Net Zero Beyond Refrigeration
Heat Pumps Technology Brief

" Strategies to support users of refrigeration, air conditioning and heat pump technologies to achieve carbon reduction through effective policy implementation, financial incentives, and emissions monitoring. "

Introduction

The IOR Environment Working Group has identified a number of key technologies that need to be better understood by users of cooling and heating equipment, in order to support the path to net zero (www.ior.org.uk/beyondrefrigeration). The technology of heat pumps is outlined here, with an explanation of the different types of heat pump available, how they can help you to reduce your emissions and some frequently asked questions. This provides a general introduction to the technology – for a comprehensive guidance on whether this technology is the right one for your site, you should contact manufacturer, supplier, installer or consulting engineer.

About Heat Pumps

Heat Pump technology can help to achieve net zero target by providing highly efficient heating sources in many cases. This Technology Brief seeks to outline the different technologies and their suitability for those unfamiliar with this technology.

All heat pumps use a refrigeration cycle to extract low temperature – often referred to as low grade - heat from a source and reject high temperature heat to a heat emitter. In building applications, the heat pump can be used as an alternative to a boiler for space heating and domestic hot water. This alternative will become increasingly in demand as the UK moves away from using fossil fuel as a primary heat source for space and domestic hot water heating.

The key characteristic of a heat pump compared to a boiler is that the amount of heat produced is greater than the energy used to drive the process, e.g. the electrical energy supplied to the compressor motor and fans or pumps. For this reason the cost of heat provided by a heat pump can be less than the cost of heat provided by a boiler, even though the cost of electricity is greater than alternative fuel sources.

Note: The term heat pump covers a vast range of application types and there is no "one size fits all" approach. UK Government policies to promote and incentivise the use of heat pumps are focussed on the domestic heating market, where replacing fossil fuel burning gas boilers with air to water heat pumps in well insulated homes, can provide a high efficiency solution in operation, provided that the homeowner invests in retrofitting pipe and radiators. This technology cannot simply be used to replace an existing boiler. When it comes to retrofitting an existing domestic property other options such as air to air or multi split which provide more controllable and near instantaneous heating may be a more efficient solution. In all cases a qualified building services or heating engineer should be engaged to provide specific advice and recommendations.

The heat source can be air, ground water or the earth itself and the purpose of this guidance is to briefly explain these differences and how they can be applied in practice in domestic and residential use to significantly reduce our carbon footprint as a nation.

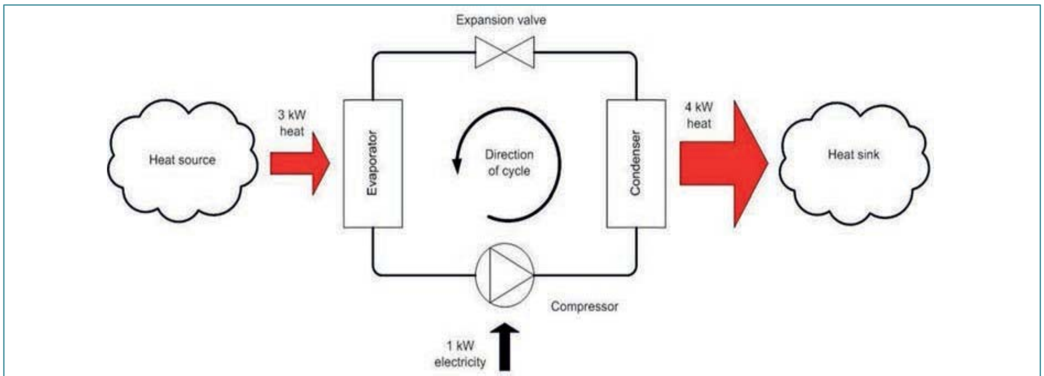


Fig 1 - A basic heat pump circuit

1. Air to air heat pumps

Air to air heat pumps are typically found in small shops or small offices, or more complex systems are often found in larger office blocks, hotels and other commercial buildings. Air to air heat pump air conditioning systems offer a good solution in cases where there is a constant cooling requirement in some parts of the commercial building – server rooms, for example – and the heat being rejected from these areas can readily be recovered and used for hot water preparation or applying heat to other occupied areas, or because there may be meeting rooms which are often only used for short periods of time and don't therefore demand heating all day every day.

