Air to Water Heat Pumps

by Bob Hedden

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In the beginning of 2020 Efficiency Vermont posted the following to their website.

"Air-to-Water Heat Pumps

Hydronic or water-based heat distribution systems can integrate with air-to-water heat pumps, which heat water that's circulated around the building through pipes and emitters. These systems can also chill water for air conditioning and have the potential to heat domestic hot water as well.

FOR RESIDENTIAL & BUSINESS

Rebate up to $5,500 cash back $50 bonus for applying on line

Effective Date: *January 1, 2020*

Offer subject to change.

- *$1000/ton rebate - maximum of 5 tons*
- *$500 moderate income bonus (see details below)*
- *Installation of air-to-water heat pumps can be complex and should be performed by a licensed contractor who is familiar with HVAC controls.*
- *Generally, fossil fuel heating system must be maintained as a backup heat source.*
- *Existing boiler may need to be upgraded to be compatible with heat pump.*

Moderate Income Bonus

Vermonters whose household income meets the guidelines below may qualify for a $500 bonus rebate."

In late December Efficiency Vermont also released the promotional brochure for their annual Better Buildings by Design conference. It featured a workshop titled "Fossil Fuel Free at Last: Air to Water Heat Pump and Ventilation Retrofit". Efficiency Vermont employees started talking about these heat pumps as replacements for conventional boilers as a real game changer that would enable Vermonters to finally stop heating with fossil fuels.

Matt Cota asked me to attend the Better Building by Design conference and do some research on this equipment to learn if these heat pumps really are viable replacements for fossil fuel fired boilers. The following is what I learned.

There were two presentations at the conference that addressed the heat pump boiler, the Fossil Fuels Free at Last presentation and HVAC 2020 A Showcase of Emerging Systems presented by Matt Sargent, Senior Energy Consultant for Efficiency Vermont. In his presentation Matt talked about Air to Water Heat Pumps (AWHPs). The following is from his slides.

Benefits of AWHPs

• Comfortable- Zonal, Fully Distributed, Reduced stratification, Quiet

A better alternative than air to air ductless heat pumps?

Matt told the crowd that AWHPs were much better than the air to air ductless heat pumps for the following reasons:

Ductless heat pumps are point source heaters

• Limitations of ductless heat pumps

– Comfort Issues (inherent to space heaters)

– Lack of system integration

– Aesthetics (they are not pretty)

– Poor Multi-zone performance- sizing is very critical

Both indoor and outdoor parts need to be cleaned.

He went on to tell us there are two types of AWHPs- Mono-block where the refrigerant to water heat exchange is outside requiring the use of glycol anti-freeze in the supply and return water, and split systems where the refrigerant to water heat exchange is inside requiring the refrigerant to be piped from outdoors to indoors. Since the compressor is indoors, the split systems are noisier in the building (over 50 decibels).

Currently there is no HSPF or SEER rating for AWHPs. AHRI does not list or test them. Neither does Energy Star. Typically, manufacturers claim COPs at 120 degrees F supply temperatures of 2 at 5 below zero degrees F and 2.35 at 17 degrees F outside temperatures. The limited field data indicates COPs drop below 2 at around 10 degrees F.

Matt reports that the performance for AWHPs is:

- Overall – Very Good!
- Better with low supply water temperatures
- Similar to ductless, but does not account for distribution energy
- Good cold weather performance, but…
- We need a good metric and cold climate specification
- While we have no good third party evaluation yet, it appears the COP at varying temperatures will be similar to ductless mini-split heat pumps.

Matt recommends that AWHPs be installed with buffer tanks to prevent short cycling and to optimize operation. He also recommends the use of plate heat exchangers especially with mono-block units to minimize the amount of glycol required. The trick is to use the antifreeze zone as the main zone, and use plate heat exchangers for the other zones. Monoblock systems use more energy and require more maintenance because of the anti-freeze and complexity of heat exchangers and circulators.

