Promotion of efficient heat pumps for heating

(ProHeatPump)

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Report on renewables and heat pumps

Work Package 5
Heat Pumps and Renewables

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1. Summary

This report reviews gas engine driven heat pumps and gas fired absorption heat pumps that are alternative technologies to electrical driven heat pumps. Such type of heat pumps could use biogas instead of natural gas or liquefied petrol gas, or even wood for absorption machine. Direct use of solar energy is also possible. Greth, ESS have contributed to this report.

2. Table of content

3. Gas engine heat pumps

3.1. Typology

Gas engine heat pumps (GHP) differ from a conventional heat by the fact that the compressor is driven by a gas engine rather than an electric motor. One of the major differences with electrical driven heat pumps is that part of the heat released by the engine is recovered and used for heating the water. The heat can be collected from the engine cooling water or from the exhaust gas for large systems.

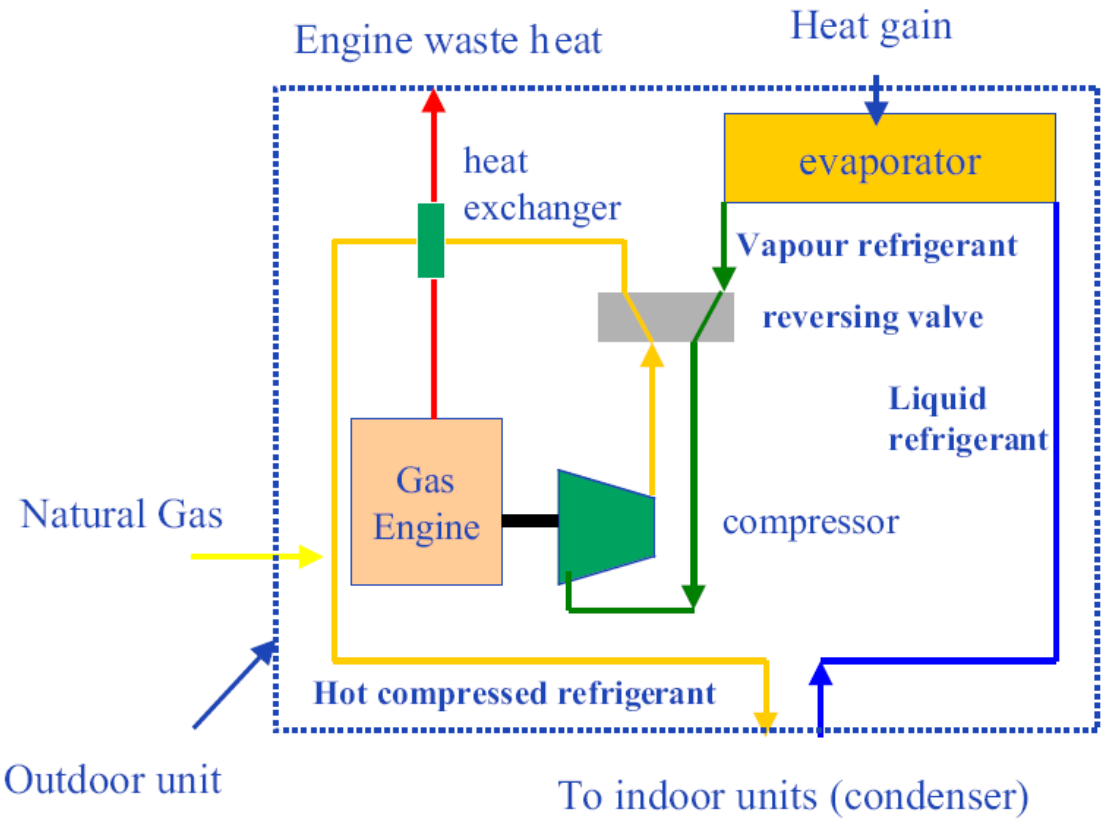


Figure 1: Description of a gas driven heat pump

Generally, gas heat pumps use ambient air as heat source, but in some cases ground couple systems are used. For the case of air-source systems, the COP will never drop below 1, even in case of very low ambient temperatures. This means that for the worst case, the useful heat is equal to the combustion heat. Furthermore, GHP manufacturers claim having better performance in part load compared to electrical driven heat pump. This might be true with the first generation of heat pumps, but for new heat pumps with variable speed compressor this not the case anymore.

