1 + 1/3), or an overall COP of 1.5.

The Math

We can show that the overall COP is equal to $(COP_A * COP_D) / (COP_A + COP_D - 1)$, where COP_A is the air source heat pump COP, and COP_D is the heat pump domestic water heater COP (see Figure 3). Does this work for our example, with a 2 COP heat pump water heater and a 3 COP air source heat pump? The overall $COP_{OVERALL} = (2 * 3) / (2 + 3 - 1) = 6 / 4 = 1.5$. Bingo.

Our takeaways so far:

- The overall COP has not fallen anywhere close to 1, where we would have no benefit relative to an electric-resistance water heater.
- A COP of 1.5 is still way better than a COP of 1.
- But a COP of 1.5 ain't a COP of 2.

But we're actually not done yet. Some important corrections are in order. If that heat pump water heater were in the basement,

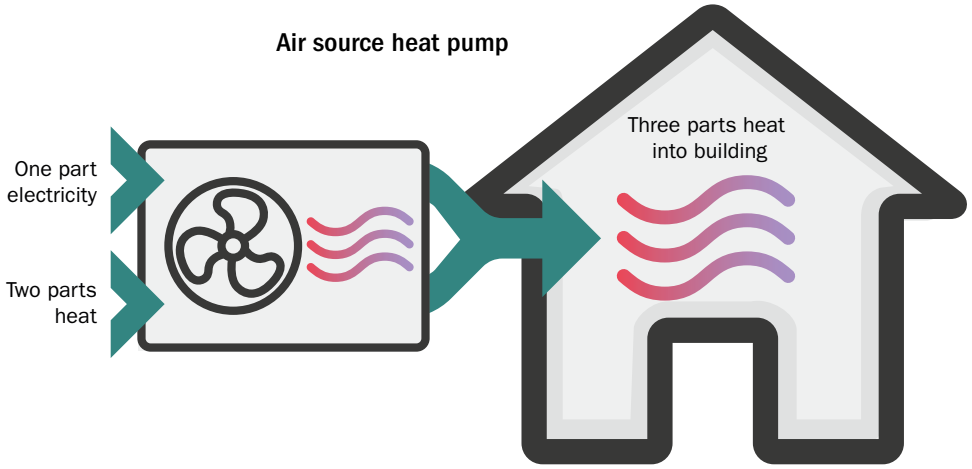
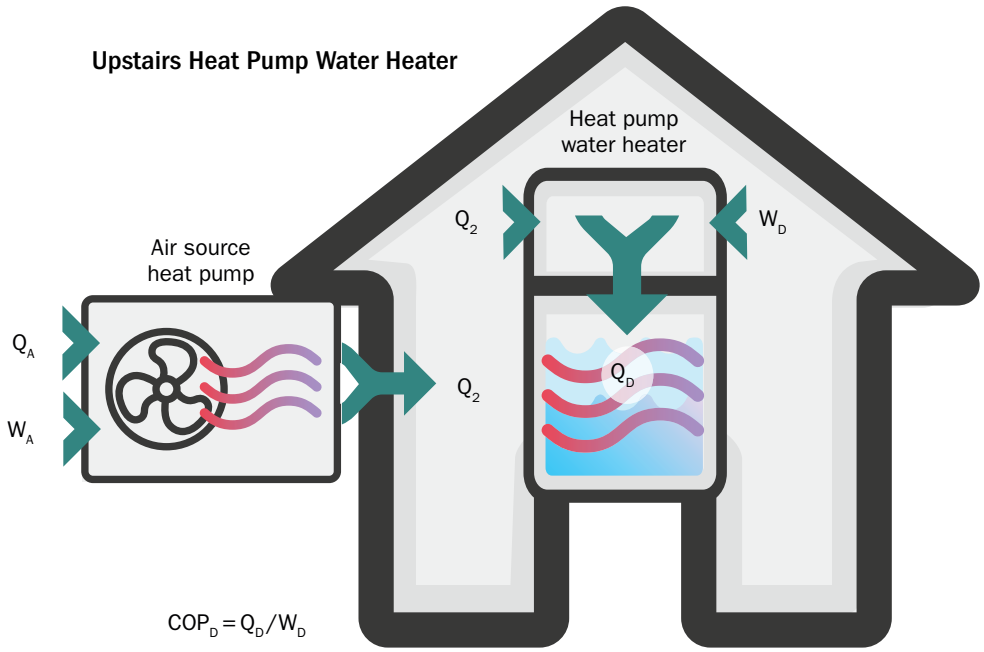


