RESEARCH NOTES - Heat Pumps
DATE 2013

1.0 Principles

1.1 Ground source heat pump (GSHP) systems work by pumping a refrigerant through buried pipework to extract the latent heat in the ground; this heat is then used to warm water for heating a building. The pumps themselves are electrically powered, but the heat extracted from the ground can be several times the amount of energy required to run the system. This factor is the "gain" or "coefficient of performance" (CoP). Air source heat pumps (ASHP) are similar but have external fan units (similar to those used for chilling air conditioning, but working the other way round) to extract heat from the surrounding air.

1.2 Judging the overall efficiency of the system is only possible if one takes into account the efficiency of the system that generated and distributed the electricity, of course. In the UK, once generation and transmission losses are taken into account, mains electricity works out at about 30-31% efficient. Many heat pump system manufacturers quote a gain of "up to 4" - in other words, every watt of electricity used delivers 4 watts of heat into the building. It would seem, however, that in practice gains are usually closer to 3 or below even when working optimally; this is particularly true if the heat source is cool (such as winter air for an air source heat pump or cold winter ground for a shallow-trenched GSHP system). In such conditions, therefore, it would appear that a heat pump system may deliver total efficiency (including that of the electricity system) of 3 x 31% = 90-95%. This compares with efficiencies for the best condensing boilers of 92-97%.

If "green" electricity is used, of course, heat pump systems can be considered zero-emission.

1.3 The rating of a GSHP system tends to be lower than that of an equivalent conventional boiler; whereas a normal boiler works for say 4 hrs each day, a heat pump tends to be left ticking over almost round the clock. Typical output for a building insulated to current part L standards will be around $40W/m^2$; for older houses assume $80\text{-}150W/m^2$.

2.0 Installation

2.1 Any GSHP system comprises the energy source pipework, the heat pump and the heat distribution system. The options are:

2.2 **Heat source**

Generally, a length of pipework in the ground. Options are:

i) a vertical borehole - typically 100-150m deep. The most expensive option but uses least ground

ii) horizontal straight pipe - has to be buried by about 1m.

iii) horizontal coiled ("slinky") pipe. Also buried by about 1m. Assume 10m trench per kW delivered. The cheapest option in most circumstances.

The length of pipework needed will depend on ground type. Best conditions are solid, damp ground - below water table is ideal. Worst conditions are dry, friable soil such as dry peat.

2.3 **Heat distribution**

The output from a GSHP system is water heated to typically 35° - 40°. Heating water to higher temperatures is possible but, because of the laws of thermodynamics, at lower and lower "gain" coefficients.

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Because of its relatively low temperature, the water is most efficiently used to supply underfloor heating. Note that the ufh pipework must be designed for this low temperature, not for the 55° typically available from a boiler.

2.4 Air source heat pumps use an external fan unit rather than a length of buried pipe, and so are very much cheaper to install. They are even more prone to loss of efficiency in cold weather because their heat source will often be colder than the ground.

2.5 A secondary issue with air source heat pumps in Britain's cool and damp winter climate is that of icing. The evaporator coils that absorb heat from the surrounding air are often below 0° in winter, and can become encrusted with ice, reducing their effectiveness. To solve this problem, the coils are usually automatically heated periodically to defrost them. This energy use is rarely included in efficiency figures. Cheaper ASHP units (with smaller heat exchangers working harder) are more prone to icing than more expensive, larger units.

2.4 Domestic hot water

GSHP systems are usually set up to also prewarm the dhw, but an alternative heat source (usually a conventional electric immersion heater) will be required to heat the water the rest of the way as their efficiency tails off very markedly as they try to achieve higher water temperatures.

3.0 Costs

3.1 Installation

Because the size of an installation depends on so many factors (building size and heat losses, ground conditions etc.) installers are cagey about giving direct price comparisons with conventional systems. GSHP is certainly more expensive to install, however. Recent typical figures are approx. £800-£1400 / kW. For a domestic sized installation, the price currently appears to be in the order of 2 or 3 times more expensive than a boiler - say £8000 - £12000 for an average house, £12000 - £20000 for a large one. This excludes the heat delivery system, e.g. underfloor heating.

ASHP, because it doesn't require buried pipes, is substantially cheaper than GSHP, but still much more expensive than a conventional condensing boiler. A typical installation for a well-insulated medium-sized house might cost in the region of £6500-8500.

At present replacement HP installations can qualify for a government grant under the Renewable Heat Premium Payment scheme. See the Energy Saving Trust website for details.

3.2 Running Costs

In the past few years, as fossil fuel prices have risen, heat pump systems have become more competitive. Maintenance costs are very low - little or no servicing is required on an annual basis (quick look at the pump, perhaps top up the refrigerant), and the plant lifespan is good - say 20 years fairly easily.

From 2014, heat pump systems may be eligible for payments under the domestic Renewable Heat Incentive scheme. This will pay the owner of a system a sum based on its capacity for a period of seven years from installation. It is expected that any systems installed since 2009 will be eligible. See the Energy Saving Trust website for details.

4.0 Other Considerations

4.1 The big boiler manufacturers are beginning to see GSHP as a viable technology - both Dimplex and Bosch Worcester have started supplying systems in the last year.

4.2 GSHP systems team well with solar thermal panels to aid water heating on warm days, reducing the heat pump's energy use still further.

4.3 As with any other alternative energy heat source, the first move has to be to insulate well. Alternative energy costs more, and you don't want to waste it unnecessarily.

5.0 Summary

5.1 Pros

- Low (or zero) carbon emissions if used with "green" electricity
- Long lifespan and low maintenance
- Can be cheaper to run than some fossil fuels

5.2 Cons

- High installation cost
- Requires space for source coils, and extensive excavation (GSHP)
- May be no more carbon efficient than ordinary condensing boilers if powered by conventionally-generated mains electricity, for a much higher initial cost
- Only really a sensible option for very well insulated (usually new) homes, in order to minimise system size and cost.
- Air source fan units are often noisy.

An excellent article examining the pros and cons of Air Source Heat Pumps in greater detail has been prepared by the AECB (the leading organisation for sustainable construction in Britain). The article can be downloaded here:

http://www.aecb.net/publications/air-source-heat-pumps-friend-or-foe/