After Matt's presentation I attended the provocatively tilted presentation "**Fossil Fuel Free at Last: Air-to-Water Heat Pump and Ventilation Retrofit Case Study" by Brian Just, Manager of Engineering for VEIC.**

Brian's learning objectives for this project were:

- Learn how air-to-water heat pumps are functioning in New England's Climate Zone 6
- Identify 5 key non-energy benefits that can help move the needle on HVAC retrofit projects
- Understand the basics of how to install an air-to- water heat pump with the benefit of an open- source design and detailed photographs
- Learn the key design features and options for low-temperature distribution, including how to set up a new home for near-seamless retrofittability in the future at minimal cost.

Brian's presentation was about how he installed an AWHP in his home. His goals for the project were to get rid of propane as a fuel source, make his home more comfortable, healthier, and safer, reduce his impact on climate change, increase efficiency, and maybe save some money. He did not explain why it was so important to get rid of propane and no one asked.

He started his presentation by talking about heat pump basics. There are four basic types: air to air, water-ground to air, water- ground to water, and air to water. This project will focus on air to water (AWHP). The big challenge for using this technology as a retrofit is typical residential fossil fuel boilers operate at system water temperatures of 180 degrees F. AWHPs operate at 120 degrees F or less.

He then presented the following benefits of hydronic heating:

- Distribution efficiency- circulators use less electricity than fans, there are no duct losses, hot water pipes take up less space than ducts.
- No moving air– Quiet-
- Air to air heat pumps can blow cold air during the defrost cycle,
- Less movement of dust and allergens.
- Placement and comfort

Brian missed one of the great advantages of hydronic heat- you are able to heat the domestic hot water with the same boiler you are using to heat the building. By deciding to use a heat pump water heater he failed to take advantage of indirect water heating. One of the reasons was the output from the AWHP was not sufficient to heat both the building and the hot water.

Brian then told us about the pros and cons of retrofitting an AWHP in an existing home.
Pros-

- Contractor network skilled at hydronics
- Boilers in 60% of VT homes
- AWHPs common in developed world

Cons-

- In most cases, not a drop-in replacement
- Distribution system must be (made) compatible
    - Need more heat emitter surface area with low temperature water!

- Existing baseboard and radiators may only put out 25- 30% of the heat (180F vs. 120F)

Because of the low water temperature created by the AWHP it will not work on the typical series loop distribution system installed in almost every Vermont home that uses fin-tube baseboard. The 120-degree water drops to 80 degrees very quickly. Each low temperature emitter installed in an AWHP distribution system must be piped in a "home run" system. This is a very disruptive project for an existing home with a series loop system. You cannot just replace the old baseboard with new high output emitters, you must replace all the piping as well. The AWHP system also requires a large (at least 70 gallon) buffer tank be installed or the system will short cycle. The AWHP probably will not be able to deliver enough heat during cold weather, so back-up heat is required. You could use the existing boiler as back up, or put electric resistance heat elements in the buffer tank for back up or use a wood or pellet stove.

The Just home was not a great candidate for a conversion. It is 2 stories, slab-on-grade, 2100 square feet, with no cooling. The heating was provided by a 17-year-old propane boiler that was working. The first level was radiant slab (which could work with the 120 degree F water from the heat pump, but the second floor was fin-tube baseboard with no room-to-room control which certainly would not. The water was heated with an indirect tank. This made the mechanical room a "sauna in the summer." Brian believed his propane boiler represented a carbon monoxide hazard. He also feared than when it died he would have to wait a long time to get it replaced. Finally, he did not like where his upstairs thermostat was located. Brian also concluded that it would be too complicated and expensive to do indirect water heating and decided to go with a heat pump water heater instead. He also decided to use a wood stove for cold weather back up whenever it dropped below 10 degrees F. He used a half cord of wood from October 2019 to January 2020.

At the time Brian began his installation there were five manufacturers making units available in Vermont. Four were mono-bloc systems and one was a split system (the Nordic). None of the companies are very well know. Brian went with the split-system and used a 70-gallon buffer tank with electric heater elements for back-up. He did not integrate his AWHP with domestic water heating or air conditioning.