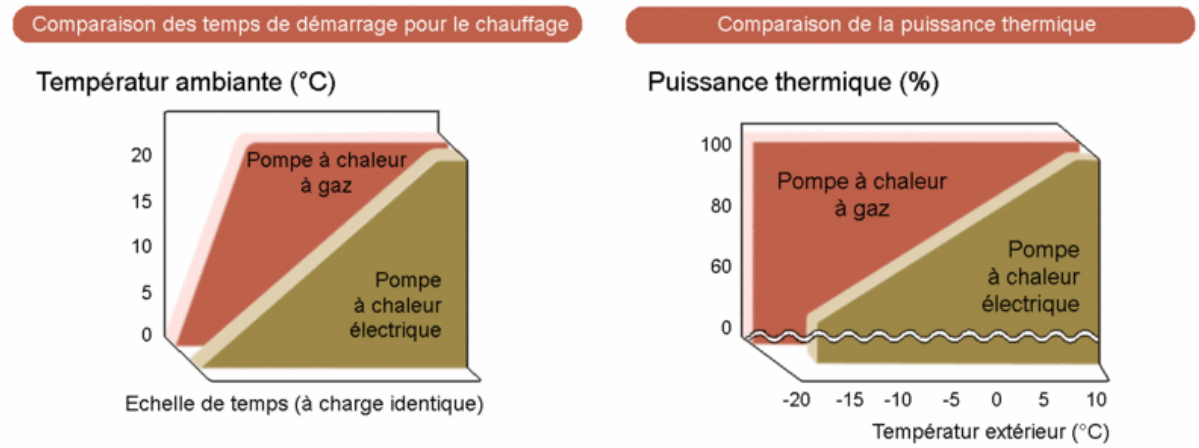


Figure: Comparison of gas and electrical heat pumps (source gaz-naturel Suisse)

3.2. The market

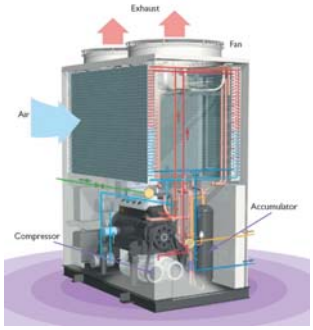
The market for such type of heat pumps is relatively limited in Europe, as the gas to electricity rate is not sufficiently attractive to compensate the extra investment costs. Although their features of variable speed drives that enabled them to provide more constant air flow, better humidity control and higher efficiency, other factors such as operating and maintenance costs, fewer qualified repair personnel resulting in questions of long term maintainability, and the environmental impact of internal combustion engine emissions all resulted in relatively low sales. And despite gas industry promotion, the only manufacturers remaining in the business are from Asia (mainly from Japan).
Japan is today the unique country where this technology as a significant development. Since 1998 almost 40000 units are sold and installed with capacities ranging from 20 to 100 kW. These units are mainly used in medium size buildings such as schools, offices, commercial or industrial buildings and hotels. Domestic applications remain marginal only 7% of the market. The GHP business is strongly supported by the Japanese gas industry.

3.3. The manufacturers

The four Japanese companies selling gas heap pumps are listed in the table below. Some of them are commercialised in Europe. In addition a Korean company is mentioned but not technical data have been found. York (USA) has started marketing GHP in the 90's but they stopped this product due to low sales and maintenance problems.

Company	Capacity	Web-site
AISIN	14-56 kW	http ://www.aisin.co.jp/life/ghp/english/
SANYO	25-80 kW	http://us.sanyo.com/industrial/HVAC/
MHI	40-71 kW	http://www.mhi.co.jp/enews/e_0930.html
YANMAR	33-67 kW	http ://ymr01.yanmar.co.jp/en/rd/energy_living.html
LS CABLE		http://www.lsholdings.co.kr/eng/press/press_view.asp?seq=4&

