Heat Pumps Code of Practice – Installation Guidelines

Version 6.0 – 27.09.2018

HEAT PUMP INSTALLATION GUIDELINES

1. HEAT PUMP DESIGN AND REGULATIONS

Heat Pump technology has been used successfully for more than 50 years and the most important step in designing and installing a heat pump system is the correct sizing of the heat pump. This has to be done accurately to allow the heat pump to properly deliver the Heating (by covering the heat loss of the building) & DHW requirements (depending on relevant hot water taping profile) for the proposed dwelling/building. This is to be done in accordance with the current regulations and guidance documents published by the relevant bodies. i.e. CIBSE, NSAI standards, Building Regulations, etc. to allow the designer or installer of a heat pump to select the most beneficial solution for the end user, from both a capital cost investment and running & maintenance costs point of view. For new buildings the capital cost is not a decisive factor in using or not the heat pump, as more and more heat pumps are being used as the preferred heat source and also this initial cost can be easy enough absorbed in the overall cost of building a new dwelling. As a retrofit solution though the cost of installing a heat pump can be prohibitive, as it has to be done in conjunction with some other major upgrades – fabric & ventilation of the building – , to ensure that the new heat source will work efficiently and will suit this type of application.

Heat Pump efficiency is the ratio of the heating or cooling delivered to the electrical energy required to operate the system using a refrigerant.

The ratios are given in two ways:

- Coefficient of Performance (COP) – the ratio of heating delivered to the electrical energy input
- Energy Efficiency Ratio (EER) – the ratio of cooling delivered to the electrical energy input

The higher the COP or EER, the greater is the efficiency of the heating or cooling system. COP can be calculated by taking the heating output (in kW) and dividing it by the electrical input (in kW). These values can be found in the energy rating label or manufacturer's information.

You can also get a Seasonal Coefficient of Performance or Seasonal Performance Factor (SCOP or SPF) – the ratio of heating delivered to the electrical energy input on an annual basis. The COP values reflects the efficiency of the heat pump in certain laboratory testing conditions 7°C outdoor & 35°C flow temperatures, where the SCOP/SPF looks at the annual efficiency of the heat pump and takes in account the variation of the outdoor temperature throughout the year – usually the COP is greater than the SCOP/SPF, but the lather is more of a true reflection of the efficiency of the heat pump.

A *Refrigerant* is the fluid that facilitates the energy transfer to take place between the outdoor and indoor, due its special physical & chemical properties and it is used by all heat pumps. The EN378 F-Gas European Standard guides people in the areas of design, construction, installation, operation and maintenance on

the Safety and Environmental use of vapour compression systems for refrigeration, heat pumps, chillers and air conditioning systems.

There are two main types of refrigerants: *Natural type*: i.e. ammonia, propane and CO_2 and *synthetic type*: i.e. R134a, R407C, R410a and most recent R32. The F-gas regulation is driving industry to use lower GWP refrigerants in many applications and EU regulation (517/2014), which came into force on the 1st January 2015, introduces a ban on new equipment using HFC refrigerants with a GWP of over 2500 by 2020. The regulation also introduces a phase down, related to GWP and measured in CO2 equivalent tonnes, which will drive industry to use lower GWP options. As a result, a new family of refrigerants – both pure fluids and blends – has been (and continues to be) developed - these are Hydro Fluoro Olefins (HFO). A feature of many of these products (and some existing refrigerants such as R32 and Ammonia) is that they exhibit lower flammability, and hence a new classification has been introduced by ASHRAE to cover this feature – A2L. (In the case of Ammonia the classification is B2L, due to its toxicity).

There are a few important things to be considered when designing the system and sizing the heat pump, in accordance with NSAI recommendations the system "should be designed and constructed in accordance with the Building Regulations, Irish Standards, the EU Energy Performance of Buildings Directive (EPBD) and the Building Energy Rating scheme (BER)":

Heat loss calculations in accordance with NSAI SR50-1 should be done for the proposed dwelling, either for new, renovation or retrofit project and the heat pump should be sized in accordance with this and in-line with current recommendations from SEAI regarding "Heat Pump Tool for DEAP 2016". See below example of heat loss calculations based on above standard based

"7.6 Fabric Heat loss
Fabric heat losses are losses directly through the walls, windows, doors, floors and ceiling of the room. For ease of calculation, it is assumed that these losses are at a uniform rate through each surface. The heat loss rates are obtained by multiplying the area of each individual surface by the design temperature difference and the heat transfer co-efficient called the 'U' Value. For further details reference should be drawn from I.S. EN ISO 13789.

The 'U Value' of a building fabric is the thermal conductivity of a material (rate of loss of heat in watts) that will flow through one square metre of the material when there is a temperature difference of one degree Kelvin (K). To calculate the heat loss through the whole wall for each degree difference, multiply; the 'U' value by the wall area and then by the temperature difference between the inside and outside of the wall.

Design heat loss through wall = Surface area (m²) x 'U' Value (w/m²/°K)x Temperature difference (ΔT)

Fabric Heat Loss (Watts) = Area (m²) X 'U' Value (W/m²x°C) X ΔT (°C)

The 'U' value of a material can be found from the manufacturer or from tables such as that TGD Part L

Appendix B. Methods can also be found in I.S. EN ISO 6946 and also in the CIBSE guide.

I.   on SR50-1 fabric heat loss calculation and ventilation rates:

Domestic Heat Loss Calculation worksheet								
ROOM Kitchen/Dining room		Job Title					Page of	
Design Room Temp	21	No. of air changes per hour ac/h	Room Volume (meters)			Amount of air to be heated per hour m³/h	Air change factor W/m³.K	Design Temp Diff degC	Heat Loss Watts
Subtract Outside Design Temp	-3								
Design Temp Diff	24		Length (m)	Width (m)	Height (m)				
Ventilation Heat Loss		3	4.9	2.7	2.4	95.256	**0.33**	24	754.42752
Fabric Heat Loss						Area m²	U-Value W/m².K		
Floor			4.9	2.7		13.23	0.77	24	244.4904
Ex Wall (Gross area)			7.6		2.4	18.24			
Glazing				1.1	1.05	1.155	1.6	24	44.352
Door				1.75	2.1	3.675	1.6	24	141.12
Ex Wall (Nett area)		**Subtract glazing and door areas from gross external wall area**				17.085	0.35	24	143.514
Ceiling or Roof (Gross area)			2.33	1.92		4.4736	Heat gain from bathroom		
Roof Glazing				-	-		-	-	-
Celing or Roof (Nett area)		**Subtract roof glazing area from gross roof area**				4.4736	1.41	-1	-6
Internal Wall 1			-		-	-	-	-	-
Internal Wall 2			-		-	-	-	-	-
Party Wall			2.7		2.4	6.48	1.02	11	72.7056

Other	-	-	-	-	-	-	-
Design Heat Loss from Room (Sum of Watts for all elements)							1394.60952
Exposed Location?	Yes	If Yes, add	10	% to Design Heat Loss			139.460952
High Ceiling?	No	If Yes, add	-	% to Design Heat Loss			-
Total room Heat Loss							1534.070472

7.7 Ventilation Rate

The difference between the inside and outside temperatures and the rate at which the air enters and leaves the building will affect the ventilation heat loss. The ventilation heat loss rate of a room or building is calculated by the following formula;

Rate of Heat Loss = V * N * ΔT * 0.33 where;
V = the volume of air in the room (m3),
N = number of air changes per hour,
ΔT = Temperature difference between the outside and the inside, and,
0.33 = is a constant factor. It represents the specific heat and density of air.

The principal design considerations are:

- the required internal temperatures of each room,
- the design outside temperature (Range -1°C to -3°C), and
- the ventilation rate of the room(s).

The calculations should include provisions to ensure that the heating up time of the entire system is not excessive. The general principle is to calculate the heat loss rate and the correct radiator (heat emitter) sizes, for each room in turn. Then total all heat losses to obtain a total figure.
For further details reference should be drawn from I.S. EN ISO 13789."

II. The hot water requirement to be taken in account is based on the hot water taping profile for the dwelling; to be noted that most of the heat pumps are sized to cover either the heating or DHW load, not the combined one, as the DHW production is done outside the heating demand. The DHW requirement is to be calculated according to EU Ecodesign Standardised User Profiles i.e. S-Small, M-Medium, L-Large and XL-Extra-large or based on occupancy average usage in line with current standards.

III. Oversizing the heat pump will significantly increase the installed cost for little operational saving, and will mean that the period of operation under part load is increased. Frequent cycling reduces equipment life and operating efficiency.

If the system is undersized, design conditions may not be met and the use of top-up heating, usually direct acting electric heating, will reduce the overall system efficiency

IV.	A Heat Pump system can be designed to provide all the required heat – a monovalent system. However, because of the limitations in maximum heat output of single phase heat pumps it may be prudent to consider a bivalent system where the heat pump is designed to cover the base heating load, while an auxiliary system covers the additional peak demand – a bivalent system.

V.	The majority of heat pumps have an operating temperature limit of 50°C – 55°C in most applications. Reducing the output temperature required from the heat pump will increase its performance; ideally the flow temperature should be 35°C for UFH systems and 45°C for Fan coil/Low temperature radiator systems. These are not suitable for monovalent operation in combination with existing or traditionally sized, high temperature wet radiator distribution systems, or for providing all the domestic water heating as they will not be able to raise the water temperature to that required (60°C) to avoid the risk of Legionella. In this instance most heat pumps use a booster heater/electrical immersion to complete the Anti-legionella/Disinfection cycle. A few heat pumps, however, can provide output temperatures of up to 65°C and specially designed two stage compressor heat pumps can provide output temperatures of up to 80°C.
NOTE: You should check with the Heat Pump Manufacturer/Supplier if the heat pump is suitable for your dwelling.

VI.	Pipe sizing and circulation pumps are critical for the correct operation of the heat pump and the heating system. The designer/installer of the heat pump should make sure that a minimum DN25 (1" copper or 32mm PEX or MLC pipe) Flow & Return pipe work is in place from the heat pump to the distribution manifolds or motorized valves, to allow the heat pump to achieve its minimum required flow rates that enables the heat pump to deliver the output that it was designed for. Same for the circulation pump. Under sizing the pipe work will have a knock-on effect: the building will hardly reach the desired comfort temperature and as a result will have frequent cycling of the compressor, reducing its life time.

VII.	Correct sizing of the heat emitters – base on heat loss calculations, see paragraph "I "above – making sure that the heat output delivered by the heat pump can be efficiently transferred to the building and correct sizing & appropriate location of the DHW cylinder making sure that we are getting the benefits of the heat pump, as the DHW production is usually at much lower efficiency than heating efficiency.

VIII.	For renovations/retrofit projects only under certain circumstances existing pipework, heat emitters or DHW cylinder may be reused. For the heating system this is to be assessed based on provided heat loss calculations on a room by room basis. Firstly is to be assessed if the existing heat emitters output can meet the heat load required based on a lower flow temperature provided by the heat pump by using the manufacturer's correction factors.
i.e. – at Δt=50°C (flow temp. 80°C/return temp. 60°C and room temp. 20°C) a radiator's output is 2,000Watts. Same radiator at Δt=30°C (flow temp. 55°C/return temp. 45°C and room temp. 20°C) and correction factor of 0.424 will only deliver 850Watts and furthermore at Δt=22.5°C (flow temp. 45°C/return temp. 40°C and room temp. 20°C) and correction factor of 0.3 will only deliver 600Watts.

Reusing the pipework is not recommended, as most of the time the existing pipework has been designed for gas or oil boilers systems with higher flow temperatures and flow rates used which are not suitable for low temperature heat pump systems. The same principle will apply for existing DHW cylinders. If a high temperature heat pump is being used, capable of delivering 80°C flow temperature, it is possible to use the existing heating and DHW system, considering though the reduced efficiency/SPF of the new system.

Also it is to be considered the compliance with the ErP Energy Label and EU ECODESIGN Lot 1&2 directive for combination heaters when considering reusing an existing DHW cylinder. See below guidance on determining the correct Δt for different flow/return and air temperatures:

The following note should be considered when replacing the heating system i.e. Radiators, boilers etc. - this guidance note is for information only. The radiator is sized according to the heat required for a given room.