The following is from the Nordic website:

> "Our air to water heat pumps are traditional air source heat pumps, which means they don't require a ground loop to collect their heat. Instead, they use the outdoor air as their heat source in the winter and heat sink in the summer. There is no outdoor collector system, resulting in a lower installation cost.
> Our air-to-water heat pump (ATW Series) heats water for in-floor radiant heat and cools water for air conditioning via hydronic fan coil. While air source heat pumps sometimes have a reputation for performing poorly in severe cold weather, we've made several modifications to our air source heat pumps to improve their performance, even in the dead of winter.
> This heat pump has an oversized outdoor unit for superior heating in colder outdoor temperatures. It's also equipped with intelligent defrost logic, which minimizes the energy needed to defrost the outdoor coil. Finally, the compressor section of the machine is located inside your home, where it is protected from harsh outdoor weather.

> The ATW Series is available in sizes from 2 to 6 nominal tons, for whole-home applications, and operates down to -7°F (-21.7°C) at which point back-up heating is required. "

The output for the largest model is 38,400 BTU/hr. at 120 degrees F output temperature and 17 degrees F input temperature. The COP at 17 degrees F is 2.08.

Note- The heat loss for the average Vermont home is much higher than 38,400 BTU/hr., therefore, it is imperative that when installing an AWHP in a home, that the home also be properly air sealed, insulated, and ventilated to lower the heat loss.

Brian's reflections on the installation:

- Very happy with system so far.
- Needed new $1000+ electric panel (bummer)
- The whole project took longer and cost more than original estimates
- Needed a fair bit of utility room space for split system, buffer tank and HP water heater
- Really glad they went with HP water heater

Brian's number one big take away from this project is "In 99% of existing homes, putting in an AWHP is NOT simply a boiler swap." His total savings is projected to be $260 a year. Based on current usage he projects the 12-month cost of running the AWHP for heat only will be $823. His old propane boiler was $1,084. He estimates a new propane boiler would be $745. He has used about half a cord of wood from October '19 to the middle of January '20 so he guesses he will use about a cord a year. His total costs for the boiler and buffer tank was $6,657 and distribution system upgrades were $9,893. The heat pump water heater was $3,865. These prices include EVT rebates. The payback is about 60 years.

Mr. Just's conclusions are that we should challenge pay back as the lens we use to evaluate projects. He asked how we attach a price to the following benefits his family now enjoys.

- No combustion / propane is gone
- Room by room temperature control
- Balanced slab heat
- Less window condensation
- Warm radiators / no possible burn surfaces
- HPWH scavenges waste heat (slab, AWHP, buffer tank, pumps, electronics)
- Cool-dry zone (HPWH + no boiler)

For new homes Brian quotes a recommendation by John Siegenthaler: "If putting in fossil fuel systems now, I would advocate design for maximum of 120 degrees F supply water temperature at design load conditions, and supply through a mixing valve if necessary." Brian recommends running a 200-250-amp service to the house as well to enable an easy conversion to an AWHP in the future.

His call to action for the audience was "we have to use creativity to encourage people to see past the $ only approach. Payback is the wrong metric." His closing thoughts were:

1. AWHP not right or easy for every existing home

2. 100% of new homes need to be built with **low temperature infrastructure** in place.

"In most cases, AWHPs should probably not be characterized as a straightforward boiler replacement option. "

After Brian's talk I spoke to manufacturer's representatives from Daikin, Runtal, and Emerson Swan and they all agreed that AWHPs are not a retrofit option. They are only for new construction specifically design for low water temperatures.

Since Brian and Matt both recommended using heat pump water heaters with AWHP installations I next went to the Heat Pump Water Heater presentation by Diane Cabral from Rheem Water Heaters.

Diane started by showing that 16% of a typical home's energy use is water heating. She then showed how the DOE Energy Guide claims that heat pump water heaters are more efficient and cost less to operate than electric, natural gas, or propane water heaters. She did not even mention oil fired water heaters or indirect water heaters.

She said the advantages of the Rheem water heater were it only created a 49 DBA sound level (about the same as a refrigerator). With the rebates they cost about $500 more than a standard electric water heater and will pay for themselves in about a year when installed instead of a conventional electric water heater

How they work: Ambient air is pulled into unit and heat is absorbed by the evaporator coil

• The Compressor increases the temperature of the refrigerant
• Heated refrigerant is pumped into the condenser coil
• Condenser coil tubing is wrapped around the tank and transfers heat from the refrigerant to the water

Heat pump water heaters suck heat out of the room they are installed in and put it into the domestic water. This maybe fine in the summer, but chilling your basement on a cold day is less than ideal. They need to be installed in about 700 cubic feet of space to provide enough air to exchange the heat. The room they are installed in has to be at least 38 degrees F. They need a condensate drain.

