FACT SHEET 11
Heat Pumps (heating only)

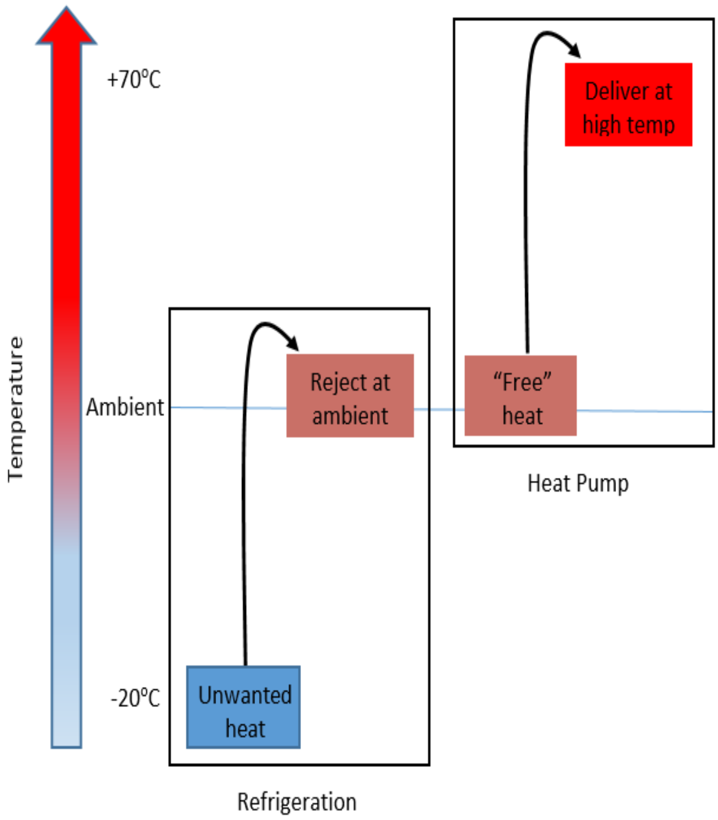
1. Description of market sector

This market sector includes heat pumps used for a variety of heating applications. The sector excludes reversible air-conditioning / air-to-air heat pump units – these are discussed in Fact Sheets 8 and 9.

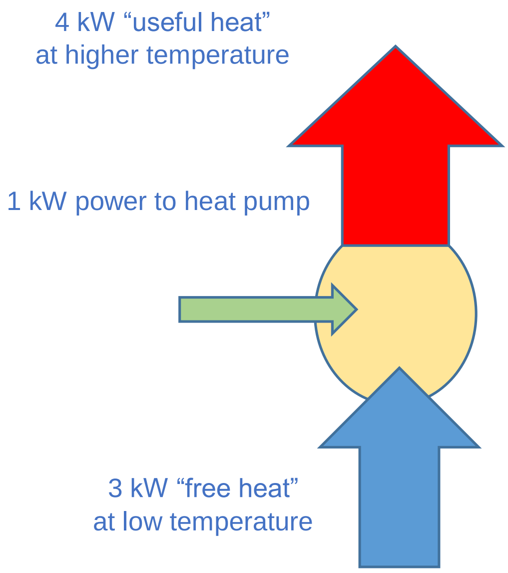
Introductory comments about heat pumps: Heat pumps are based on almost identical technologies to refrigeration systems – the only difference is the temperature level at which they operate, as illustrated on the left.

A refrigeration plant, with the primary objective of producing cold, absorbs heat at a low temperature (below ambient) and rejects that heat at a higher temperature (just above ambient). A heat pump, with a primary objective of providing heating, absorbs heat from a suitable source (usually at a temperature close to ambient or above ambient) and delivers that heat at a higher temperature (often in the range 30ºC to 90 ºC).

The actual equipment required is similar to refrigeration: an evaporator to collect heat, a compressor, a condenser to reject or deliver heat and a suitable refrigerant. As heat pumps operate at higher temperatures than refrigeration systems, different refrigerants may be required to suit the higher temperatures.



The importance of heat pumps: Heat pumps "move heat" from a low temperature (where the heat is of no use) to a higher temperature, where the heat can be used to heat a building or a process. The amount of energy required to move the heat depends on the temperature difference between the heat source and the heat user (referred to as the "temperature lift"). With a low temperature lift it requires relatively little energy to move a large amount of heat. For example, a heat pump may be able to deliver 4 kW of heat with an energy input of only 1 kW – this is potentially a very efficient way of supplying heat. Heat pumps become especially important if low carbon electricity is used to power the compressor – it makes it possible to supply heat with considerably lower CO_2 emissions than a fossil fired boiler system.



Market sub-sectors

The heat pump market is very wide ranging. Heat pumps are used in residential, commercial and industrial applications and they vary in heating capacity from a few kW to many MW. This Fact Sheet provides only a brief overview of some of the key applications of heat pumps – it is not intended to cover all applications in a comprehensive manner.

