Thermal Heat-Pump Technology

The Future Beyond 100% in America?

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Thermal Heat-pump Technology – The Future Beyond 100% in America?

Why is there a need to consider developing thermal heat pump technology?

This is the fundamental question facing the fossil fuel industry.

This paper will attempt to answer this question from the perspective of the heating oil/biofuel dealers in America today.

If a rationale to pursue heat pump technology can be established, the next question is what technology should be pursued?

European Policies

- On 18 February 2013, the EU Commission released energy labelling of space heating appliance requirements.
- In February 2016, the Commission proposed an EU heating and cooling strategy which will focus on “upgrading heating and cooling equipment, such as boilers, to the latest, most- efficient technologies.”

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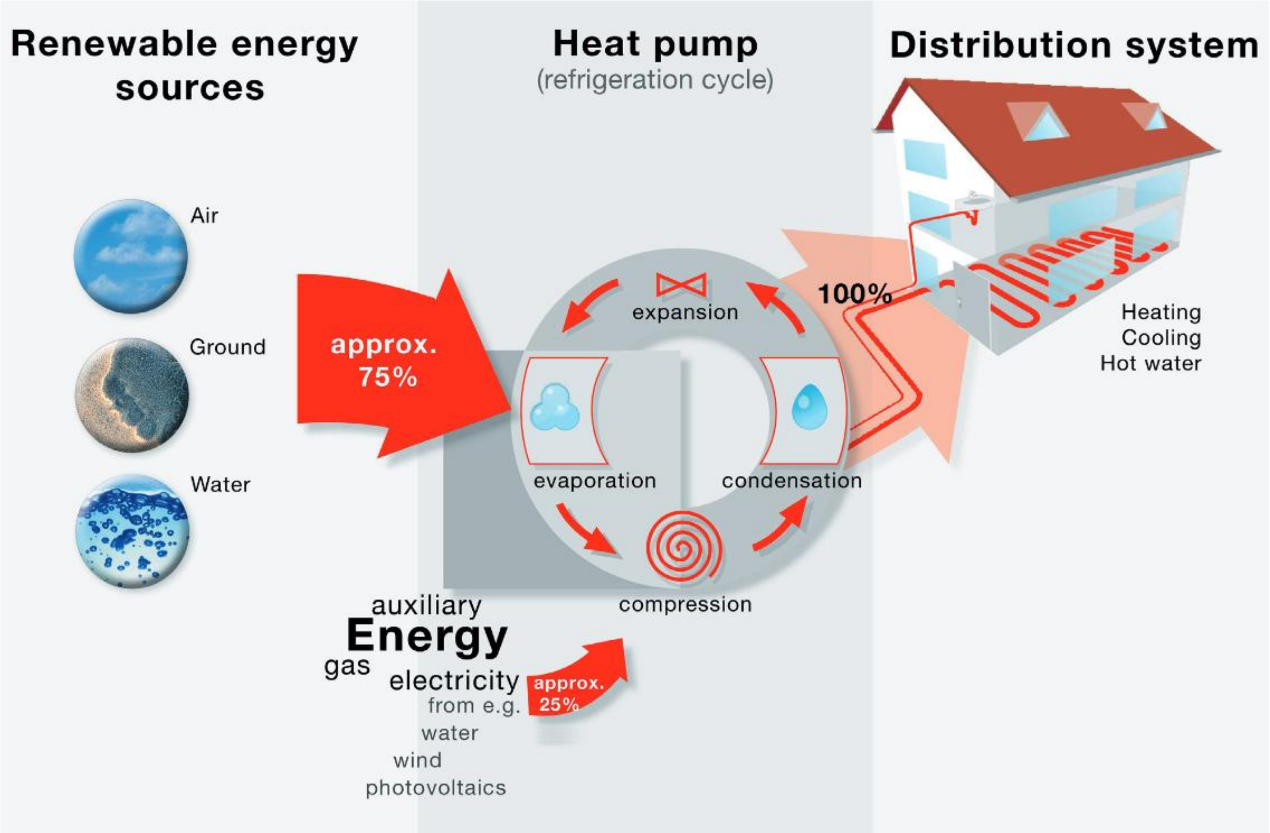
European Policies

Classifying thermal heat source (air, water or earth) of a heat pump allows policymakers to include heat pumps as qualifying for mandated renewable portfolio components and/or renewable energy credits/incentives.