They use electric heat elements to provide back up in case hot water draw exceeds supply.
In case of power failures, they draw too much electricity to reasonably be powered by a normal back-up generator.

Conclusions from Matt Sargent about heat pump water heaters:
Be deliberate about the water heating strategy
– It can be the biggest load in the house

- Heat pump water heaters may need cooling and noise mitigation strategies
- Water conservation and heat recovery are just as important as high efficiency water heating

The final seminar I attended was presented by Efficiency Vermont's home performance expert and gifted teacher, Dave Keefe. He gave an illuminating presentation on fixing existing homes. The following are the slides from his presentation. For years Dave and I have been trying to convince home performance contractors and HVAC contractors that we both have the same goals and should be working together instead of fighting each other. His presentation is not too different than my equipment sales presentations. It is interesting to see he shares our frustrations in how to inspire homeowners to invest in improving their homes.

Dave started by explaining why we should still care about home performance.

- Climate change is hitting us here faster and stronger than we expected
- Average winter temperature in Burlington has increased 7 degrees in less than 50 years
- Space heating of existing buildings is a big part of the fossil fuel (carbon) load in Vermont
- Fixing the existing buildings is essential

Current activity in Vermont

- Weatherization Assistance Program- About 800 jobs/yr, about $10K average
- Home Performance with ENERGY STAR- About 800 jobs/yr., about $8K average
- Limited info about average savings from those two programs, but probably about 20% or less
- Efficiency Vermont's attic/basement incentive, about 100 projects/yr., not comprehensive, quality uncertain

How are we doing?

- There are about 200,000 houses/small apt buildings in Vermont
- We are doing less than 2000 per year, less than 1%
- Average savings are probably less than 20%
- That means our effect is less than 0.2% per year
- At that rate, it will take 250 years to cut usage in half
- Vermont's goal in 2008 was to get 25% savings in 80,000 homes by 2020. To do that, we would have had to do at least 5 times as much as we actually did

- In 2019 the Vermont legislature allocated more money for weatherizing homes. Some of it went to WAP, some to EVT
- Efficiency Vermont has increased incentives, especially for moderate income households, and is recruiting and training new contractors. There is also financing with income-sensitive interest rates.
- One of the main limitations going forward is contractor capacity. We need many more people with the appropriate skills

Misconceptions

- Houses have to "breathe", you don't want them "too tight"

Installing insulation is simple, any moron can do it
• The most skilled people should be the auditors
• Leaky houses are healthier
• If I'm going to have to borrow money to do it, it doesn't make sense
Of course, the windows need to be replaced
• My house doesn't need anything, it's only 20 years old

Complications-

- People have to be pushed to do something now in exchange for a future benefit. We're not good at that. The default is always to do nothing
- The future benefit is uncertain. Maybe it can't be counted on
- Split incentives in rental situations
- Folks move a lot, and might not want to put money into a building they might sell sometime soon
- It doesn't make things look any better, there's nothing to show off
- It ain't sexy

Fixing existing homes:

Is messy and dirty, but you have to be clean • Seems very invasive to the customer
• Is more complicated than new construction • Often requires diagnostic problem-solving
• Requires good interactions with many different customers
• Generally consists of small projects, so you have to sell several • Usually doesn't allow you to build anything
• Don't get no respect

- Can be rewarding if you like to solve puzzles and help people
- Is a good way to do your part in fighting climate change
- Involves making people more comfortable, healthy and happy
- Is something that you can sell in good conscience, it's in your customer's best interest
- Is well-suited to small owner-operated companies
- Helps preserve our housing stock
- Might be a pretty good business opportunity in Vermont right now

Payback:

Payback is the amount of time needed to generate savings equal to the initial investment.
Common way of looking at energy investments
Almost never used for non-energy investments What's an acceptable payback?
2 years? 5 years? 10 years?