System developed by Aisin



System developed by Sanyo

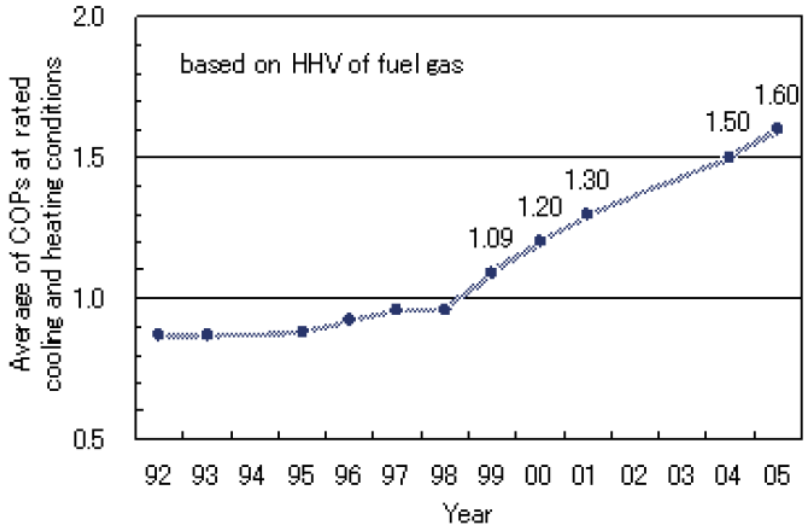
GHP developed by Mitsubishi Heavy Industry (MHI)

GHP by Yanmar

York Triathlon (not commercialised anymore)

3.4. The performances

It is difficult to compare directly a gas and electrical driven heat pump, as for electrical heat pump the primary energy efficiency depends on the production method of electricity its efficiency and the losses in the distribution network. Nevertheless we can easily compare gas driven heat pumps with gas boilers. Condensation boilers can reach efficiencies equal or slightly over 100%. For gas driven heat pumps, test realised in Japan have shown that the average efficiency between 1997 and 2005 has increased from 90% to over 150%. These high performances have been reached by using more efficient heat exchangers, the use of scroll compressors and improvement of the gas engine. The refrigerant fluid used today is HFC410a



Evolution of the performance of gas driven heat pumps in Japan (source IEA-HPC Vol 24, n°1, 2006)

The table below presents the performance of gas driven heat pumps system. The data are from test results in Switzerland or from the manufacturers.

Company	Aisin	Sanyo	Sanyo	MHI	Yanmar
Model	TGNP140N	SGP-E70J2GU2	SGP-E70K1GU2	ECO7	
Heating capacity (kW)	18	26.2	25.0	40.0	33.5
Cooling capacity (kW)	18	22.4	22.4	35.5	28.0
Electrical consumption of the auxiliaries (kW)	0.6	0.7	0.58-0.55	1.21-1.12	0.71-0.65
COP	1.3	1.2	1.41-1.35	1.59	1.3-1.13
Mass (kg)	450	700	640		700
Water temperature (°C)	54	45			
Return water temperature (°C)	42	40			
Noise level Decibels	52	58	56		53
Refrigérant	R407c	R407c		R410a	

4. Absorption heat pumps

4.1. Principle

Gas fired heat pumps or absorption heat pumps use heat as main energy source. For domestic and small scale applications, the heat is generally generated by the combustion of gas. Absorption machine are based on the capacity of a liquid or a salt to absorb the flowing refrigerant. The most common fluids uses are:

- water (refrigerant) and lithium-bromide (absorbent);
- ammonia (refrigerant) and water (absorbent).

Absorption heat pumps are also named 'three sources' machines as they require a low temperature source where heat is extracted, a medium temperature source where the useful heat is produced and a high temperature source for regenerating the absorbent (gas combustion). The electrical consumption of the auxiliaries represents 1% to 3% of the gas consumption for heat loads in the range of 30 kW to 40 kW.

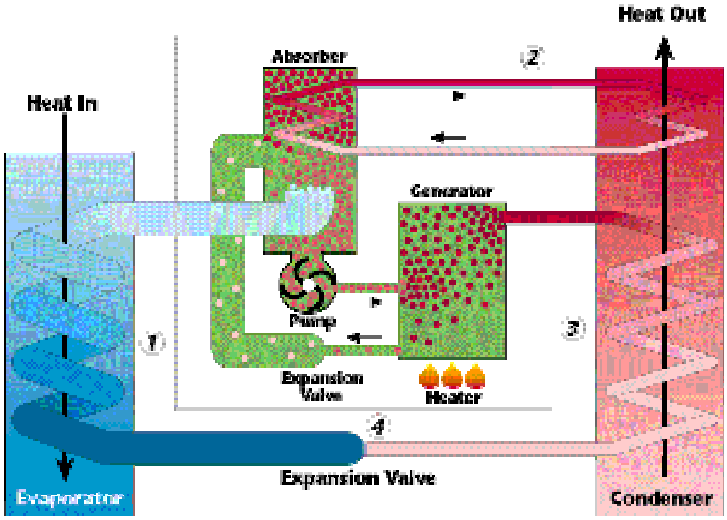


Figure : Principle of an absorption heat pump.

