Hot Fridge

By Peter Mulvihill, Origen Energy Ltd

For specifiers, designers, M&E Engineers and operators Heat Pumps inevitably are subject to the Marmite Effect - you either love them or hate them.

The rumours are rife and diametrically opposed:

"I put one in and it was amazingly efficient"

Versus

"I put one in and it was amazingly inefficient"

When considering a heat pump being integrated into a system it is necessary to know the rules, regulations, common mistakes, pros, limits of use and methods of sizing – so let's go!

Heat Pump Family Tree

First of all the term "heat pump" covers a genus of varying machines. In summary the main types are:

Monoblock: Infers the evaporator, condenser & compressor are in one single casing; the refrigeration cycle occurs in one location.

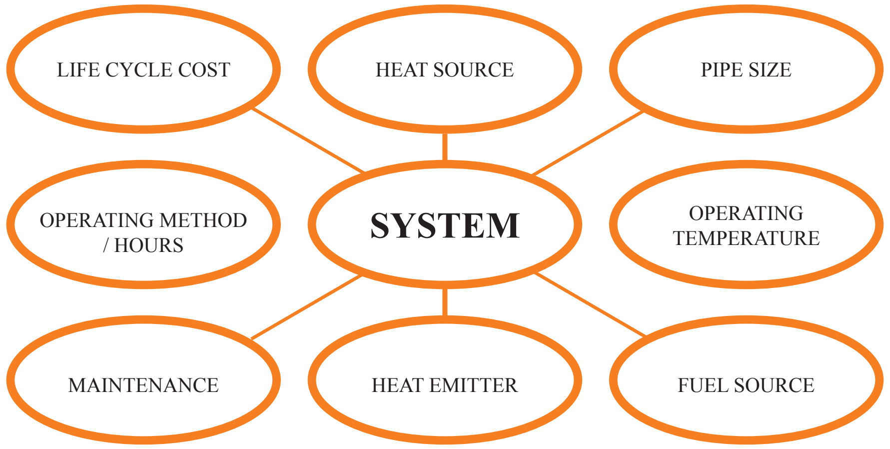
Split or DX (Direct Exchange): Infers the evaporator, condenser & compressor are split; the refrigeration cycle occurs in different locations i.e. inside & outside the building.

Absorption Refrigeration Heat Pump: Uses natural gas as the energy for the refrigerant cycle instead of an electrically powered compressor, typically Monoblock can be air or ground source type unit. Generally very reliable as only two moving parts, solution pump & fan for air source models.

That's The Sum of It

So you're considering a heat pump; the main point to remember is that the heat pump is just one component in the system; this single word carries a lot of weight in any design or when considering any heat source, more so than any other aspect, the system must be compatible for the heat source and vice versa.

A "system" means:



All must be considered in tandem or the system will not add up to the sum of its parts.

Heat pumps can operate in outdoor temperatures to below -20°C and can use only the compressor supply over 70°C output to the system. They can use electricity as the driver of the compressor or they can use natural gas.

Radiators Laid Bare

The most common point expressed when a heat pump is proposed for an existing or extended system relates to the radiators, are they large enough? The answer is if they are large enough for a condensing boiler then they are suitable for a heat pump. Commonly radiators are sized incorrectly. Radiator selection is generally carried out at a∆T of 50K; this means the MWT (Mean Water Temperature) difference between the water in the system and the room is 50K. However even with a brand new condensing boiler this is a physical impossibility:

Standard Boiler Radiator Size:
80°C/60°C: [(80+60)/2] -20 = 50k ∆T @ 50K the size factor is = 1 for radiators, so a 1kW radiator is a 1kW radiator, complicated stuff!

Condensing Boiler Radiator Size:
60°C/40°C: [(60+40)/2] -20 = 30k ∆T @ 30K the size factor is = 0.51 for radiators, so a 1kW radiator is a 510W radiator – half the output from the radiator versus a standard boiler @ 80°C.

Heat Pump Radiator Size:
60°C/50°C: [(60+50)/2] - 20 = 35k ∆T @ 35K the size factor is = 0.643 for radiators, so a 1kW radiator is a 643W radiator - 20% more output than a condensing boiler.