Electric HP View of Renewable Heating



Source: European Heat Pump Association

EU Policies Have Led to the Development of:

- cold climate electric heat pumps
- gas engine heat pumps
- sorption heat pumps

US Policies

The United States may be a bit of a different story. There is no federal energy policy. The closest federal policy element impacting energy efficiency is EPA's Clean Power Plan which reduces carbon emissions from power plants by allowing States to implement a variety of energy efficiency programs for compliance. However, this has been stayed by the Supreme Court for now.

US DOE Regulates Minimum Appliance Energy Efficiency

Minimum AFUE Energy Conservation Standards for Residential Boilers Effective 2021:

Oil-fired hot water boiler	86%	Automatic means for adjusting temperature required (except for boilers equipped with tankless domestic water heating coils).
Oil-fired steam boiler	85%	None

Residential Energy Policy is Currently Driven by Key States

- Many progressive States, like Massachusetts, Vermont, Connecticut, New York and California are moving forward with their own energy efficiency and carbon reduction plans. With the help of utility energy efficiency policy, specifically designed electric heat pumps are making inroads in colder climates. Some states are allowing natural gas utilities to use energy efficiency funds to incentivize fuel switching from heating oil to natural gas.
- State public policies are being drafted today which are designed to achieve 50% to 80% carbon reduction by 2050. This takes the form of shifting from fossil fuels to renewable energy. It also takes the form of energy efficiency.
- To take part in policy discussions today, any industry needs to have the technology in hand to credibly project future energy and carbon savings.

Strategic Investment

Clearly, biofuels are credible solutions to reduce carbon emissions significantly by 2050, especially with fuel flexible plug-and-play atmospheric burners now being developed. Given the EU's moving toward cold climate heat pump solutions (electric, absorption, adsorption and engine driven), it behooves the US fuel dealers to begin to invest strategically in thermal heat pump technology.

Simply Put

Public policies are being developed today that require high efficiency heating solutions greater than a COP of 1.0, and the Oilheat/biofuel industry needs to be a part of this solution set or be left behind.

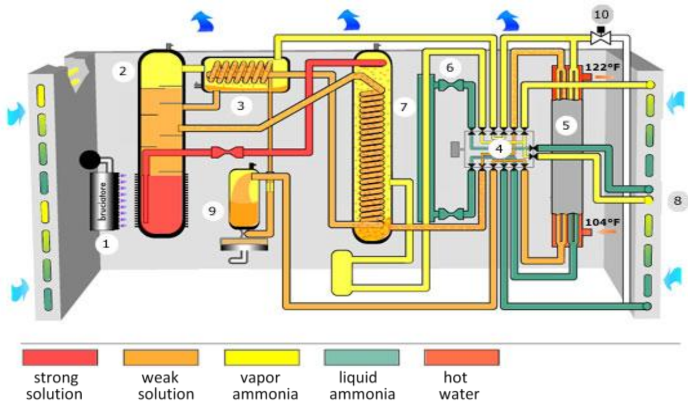
Technology Choices

	Absorption Heat Pump	Adsorption Heat Pump	Gas Engine Heat Pump
Capacity range (heating)	10 to 100s of kW (34.1 to 341.2KBtu) (installed as modular units)	<15kW (51.2kBtu)	20 to 100s of kW (68.2 to 341.2KBtu) (installed as modular units)
Performance range	Heating: 120-160% Cooling: <100% DHW usually standard	Heating: 120-140% Cooling: n/a DHW usually standard	Heating: 120-160% Cooling: 120-140% DHW usually requires add-on
Installation / maintenance	Annual gas safety checks but little other maintenance requirements	No moving parts so very limited maintenance	Requires annual safety check & oil change. Major overhaul/service every 10- 20,000 running hours.
Applications	Typically designed for hydronic heat distribution generally heating-led	Typically designed for hydronic heat distribution (underfloor/ fan coils) generally heating-led	Typically designed as air-based systems for heating/cooling, traditionally more cooling than heating-led
Operating parameters	Relatively wide due to low temperature heat source requirement & high flow temperature achievable	relatively limited due to high temperature heat source requirement & relatively low flow	Relatively wide due to low temperature heat source requirement & high flow temperature achievable
Level of commercialization	Robur has installed >10,000 in Europe with annual sales in the range of low 1,000s per year.	Residential scale version available since 2010 but only 2-3 products low 100s installed in total	Mature product with around 800,000 installed in total and 10,000s installed per year in Japan. Just 100s in Europe