The heat is measured in Watts (W) or British Thermal Units (BTUs) [1W = 3.412 BTU]

Heat requirement
The heat required for a room depends on two factors: the temperature you want to maintain in the room and the rate of heat loss from that room. The following are recommended temperatures required for rooms depending on their type:

Living areas i.e. – sitting room, dining room, play room:	18-21°C
Other areas i.e. – kitchen, hall, toilet, bedrooms:	16-18°C
Bathrooms (with shower):	22°C.

Once the heating requirement is known, based on heat loss calculations as shown on paragraph I above, the radiator size can be calculated. For the example below the room has a heat loss of 350W.

Radiator sizing
Radiator outputs are typically based on a water-to-air temperature difference Δt=50°C. For heat pumps operating at low temperatures, this output will have to be in line with the design flow temperature i.e. flow 45°C, Δt=22.5°C making sure that we are achieving high efficiencies.

The higher the Δt value, the higher the radiator output will be. Traditional gas or oil non-condensing boilers operate with higher flow and return temperatures 75/65°C, while condensing boilers operate at lower flow and return temperatures 65/55°C, to increase their efficiency. Similarly then for heat pumps we are aiming for as low temperatures as possible 45/40°C, to increase their efficiency – see below examples.

$$\Delta t = \frac{(Flow\ temperature + Return\ temperature)}{2} - Room\ temperature$$

i.e. – standard efficiency boilers, 75/65°C and room temperature 20°C

$$\Delta t = \frac{(75°C + 65°C)}{2} - 20°C = 50°C$$

– condensing boilers, 65/55°C and room temperature 20°C

$$\Delta t = \frac{(65°C + 55°C)}{2} - 20°C = 40°C$$

– heat pump technology, 45/40°C and room temperature 20°C

$$\Delta t = \frac{(45°C + 40°C)}{2} - 20°C = 22.5°C$$

The temperature difference reduces the output of the same radiator. Many radiator manufacturers supply information for radiator output based on a ΔT value of 50°. The following table is an example of information provided by the manufacturer:

Radiator Height (mm)	Radiator Length		Heat Output at ΔT 50°	
	mm	inches	Watts	BTU
300mm	400	16	186	636
	800	31	382	1305
	1000	39	480	1638
	1200	47	578	1972
	1600	63	774	2641
	2000	79	969	3308

Where radiators are to be installed for different ΔT values, the stated radiator outputs must be multiplied by a conversion factor to account for the different ΔT value. Manufacturers should be asked to provide conversion factors for different ΔT values. The following table is an example of conversion factors to be applied to outputs quoted at ΔT 50°:

ΔT	Multiply Output by
Δ40°	0.7482
Δ45°	0.8720
Δ56°	1.1587
Δ60°	1.2675

The conversion factor allows the calculation of the radiator output where the operating temperatures result in a ΔT value different to ΔT 50°C. For example, where replacement radiators with a ΔT value of 40°C are being installed, and the stated output at Δ50°C is 480W, multiply by 0.7482 to get the output for the replacement radiators.

480W x 0.7482=359W

The radiator output is now 359 W. This may mean you need to increase the size of the radiator to meet the heat requirement of the room depending of the heat loss calculated.

Also please see graph below showing the correlation between flow temperature, COP and outdoor temperature.
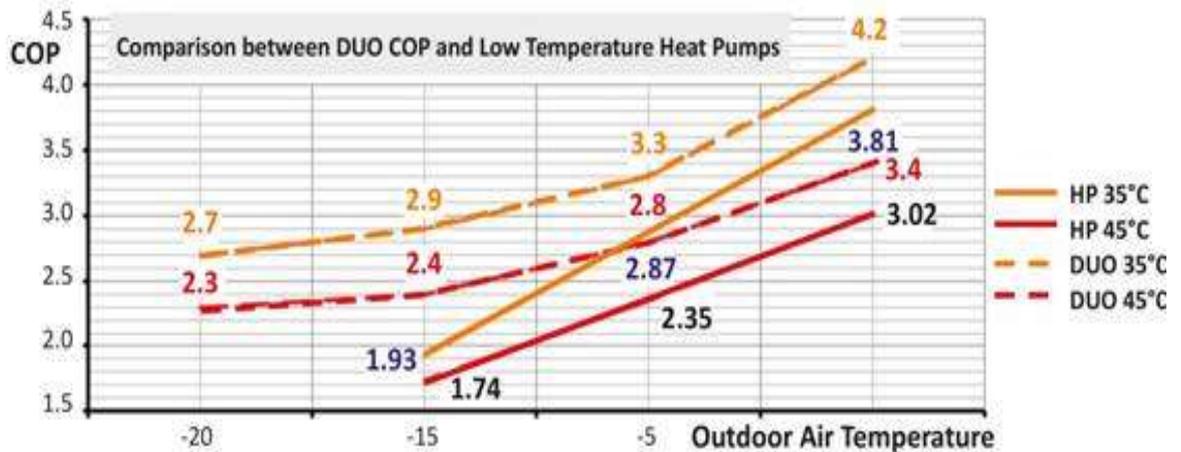
2. SPACE HEATING

The first aim of the space heating control circuit is to operate the heat distribution system at the lowest temperature that will still meet the required comfort conditions. This will optimise the efficiency of the heat pump. The three main control options are:

2.1 <u>Weather compensation</u>: This is the most efficient form of control. The output temperature from the Heat Pump is adjusted according to the outside air temperature. As the outside temperature rises the output temperature is reduced, so the Heat Pump never works at a higher temperature than necessary. In general an outside temperature sensor sends signals to a controller. This automatically controls the output temperature according to a factory set curve defining the relationship between the outside air temperature and the Heat Pump output temperature. For water distribution systems the operation of the heat pump compressor is usually controlled in response to the return water temperature, so this is lowered as the outside air temperature rises.

Most heat pump manufacturers have the outdoor temperature sensor built in the outdoor unit. If this is not the case or if the unit is south facing, i.e. in a sun trap location, it is recommended to have an outdoor temperature sensor installed, ideally on a north facing wall, considering though that the heat pump supplied is capable of weather compensation control.

2.2 <u>Room thermostat/sensor control</u>: A room temperature sensor located centrally in the house can be used in conjunction with an outside air temperature sensor to influence the curve control function (or weather compensation function). It is recommended the use of thermostats/sensors that have built-in LCD display showing the existing/desired room temperature or a type of temperature control system that will enable the end user to see these values.

If there is a room thermostat/sensor controlling the temperature on one floor, it is <u>not recommended</u> to have this installed in a kitchen or room with opened fire; also its position has to be <u>out of direct sunlight</u>. These measures will enable a proper reading of the room temperature, without the influence of external factors.

2.3 <u>Fixed temperature</u>: The Heat Pump is switched on and off by an in-built return temperature sensor and always operates up to its maximum working temperature. This method of control does not offer optimum savings from the Heat Pump. Usually a single room temperature sensor is used to control the operation of the heat pump compressor. In addition the operation of the Heat Pump can be controlled by a timeclock; however, for water-based distribution systems there will not be the same potential for intermittent heating as there can be with conventional gas or oil fired heating systems.

With output temperatures between 35°C and 55°C the response time of the heating system is long. Heat pump systems are therefore designed to maintain a stable temperature rather than be able to raise the temperature quickly immediately before occupation. Night setback can be applicable but with a setback of 2°C to 4°C.

3. <u>Heat emitter sizing</u>

The heat losses of the building must be 100% covered by the heat emitters and these should be designed and installed in accordance with the current NSAI SR50-1 standard for heat and ventilation losses.

The Heat Pump system must provide 100% of the calculated design space heating requirement at the selected internal and external temperatures after taking into consideration the flow temperature at the heat pump when it is doing space heating. In exceptional outdoor temperatures, below design levels, the heat pump can use a built-in back-up heater to cover the extra load – the temperature point where the back-up heater is allowed to come on is called *equilibrium temperature*. Great care should be taken in not oversizing the heat pump by considering too low outdoor temperature design, as this will have the adverse effect on the performance of the heat pump at higher outdoor temperatures resulting in cycling, lower efficiency and reduced life expectancy of the unit. Performance data from both the heat pump manufacturer and the heat emitter system designer/supplier should be provided to support the heat pump selection. Where bivalent systems are being used, either for new or existing dwellings, it is recommended that the heating base load should be covered by the heat pump, enabling the end user/beneficiary of this system to get the benefits of a renewable system and do not relay on a secondary space heater.

For installations where other heat sources are available to the same building, the heat sources shall be fully and correctly integrated into a single control system. A Heat Pump must be selected such that the combined system will provide at least 100% of the calculated design space heating requirement at the selected internal and external temperatures, the selection being made after taking into consideration the space heating flow temperature assumed in the heat emitter circuit and any variation in heat pump performance that may result. Heat pump thermal power output for the purposes of this section shall not include any heat supplied by a supplementary electric heater within the design temperature range.

To be considered that the use of UFH systems working up to 35°C results in higher SCOP/SPF's than the use of Fan coil/Low temperature radiator systems working up to 45°C; the control & responsiveness though of an UFH system is not as the same level compared with a Fan coil/Low temperature radiator system – each system therefore will have its own advantages & disadvantages. Air-to-air fan coil units are becoming more and more popular, especially for certain retrofit applications, typically with air heated at 20°C and refrigerant not exceeding 30°C.

Also the Exhaust-air heat pumps are becoming a more popular solution especially for passive-houses and apartment developments due to the fact these have a Mechanical Ventilation and Heat Recovery (MVHR) part of the indoor unit. It uses the MVHR pipe distribution system to provide heating or cooling without the need for the traditional "wet" distribution system. Also the DHW cylinder is part of the same indoor unit.

For installation of Heat Pumps in existing buildings with existing heat emitters this will require special attention. More than likely the existing heat emitters have been sized and installed to suit a heat source that can provide a much higher flow temperature i.e. 70-80°C, therefore the existing heat emitter may not be suitable. In this instance we would recommend that these would be replaced, as well the distribution heating pipework to make sure that minimum flow rates required for the heat pump to deliver the required thermal output can be achieved. Nevertheless if fabric & ventilation improvements have been carried out to the existing building i.e. –

walls & roofs U-Values have being considerably improved, glazing & doors have been upgraded, the existing system may be suitable; in saying that the existing heat emitters should be checked to make sure the thermal outputs of these will suit the new heat source and existing pipe work is suitable for the proposed application. Some Heat Pumps that can deliver flow temperatures up to 80°C could be considered as a direct replacement without the need of replacing the existing heat emitters of pipe work; these type of applications though have lower SCOP/SPF's than the typical 50-55°C ones.

Minimum output from the compressor is to be absorbed by the installed system, making sure that minimum flow rates and minimum Δt's are being maintained in accordance with manufacturer's specifications.

4. Domestic Hot Water – DHW

The Heat Pump is likely to be operating less efficiently when providing domestic water heating because higher output temperatures are required. Where the domestic hot water system includes a storage cylinder, it will be cost effective to make maximum use of any cheaper tariff periods for electricity. The basic control device is therefore a timeclock and a tank thermostat. The auxiliary immersion heater should not be able to operate at the same time as the heat pump is supplying heat to the domestic hot water cylinder. A tank immersion thermostat or sensor, rather than a strap-on one, should be used to sense the stored water temperature as it is more accurate.

The DHW cylinder should be located within the envelope of the building in a heated space, ideally in airing cupboard or hot press, minimising the heat losses from the cylinder to the surroundings. If the DHW cylinder cannot be located within the envelope of the house it should be brought to the end users attention that the running costs for DHW production will generally be higher.

In general Heat Pumps will not carry out space heating at the same time as domestic hot water production. The Heat Pump manufacturer will recommend the domestic hot water cylinder heat exchanger or coil specification. Domestic hot water heat exchangers for Heat Pump systems require a much greater heat exchanger performance as compared to traditional combustion-based heat sources (i.e. boilers). For coil-type heat exchangers, this usually requires a significantly greater heat exchanger area.

There are 3 main types of DHW storage cylinders:

- Integral storage cylinder, where the Heat Pump's heat exchanger is within the same casing with the DHW cylinder;
- Separate storage cylinder, where the Heat Pump's heat exchanger is outside the casing of the DHW cylinder and
- Fresh water technology, which is an integral thermal store and the DHW production is done instantaneous, therefore not stored.