4.2. The market and the manufacturers

Large absorption machine (over 50 kW) are common as refrigeration machines, but for lower capacities there is only a limited number of manufacturers. Some of them are only manufacturing air-conditioning systems, which can eventually produce hot water. For very small capacities (below 2 kW) portable systems for camping exist.
For domestic application the only company proposing commercial product is ROBUR, other companies are developing systems but mainly for cooling.
Since 2004 Buderus is marketing the Loganova diffusion absorption heat pump, for capacities from 3.6 kW for hot water production to 19kW for heating. A COP of 1.5 is claimed, but no detailed data can be found.

Company	Heat load	Web site
ENTEX	2-10 kW*	http://www.entex-energy.ch/technology1.html
BUDERUS	3.6-19	www.buderus.ch/public/pdf/produkte_pressetexte_d/presse_dawp.pdf
Ambian Technologies		www.eere.energy.gov/de/pdfs/conf-03_der_pr/rockenfeller.pdf
Cooling Technologies	17 kW**	http://www.coolingtechnologies.com/
ROBUR	36-180 kW	http://www.robur.com/pag_risultati_comparativa.jsp?idc=10&idl=2
YAZAKI	100-300 kW	http://www.yazakienergy.com/
CLIMATEWELL	76 kW***	http://www.climatewell.com/

* Cooling only
** Cooling and hot water production
*** Reversible

Absorption heat pump from Robur

Absorption cooling machine from Cooling Technologies

Absorption cooling machine (18 kW) from Cooling Technologies

4.3. The performances

The performances of absorption heat pumps have significantly increased these last years by the use of more complex cycles and more efficient components. Heating COP over 1.4 can now be reached.

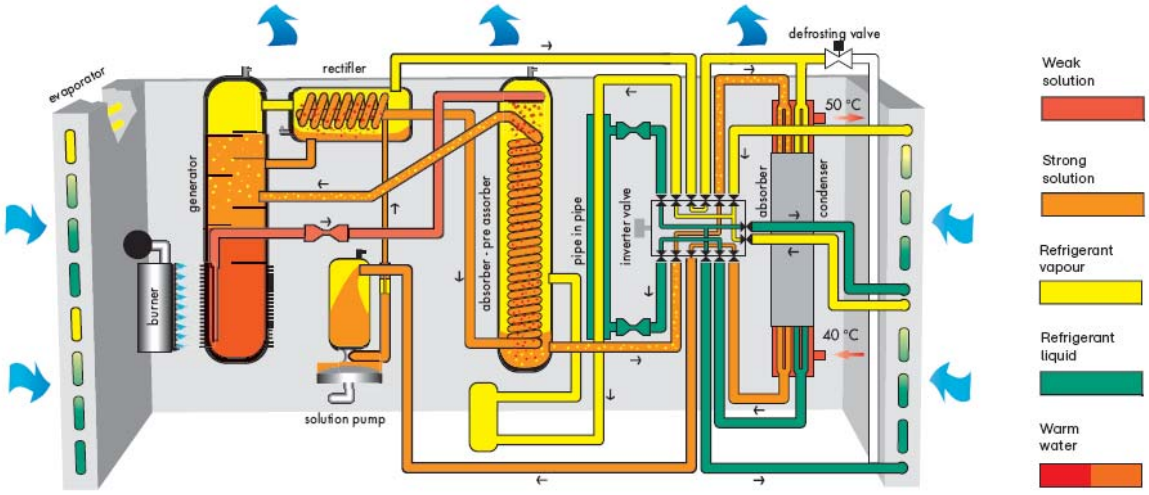


Figure : Principle of a absorption heat pump with a generator absorber heat exchanger (GAX).