Robur - Absorption

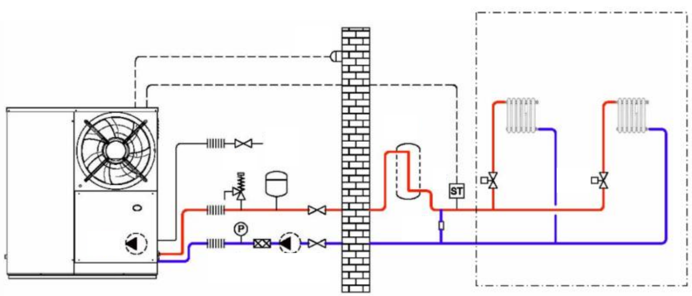
Europe uses the lower heating value of gas (LHV) for their GUE rating, compared to North America which uses higher heating value (HHV). The difference is nominally 11%. So a GUE rating of 157% is actually equivalent to a 1.40 COP. (That is why you see condensing boilers in Europe have a GUE above 100%).

Robur Reversible Air to Water Heat Pump Unit



Nominal heating output	35.2kW (120.4kBtu)
Heating Gas Utilization Efficiency (GUE)	126%
Max outlet water temperature	60°C (140°F
Nominal cooling output	16.9kW (57.7kBtu)
Cooling Gas Utilization Efficiency (GUE)	60%
Min. cooling water temperature	3°C (37.4°F)

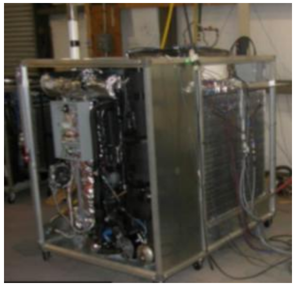
Robur Residential Heating Only Absorption Heat Pump



Operating point Air 7°C (44.6°F) Supply Water	**50°C (122°F)**
G.U.E. gas usage efficiency[8]	157%
Thermal power	17.6kW
Operating point Air 7°C (44.6°F) Supply Water	**35°C (95°F)**
G.U.E. gas usage efficiency	169%
Thermal power	18.9kW (64.5kBtu)
Max Heating Hot temperature	65°C (149°F)
Max DHW temperature[9]	70°C (158°F)

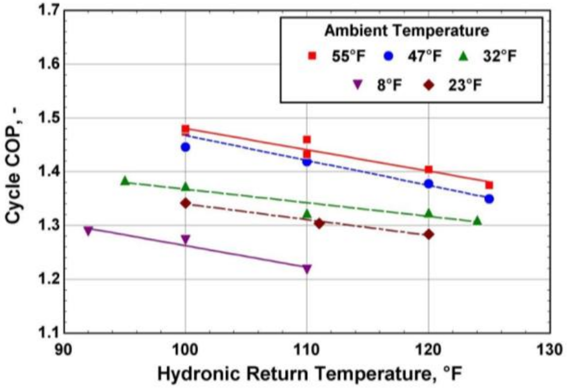
SMTI - Absorption

Residential Space/Combi Heating: (2013) DOE program to develop a larger model designed for residential space and water heating. Three full-scale “Alpha” packaged prototypes are currently under test with very positive results. The heating output of these initial prototypes is 23.4kW (80kBtu), although the design is easily scalable to lower capacities. Testing has confirmed operation down to -28.9°C (-20°F) ambient and up to 71.1°C (160°F) supply water temperature. Two “Beta” prototypes now completed with one on test at GTI and 2nd in in laboratory testing at SMTI.



Commercial Space/Water Heating: The focus of a three-way CRADA (Cooperative Research and Development Agreement) between SMTI, Oak Ridge National Lab (ORNL) and A.O. Smith (AOS) is a 41kW (140kBtu) output absorption heat pump for commercial applications. These units can be linked together to provide capacities exceeding 146.5kW (500kBtu). The first prototype was delivered to ORNL in January 2016, with a refined Beta prototype ready for testing during 2nd QTR 2016.