So with both a condensing boiler & heat pump operating at 60°C flow the result is that the **heat pump requires a smaller radiator**.

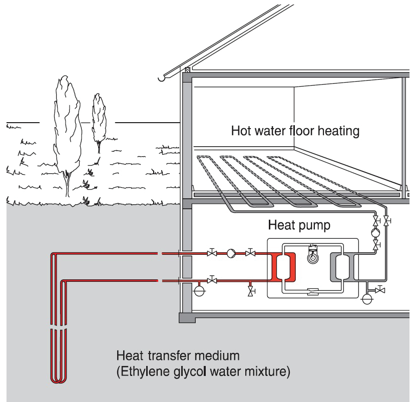
Sizing Ground Source Heat Pump Collector's (<30kW)

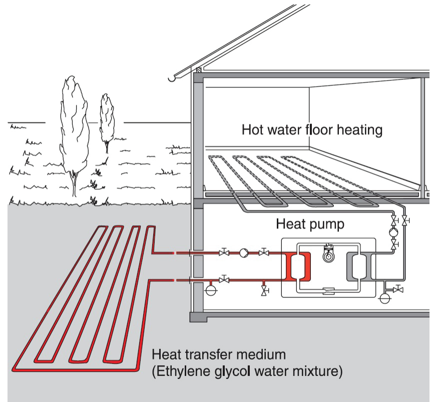
When sizing a heat pump collector (Monoblock Geothermal) the required equation is:

1. Vertical Borehole Type: $\frac{\left[kw - \left(\frac{kw}{cop}\right)\right]}{50}$ = Metres Borehole Required

2. Horizontal Loop Type: $\frac{\left[kw - \left(\frac{kw}{cop}\right)\right]}{20}$ = Collector Area required (m^2)

3. Horizontal Loop Type: $\frac{\left[kw - \left(\frac{kw}{cop}\right)\right]}{16}$ = Metres of Collector Pipe Required





- kW is the max output (in Watts) of the unit @ design condition, if weather compensated then lowest flow temperature.
- COP = coefficient of performance at this temperature.
- 50 is an average value of soil thermal extraction in W/m as per BS 15450
- 20 is an average value of soil thermal extraction in W/m2 as per BS 15450
- Both kW output and COP change depending on Tflow (As with a boiler)

Regardless of which system is employed to save yourself a lot of hassle always pipe in a reverse return manner. In relation to borehole types a common occurrence is for people to use a single 40mm diameter U-Probe as oppose to a Double 32mm Diameter U Probe. BS15450 geothermal extraction rates are based on a double 32mm diameter probe, "Ahh but the bigger 40mm pipe makes up for the loss of a probe" - codswallop.

Take 2 minutes with a calculator and anyone will see a single 40mm U-Probe far from making up for the loss of a probe is in fact 22% less surface area than the smaller 32mm double U-Probe. Less surface area = less heat transfer = less energy from the ground = lower COP = increase running cost.

Additionally as the cross section of a 32mm pipe is less than that of a 40mm pipe the time to heat up the fluid in a 32mm pipe is less than a 40mm pipe, the increased wall thickness in a 40mm pipe also impedes heat transfer. In summary for depths up to 150m use a 32mm double U-Probe over a 40mm single pipe as per BS &EN standards.

Sizing Air Source Heat Pump

Sizing of an Air Source Heat Pump is more complicated and there can be no simple equation as the kW output of an air source heat pump changes significantly with respect to outside temperature and also from manufacturer to manufacturer.

For Example: @ Air 7°C Water 35°C Heat Pump X = 20kW Thermal Output to heating system.
@ Air -5°C Heat Pump X = 15kW;
@ Air +20°C Heat Pump X = 25kW, that's a 40% swing in output.
"Ahh" you're thinking, great in the summer, I'll be able to heat my hot water twice as fast, however if your pipes are sized for the -5°C flow rate the coil surface area will not be sized large enough for the summer kW load and you will not get the anticipated result. This is not negative as long as it is designed for into the system.

Once you know your kW load ask the heat pump supplier/manufacturer for the performance chart of the unit, if they look at you as if you have ten heads pick different supplier – one who knows what you & they are talking about.