5. Electrical requirements

All electrical work to be carried out is to be in compliance with current electrical regulations i.e. RECI standards and completed by a RECI certified installer.

On completion of the electrical work the home owner should be provided with a RECI Certificate/Commissioning form stating that all work was completed in accordance with the current legislation.

Heat Pump manufacturers to provide all relevant data, installation manuals, load requirements, etc. to make sure that the Heat Pump and all heat pump related equipment is installed in accordance with the manufacturer's specification and current electrical regulations.

It is recommended the installation of electrical meters for the outdoor and indoor units, if applicable, to separate the heat pump electrical usage from the domestic electrical usage.

6. Commissioning & Maintenance

6.1 Commissioning

Heat Pump systems shall be commissioned according to the manufacturer's instructions and the system design parameters and an Energy Label for the combination system – heating & DHW should be provided for the end user. The designer/installer of the system should provide the "designer/installer sign-off form" making sure that all relevant data is made available for the completion of the final BER assessment.

Heat Pump Association of Ireland will be issuing a "HPA Passport" enabling each manufacturer to certify their installers, confirming therefore that they have been trained & certified to install their product in conformity with manufacturer's specification and corresponding Irish legislation.

A handover package to home owner has to be made available, so the home owner can have a basic understanding of the system installed. This should include the end user's guide for the heat pump, heating, DHW and controls installed. Also is recommended the commissioning form to be part of this package stating all parties involved in completing the installation – i.e. mechanical contractor, electrical contractor, F-Gas refrigeration engineer (if applicable), commissioning engineer, etc. alongside with the service/maintenance recommendations.

Label indicating the flow rate required by the Heat Pump shall be fixed on the manufacturer's equipment. The heat pump and its associated pipework shall be flushed and to all air removed from the installed pipework. The installation shall be physically inspected and commissioned by a suitably qualified engineer, trained and registered with the manufacturer to ensure the system is installed and operates as per the manufacturer's specifications. As part of the Heat Pump commissioning the engineer has to make sure that the Heat Pump is working in accordance with the provided performance parameters, designed flow & return temperatures are being achieved for both heating and DHW production.

It is considered good practice, the use of a pre-commissioning form provided to the installer and confirmation that all recommended pre-commissioning work has been completed prior to the commissioning engineer attending site.

For Air-to-water heat pumps the commissioning engineer has to ensure that the minimum air circulation is being met by checking the location & installation details of the outdoor unit and if changes are to be made, recommendations are to be given to the installer/end user for these to be completed. If the Air-to-water heat pump used is Monobloc type to ensure that an anti-freeze fluid mixture been used that will protect the Heat Pump hydraulic components in freezing conditions in the event of a power failure.

6.2 Maintenance

Heat Pumps can operate for 20 years or more, but they do require regular scheduled maintenance. The installer should leave written details of any maintenance checks you should undertake to ensure everything is working properly. Consultation should be made with your supplier for exact maintenance requirements before you commit to installing a Heat Pump. Please see below some of the typical maintenance requirements for indoor units and outdoor units, where applicable:

6.2.1   Indoor units:
Cleaning the unit
Checking heating & DHW on/off temperatures
Electrical connections safe & sound
Water filter, water pressure and expansion vessel pressure
3 way valve changing from CH to DHW
Switch box
Booster heater cutting on/off - if applicable

6.2.2   Outdoor units:
Cleaning the unit, especially the coil as dirt, cobwebs, etc. can have an effect on the efficiency of the heat pump; the fins are to be cleaned with soap & water, no other chemical substances
Fins to be straightened, if necessary
Electrical connections safe & sound

2. HEAT PUMP TYPES

2.1 AIR SOURCE HEAT PUMPS – Air-to-water, Air-to-air and Exhaust-air

Air source heat pumps work by using electrical energy to extract energy from the outside air and transfer it inside as heat, which makes it an efficient way of heating. There are two main types:

I.   AIR-TO-WATER where the extracted energy from the outside air is being transferred through a heat exchanger to water; these systems can provide full Heating & DHW production

II. AIR-TO-AIR Heat Pumps where the extracted energy from the outside air is being transferred through a heat exchanger to air; these systems can provide full Heating.
III. EXHAUST AIR Heat Pumps where extracts heat from the exhaust air of a building and transfers the heat to the supply air, hot water and/or hydronic heating system

The main components are as follows:
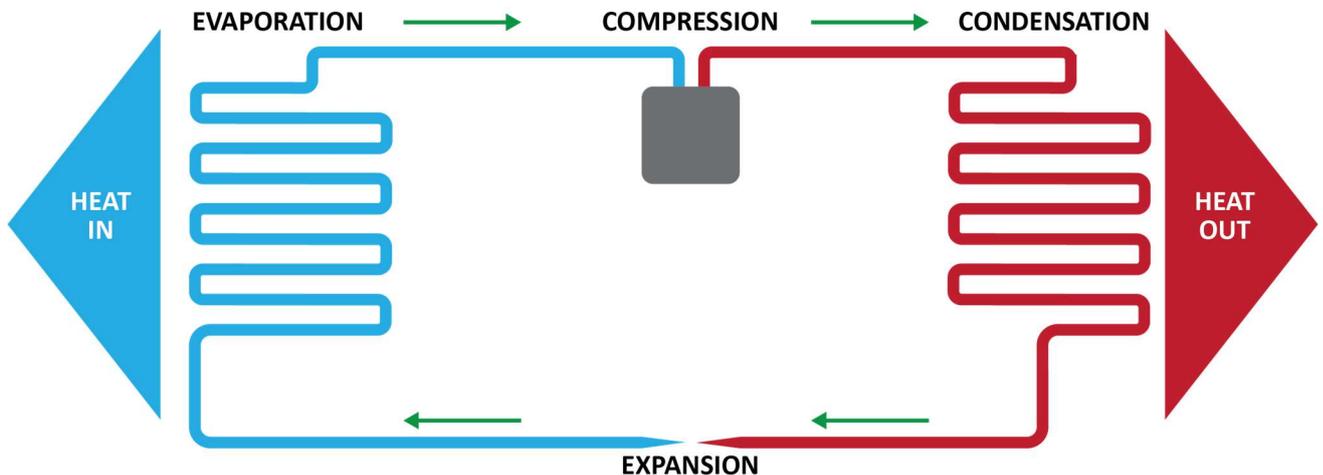
Evaporator: A heat exchanger that absorbs heat from the surroundings, (the outdoor unit).

Compressor: Reduces the refrigerant gas volume by compressing it, causing the gas temperature and pressure to rise, and pumps the refrigerant around the pipework/system. The compressor may operate as a fixed- or variable speed system.

Condenser: A heat exchanger that releases heat to the surroundings, (the indoor unit).

Expansion valve: Allows the refrigerant condensate (liquid) to expand, lowering the pressure and temperature.

Coil/pipework: Continuous, closed-circuit tubing through which refrigerant flows and heat transfer occurs. The pipes generally have fins to increase the surface area for the heat exchange process.

Refrigerant: The compound that circulates through the heat pump system in liquid and gas state, alternately absorbing and releasing heat

Reversing or 4 way valve: Changes the direction of flow of the refrigerant to reverse the heat pump function from heating to cooling or vice versa. The reversing valve also allows the pump to switch into defrost mode

Fan(s): Draws air across the evaporator coil (for heat extraction) and moves air away from the condenser coil (for heat distribution/removal).

There are five main processes in the cycle:

1. In the evaporator (outdoor unit), low-pressure, low-temperature liquid refrigerant absorbs heat from its surroundings and evaporates, converting to a gas state and absorbing energy as it does so (latent heat of evaporation).

2. It passes through the compressor where the low temperature gas is reduced in volume, resulting in a rise in both temperature and pressure.

3. As a heated and high-pressure gas, it passes through the condenser (indoor unit) where the gas condenses (latent heat of condensation) with a release of heat to:

- the water flowing on the other side of the heat exchanger and using a circulating pump we transfer this energy into the heating & DHW system – **Air to water system**.
- or to the air surrounding the coil, as a fan moves the warmed air away from the coil it's distributing the heat it throughout the indoor space – **Air to air system**.

4. Still under pressure, the cooled refrigerant, now in liquid state, passes through the metering device, where rapid expansion results in a reduction in pressure.

5. In the low-pressure, low-temperature state, the refrigerant flows back into the evaporator, and the cycle is repeated.

The efficiency of an Air Source Heat Pump system is varies along with the temperature differential between indoor and outdoor air and the require flow temperature. A Heat Pump's rated efficiency/COP is for an outdoor temperature of 7°C and flow temperature of 35°C, so when designing a system it is important to understand how it will perform at lower temperatures. When the Heat Pump is in heating mode, as the difference between outdoor temperature and desired indoor temperature increases, the efficiency of a Heat Pump system decreases. Different Heat Pumps will perform very differently at sub-zero temperatures – some may keep performing down to -25°C while others will struggle at temperatures below freezing.

Another temperature-related factor that can impact on efficiency is the extra energy that may be required for defrosting at low temperatures. At just a few degrees Celsius, any water vapour in the air will start to condense and freeze onto the evaporator (outdoor heat exchanger) coil. This will disrupt the heat flow, and the coils must be de-iced for heating to be able to continue. Certain Heat Pumps don't require a buffer vessel as part of the heating system but they do require a minimum volume of water to be contained within the pipework, to allow the defrost cycle to happen – i.e. 20-25ltr.

For optimal Heat Pump efficiency, a system must be correctly sized to minimise energy losses that occur during the defrost cycle. The defrost cycle is necessary to remove ice build-up on the evaporator coil. Ice build-up occurs at around at 0-4°C (especially in high humidity), when any water vapour in the air will start to condense and freeze onto the evaporator (outdoor heat exchanger) coil. This will disrupt the heat flow, and the coils must be de-iced for heating to be able to continue. To remove ice build-up on the coils, most Heat Pumps have a defrost cycle where the system switches into cooling mode (taking some heat from inside), which could effectively cool the room.

Some systems have a closed loop cycle to use waste heat from the motor/compressor to defrost the coils. While this is occurring, no heat is supplied to indoors. The defrost frequency and performance are critical to Heat Pump efficiency. Undersized Heat Pumps will need to defrost frequently in low ambient temperatures, reducing the system's ability to reach and maintain set point. If the defrost cycle

operates too frequently or if it does not operate often enough, it will not provide sufficient heating, and Heat Pump operation will be compromised.

The defrost cycle control is either:

- a time-temperature defrost starting and stopping at pre-set times (30-, 60- or 90-minute intervals); or
- on-demand defrost, which is generally more efficient because it operates only when it detects frost build-up on the outdoor coil by monitoring air and coil temperature, outdoor airflow, pressure differential across the coil and refrigerant pressure. Most ASHP have an on-demand defrost control.

Systems that include a dry-coil defrost cycle briefly run the outdoor fan at maximum speed before the system starts to heat again, to remove any water that may still be on the coil fins and would immediately refreeze. This operation can be seen by water vapour blowing from the outdoor unit before the heating cycle resumes.

Correct Heat Pump sizing is critical to efficiency and performance. The unit should be selected for the heating load that is required. If the Heat Pump is too small or too large, the system will use more energy than necessary, increasing running costs and losing efficiency, and heating/cooling requirements may not be met.

A correctly-sized Heat Pump system, when compared to a poorly-sized system, will have:

- shorter total compression run times and start on/offs
- lower frequency operation speeds
- reduced defrost mode running
- all the above translated in overall lower heat pump running costs.

If unit is:	Performance	Effects
Undersized	Operation may be in defrost mode too often (see 3.4 Impacts of defrost cycle on efficiency).	• System is not delivering heat. • System may be blowing out cold air.
	Booster heating may be required.	• Increased running costs. • Reduced efficiency.
	Operation may be at full capacity too often.	• Increased running costs. • Reduced efficiency. • Undue wear and tear.
Oversized	Increased start-up power use.	• Increased running costs. • Reduced efficiency.
	Short cycling because output exceeds demand.	• Too much air movement (draught) even at low fan speed. • Increased noise. • Undue wear and tear.
	Runs at low load too often.	• Reduced efficiency.

Installing an undersized Heat Pump unit will significantly increase running costs, to the extent that the extra annual running cost will be more than the cost of installing a unit that is the next size up. Where a large-capacity Heat Pump is required or the space being heated is large, installing two smaller units may give better heat distribution within the space and better control than the large single unit.