Heat pumps can be categorised in a number of different ways. An important parameter is the type and temperature level of the heat source. The main types of heat source are:

a) ambient air
b) water (e.g. from a river or ground water)
c) the ground, either at ambient temperature or at a higher temperature (e.g. from a geothermal heat source)
d) waste heat (e.g. industrial waste heat, sewage or heat rejected from a refrigeration plant)

Heat pumps are also categorised by the way heat is delivered. Three common examples are:

a) space heating via a ducted air system
b) space heating via a hot water system (either radiators or underfloor heating)
c) heating domestic hot water or process hot water

The relevant combinations of heat sources and heat users define the operating temperatures of the heat pump and are critical to the selection of a suitable refrigerant. Some specific examples of heat pumps for which data is provided in this Fact Sheet include:

1) Residential space heating with an air-source heat pump heating water for underfloor heating
2) Residential domestic water heating
3) Large district heating heat pump with heat from municipal sewage system

These examples are chosen to illustrate some of the many heat pump applications. This Fact Sheet does not discuss reversible air-conditioning / air-to-air heat pump systems. These are widely used to provide both air-conditioning and to operate as an air-to-air heat pump in cool or cold weather. The relevant refrigerant options for reversible air-to-air systems are discussed in Fact Sheets 8 and 9.

In some applications it is possible to combine a refrigeration plant and a heat pump into a single unit. For example: (a) a supermarket system that provides cooling to food display cases and space heating to other parts of the store, and (b) an industrial pasteuriser system providing simultaneous heating and cooling to a liquid being pasteurised.

Typical system design

A significant proportion of heat pumps use a vapour compression cycle. Most small and medium sized systems use a direct expansion (DX) design. Large systems often use flooded evaporators.

Alternative technologies

Various alternative technologies can be used for heat pumps. An important example is mechanical vapour recompression. This is sometimes referred to as an “open-cycle heat pump” and it is used in certain types of industrial evaporation or distillation system. Evaporated steam is the waste heat source; it is compressed and then condensed in a heat exchanger to provide heat to the evaporation process. Various types of domestic absorption and adsorption cycle heat pumps are the subject of research, although it is unclear as to whether any of these technologies will become commercially successful. Large absorption systems are sometimes used for industrial applications.

Changes driven by ODS phase out

CFC-12 was used for many heat pumps prior to 1990. Various HFCs have been used including HFC-134a, R-410A and HFC-245fa for high temperature heat pumps.

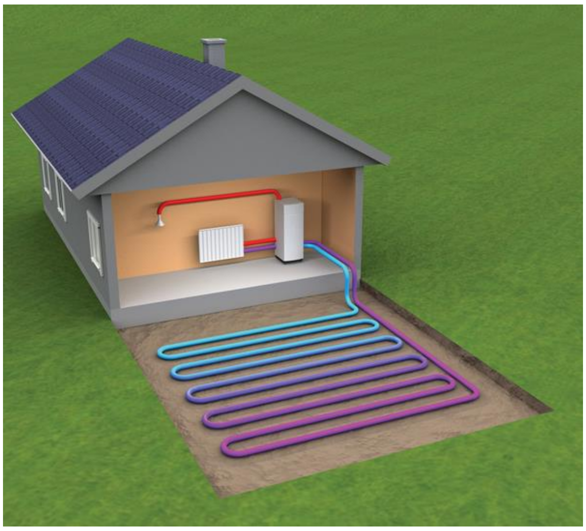
Air-source heat pump for space heating

Air-source heat pump for domestic hot water

Table 1: Heat Pumps (heating only): summary of characteristics of HFC equipment

Market sub-sector:		Residential space heating, air to water	Residential domestic hot water heating, air source	Large district heating system, waste sewage
Typical refrigerant charge		3 to 6 kg	1 to 2 kg	250 to 7000 kg
Typical heating duty		4 to 20 kW	1 to 5 kW	500 to 5000 kW
HFC refrigerants widely used		R-410A (GWP[1] 2088)	HFC-134a (GWP 1430)	
Refrigeration circuit design		Factory sealed direct expansion or factory pre-charged split units		Factory built chiller
Manufacture / installation		Factory built, pre-charged with refrigerant. Site installed refrigerant pipework for split units.		
Typical location of equipment		Evaporator often located outdoors. Condenser of split units usually indoors.		Limited access
Typical annual leakage rate		< 1%	< 1%	2% to 5%
Main source of HFC emissions		Losses at end-of-life	Losses at end-of-life	Operating leakage
Approx. split of annual refrigerant demand	New systems	90%	90%	50%
	Maintenance	10%	10%	50%

[1] All GWP values are based on the IPCC 4th Assessment Report



Ground source heat pump for space heating

Ground source pipework being installed

Large district heating heat pump using waste heat in treated sewage water

2. Alternatives to currently used HFC refrigerants

Table 2 provides a summary of alternative refrigerants suited to the three heat pump applications being used as examples in this Fact Sheet. As discussed above, there are many other heat pump applications and these may require other alternative refrigerants.