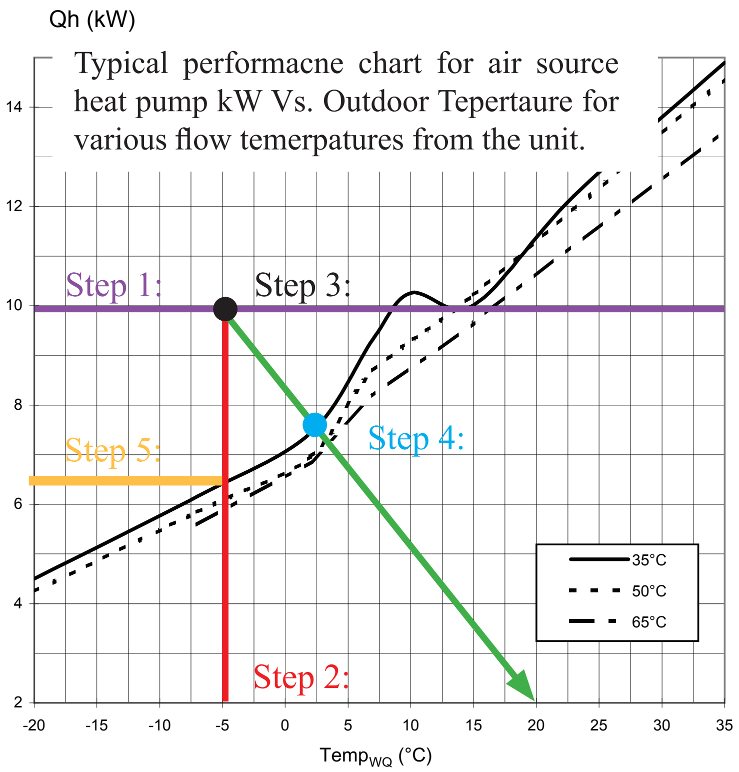
STEP 1: Draw a line horizontally at your kW load.

STEP 2: Draw a line vertically at your outside design temperature (-5°C , -3°C etc.)

STEP 3: Where 1&2 intersect is your operating point at To design condition.

STEP 4: Draw a line from STEP 3 to +20°C on the x-axis. This is the reduced heating load as the outdoor temperature increases. Where this line crosses the heat pump performance curve is the "bivalent point", a fancy word meaning to the left of this point another heat source input is required.

STEP 5: Where STEP 2 crosses the performance curve draw a line left, the difference in kW between lines 1&5 is the size your second heat source needs to be. i.e. boiler, immersion etc.



Heating Cost Comparison – It's All About The Money

Below is a table comparing costs per kW of the various heat sources currently used in the market. From the table it can be clearly seen that the absorption heat pump has the lowest running cost and second lowest carbon emissions, followed by the electrical heat pump. As a general rule a properly sized electric heat pump system should have a running cost in the region of 25% lower than a mains gas boiler and half the running cost of an oil based heating system. The savings are significantly more for an absorption heat pump and when forecast over a 10 year running period it can accumulate into a six figure sum.

Based on the heating cost per kW adjusted for plant efficiency it can be seen that heat pumps have the lowest running cost of any system and when considering carbon dioxide emissions are second only to biomass in terms of carbon reduction.

The chart is based on a water flow temperature of 50°C; two points therefore come to mind immediately;

A) Legionella Disinfection requires 60°C: Heat pump`s can either operate at 60°C by themselves or use an immersion from 50°C for the last 10K once a week. For large systems CIBSE cites chlorine dosing of the mains supply as a more effective means of disinfection.

B) Is 50°C hot enough for radiators? As dealt with earlier if the heat emitter, UFH or Radiators, is sized correctly then the flow temperature is not as critical – as long as the system is sized correctly - Remember a condensing boiler operates at 50°C too.