They include the following types:

Split unit heat pumps are similar to split unit air conditioning units but may be optimised for heating. The internal and external unit are linked together with refrigerant pipework. Where these systems are reversible air conditioning systems the indoor and outdoor units can act as the evaporator or the condenser depending on the operating conditions of the unit at any given time. Reversible Air Conditioning systems including variable refrigerant flow (VRF/VRV) and Multi-split systems also come under this category. A VRF/VRV system may operate with some indoor units operating as condensers and others operating as evaporators simultaneously, providing very efficient heat recovery by providing some or all of the usable heat from other areas of a building that need to reject heat.

Figure 2 – Outside unit of a split air source heat pump

Externally mounted air to air heat pump packaged units are located on a roof or adjacent to a wall with insulated ductwork transferring heated air into the building. There may also be a provision for the variable introduction of fresh air directly.

Benefits:

- Split type systems are more efficient than packaged ones due to the additional sub-cooling available in the pipe run. Typical efficiency is between 4 and 6kW of heat for every kW of power consumed.
- Quick response to changing outdoor conditions and variable heating requirements in the building.
- Outside "fresh" air can be easily introduced in air supply systems, allowing filtering and air treatment to be embedded in the system design.

Drawbacks:

- Air source heat pumps are subject to ice formation on the outdoor coil and require defrosting periodically (achieved automatically but sometimes with loss of output for short periods of time).
- Efficiency drops off as the outdoor temperature drops below -5ºC.

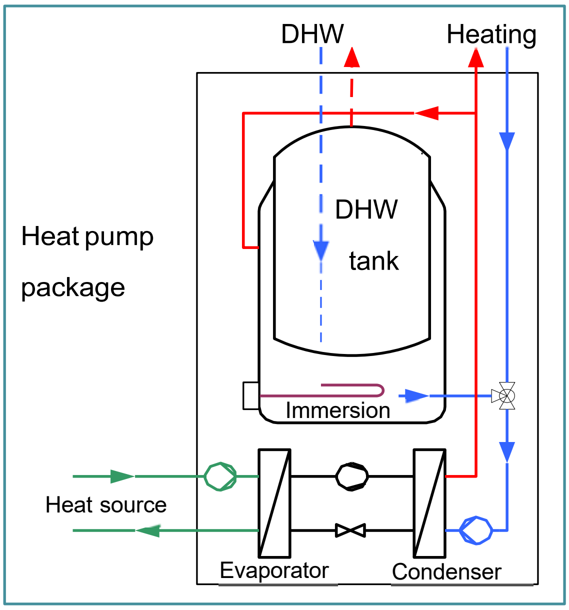
These are typically found in small shops or small offices, or more complex systems are often found in larger office blocks, hotels and other commercial buildings.

2. Air to water heat pumps

These systems are most commonly used in new build domestic or commercial buildings where hot water for radiators or underfloor heating is required.

The most common type of heat pump in use, predominantly used in the domestic market due to their similarity in design to the traditional gas/oil boilers in use in the UK housing market.

Air to water heat pumps (sometimes referred to as "monoblock" units), **air to water "split" systems** and **exhaust air to water heat pumps** are usually provided as unitary packages for external mounting or as split units with only the evaporator unit mounted outside. Indoor heating can be supplied by traditional radiators (although they need to be substantially larger than when using gas/oil boilers to heat the property) or by underfloor heating. They normally have to run at lower flow temperatures than traditional systems to achieve the energy efficiency levels published so are best suited to new-build, heavily insulated, homes. They are slow to react to fluctuating outdoor temperatures or indoor needs due to the lower flow temperatures.