High cycle COP > 1.2 at -13.3°C (8°F) which means fuel COP > 1.0 at -13.3°C (8°F)

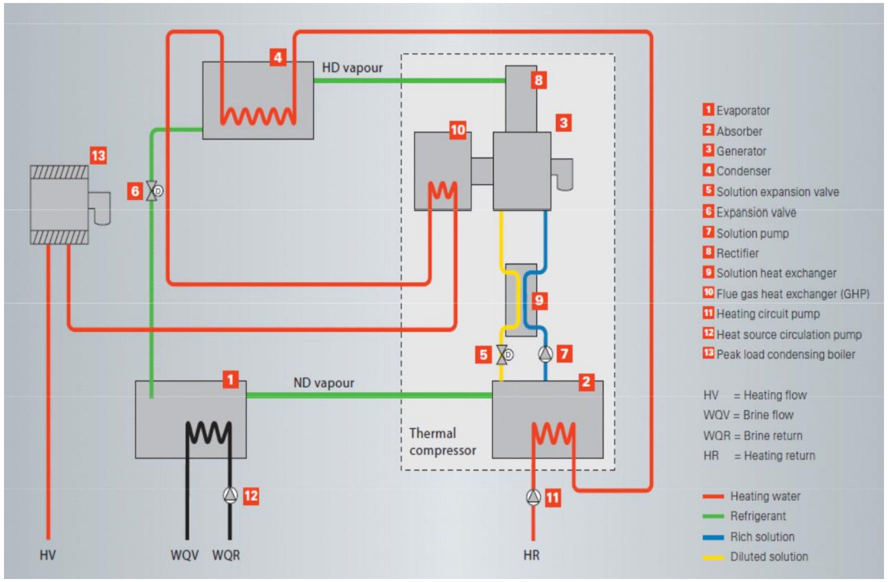


SMTI - Absorption

Residential Water Heating: 2010-2013 DOE program that resulted in the development and testing of three working prototypes, one of which was later installed as a controlled field test unit. Follow-on funding and support from gas utilities and NEEA has resulted in efficiency increases approaching theoretical maximum, and the fabrication of seven refined prototypes, five of which were installed as field test units.

Viessmann - Absorption

Vitosorp 300 Absorption Heat Pump



Its output is between 1.6 and 16 kW (5.5 and 54.6kBtu) with a modulation ratio of 1:10. This makes it particularly suitable for use in single and two-family European homes. Compared with a modern gas-fired condensing boiler, an energy saving of more than 40% can be achieved by coupling environmental heat.

E-Sorp - Absorption

Developing a compact, power modulating gas absorption heat pump up to 18 kW (61.4kBtu). The key component here is the GAX generator/absorber; the value of the entire system depends on its performance measurements as per the standard in force (EN 12309) demonstrating that, for applications with a low supply temperature 35°C (95°F) or high supply temperature 55°C (131°F) for the heating system, the maximum seasonal efficiency of gas consumption was 167% or 152%, respectively.

The results of the project show that at low capacity, 5 to 18 kW (17 to 61.4kBtu), a fully modulating gas-fired absorption heat pump can make a useful contribution to reducing primary energy consumption.

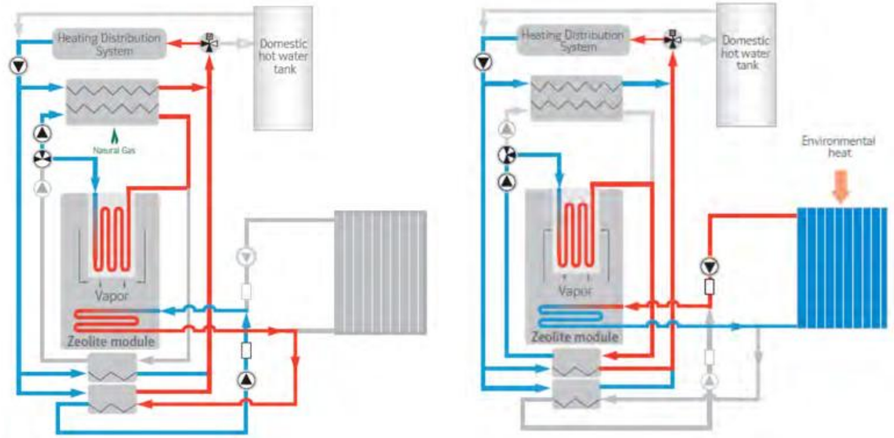
E-Sorp Heat Pump

Vaillant - Adsorption

Vaillant Gas-Driven Heat Pump

The system uses water as the refrigerant, together with a zeolite adsorbent, and consists of the heat pump itself, a solar collector which acts as the low temperature heat source and a water storage tank. In summer, the solar collectors can provide domestic hot water. It is only intended for use with underfloor heating systems with maximum output temperature of 40°C (104°F) and under these conditions has a projected reduction of annual energy use of 18% when compared with a condensing boiler.