In the table below the performance of the ROBUR heat pumps are given. All the other commercial products have high heat load (over 100 kW) or are dedicated to cooling.

Company	Robur	Robur	Robur	ORNL
Model	GAHP-A	GAHP-W LB	GAHP-W	Proto
Type	Air-Water	Ground-Water	Water-Water	Air-Water
Fluid	Eau-NH3	Eau-NH3	Eau-NH3	Eau-NH3
Heating capacity (kW)	36,2	35,3	38,8*	45
Cooling capacity (kW)	-	16,9	18,4*	
Auxiliary electric consumption (kW)	0,9	0,54	0,9	1,3
COP	1,44	1,39	1,54	1,55
Mass (kg)	350	286	286	
Water temperature (°C)	60	60	65/3	
Noise (decibels)	54	47	47	

* Simultaneous production of heat and cold water

4.4. Solar driven absorption heat pump

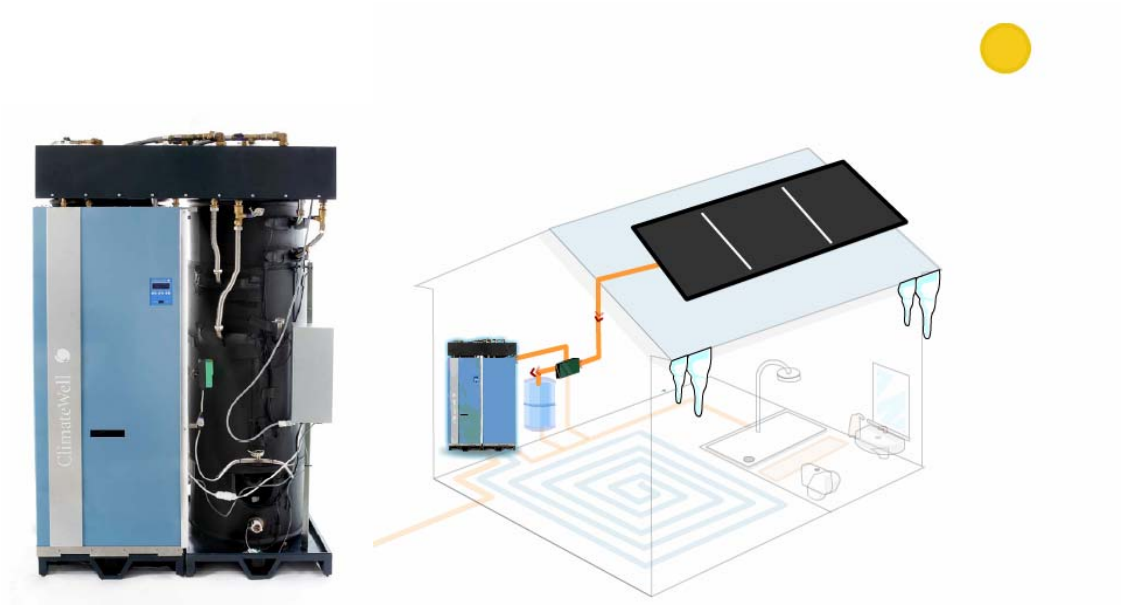
ClimateWell AB is a supplier of highly efficient solar air conditioner equipment with the unique ability to store energy and convert hot water to cooling and heating. For the first time, a solar powered climate system can fully meet the heating and cooling requirements of a residential house. Our modular product concept also creates opportunities to design systems for hotels and offices. Hot water is the energy source for the air conditioners, which hence use only an absolute minimum of electricity. It is thus also possible to use hot water from district heating or co-generation to power the systems.

Mode	Storage Capacity*	Maximum Output Capacity**	Electrical COP ***	Thermal Efficiency
Cooling	**60 kWh**	**10/20 kW**	**77**	**68%**
Heating	**76 kWh**	**25 kW**	**96**	**160%**

* Total storage capacity (i.e. including both barrels)

** Cooling capacity per barrel: 10 kW cooling is the maximum capacity. If both barrels are used in parallel (double mode) the maximum cooling output is 20 kW and the maximum heating output is 25 kW.