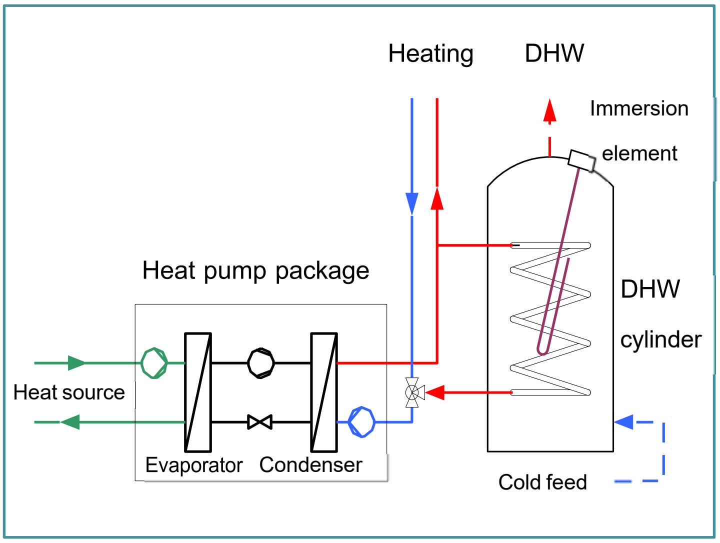


Figure 4 – Example heat pump package with external domestic hot water cylinder

Figure 3 – Example heat pump package with integral domestic hot water tank

Benefits:

- Split type systems are more efficient than packaged "monoblock" ones due to the additional sub-cooling available in the pipe run. Typical efficiency is between 3.5 and 5kW for split type and 3 and 4.5kW for monoblock type for every kW of power consumed.
- Look like traditional heating systems so are more readily accepted by householders.

Drawbacks:

- The split type units may require multi-trade involvement in the installation due to the refrigerant regulations requiring refrigerant pipework to be installed by a certified professional.
- Air source heat pumps are subject to ice formation on the outdoor coil and require defrosting periodically (achieved automatically but sometimes with loss of output for short periods of time).
- Slow response time when changing outdoor temperatures change the heating demand on a property. Slow to heat from cold at start-up if heating has been switched off for a period of time.
- Efficiency drops off as the outdoor temperature drops below -5^{o}C.

3. Ground Source / Geothermal Heat Pumps

This equipment is usually suited to larger new buildings where there is space available for the necessary pipes. Ground source systems use one of two systems for heat extraction:

- Boreholes drilled into the ground at typical depths between 40 and 100m, with plastic tubes inserted into them to allow a flow and return of a water-based solution.
- Shallow trenches dug at around 1.2m deep into which a long looping plastic pipe, normally referred to as a "slinky", is laid and buried.

The heat from the ground is absorbed by the water solution flowing through the pipes in both cases. They work on the principal that, in the UK, the ground temperature approximately 1m below ground is relatively stable all year round, regardless of the air temperature and weather conditions being experienced above ground. This enables a heat pump to work in stable conditions year round, enabling design to be optimised for those conditions.

Normally connected to a heat pump transferring heat via water into the building and delivering heat through underfloor heating circuits, or traditional style radiators in the same way that an air to water system described in section 2 (air to water heat pumps) does, they can also be connected to heat pumps delivering air heating in the same way as described in section 1 (air to air heat pumps) does.

Figure 4 – Components of a ground source heat pump

Figure 5 – Shallow horizontal ground loops

Benefits:

- Ground source systems do not normally need to have defrost cycles activated because they do not frost up the same way that air source systems do, and so do not have the periods of no heat being delivered.
- Energy efficiency is maintained through colder outdoor temperature conditions. Typical efficiency is between 6 and 7kW for every kW of power consumed.

Drawbacks:

- Expensive to install compared to air source due to drilling or earth moving costs.
- Boreholes may require permission from local authority to drill, and geological surveys may be necessary to determine suitability.
- Shallow trenches for horizontal pipe laying require a large area of ground to be dug up and used so they are not really suitable for retrofit to existing properties without major disruption to landscaping.

4. Open Loop Water Source Heat Pumps

Open loop water source heat pumps will provide solutions for large commercial buildings or as part of a heating network supplying multiple buildings. These heat pumps can extract heat from water stored in tanks, lakes, rivers or reservoirs; natural aquifers – layers of water occurring between layers of porous rock; or flooded disused mines.

They work in the same way a ground source system does but the water is directly extracted and pumped back into the larger body of water rather than in a closed loop. This use of naturally occurring water means the use of the water for heat extraction may require an abstraction and/or disposal licence from the Environment Agency and the quality of the water may require water treatment and filtration to make it safe for use.