Max. heating capacity	10kW (34.1kBtu)
DHW capacity	12.5kW (42.7kBtu)
Roof for installations of solar collectors	min. 8 m^2 (86ft2)
Floor heating or panel heating with flow temp.	< 40°C (104°F)

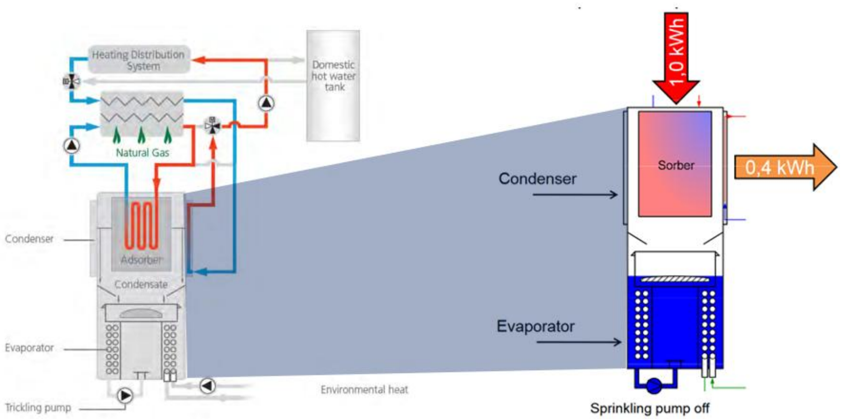


Vaillant Gas-Driven Heat Pump During the Desorption Phase (Left) And The Adsorption Phase (Right)

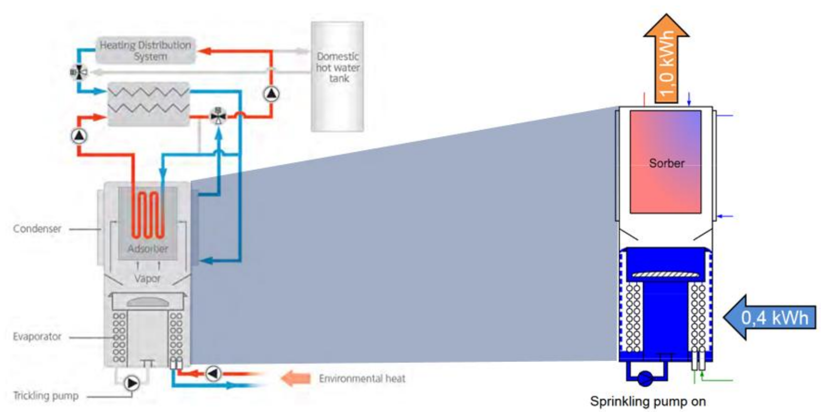
Viessmann - Adsorption

The Vitosorp 200-F consists of a zeolite heat pump module and a gas condensing boiler. The 11 to 15 kW (37.5 to 51.2 kBtu) capacity heat pump module covers the base load of the building's heat demand with natural heat. The integral gas condensing boiler fuels the heat pump process and covers peak loads on particularly cold days. It also acts as a booster for quick and convenient DHW heating. Hot water temperatures of up to 75°C (167°F) are feasible (recommendation < 55 °C [131°F]).