*** Coefficient of Performance (COP) = cooling or heating output (kW) divided by electrical input. The only electrical input is 4 small circulation pumps and internal controls. COP in conventional compressor-based chillers and packaged air conditioning units are usually stated as cooling capacity (kW) divided by compressor electrical input. Since the ClimateWell 10 doesn't have a refrigeration compressor, COP is stated here as annual cooling/heating energy delivered divided by total electrical input of the pumps and internal controls.



Absorption solar heat pump

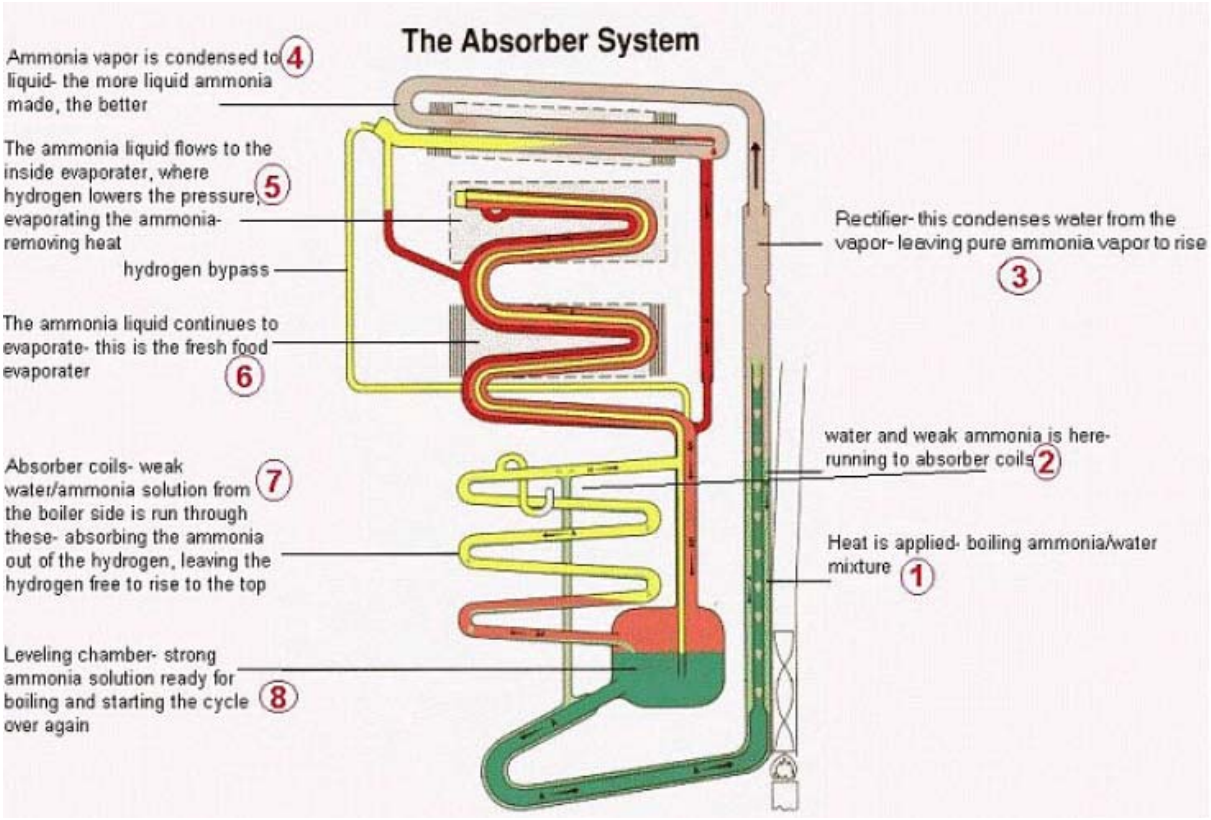
5. Diffusion absorption heat pumps and solid state adsorption heat pumps

5.1. Principle

Two alternative cycles can be adopted for gas fired heat pumps. The first one is based on absorption-diffusion cycles and the second one on solid state adsorption.

Diffusion-adsorption cycles use of third fluid (hydrogen or helium) in which the ammonia vapour is absorbed and transported. This allows suppressing the circulating pumps. Two companies are presently developing such technologies.

In adsorption cycles the liquid absorbent is replaced by a zeolith structure, which adsorbs the refrigerants. Such cycles need two adsorbers, while the first one adsorbs the refrigerant the second one is regenerated at higher temperature.