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	Biomass Boiler (60°C Flow)	LPG Gas Boiler (50°C Flow)	Heat Pump (50°C Flow)	LPG Gas Heat Pump (50°C Flow)	Nat Gas Heat Pump (50°C Flow)	Nat Gas Boiler (50°C Flow)	Oil Boiler (50°C Flow)
	Efficiency: 90%	Efficiency: 90%	Efficiency COP Air 7C : 3,5	Efficiency COP Air 7C : 1,5	Efficiency COP Air 7C : 1,5	Efficiency: 90%	Efficiency: 90%
	Pellet Cost / kWht: € 0,07	LPG Cost / kWht: € 0,13	Elec Cost / kWhe: € 0,20	LPG Cost / kWht: € 0,13	Nat Gas Cost / kWht: € 0,07	Nat Gas Cost / kWht: € 0,07	Oil Cost / kWht: € 0,09
	Htg Cost / kWh: Cent 7,34	Htg Cost / kWh: Cent 14,72	Htg Cost / kWh: Cent 5,60	Htg Cost / kWh: Cent 8,83	Htg Cost / kWh: Cent 4,36	Htg Cost / kWh: Cent 7,27	Htg Cost / kWh: Cent 10,27
Increased Running Cost Vs. Heat Pump	24%	62%	0%	37%	-29%	23%	45%

	Biomass Boiler	LPG Gas Boiler	Elec Heat Pump	LPG Gas Heat Pump	Nat. Gas Heat Pump	Nat Gas Boiler	Oil Boiler
CO2 Kg/ kWht:	0,025	0,229	0,152	0,153	0,137	0,205	0,257
Increased Carbon Dioxide Emissions Vs. Heat Pump	-509%	33%	0%	1%	-11%	26%	41%

NOTE:
1. Prices based on SEAI October 2012 Fuel Cost Comparision Rep. Ireland.
2. Emissions based on SEAI factors Rep. Ireland.
3. Biomass emissions based on CIBSE Bio-Heating Guide.
4. Comparison based on above conditions.

Fig 1: Table comparing running cost of each system versus an electrical heat pump as the datum per kW adjusted for efficiency.

In graphical terms the below chart is a representation of the above table for the difference in cost per kW of each system, using an electrical heat pump as the datum.

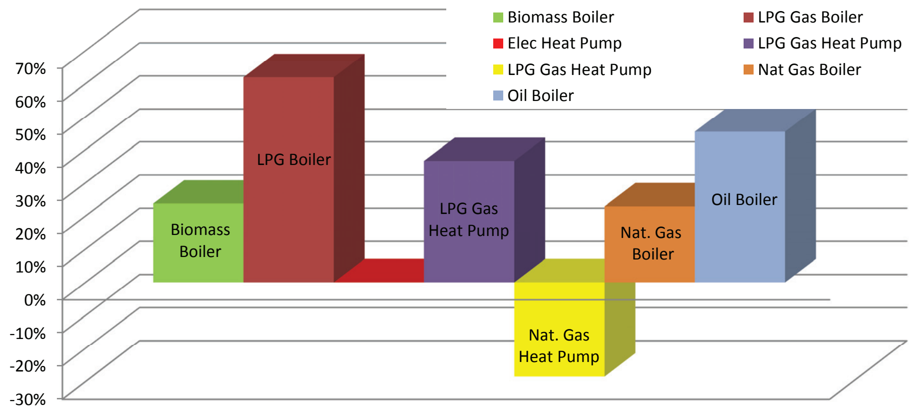

Fig 2: Illustrative comparison showing running cost of each system versus an electrical heat pump as the datum.

So You Think You're Compliant?

So you've got your project, you've got your heat pump sized correctly – So you think you're complaint?
Below is a short list of applicable standards and useful guides, however one overlooked recent Irish addition is the "Triple E Register"; compiled by SEAI this is a government implemented statutory binding (SI151) rule which in summary states; if your project is funded or part funded with public money you must use approved equipment from this list. With respect to heat pumps there are currently circa 60 approved air source & ground source models.