Vitosorp 200-F gas adsorption heating appliance



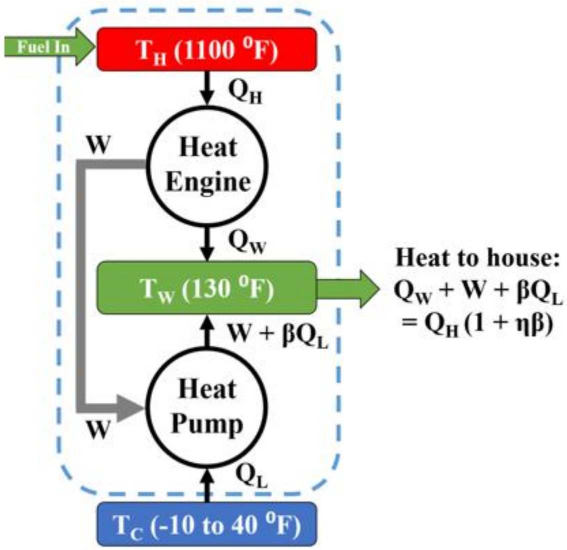
Viessmann Compact Heating Appliance Desorption

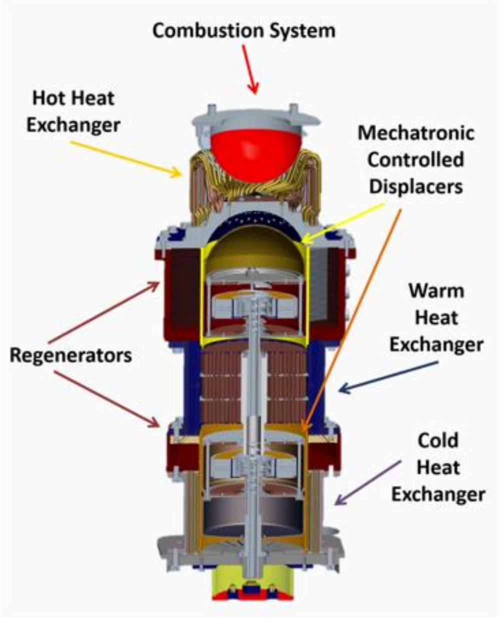


Viessmann Compact Heating Appliance Adsorption

Vuilleumier Heat Pump

The Vuilleumier cycle is based on the same thermodynamic principles as the Stirling cycle. The VHP moves a working gas, such as helium, between three chambers within a closed system. Two displacers reciprocate within a cylinder to move the working gas between separate hot, warm, and cold chambers.

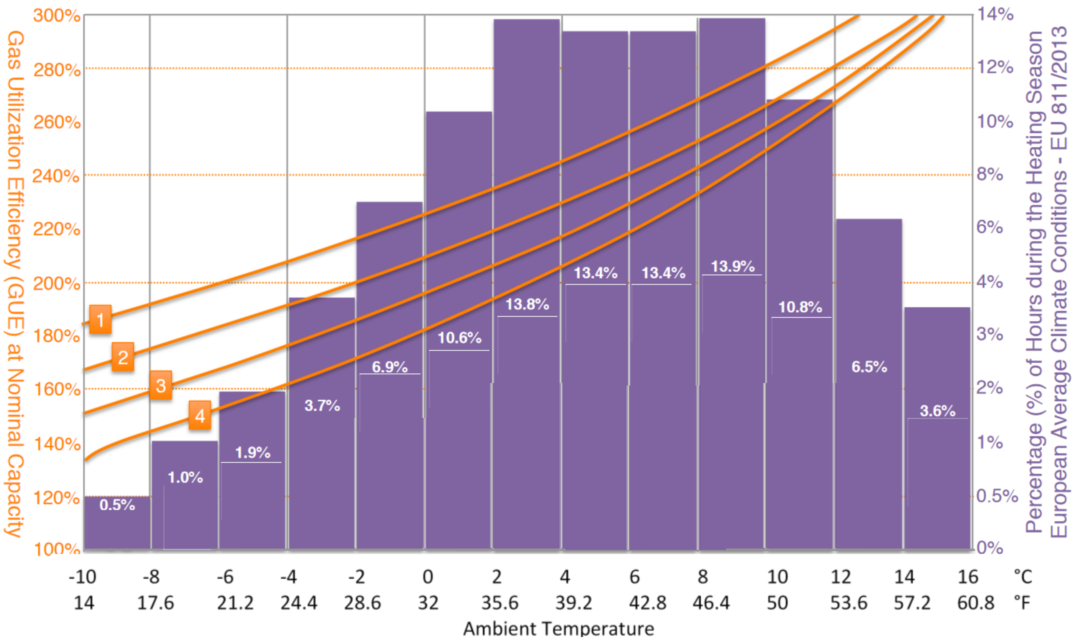




ThermoLift Vuilleumier Heat Pump (VHP)