Principle of a diffusion-adsorption cycle

5.2. The manufacturers

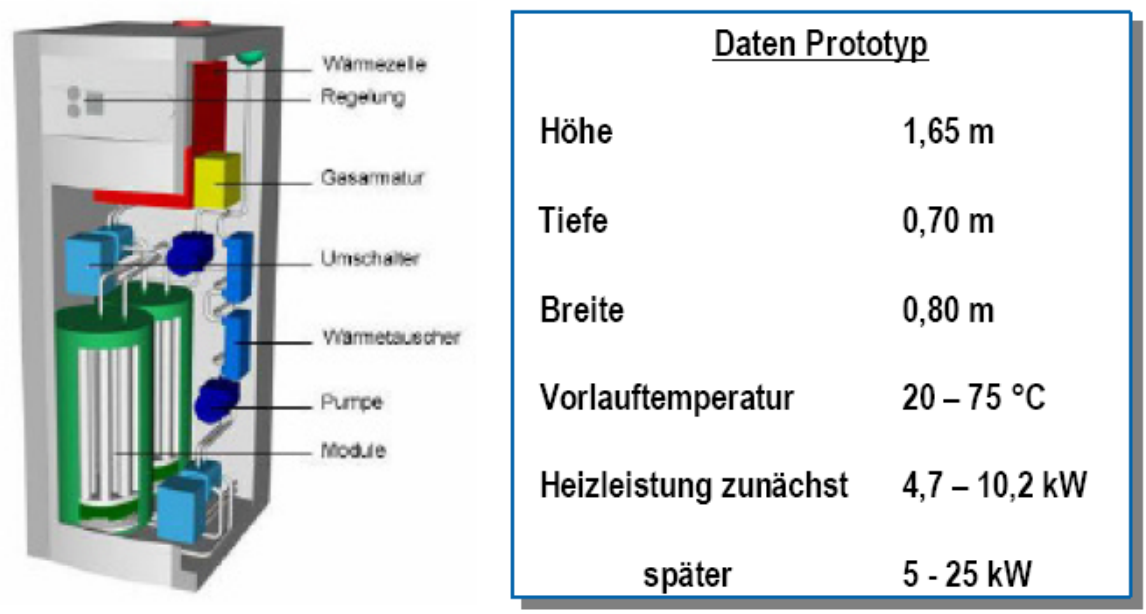
Three manufacturers are developing such technologies. However the products are still at the prototype stage or in field tests before marketing.

Company	Heat load	Web site
ENTEX	2-10 kW	http://www.entex-energy.ch/technology1.html
BUDERUS	7-15	www.buderus.ch/public/pdf/produkte_pressetexte_d/presse_dawp.pdf
VAILLANT*	5-25	

* solid state adsorption

Diffusion-absorption heat pump by Buderus (Loganova model) in field tests since 2006