There are two main types of Air-to-water heat pumps:

- **MONOBLOC** where the heat exchanger to transfer the energy from compressor to water is built by the compressor in the outdoor unit. This type of Heat Pump require water based Flow & Return connections
- **SPLIT** type where the heat exchanger to transfer the energy from compressor to water is built by the in the indoor unit. This type of Heat Pump requires F-Gas Refrigerant pipe work connections. In this case we could have a WALL HUNG INDOOR unit and an INTEGRAL INDOOR UNIT.
- Typically the MONOBLOC & SPLIT with Wall Hung unit connect to a Separate DHW Cylinder and the SPLIT with Integral unit has the DHW cylinder built-in the indoor unit.

Both type of Heat Pumps Monobloc & Split are widely used each of these having the own benefits, making either/or the other the preferred unit mostly driven by installers. Please see below recommendations when locating the outdoor, indoor and cylinder, also some installations examples:

There are a few important things to be considered when deciding on the location of the outdoor unit and indoor unit/cylinder:

1. OUTDOOR UNIT: most important is that proper circulation of air all around the unit being provided; lack of this will cause lower efficiencies and too often defrost cycles resulting in high running costs - this to be done on every installation in accordance with manufacturer's specifications.
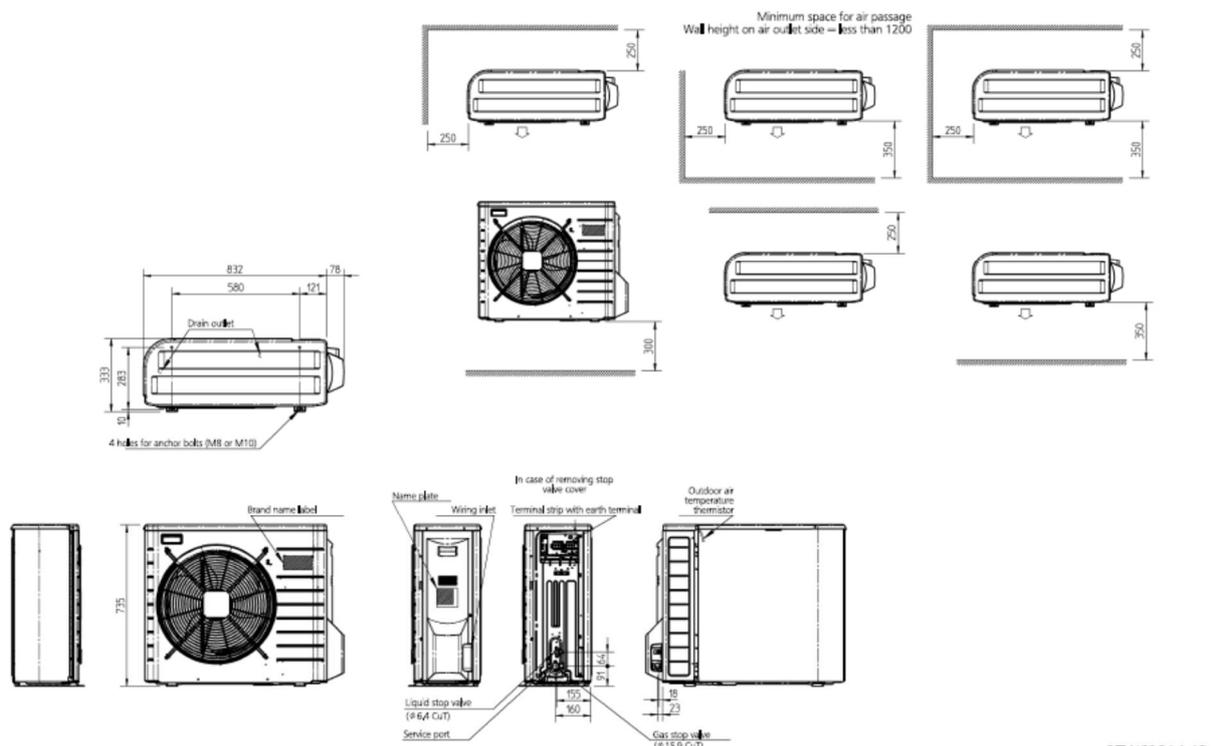
2. The OUTDOOR UNIT should ideally be located in close proximity of the dwelling and by doing this we are ensuring that we are minimizing the pipe run between the outdoor and indoor/cylinder, therefore reducing the pipe heat losses. Is to be taken in account that especially during winter time condensation is going to be generated from the evaporating coil, so provisions are to be made that the condensate is being collected and drained away. The installer is to ensure that under no circumstances the

condensate will be draining on the foot path as this can freeze during winter, creating a hazard for the home owner.

3. The OUTDOOR UNIT can be mounted at ground level feet ensuring that a minimum gap is maintained between the ground level and the bottom of the unit, so no debris can be accumulated underneath the unit. If the unit is installed at height, it to be confirmed by the manufacturer what is the maximum permissible height and what are the implications regarding the future service and maintenance of the unit.

4. The OUTDOOR UNIT can create a certain level of noise – to be confirmed by each manufacturer – and in certain conditions, depending on the site limitations is it to be agreed the suitability of the installation in close proximity of bedrooms. Most heat pump manufacturers have a "quiet level" function that can be activated, limiting the noise produced within certain time schedules.

5. The INDOOR UNIT and CYLINDER or INTEGRATED INDOOR UNIT that contains the cylinder, should be located as centrally to the dwelling as possible, allowing a good balancing in the heating and DHW distribution pipework. This should be installed in accordance with the current Heating & Plumbing Regulations ensuring servicing and maintenance space is provided around the unit, in accordance with manufacturer's specifications.

Please see below some examples of OUTDOOR and INDOOR/CYLINDER installations:

Air-to-Air Systems:

INDOOR UNITS

OUTDOOR UNIT

Mini-split heat pumps and air conditioners offer superior performance and energy efficient solutions.

Heat energy is absorbed and transported between the indoor and outdoor units via refrigeration lines. The heat energy is then redistributed.

With most multi-zone systems, up to four indoor units can be used.

Air-to-Water Systems:

Exhaust Air Heat Pumps - EAHP

Overview

Used in air-tight, low energy homes and apartments, where ventilation is a must and the major heat loss of the dwelling is due to (the necessary) air changes, EAHP technology was developed in Denmark and Sweden in the early 70's during the oil crisis. Air is drawn through ducts to the heat pump usually from the bathrooms, utility and kitchen areas. The cold waste air is discharged to outside through another duct, and condensation to a drain. Not only that, the additional heat generated internally from lighting, people and domestic appliances is also utilized through heat recovery. These heat pumps are normally used in new low energy homes and rarely suitable for retro-fits.

Heat recovered from the exhaust air may also be augmented by additional outside air drawn into the machine. Heat is transferred to the hot water system and the

heating system via radiators, floor heating or sometimes to an air heating battery in a supply air heating system.

Types

There are three main types: -

1. EAHP units that provide space and water heating with inlet air ducts only – outside air is drawn into the building through special air inlets fitted with filters and volume dampers located in the outside walls of living areas and bedrooms. As you can only obtain a limited amount of heat from the building's waste air, additional energy may be taken into the machine from a supplemental air supply.
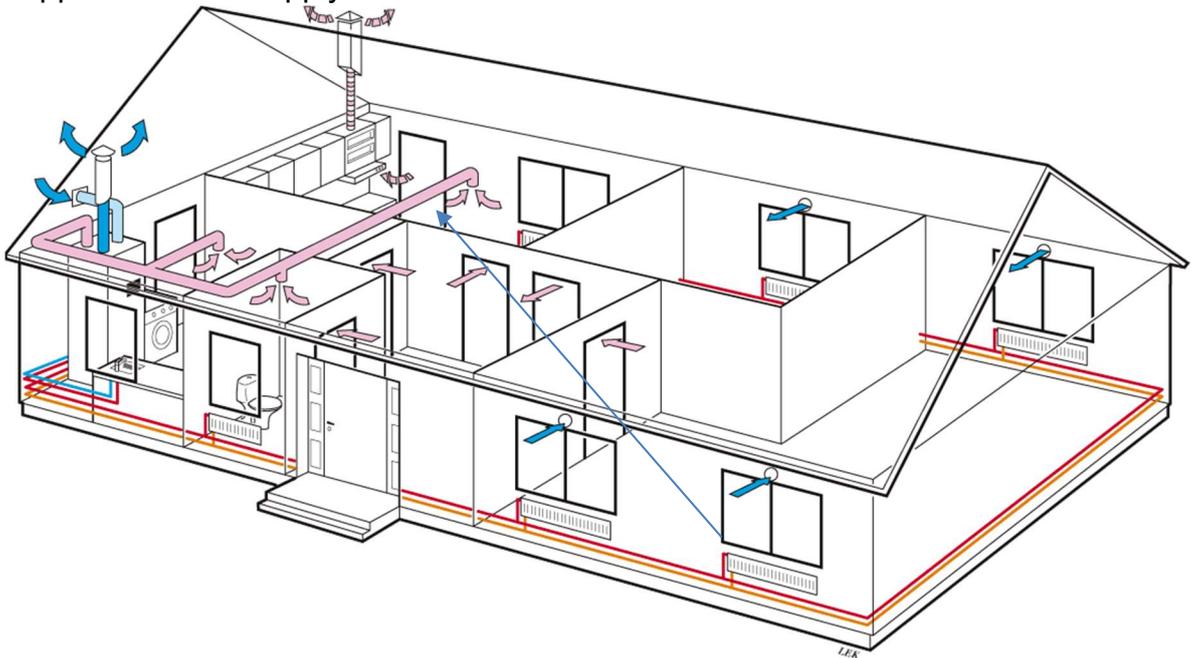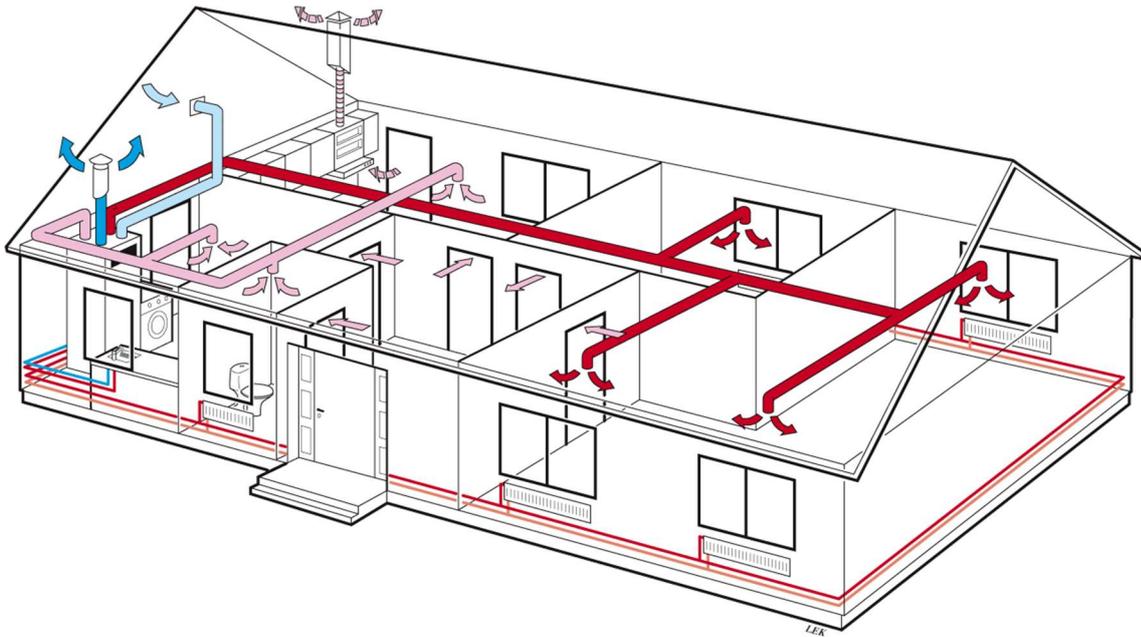