Table 2: Lower GWP alternatives for heating only heat pumps

Refrigerant	GWP	Flammability[2]	Comments
Residential space heating air-to-water (underfloor heating)			
HC-600a HC-290	3 3	3 3	When air-source heat pumps are located completely outdoors and situated safely, higher flammability refrigerants can be used with good efficiency.
HFC-32	675	2L	Lower flammability refrigerants can be considered for both outdoor and some indoor locations.
R-446A R-447A	460 582	2L 2L	Newly developed blends with properties similar to R-410A. Also being considered.
Residential domestic hot water heating, air source			
R-744 (CO_2)	1	1	R-744 is well suited to water heating because of large temperature range of the water being heated (e.g. from 10ºC to 70ºC, heated in one step). Several million are in operation in Japan, but subsidies were provided. R-744 water heaters are not common outside Japan.
HFC-32	675	2L	HFC-32 recently introduced in Japan for water heaters.
Large district heating system, using waste heat from treated sewage			
R-717 (ammonia)	0	2L	Used in a number of large district heating and space heating installations, especially in Northern Europe.
HFO-1234ze	7	2L	Being considered for heat pumps with large centrifugal compressors as an alternative to HFC-134a.
HFO-1233zd HFO-1336mzz	5 9	1 1	Newly introduced fluids suitable for low pressure centrifugal compressors. May be used in large heat pumps, especially with a high delivery temperature (as an alternative to HFC-245fa).

[2] Flammability classes based on ISO 817 and ISO 5149
3 = higher flammability; 2 = flammable; 2L = lower flammability; 1 = no flame propagation

3. Discussion of key issues

Safety and practicality

Some heat pumps can be located outdoors or in a restricted access machinery room. Others are installed indoors or parts of the refrigerant circuit are indoors. A number of flammable alternatives can be considered depending on the location of the refrigerant circuit parts. These can be used safely under existing safety codes.

Commercial availability

There is little commercial availability of residential space heating heat pumps using flammable refrigerants, but this is likely to change significantly over the next 5 years, particularly for lower flammability refrigerants.

R-744 water heating heat pumps are widely available, especially in Japan. New options such as HFC-32 have recently been introduced to improve efficiency and reduce cost.

Large district heating heat pumps are often built on a "one-off" basis (in the same way as large industrial refrigeration systems). A number of large ammonia systems are already in operation. HFO based systems are already in use and can already be considered for new designs.

Cost

The cost effectiveness of heating-only heat pumps depends on the relative life cycle costs of a heat pump and the relevant competing technology (e.g. a gas fired boiler). With current energy prices this often makes heating-only heat pumps financially unattractive but in many countries there are financial support schemes to stimulate demand. With a decarbonised electricity grid, heat pumps become very attractive in terms of low CO_2 emissions, but will only be cost effective if the end user is paying for the CO_2 emissions from competing alternatives such as gas-fired boilers.

The financial case for reversible air-conditioning / air-to-air heat pumps is usually quite different. The capital cost is required to provide summer-time cooling. The provision of winter-time heating can be made with little extra capital investment.

Use of some of the refrigerant alternatives listed in Table 2 could create a small cost increase compared to the currently used HFCs. For example a large district heating system has a significant refrigerant charge and HFO-1234ze is more expensive than HFC-134a. However, the refrigerant cost remains a small percentage of the total heat pump installation cost. Small R-744 heat pumps can be significantly more expensive than HFC systems.

Energy efficiency

It is expected that many of the alternatives listed in Table 2 can be used with approximately the same efficiency as currently used HFCs. R-744 may be less efficient except in certain types of water heating application.

The most important issue related to heat pump energy efficiency is the temperature lift of the system (the difference in temperature between the heat source and the heat user). Fundamental design choices such as use of conventional hot water radiators or of underfloor heating will have a much greater impact on heat pump efficiency than the choice of refrigerant.

Applicability in high ambient

There are no issues related to operation in high ambient temperature, as heat pumps supply heat at a temperature well above ambient.

Opportunities to retrofit existing equipment

It is not usually appropriate to retrofit existing heat pump systems with an alternative refrigerant.

Technician training

HCs: Technicians doing maintenance need training that addresses handling of higher flammability refrigerants. There are well established training courses available in regions already using HCs for domestic refrigerators. There are far fewer technicians trained for use of HCs in domestic heat pumps. The refrigerant charge of a heat pump is much higher than that of a refrigerator and this has an impact on the risks during maintenance and hence on the training requirements.

Lower flammability HFCs/ HFOs: Training will also be essential for maintenance of systems with lower flammability refrigerants. These are not yet in widespread use for heating only heat pumps. There is rapid growth in the use of lower flammability refrigerants for reversible air-conditioning / air-to-air heat pump systems. Training is available for these systems and is transferable into the heating only heat pump market.

Minimising emissions from existing equipment

The majority of emissions from residential heating only heat pumps that are properly installed occur at end-of-life. Refrigerant must be recovered prior to dismantling a system to minimise these emissions. Recovery equipment can be used on-site to recover the refrigerant. Alternatively mono-bloc units can be sent to a recycling plant for refrigerant recovery. The refrigerant in split systems can be pumped to the outdoor unit which can then be sent to a recycling plant.