There is also a "Heat Pump Association of Ireland" comprising the various manufacturers present in Ireland who have signed up to a code of practice for the industry. (www.hpa.ie)

Other standards & useful guides include:

• F-Gas Regulation: Design, install, maintenance – even the size of the plant room for the heat pump.
• Triple E Register: List of approve units for public funded projects.
• Irish Building Regulations Part L
• SEAI Compliance Guide For TGD Part L (Seen Section 8 which is specifically for heat pumps)
• SR50-1 Code of Practice (to be Published by NSAI)
• BS15450: Heating Systems in Buildings; Design of Heat Pump Heating Systems
• Energy Saving Trust Guide CE82 for specifier's
• BSRIA technical Note on Ground Source Heat Pumps
• EN378: Refrigeration Systems & Heat Pumps

Remember, whether it is a heat pump, boiler or any heat source in order to operate as envisaged it must be designed as a system. Most of all be creative; use every degree of heat and wasted Watt to improve your system.

Origen Energy Ltd is a leading Renewable Energy specialist company with three offices around Ireland. Origen Energy is one of Ireland's leading renewable energy and district heating specialists. The focus of Origen Energy is to provide quality engineered solutions that lower energy costs, whilst offering maximum efficiency and comfort. We ensure both domestic and commercial projects are as energy efficient as possible and comply with all necessary energy regulations, guaranteeing a reduced carbon footprint. We design and supply fully engineered renewable energy solutions to the residential, commercial and industrial sectors via our in house specialists including design engineers, CAD technicians and system specialists. Bespoke system design is our standard.

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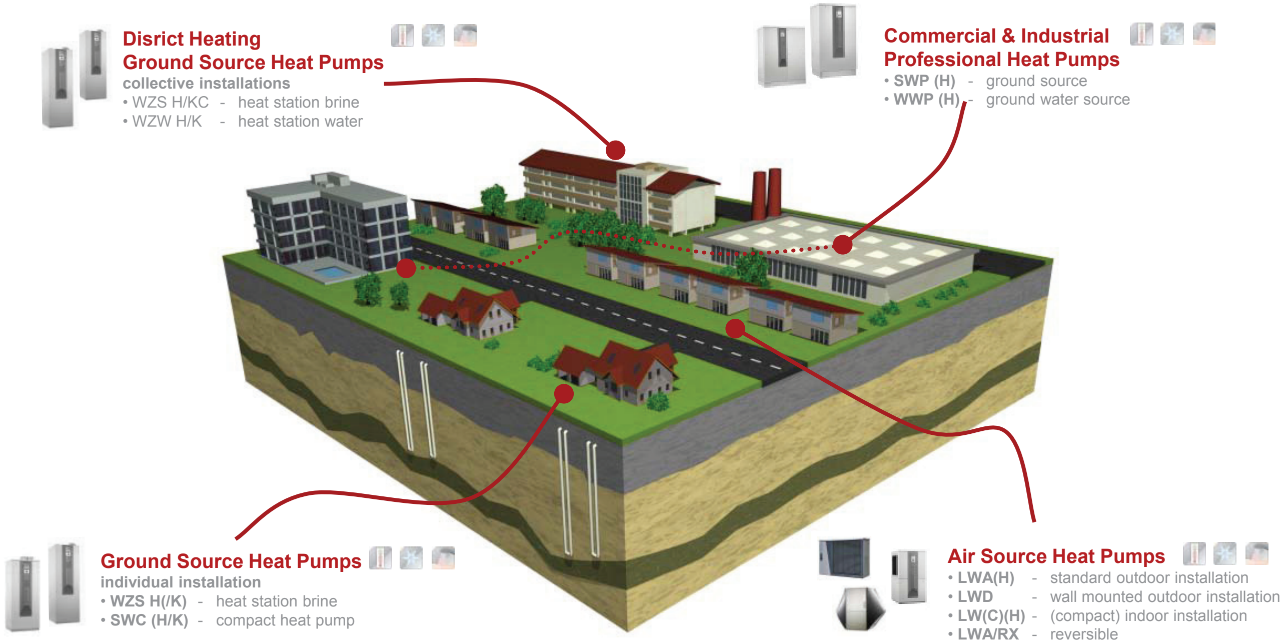
Origen Energy Ltd. provides IEI accredited training courses on site in your company offices for heat pump system design.

Please contact a member of Origen Energy via email: energy @origen.ie or phone 01-4191940 (Dublin), 021-4321066 (Cork) to arrange a free CPD training course for your company. Or visit www.engineersireland.ie/CPD-Training for more information.



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