EAHP with Inlet only ducting – type 1

Specialised air inlets with filters 1

2. EAHP units that provide space and water heating with both supply and exhaust inlet air ducts

EAHP with supply and exhaust ducting - type 2

3. Units that heat hot water only from ventilation often from the room they are located in, or adjacent bathrooms. These usually feature an additional built-in heat source suchas an electric back-up immersion but may also have heating coils for interconnectuion to the heating system, solar thermal or even both.
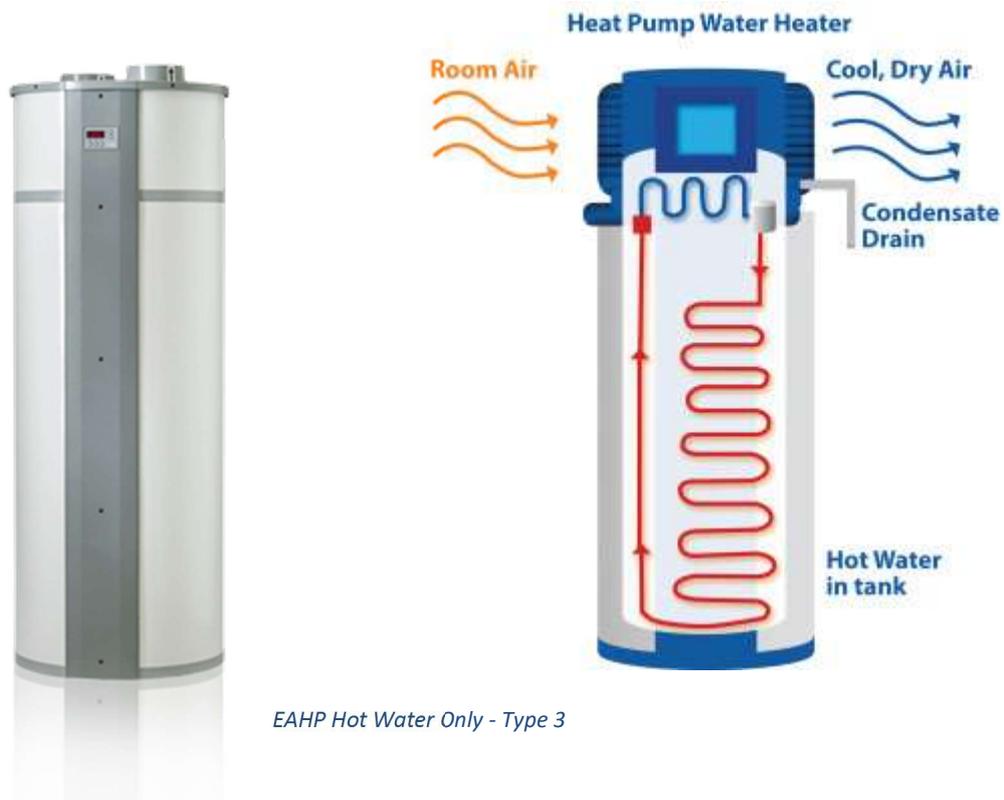
EAHP Hot Water Only - Type 3

Points to Note The heating systems for EAHP types 1 & 2   are usually radiators or floor heating and are similar in nature to those used with air to water or ground-

source heat pumps in that they are usually low temperature systems with the UFH running in the 28° to 40°C range and radiators to max 55°C. Those systems are also usually variable in temperature with the load determined by weather compensation.

Important Design & Installation Points

1. The (types 1 & 2) EAHP must not be installed in buildings with uncontrolled ventilation infiltration, open fireplaces, poor insulation or a heat demand that exceeds the output of the chosen unit from the heat pump process alone. Shortfalls in energy needed may in those cases be provided by supplemental electric heating for instance leading to customer complaints about high running costs.
2. Ventilation ducting systems need to be properly designed to ensure sufficient air flow to the heat pump. This is a critical item – without sufficient air flow the EAHP will not function properly.
3. The extract air, from which the EAHP extracts energy as its heat source, must be well insulated if not running within the heated fabric of the building (passing through attics etc.)
4. Setting fan speeds and balancing of air flow is critical for correct operation, conservation of energy and to minimise noise.
5. Use of attenuators or acoustic flex ducting at the ventilation entry / exit points on the heat pump may need to be considered.
6. Proper ducting systems must be used and to minimise required fan power and ensure correct airflow with reduced noise. Rigid metal, plastic or a bespoke system with manifolds / foam EPE ducting should be considered.
7. Where flexible ducting is used, often for instance from the EAHP to the ducting spigots from the ceiling overhead, bear in mind access to the jubilee clips for future replacement of those ducts…i.e. the ends of the flexible ducting should not 'vanish' into the ceiling or plastered walls!
8. The discharge or waste air from an EAHP can be very cold (from 1° and often as low as -15°C) so it is critically important that that run of ducting is to be insulated with diffusion tight insulation or to be made from EPE foam. ANY Gaps in insulation will lead to condensation on ceilings or water running down the discharge duct and into the machine causing damage.
9. A correctly plumbed drain is required from an EAHP for disposal of condensate and potential discharge from the safety valves' tundish.
10. EAHPs are usually located within the house or apartment, in a hot press, utility room or even kitchen. They should NOT be located in a garage or outhouse!
11. The manufacturers' installation guidelines should always be closely adhered to and installers should be trained by the relevant manufacturer or agent for product specific installation procedures.
12. The end user should be instructed on correct operating use and routine maintenance items such as air filter changing etc.

Typical Exhaust Air Heat Pump for Heating & Hot water
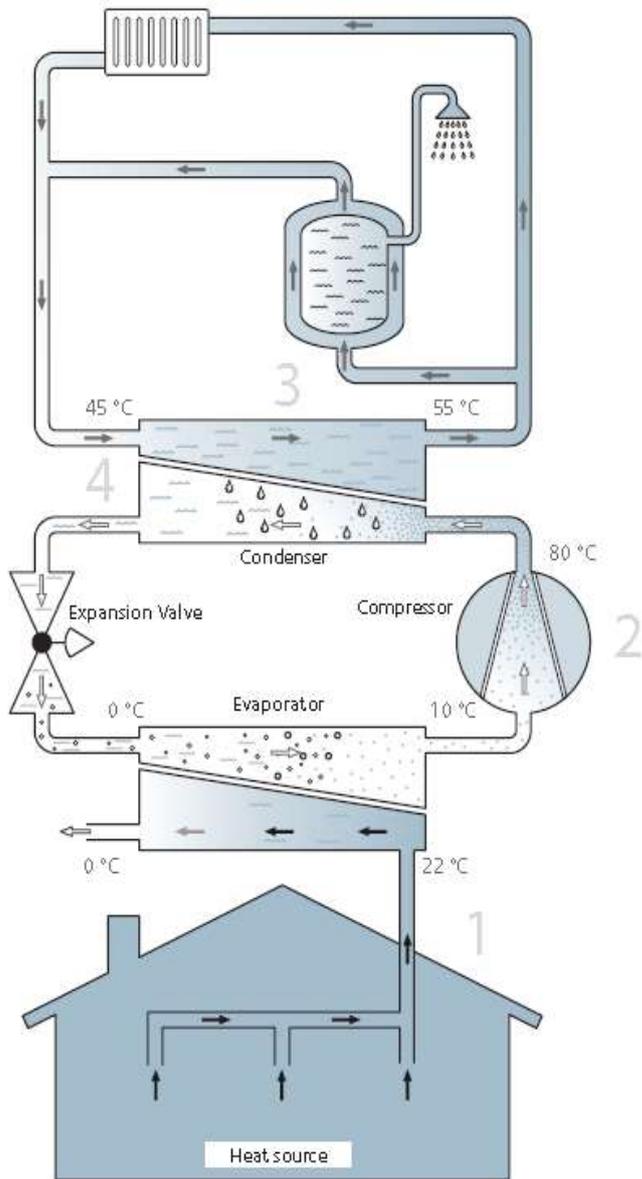
1. Warm exhaust air is blown across the heat exchanger and heat is transferred into the refrigerant circuit. The cold exhaust air passes to the outside of the house.

2. The compressor raises the pressure of the refrigerant, resulting in an increase in temperature in the heat pump.

3. Energy extracted from the exhaust air is transferred into a water-based heating system to heat your home and hot water.

4. In the condenser, the refrigerant reverts to liquid form, ready to turn into gas once more and to collect new heat energy.
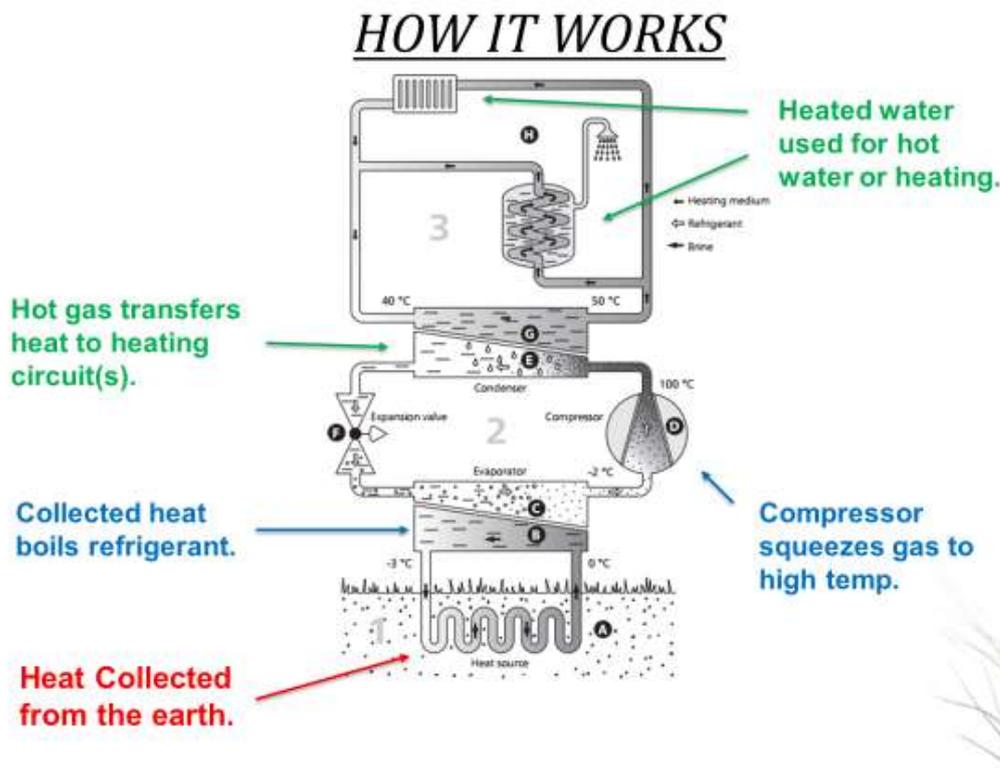
2.1 GEOTHERMAL Heat Pumps – Ground source closed and opened loop

Overview

With the aid of a ground source heat pump, solar energy stored in the ground can be collected and used to heat your home. Often referred to as *geothermal heating*, the heat collected is mostly from the sun in fact and not the earth's core.

Warmth builds up underground from the first days of spring when the surface temperature of the earth starts to increase, to high summer, when the rays of the midday sun penetrate down into the ground. Warm rainwater also permeates the upper layers of the ground. By the time the autumn leaves are falling, there's enough energy stored in the ground to heat up your house throughout the coldest winter. A heat pump captures and upgrades this naturally occurring warmth, so even if the summer seems wet and cool, it can still provide enough energy to maintain a comfortable indoor temperature throughout the coldest winter.

Ground source heat is pure, stored, solar energy that is retrieved from deep in the ground with a bore-hole, the bottom of a lake or a few metres below the lawn. The most suitable is determined by the house's energy requirement, the existing heating system and the plot. The system provides a convenient supply of heat and hot water, and can also provide cooling during hot days. The tubing called a collector which is buried in the garden or placed in a borehole contains a mixture of water and antifreeze. *(there are also DX or Direct Evaporating heat pumps detailed in a separate section).*

HOW IT WORKS

Heated water used for hot water or heating.

Hot gas transfers heat to heating circuit(s).

Collected heat boils refrigerant.

Heat Collected from the earth.

Compressor squeezes gas to high temp.

Types of Ground Source Heat Pumps (GSHP)

There are three main types of GSHP:

***Brine* to Water** – the most commonly used type takes heat energy from closed loops buried in the soil, placed in a lake or through a borehole probe.