Figure 2. Two parts of heat from the air outside the house combine with one part electricity consumed by the space-heating heat pump to make three parts of heat put into the house. But how much of the heat put into the house ends up in the water heater?



$$COP_D = Q_D/W_D$$
$$Q_2 + W_D = Q_D$$
$$Q_2 = Q_D - W_D = Q_D - Q_D/COP_D$$
$$COP_A = Q_2/W_A = (Q_D - (Q_D/COP_D))/W_a$$
$$COP_{OVERALL} = Q_D/(W_D + W_A) = Q_D/((Q_D/COP_D) + (Q_D - Q_D/COP_D)/COP_A)$$
$$COP_{OVERALL} = (COP_A * COP_D)/(COP_A + COP_D - 1)$$

Figure 3. By balancing the heat supplied by the space-heating heat pump with the heat used by the water heater, we can develop a relationship for the overall water-heating efficiency.

it would be drawing heat from cold basement air, not warm upstairs air. What's the temperature down there? Certainly cooler than the 70°F upstairs. A basement in winter can easily be 60°F or cooler. Without any heat source, like a furnace or boiler, it can even be as low as 40°F. And it is further cooled by the heat pump water heater. In short, a heat pump water heater in the basement operates at a lower temperature, and so at a lower efficiency, than a heat pump water heater surrounded by nice warm 70°F upstairs air. And even though the heat pump water heater upstairs is drawing heat from the air, it is not necessarily lowering the upstairs air temperature, because the upstairs is being actively heated to its set point—for example, 70°F—by the main space-heating system. Finally, the heat pump water heater upstairs is losing heat to the space through its jacket, which contributes to space heating in winter. In fact, it contributes to the very heat that serves as a source for the heat that goes into the water.

In the summer, the heat pump water heater upstairs will also operate more efficiently, both because it is drawing its heat from a space that is warmer than the basement, and so its efficiency will be higher, and because it is cooling the upstairs, reducing the need for air conditioning, and so reducing cooling-energy use. So whereas a 2 COP heat pump water heater, working with a 3 COP air source heat pump that is heating the space around it theoretically delivers an overall COP of 1.5, the overall actual COP is really higher than 1.5. It may even approach the 2 COP in the basement, depending on the climate.

What's happening here? Basically, in winter, the water is being heated by a two-stage heat pump. The first stage draws free heat from the outdoors and delivers it to the indoor space. The second stage draws heat from the indoor space and delivers it to the water. It's not robbing Peter to pay Paul. Really, Peter is helping to pay Paul's bill.

The numbers change if the space is heated with a fossil-fuel device, like a boiler or a furnace. The issue here is that the heat pump water heater does not get any free heat from the outdoors or from the basement, and so the overall cost and energy impact is higher. In a house with a boiler or furnace in the basement, the heat pump water heater typically recoups free waste heat from the fossil-fuel heating plant; that makes sense. But if it is located upstairs, the heat pump water heater adds to the load

of the furnace or boiler. Q_2 is no longer free; it is being paid for with the fossil fuel. The heat pump water heater is heated about 50% by electricity (used by the heat pump) and 50% by the fossil fuel (a little more if we account for combustion efficiency and losses). Here, we are robbing Peter to pay Paul.

Where to Put It Upstairs?

A separate question is where to put the heat pump water heater upstairs, for the case where the space is heated with a heat pump. Closets are discouraged, because we don't want the water heater to be cooling a closet and so operating at a low efficiency. If a closet is unavoidable, it must have a louvered door, preferably with louvers at the top, close to the heat pump air return, and louvers at the bottom, where cooled air can leave the closet. A ventilation fan may even make sense for a heat pump water heater in a closet. But the ideal location for a heat pump water heater located upstairs is in a mechanical room, where you also want to put as much equipment creating waste heat as possible. Maybe the solar PV inverter goes there, along with any second freezers or refrigerators, and the electric panel. Maybe that's the space where the plumbing waste heat recovery heat exchanger goes. Maybe that's where you put a charging station for the cell phones, battery chargers, and other rechargeables. In an ideal world, this mechanical space is next to the kitchen, and the body of the main refrigerator is recessed into this space. All that nice refrigerator waste heat made available for use by the heat pump water heater! Heat pump water heaters love waste heat; it's like food for them. A final option upstairs is an open space, which is also a good choice, but still try to put as many as possible of those same sources of waste heat nearby.

The bottom line is, if the building is heated with a heat pump, don't worry too much if it has no basement, or if you need to put heat pumps in apartments in a building. That upstairs heat pump water heater is still way better than electric-resistance heat. And if you put it in a room that has some waste heat from electronics and other appliances, it may even be more efficient than a heat pump in the basement.

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