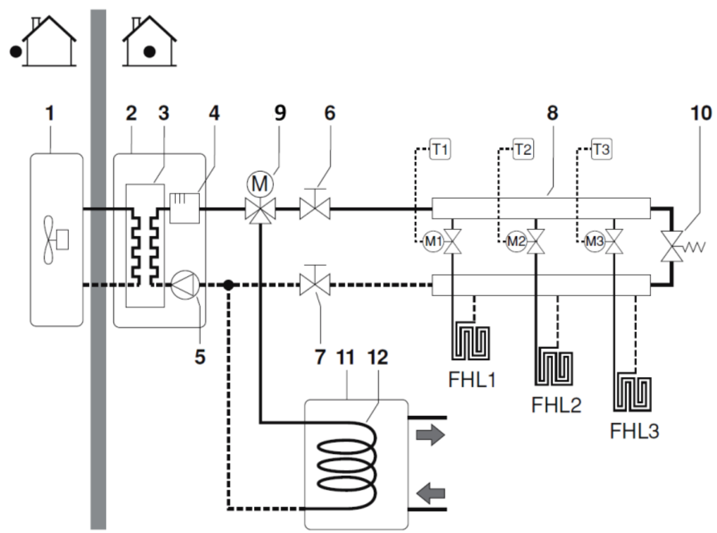
boostHEAT

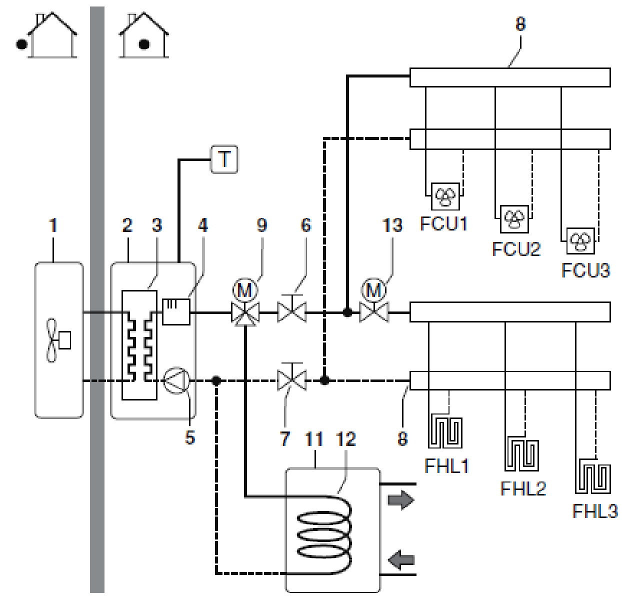
The center of the technology is a new type of thermal compressor that uses the heat from the burner, instead of mechanical energy, to compress a natural refrigerant. The fossil-fueled thermal compression device activates a high temperature air-water heat pump using a carbon dioxide cycle. Field prototype testing by GDF SUEZ in 2015 yielded impressive efficiency results.



Hybrid Electric Heat Pumps

It is also important to understand where electric heat pump systems are moving. Clearly they see electric heat pumps, if not replacing boilers and furnaces in cold climates, then at least providing the bulk of heating energy above a certain ambient temperature. For example, in New England, mini-split and multi-split heat pumps are being promoted to homes to provide higher ambient temperature heating and adding summer cooling to a home while the existing furnace or boiler is set to operate at an ambient temperature below where the heat pump is effective. In Europe, we are now seeing new Electric/Gas Hybrid heat pumps for hydronic systems. It may be time to take note of this new development.





Conclusions

Will cold climate electric and thermal heat pumps, with COP > 1.0 make it into the market?

The answer is that they already are in the market.

Will public policy favorable to thermal heat pumps become law?

In Europe, this has already happened.

In the US, key cold climate States are developing regulations for 2050 that will impact heating and will likely involve natural gas-driven heat pumps.

Will oil/bio-fueled thermal heat pumps be viable products in the US?

The answer depends on future regulation and technology development.

Conclusions

Given the preceding political and technological developments, the Oilheat/biofuel communities should closely follow thermal heat pump development, prudently invest in developing a technological pathway to success for liquid fuels, and engage in the political/regulatory process to show a viable pathway toward 2050 environmental and energy efficiency goals being discussed today.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