Water to Water –Open-Loop System This type of system uses well or surface body water as the heat exchange fluid that circulates directly through the geothermal heat pump system. Once it has circulated through the system, the water returns to the ground through the well, a recharge well, or surface discharge. This option is practical only with an adequate supply of relatively clean water, and if all local codes and regulations regarding groundwater discharge is met.

DX (direct exchange) or Direct Evaporation These heat pumps use copper or aluminium pipes filled with the refrigerant gas and normally coated with a PE plastic layer to directly absorb heat energy from the earth in horizontal arrays

(Ground source heat pumps (GSHP) work by using electrical energy to extract energy from the ground or ground water and transfer it inside as heat, which makes it an efficient way of heating. There are two main types/three main types

I. GSHP CLOSED LOOP where the extracted energy from the ground is being transferred through a closed loop either horizontal or vertical pipe arrangement using a brine/glycol mixture to harvest the energy from the ground
II. GSHP CLOSED LOOP Direct Evaporating or DX where the extracted energy from the ground is being transferred through a closed loop either horizontal or vertical pipe arrangement using a refrigerant to harvest the energy from the ground
III. GSHP OPENED LOOP where the extracted energy from the ground is being transferred through an opened loop either horizontal or vertical pipe arrangement using the energy from the ground water)

THE ABOVE 2 CLSIFICATIONS TO BE AGREED BY HPA MEMBERS!

The three main components are, as follows:

1. The **collector (or loop)** - this extracts energy from the ground. There are several different types and layouts of collectors, and these are described later in this chapter
2. The **heat pump** - converts the energy from the ground to usable energy in your home for heating or cooling and DHW
3. The **distribution system** – maintains your home at a constant temperature by providing heat or cooling through radiators or underfloor heating.

There are four main types of CLOSED LOOP brine/glycol mixture collectors: horizontal, vertical, slinky and pond loops – see figure below:

General Points to note

Unlike gas and oil boilers, heat pumps are generally designed deliver heat at lower temperatures over much longer periods. During the winter they may need to be on constantly to heat your home efficiently…note this does not mean the compressor, the 'engine' of the heat pump is always on, but the control systems' strategy usually will be able to call on it as necessary to maintain the balance of heat required for the building versus the temperature outside. You may also notice that radiators won't feel as hot to the touch as they might do when you are using a gas or oil boiler which is firing heat into the building in timed 'bursts'…. You will be more comfortable allowing the heat pump to calculate and maintain the warmth (and perhaps cooling) of the building and production of hot water rather than the occupants trying to do this with switches or timers.

Note that whilst pipework design and principles may seem to be broadly similar to the installation of an oil or gas boiler, there may be some differences. For instance, a buffer tank may be required, or else a strategy for the disposal of heat as the heat pump's 'work-load' is satisfied and it waits to switch off for a short period. Heat pumps with fixed speed compressors as a rule will need a buffer tank sized at 20L per kW output, inverter or variable speed machines will be able to cope with much smaller buffer tanks. Usually, the heat pump manufacturer will provide design guidance and particular recommendations for their systems' layouts and these as a rule should be closely studied and adhered to. Water travelling through the heating system will be at a lower temperature than oil/gas systems so less energy can be passed through smaller pipes; for this reason, it is critical that careful attention is paid to the system design and pipe dimensions. It has been said the three most important things in heat pumps are circulation, circulation, circulation!

Note also that there is a relationship between the size and output of a heat pump to the size of hot water tank selected. The hot water tank will generally either be a tank-in-tank type with some buffer volume or at least have a very large heating coil or heat exchanger. Most standard or existing cylinders in retrofit situation will not be suitable for a heat pump. It is important again, that the manufacturers' advice should be closely adhered to.

The choice of a GSHP means that there is no outdoor machinery such as with an Air to Water heat pump. In cold weather the ground temperature will give higher efficiencies over air to water and there is energy lost to defrosting.

Another advantage of the GSHP is that especially when used with a borehole, they can provide free cooling usually used in conjunction with floor heating or fan coils. Unwanted solar gain is transferred to the rock where it may be reclaimed later.

Location of plant Most modern ground source heat pumps for domestic dwellings are quiet enough and built to an appliance styled finish that it is usually best practice to locate the heat pump in the utility room or somewhere convenient within the house or building to be heated. Many are even available with the hot water tank integrated into the same fridge-like casing saving further on installation time and adding to efficiency.

Locating heating equipment (and hot water cylinder) in a remote shed or garage will incur a loss of efficiency and higher installation and running costs of course!

Horizontal Collectors When collecting heat from a horizontal field array of pipes the area selected will need to be approximately 2 ½ to 3 times the floor area of the building being heated and are normally placed one metre below the lawn and at least 1 to 1.5M spacing. If there is not enough room for a horizontal array, then use of a borehole or energy-well should be chosen instead.

The fluid circulated in the pipes is often referred to as *brine* but is in fact a mixture of either ethylene glycol (or ethyl alcohol) and water. Care should be taken to ensure that this must be perfectly clean during the filling, mixing and flushing procedures. Pipes should have open ends taped or blanked off during laying and prior to connection at the distribution manifolds.

All ground source heat pumps whether connected to horizontal or borehole collectors should be fitted with either a brass Y-strainer or Filter-ball-valve to ensure no dirt can enter the heat pumps heat exchanger.

In Ireland the soil 1 metre below the surface is about +10°C or even warmer all year round; the incoming collector fluid will usually not fall below +5° C inbound in winter. A correctly functioning heat pump should have a temperature difference or 'delta T' of 3° to 5°C. For example, the measured brine temperature *in* could be 5° in and 2° *out* – whereby inside the heat pump's heat exchanger the temperature will be some 10°C lower than the brine out figure, -8°C. For this reason, it is required that the brine mix is protected from freezing with a mixed ratio of approximately 1/3 antifreeze to 2/3 water and a reading of -17° measured by the commissioning engineer.

Placing the collector field deeper than around one metre in Ireland does not give any advantage, in fact the soil will take longer to recover heat that would trickle inwards from sun and rain.

It is often advantageous in new builds to place the collector field *underneath* a percolation area dug for the waste water discharge to save space and excavation time.

Consideration must be given to the soil type and calculations of hose lengths need to be determined by the system provider or suitably qualified installer. Wet ground will be richer in heat versus sandy or fast draining stony soil. When the latter types are encountered it will usually be necessary to use additional plastic loops to compensate.

Testing Procedures Prior to filling the collector system with the antifreeze mix it is essential that the pipes are flushed of air and filled with water and pressure tested to 3 Bar and the whole array inspected visually. Use of compressed-air for testing is not acceptable as any very small leaks in joints would not show up – as water cannot be compressed, the pressure gauge on the test pump will register an immediate drop in case of any leak.

It is good practice not to have any joints in pipes left under the soil and when there are multiple loops (there usually are) it is strongly advised to use a purpose built manifold chamber for ease of future servicing and inspections. If jointing or repair is required it is best practice to use plastic fuse-welding with appropriate fittings.

Manifold chamber from above

Once back filled with soil, if a leak occurs - for instance damage from a digger, it will be virtually impossible to locate and a new loop will need to be dug in and installed. The collector field's operating pressure is very low; normally in the range of between .5 to 1.5 bar and leaks are an extremely rare occurrence once care is taken during the fitting process.

Manifold chamber with lid prior to back-filling

Plastic polyethylene pipes, most commonly 40mm in diameter are laid in trenches, or excavated ground for covering later, or even below the percolation area from a septic tank or waste water treatment plant.

Care must be taken that the collector piping is laid joint free in continuous rolls and obviously free from contact with sharp rocks or stones before back-filling.

Care must be taken where the collector piping passes underneath paths, walls and foundations at the entry point to the building as there is potentially risk of ice damage in very cold weather. The pipes must be insulated at those points in waterproof closed cell insulation.

Three-loop collector field for a large house – no pipe joints in the field, only inside the manifold chamber

A ground source heat pump fitted indoors with an integral Hot Water cylinder

Mini Drilling rig making a borehole in a suburban Dublin house- with a tiny garden, the owner elected to use a borehole as the more aesthetic solution over an air to water heat pump.

Closed loop boreholes used for heating and cooling are most commonly drilled 150mm in diameter. A steel casing is fitted by the drillers to stop the loose overburden and soil from falling into the well. Into the well the driller inserts a U-bend or *probe* most commonly made from one jointless extrusion of twin 40mm pipes certified to SDR11 standard and normally with a 3.5mm wall. There are also four-pipe systems of two interlocked smaller U-Bends, but as there is so much heat in the borehole, this is not 'twice as good' as some people think, but only about 5% more effective. Unlike water wells, these 'energy wells' are not lined with plastic and it essential that the probe is inserted before moving the drilling rig, otherwise the well can collapse and probe insertion becomes impossible.

Before inserting the probe, it must also be filled with water and pressure tested for leaks. It would incidentally be impossible to fit without filling as the probe would simply float in the water down the well.

Borehole depth required will normally be provided by the heat pump suppliers or services engineers calculations, and for bigger properties, multiple holes may be required. There needs to be a minimum distance of 12 to 15M between the energy wells so ne well is not robbing heat from the other. Interconnection of multiple borehole probes is treated in exactly the same way as multiple loops of horizontal arrays – a proprietary manifold chamber is strongly recommended over a home-made 'pit' and the fluid or *brine* is also antifreeze/water filled with protection to at least -17°C. Typically 150M deep energy well will yield 10kW for heating.

Shortly after drilling, the water table will settle at its normal level – the *active depth* is from the top of the water downwards. In some countries thick non-setting liquid clay called *grout* is pumped into the borehole, but water is a better conductor of heat and

grouting a hole in Ireland should only be necessary if the hole was not to fill with water or the upper level of the borehole remained empty in the case of a very low water table.

To prevent ingress of surface water and possible contamination of water aquifers, the borehole should be fitted with a neoprene cap which fits over the steel casings and is secured with stainless steel Jubilee clips. Location of the energy well should be noted and the well covered with a manhole for future access.

If the well head is above the level of entry to the building or manifold chamber, air vents must be installed to allow for venting prior to commissioning.
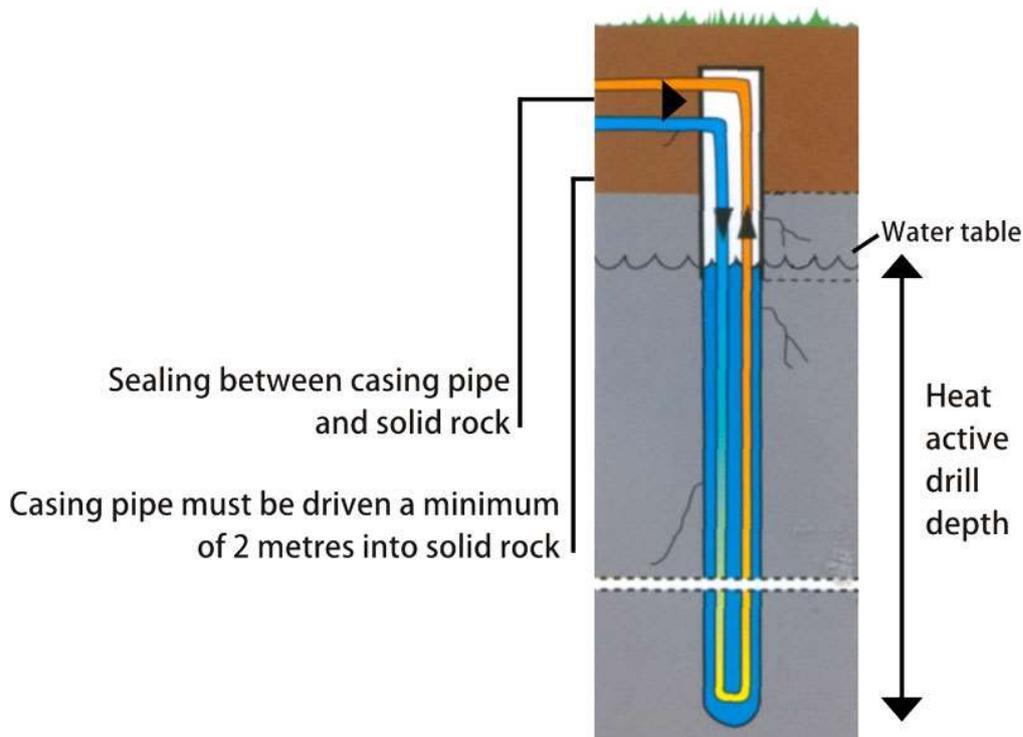

Borehole probe on a turntable to allow unwinding and insertion to the well whilst filled with water.