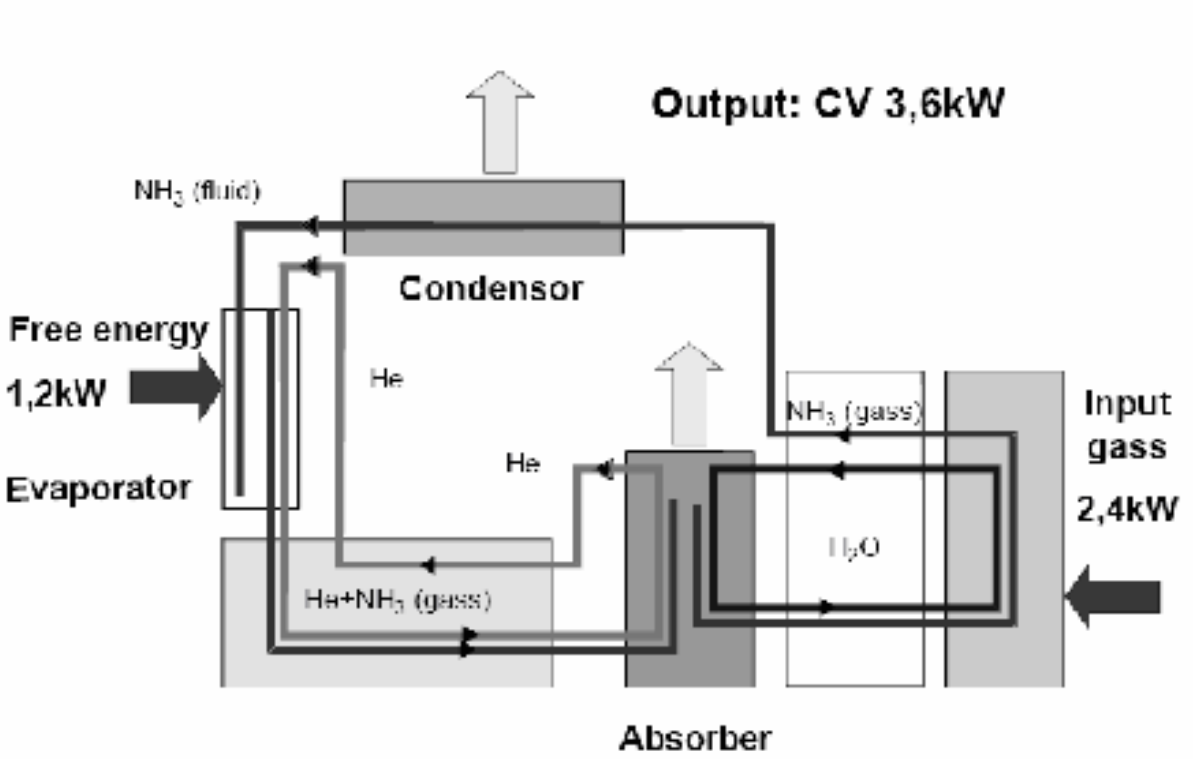
Cooling module commercialised by Entex



Zeolith adsorption heat pump by Vaillant (Prototype stage in2007)

5.3. Solar assisted diffusion-absorption heat pump

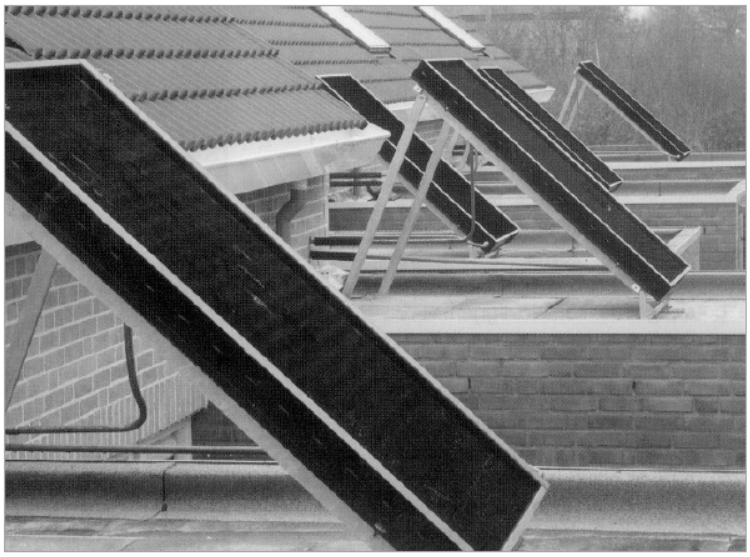
NEFIT in the late 1900 have developed a solar assisted diffusion-absorption heat pump. Due to the low heat duty of the system (3.6 kW) a condensing boiler was connected. The 'free energy" source for the absorption cycle was collected by solar thermal panels. In 2000, 63 systems were installed and the performance monitored. The overall system efficiency was 15 to 27% higher that for a stand alone condensing boiler. No commercial product is existing.



Condensing boiler:
efficiency 107%

Heat pump:
efficiency 130%

Roof collector



6. Conclusion

Gas-driven heat pumps

Biogas could be used for gas-driven heat pumps, but up to now, the manufacturers are claiming that the quality of biogas evaluated is not high enough and the engine could be damaged while using biogas.

Externally fired absorption heat pumps

Presently no manufacturer is proposing such systems, but research is being performed to evaluate the use of bio-gas.

Solar driven absorption heat pumps

Solar driven absorption or adsorption heat pumps are at an early commercial stage. Such units are particularly well suited for heating and cooling purposes. Presently the payback time for such system is not economic unless significant subsidies for the initial investment.