Benefits:

- Open loop water source systems do not normally need to have defrost cycles activated because they do not frost up the same way that air source systems do, and so do not have the periods of no heat being delivered.
- Energy efficiency is maintained through colder outdoor temperature conditions. Typical efficiency is between 6 and 7kW for every kW of power consumed.

Drawbacks:

- Expensive to install compared to air source due to drilling or earth moving costs.
- Boreholes may require permission from local authority to drill, and geological surveys may be necessary to determine suitability.
- Water quality in aquifers and open water or in flooded mines will require fine filtration and may require water treatment with potentially high on-going maintenance costs.

Training and Skilled Installation

The successful implementation of the UK Government Heat and Buildings Strategy that is incentivising the installation of 600,000 air to water heat pumps in domestic buildings requires that those making purchasing decisions have a basic understanding of the application of different low carbon technologies and can rely on expert advice. The upskilling courses delivered by the Heat Pump Association (HPA), Building Engineering Services Association (BESA) and others are designed specifically to educate the installer network to ensure they understand the application better and can, therefore, educate the property owner better in how to set up and run their new heat pump system in an energy efficient way.

For more information

- The BESA – Building Engineering Services Association www.thebesa.org
- HPA – Heat Pump Association www.heatpumps.org
- GSHPA – Ground Source Het Pump Association www.gshpa.org.uk
- CIBSE – Chartered Institute of Building Service Engineers www.cibse.org
- BESA TR30 Guide to Good Practice for Heat Pumps
- CIBSE TM50 Ground Source Heat Pumps CIBSE CP2 Surface Water Heat Pumps
- CIBSE AM16 Heat Pumps for multi-unit residential buildings
- https://www.gov.uk/government/groups/heat-in-buildings

Acknowledgements

With thanks to BESA for use of text from TB054 “Heat Pumps – What are they?” and images from TR30 “Guide to Good Practice for Heat Pumps”

Visit www.ior.org.uk/beyondrefrigeration for updates to this and other Technology Briefs.

Beyond Refrigeration - Background and Scope

- The Institute of Refrigeration (IOR) is the specialist professional engineering charity body for expert individuals working in this sector. It has a global reputation for independent technical advice and innovation. Its members provide services to users of cooling and heating services including manufacturing, supply, installation, service and maintenance, consultancy, and inspections
- Refrigeration, Air Conditioning and Heat Pump (RACHP) technologies are used to provide essential services in food production, distribution, storage and retail, industrial cooling processes in manufacturing, the climate control in spaces, such as datacentres, IT rooms, offices, shops, leisure facilities and hospitality, as well as pharmaceutical and healthcare facilities, amongst others.
- Heating and cooling in the UK is estimated to account for 10Mt CO_2e direct emissions from refrigerant use and 87Mt emissions from energy use to heat buildings.
- The sector is estimated to contribute to the UK economy through employment of around 70,000 people directly in manufacturing and service roles. It is estimated that the direct impact of cooling on the UK economy is £43Bn.

IOR Beyond Refrigeration Critical Issues and Ambitions

1. *Reducing the Need for Mechanical Cooling and Heating*

Our ambition is that policy should support businesses to consider mechanical refrigeration technology as a last resort instead of relying on "business and usual" purchasing and specification practices. This will mean the need to incentivise widespread adoption of net zero alternatives to mechanical cooling.

2. *Achieving Best System Performance*

Our ambition is that purchasers of new equipment and users of existing equipment should be supported to achieve the greatest possible reduction in energy demand and ongoing use, without compromising reliability.

3. *Balancing Heating and Cooling*

Our ambition is that policy will support the use of opportunities currently available to maximise heat recovery, sharing and storage across different business activities using heating and cooling.

4. *Making Use of Best Available Technology*

Our ambition is that the whole sector will rapidly adopt the best available, closest to net zero heating and cooling options as dominant technologies.

5. *Use Energy Intelligently*

Our ambition is for 100% renewable energy and zero carbon energy systems providing maximised efficiency, flexibility, and support grid stability.

6. *Developing the Best People and Skills*

Our ambition is that everyone involved in cooling and heating systems purchasing, maintenance or operation, has adequate technical understanding and responsibility for championing net zero.

7. *What else? Whole System Sustainability*

Our ambition is that everyone involved in cooling and heating systems purchasing, maintenance or operation has adequate technical understanding and responsibility for championing net zero.