Neoprene borehole sealing cap

Typical borehole for ground probe

Sealing between casing pipe and solid rock

Casing pipe must be driven a minimum of 2 metres into solid rock

Water table

Heat active drill depth

Anatomy of an Energy Well

Lake and river collectors

Sometimes it can be convenient to use a lake, river or even the sea as the source of heat for a ground source heat pump. This is often chosen as the sinking of collector loops in the lake is much more cost effective than using boreholes and you are lucky enough to beside such a rich source of energy. Some important points to consider for this is that special calculations will be needed to dimension the collector usually provided by the heat pump distributor or manufacturer. Again, the multiple loops are filled with antifreeze, but the use of non-toxic fluids such as propylene glycol or ethanol is preferred in case of water course contamination. Also, manifold chambers are recommended for connection of the multiple loops used.

If the lake is not on private land permissions may have to be sought for its use.

Small ponds sometimes can be used, but only if there is enough through put of water from a steam or river to replenish the heat harvested from it.

Collector on the shore before sinking with weights to the lake bed for a large Irish period country house. The 5-acre lake supplies the sole source of heat for the 26,000sq. ft. house plus a swimming pool.

Manifold chamber for a large lake collector with valves and flow regulators.

CLOSED LOOP Direct Evaporating Heat Pumps Overview & Installation detail please see below:

Direct Evaporating heat pumps, sometimes known as Direct exchange (DX), are a type of ground source heat pump.

They are similar in construction to a brine to water unit but rather than having an evaporator heat exchanger inside the heat pump unit they utilise a network of copper or aluminium pipes, normally coated in PE, laid in a horizontal configuration in the ground in order to absorb energy from the earth. The refrigerant gas on the evaporating/low side of the system is circulated directly through these pipes and absorbs energy directly from the ground.

They are slightly more efficient than a brine to water system since there is no intermediary circuit and therefore no losses in transferring energy from the ground to refrigerant gas. As the refrigerant is circulated by the compressor there is no cost associated with this unlike a brine circuit which requires a circulating pump.

DX collectors are not suitable for installation in water logged soils as they have the potential to freeze the surrounding soil. Care should be taken when installing in very dry soils to compensate for the lower levels of energy available by installing additional loops.

Installation method

Direct evaporating loops are generally supplied in a standard length and diameter by the heat pump manufacturer. The collector pipes are laid in a single trench whose width is determined by the number of pipes required to satisfy the cooling load of the heat pump and also by the length of the pipes being installed. The ends of the pipes originate and terminate at a common position where they are brazed together in a manifold.

The flow and return leg off each loop should be a minimum of 500mm from each other and from the adjacent loop. The collector should be designed so that no more than 20w per linear metre of pipe is being extracted.

The collector pipes should also be laid in a bed of fine sand (approx. 50-75mm above and below the pipework).

The main flow and return pipe from the manifold position to the heat pump must be laid in a trench connecting both positions. These pipes should be further protected by a sewer pipe or heavy gauge hydro-dare as they are often routed under driveways etc. and so are more susceptible to damage. The pipes are also copper or aluminium and the total length of the distance between heat pump and manifold should not exceed 30m to allow stable operation of the refrigeration circuit.

Correct procedure for collector installation

1. The correct number of loops required to satisfy the cooling load of the heat pump should be determined and an area designed to accommodate the loops should be excavated to a depth of at least 0.8m.

2. The narrow end of the collector should be kept closest to the house and a position for the manifold should be marked at the centre point of this end.

3. A 50-75mm bed of sand should be laid on the base of the excavation.

4. The first loop should be rolled out, starting at the manifold position and following the outer edge of one side of the collector. At the halfway point of the collector loop the pipe should be returned to the manifold position, maintaining a minimum distance of 500mm from the other pipe.

5. Continue to roll out additional pipes until all loops are laid taking care to maintain the minimum distances between loops.

6. The main flow and return should be laid between the house and manifold. This trench should remain at least 0.8m deep until it enters building housing the heat pump. At this point the distributor and manifold should be set in position with all flows connected to distributor and all returns connected to return manifold. The main flow and return to heat pump should be connected also.

7. It is imperative that no dirt or water enter the pipes during connection as this will affect the performance of the refrigeration system.

8. The pipe to the distributor should rise vertically with at least 200mm of straight pipe before entering the distributor to allow even distribution of the refrigerant through all collector pipes. It is also desirable that each distributor tail be at least 500mm long for the same reason.

9. Return Pipes should enter the top of the manifold and then turn down therefore creating a trap to aid in oil return.

10. At this point the collector is ready for brazing with copper rods. It is essential that the entire system be purged with nitrogen to ensure that all air is

expelled thereby preventing oxidisation of the internal surface of the pipe. In order to facilitate this a Schrader valve should be brazed to the outlet line to the collector at the point it leaves the heat pump. The return pipe should be covered leaving only a small hole for air/nitrogen to escape. Nitrogen should be purged through the Schrader using a set of gauges connected to a nitrogen bottle at a rate just sufficient to create a positive pressure of 2psi in the pipes.

11. All joints in the manifold can then be brazed using oxy-acetylene and copper brazing rods. When completed the return line at the heat pump should be crimped and brazed. The nitrogen pressure should then be increased to 1.5 times the system standing pressure and pressure tested for at least one hour. All joints should be tested for integrity using a leak detection solution.

12. If the heat pump is in position at the time of collector installation the collector can be brazed to it prior to pressure testing. It is important to purge the system while brazing these connections also. In order to do this, connect the gauge lines to the Schrader valves inside the heat pump, open the expansion valve (if an electronic valve is fitted) and purge with nitrogen as before.

13. The collector area can then be backfilled, firstly filling in the 50-75mm of sand cover then adding the soil that was excavated previously.

14. Once it has been confirmed that the system is leak free you can begin to vacuum the system using a vacuum pump. This reduces the pressure in the pipework below atmospheric pressure allowing any moisture contained within the pipes to boil and be extracted from the system along with the air inside the system.

15. The system is then ready to be charged with refrigerant of the type and quantity required by the manufacturer.

16. A manhole should be placed around the manifold area taking care not to place any weight on the pipework. A manhole can consist of a block built structure or a formed concrete or plastic ring.

Further installation practices to follow:

- Refrigerant carries the oil which lubricates the compressor with it as it travels. As this oil travels quite a distance in dx system, it is important that sufficient care be taken to allow for oil return within the system. Failure to do so can result in compressor damage. To cater for oil return the following should be considered at design stage
  - Pipework between the heat pump and collector should be as short as possible with a maximum distance of 30m allowable
  - The collector area should be level or have a slight gradient back towards the manifold and heat pump

- If a collector is more than 2m below the level of the heat pump it is important that oil traps be fitted at the bottom of the section where the pipe begins to rise.
- A collector should not be situated any more than 4m below the heat pump.
• All joints should be cleaned with an emery cloth prior to brazing to remove the oxidisation coating on the pipes and ensure a good quality braze.

Points to note:

- A DX heat pump is charged with refrigerant on site. This is unlike a brine to water or water to water system which normally come pre-charged.
- A good working knowledge of refrigeration is essential when installing a DX system as specific conditions on site can affect the charge required.
- You must be F-gas registered to work on the refrigerant charging of a DX heat pump
- When backfilling a collector area it is important that no machine should enter the collector area until the soil has been filled to original ground level or that at least 0.7m of cover be placed on top of pipework.
- Care should be taken not to drop any large rocks onto pipework during backfilling
- Some DX units are available with R290 refrigerant (propane). Appropriate care must be taken with this refrigerant as it is flammable.
- When releasing nitrogen from a system following a pressure test it is important to never vent in an enclosed space. Nitrogen will displace the air and can lead to asphyxiation, as Nitrogen occurs naturally in the atmosphere excessive levels are not detectable by humans. Measures should be taken to vent the gas to outside and that sufficient ventilation of the area be provided.
- In no circumstances is it allowable to discharge refrigerant to atmosphere while commissioning, decommissioning or servicing a heat pump

<u>OPENED LOOP Water Source Heat Pumps Overview & Installation detail please see below</u>:

All ground source / geothermal heat pumps are connected to the ground via a heat exchanger, usually in the form of a plastic pipe collector array. Usually horizontal and taking up a sizeable area, vertical collectors take heat from a 150 mm hole drilled into rock, the higher density rock giving better heat transfer than the shallow collectors in earth.

An alternative is to use (normally pumped) ground water as a collector medium, there are multiple risks involved but designed correctly, installed and maintained this offers a low capital investment for high efficiency. Commercially passive cooling from this source offers huge savings on running costs and capital investment on equipment.

In this section no reference is made to the delivery side, as this is covered elsewhere, but with any heat pump the design setup should run the delivery sideas cool as possible. Always follow best practice and manufactures specific guidleines.

Groundwater Heat Pumps (GWHP)
a.k.a. open loop heat pumps

Two Well **Single Well** Disposal to lake, pond, river, creek, etc.
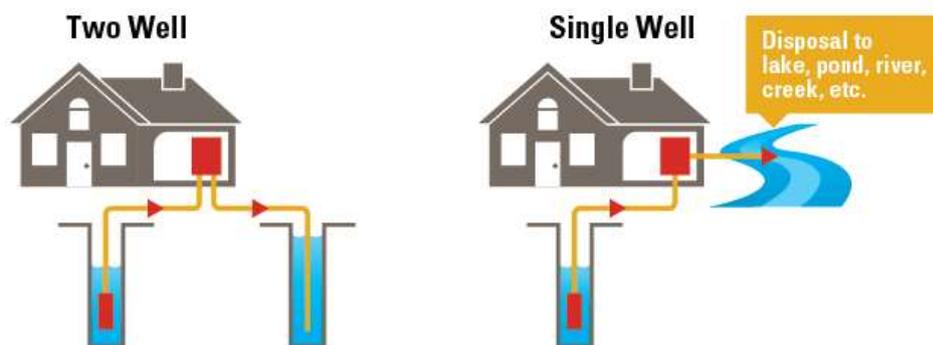
<u>Examples of open loop sources.</u>

1. Shallow wells from underground water sources
2. Reservoirs lakes, streams and rivers i.e. surface water
3. Heat recovery from plant and process, e.g. extra-large water tanks on dairy farms for pre cooling of milk.

<u>Why go open loop?</u>

Efficiency is the main reason, as the source temperature rises, so too does the efficiency. Where a well-designed ground collector averages 5°C plus over the heating season, an aquifer may provide 12°C all season long, without any fall off in efficiency as predominately the return water is injected at a different location. Where water wells

have been drilled for a domestic supply a secondary use is now the heat source for almost zero extra costs.


Geology

In limited locations in Ireland there are elevated ground water conditions, this magnifies the efficiency, this is rare but the local geology is well known throughout Ireland as its continually mapped and reported by the drilling contractors of Ireland in their drill logs.

From this geology the water quality can be accessed in advance as this may prove to be impractical from an equipment maintenance view point.

Equipment:

If the water quality is excellent then most off the shelf ground source heat pumps can be used with some protection in the form of particle filters.

After that external sacrificial heat exchangers are sometimes used. At this stage the efficiency has now been reduced as a 5°C Delta T is an expected loss across the source heat exchanger, the benefits then
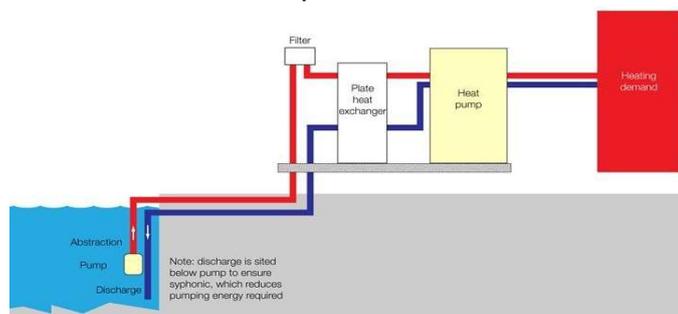
need to be accessed with higher maintenance in mind.