Annual Rate of Return:

The annual benefit, as a percentage of the original investment Common way of looking at various investments
What's an acceptable rate of return? Current savings rate?
Current Certificate of Deposit rate? Current Savings Bond rate?

If you were offered a reasonably safe investment that generated a 5% tax-free return, would you be interested? How about 10%?

A 20-year payback is a 5% rate of return A 10-year payback is a 10% rate of return
Major energy retrofits usually have more than a 5% rate of return, and often over 10%
And it's tax free for homeowners

More about payback:

- We don't use that unit of measure for non-efficiency things, so it's hard for homeowners to compare to other investment options
- Payback doesn't consider lifetime, so it inevitably steers you toward short-term measures
- The public has been conditioned to expect unreasonably short paybacks
- So, let's not talk about payback
- Let's talk about a tax-free rate of return. We can deliver a good one

It is not just about economics-

- Comfort
- Health & safety
- Building durability
- Protection from rising fuel costs • Resale value
- Carbon

Being timid hurts the long-term effort

- Once something is sort of OK, it probably won't be changed, so that's not where we want to stop
- If this year's budget won't accommodate doing both the attic and the basement well, it's better to do one well than to do a skimpy job on both. We can do the other one later.
- We don't want to be redoing the same surfaces in a decade
- Insulating the basement walls to R-5 may do more harm than good
- It's easy to find people who later wish they had insulated more, but it's hard to find someone who wishes they had insulated less.

It is not about whether the money gets spent-

- Homeowners are going to have to pay to be comfortable, one way or another

- They might be thinking it's a choice of whether to spend the money, but it's really a choice between spending it on fuel and getting nothing else, or spending it on improvements that pay for themselves and ending up more comfortable.
- It's worth noting that most of the money spent on fuel leaves the state and most of the money spent on improvements stays more local or regional

You can do complicated number crunching, but lots of things are unknown
What's the actual savings going to be?
What will energy cost in the future?
How much will I get back if I sell the house? What's the comfort worth?
What are the other non-energy benefits worth? What's the value of the environmental benefit?

The close-
"So, how much will the project cost?"

- "It's free"
- "No, really. It's free"
- "It pays for itself"
- "If you put money down, you get it back"
- "If you don't want to put any or much money down, we can finance it so that the savings make the loan payments. The interest rate is really low, maybe zero. So it's free"
- "Yeah, I'm serious. It's free"

Conclusions

The most destressing aspect of the Efficiency Vermont Better Buildings by Design 2020 conference was that while the theme was "Affordable Energy" that claimed to feature "access to the right kind of energy- equitable, affordable, reliable, and sustainable" that is "essential for growing the state's economy and addressing climate change" almost none of the presenters mentioned liquid fuels except for two bullet points in the pellet stove presentation that compared them favorably to 82% efficient furnaces burning high sulfur oil at $2.80 a gallon. In the whole two days of talking no one mentioned renewable liquid fuels at all. Clearly no one at Efficiency Vermont or any of the climate change enthusiasts assembled recognize or are even aware of all the great work we have been doing to create a renewable, sustainable, inexpensive Bioheat solution to home heating's impact on climate change.

It is interesting to note that most of the presenters have given up even trying to show a payback for any of the oil to electric magic gizmos they are pushing. It is all now about societal benefits, and saving the world. They do not even bother to try to present reasons why we would want to stop using fossil fuels, or any liquid fuels. It is just assumed in all the presentations that it is totally obvious that of course we want to get rid of the fossil fuel burning equipment and convert everything to electricity.

When was it decided and by whom that in the future electricity will be the only way to deliver energy? I don't remember anyone from our Bioheat industry being invited to the meeting. Clearly it takes less energy to deliver renewable liquid energy using our existing infrastructure to rural Vermont, than to upgrade the big, inefficient, inflexible, unreliable electric grid to meet the increased demand of replacing us. The other question is which supplier of that energy is preferable for Vermont in the future? A liquid energy grown by American farmers distributed thru existing infrastructure by local small businesses who compete with each other for customers with value added services and low prices or expensive energy created by gigantic, ugly, capital intensive, unreliable solar farms or wind towers delivered by a huge, impersonal, unresponsive, international monopoly?