Dedicated open loop Heat Pumps have a different source heat exchanger specifically designed for ground water, this would typically be a co-axial heat exchanger should. These heat exchangers can handle whatever can go through the pump screen including solids up to 8 mm, the metal is usually Titanium or Cupro-nickel which has significant corrosion resistance over the standard brazed plate heat exchangers which are the most widely used in the heat pump industry.

Water quality is the biggest issue and has to be considered immediately that a viable water source is determined. Dedicated open loop heat pump manufacturers will have a specified list of parameters on water quality covering, % solids, chemical resistance, Ph and mineral deposits to name a few.

As water temperature increases, the output of the unit will rise, after a trial pumping of the water cross reference the water temperature to the heatpump performance tables, this will determine actual Kilowatt output. This can vary by up to 30 % increase in

Kilowatt output. With the same input as for a closed loop collector the energy savings are significant.

Installation Guidelines:

Needs to broke into 3 categories in line with the 3 options on source below.

1. Shallow wells from underground water sources
2. Reservoirs lakes, streams and rivers i.e. surface water
3. Heat recovery

Shallow wells:

Shallow is important, in that the depth from where the water is pumped from, directly relates to the pumping power required to get the desired water flow. A guideline of 4-500 Watts per 10 Kw delivered will ensure low pumping costs. Normally to achieve this, a variable speed submersible is required for optimum performance, where multiple heat pumps are required, variable speed is essential.
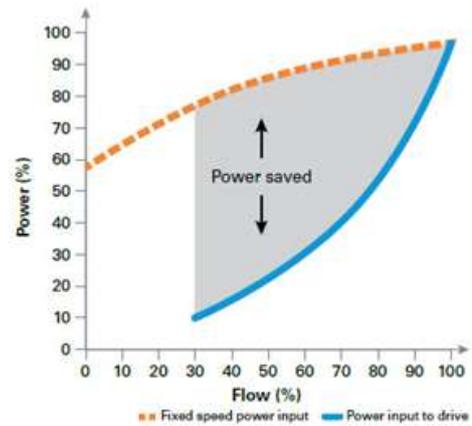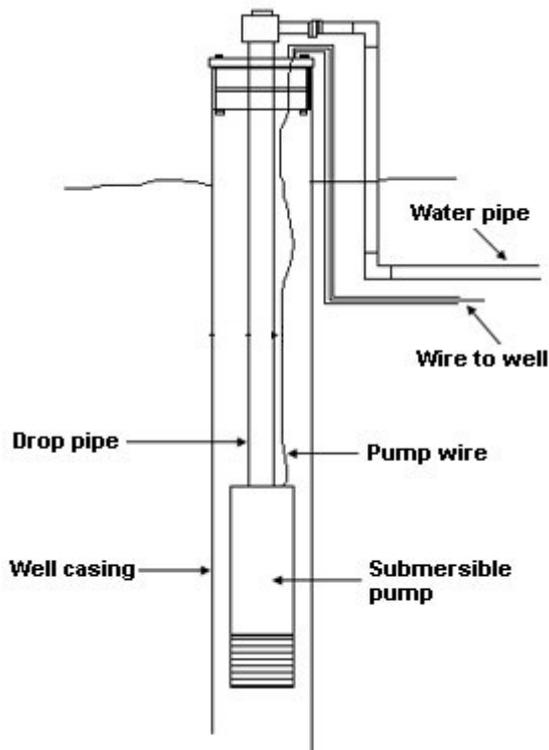
Installation Procedure

1. Evaluate building load. Select appropriate heat pump and determine flow requirements.
2. Check with local drill in reference to geology and expected depths of water table. If all indications are positive, plans can be made to proceed.
3. Prior to drilling investigate disposal of the return water, is it back to the aquifer (second well required) or are there other uses for the "chilled" water, Farm supply for cattle for e.g. explore options, to add another level of efficiency / secondary benefits.
4. The "local" driller is the best advisor / designer in much of the design of the extract and disposal well, plus providing a good estimate of water quality.
5. Be 100% sure of the water quantity!!!! At 100% demand for 48 Hr continuous loading is best practice for ensuring reliability of supply. Based on flow rates and well depth choose the lowest wattage pump applicable for the project.
6. Do a 48 Hour test as soon as is practically possible.

7. If there is any doubts in the water quality, get a chemical analysis test, cross reference this to the manufactures guidelines, see example below.

Water Quality Guidelines

Material		Copper	90/10 Cupronickel	316 Stainless Steel
pH	Acidity/Alkalinity	7 - 9	7 - 9	7 - 9
Scaling	Calcium and Magnesium Carbonate	(Total Hardness) less than 350 ppm	(Total Hardness) less than 350 ppm	(Total Hardness) less than 350 ppm
Corrosion	Hydrogen Sulfide	Less than 0.5 ppm (rotten egg smell appears at 0.5 ppm)	10 - 50 ppm	Less than 1 ppm
	Sulfates	Less than 125 ppm	Less than 125 ppm	Less than 200 ppm
	Chlorine	Less than 0.5 ppm	Less than 0.5 ppm	Less than 0.5 ppm
	Chlorides	Less than 20 ppm	Less than 125 ppm	Less than 300 ppm
	Carbon Dioxide	Less than 50 ppm	10 - 50 ppm	10 - 50 ppm
	Ammonia	Less than 2 ppm	Less than 2 ppm	Less than 20 ppm
	Ammonia Chloride	Less than 0.5 ppm	Less than 0.5 ppm	Less than 0.5 ppm
	Ammonia Nitrate	Less than 0.5 ppm	Less than 0.5 ppm	Less than 0.5 ppm
	Ammonia Hydroxide	Less than 0.5 ppm	Less than 0.5 ppm	Less than 0.5 ppm
	Ammonia Sulfate	Less than 0.5 ppm	Less than 0.5 ppm	Less than 0.5 ppm
	Total Dissolved Solids (TDS)	Less than 1000 ppm	1000 - 1500 ppm	1000 - 1500 ppm
	LSI Index	+0.5 to -0.5	+0.5 to -0.5	+0.5 to -0.5
Iron Fouling (Biological Growth)	Iron, FE^{2+} (Ferrous) Bacterial Iron Potential	< 0.2 ppm	< 0.2 ppm	< 0.2 ppm
	Iron Oxide	Less than 1 ppm, above this level deposition will occur	Less than 1 ppm, above this level deposition will occur	Less than 1 ppm, above this level deposition will occur
Erosion	Suspended Solids	Less than 10 ppm and filtered for max. of 600 micron size	Less than 10 ppm and filtered for max. of 600 micron size	Less than 10 ppm and filtered for max. of 600 micron size
	Threshold Velocity (Fresh Water)	< 1.8 m/sec	< 1.8 m/sec	< 1.8 m/sec

8. From the pump test, select the heat pump based on thermal performance charts and water quality.
9. Depending on equipment selection, fit all necessary pump protection and filtration to suit. Follow best installation guidelines for well water installations, safety valves, pressure switches and expansion tanks.
10. Avoid sacrificial heat exchangers if possible (only really applicable to large scale commercial building loads)and use dedicated open loop heat pumps
11. Dispose of the water as best suits the site, but ideally this should be into a second well back into the aquifer, this re-injection well should be as far away from the production well as is practical. Use the water for other uses if possible, last resort would be to discharge to the storm drains.
12. Ensure that the flow and return pipework are not thermally affecting each other, insulate or separate underground by 1m meter or more.
13. All underground pipework should be buried deeply enough or in some way protected from frost / freezing.
14. Never discharge to public sewers…
15. If cooling is used (commercial applications) limit water discharge temperature to 26 Deg C. This is critical to oxygen carrying capability of river water, effecting fish negatively (possibly fatally) and promoting algae growth. This is known as thermal pollution and is legislated for in by the Inland Fisheries.
16. Water is plentiful in Ireland but waste of energy and water itself is not correct. From that point ensure that the water is pumped in conjunction with the compressor running. Where the heating may be active, the compressor may be off as it may have reached its set-point.
17. For heat pump protection its good practice to have a flow-switch to ensure the heat exchanger never freezes, this can result in a failure.

Power savings of Variable speed dive over fixed speed pumps

Lake , Reservoir, Stream river collectors.

Installation Procedure:

1. Evaluate building load. Select appropriate heat pump and determine flow requirements.
2. For the most part, the discharge water is returned to the source it came from, so no real planning or thought required here, nor is "clean" water being wasted.
3. It's highly likely that the water from any of the sources will require some degree of filtration, often it's the extraction pump that needs protection, as the reality with dedicated open loop heat pumps with co-axial heat exchangers, the pump screen will be the weak link.
4. A vortex pump impellor is less efficient from a pumping perspective but it will tolerate a much higher particle dimension, as well as pulverising any organic matter.
5. Water temperatures from these sources normally range from 5°C to 10°C, any source that has lower winter temperatures than +5°C or is prone to icing should not be used, this is not a viable open loop source at this stage, and a closed loop collector should be considered.

6. Installing directly into a stream or a river is often in-practical due to risk of the pump being washed away. The pump should be installed in a protected concrete perforated chamber adjacent to the water source rather in the flow. Multiple solutions abound and what suits the site has to be engineered often on site.

7. Always use a low wattage pump, as the height of lift is often very low, so a variable speed drive may not be required. Wattage per 10 Kw should be less than 200Watt.

8. If conditions allow it can be possible to use gravity to supply the water, this

can be an engineering feat, which is worth accomplishing as pumping power is Zero. For this installation to be viable, obviously the weir has to be higher upstream than the heat pump location. To offset heat exchanger back pressure a height of 5m is normally required. Where fouling is an issue, a filter screen should be arranged to be self-cleaning, these are readily available for water supply projects, these would also be flash flood resistant, and tolerant to animal traffic.

9. Water flow, should be controlled to match the heat pumps requirements, a common error is that the water is "free" and is allowed to flow full bore. Optimum flow should be regulated to optimise the refrigeration cycle, as well as preventing un-necessary wear and tear on the pipework and heat exchanger.

10. If cooling is used (commercial applications) limit water discharge temperature to 26°C. This is critical to oxygen carrying capability of river water, effecting fish negatively (possibly fatally) and promoting algae growth. This is known as thermal pollution and is legislated for in by the Inland Fisheries.

Plant or Process Heat Recovery Collectors.

Installation Procedure:

1. Evaluate building load. Select appropriate heat pump and determine flow requirements.

2. For the most part, the discharge water is circulated back to the source it came from as the primary benefit may be the process cooling rather than the heat benefit / needs.

3. Equipment selection is critical in terms of (a) thermal output but more importantly (b) operating limits of the heat pump. Most domestic units are designed to tolerate to 20°C on the source. More specialised equipment will have source temps as high as 40°C.
4. It's unlikely that the water from any of the sources will need filtration, as the process water will be "clean" and of known quality.
5. Pumping power should be negligible, but as always careful pump selection will return better performance.
6. <u>Source Temp Vs Performance</u>:
Water flow, should be controlled to match the heat pumps requirements, especially as the temperature rises, follow the manufacturers guidelines, cross referencing outputs versus source temperature.

	Source EST °C	Source L/s	Load Flow-0.30 L/s			
			ELT 10°C	ELT 20°C	ELT 30°C	ELT 45 °C
08	0	0.30	7.21	6.39	5.57	4.72
		0.50	7.62	6.65	5.72	4.78
		0.65	8.00	6.95	5.89	4.84
	10	0.30	10.17	9.11	8.03	6.98
		0.50	10.73	9.58	8.41	7.24
		0.65	11.31	10.05	8.79	7.50
	20	0.30	13.10	11.81	10.52	9.23
		0.50	13.86	12.49	11.11	9.73
		0.65	14.60	13.13	11.66	10.20
	30	0.30	16.03	14.86		
		0.50	16.65	15.56	14.45	
		0.65	17.26	16.24	15.21	

NOTE: Operation not recommended in shaded areas

For e.g. a nominal 8 w heat pump can produce 15 Kw at elevated source temperatures of 30°C

7. Identifying suitable heat sources: this is only limited by the engineer's imagination, a thorough site investigation, will explore possibilities.

Some examples:

- Chilled water for vegetable washing.
- Process cooling water for plastic factory.
- Distillery, which will have cooling in one half of the plant and steam boilers in the other half.
- Milk cooling especially where the farm house and dairy are nearby.
- Mushroom houses, chilled water plant.