Understanding Heat Pumps

What do heat pumps do?

Heat pumps MOVE heat from one place to another

Examples

Refrigerators and Freezers

Air Conditioning / HVAC

Heating and Hot Water

How do Heat Pumps Work?

Heat Pumps compress then expand gases

- When a gas is compressed, both its pressure, and temperature rise
- When a gas expands, its pressure and temperature drop.

  Heat pumps move heat using compressors with heat taken from the “expanding” side and pass it to the “compression” side of the compressor.
- This process can be 4 to 5 times more efficient at delivering heat than traditional resistive heating.

Types of Heat Pump

Heat pumps are categorised by the medium from which heat is sourced a delivered

- Air to Air – otherwise known as air conditioning units. Traditionally used for cooling, now widely used for both heating and cooling.
- Air to Water – Uses air as a source for heating / cooling and delivers thermal services (heating or cooling using water).
- Water to Water – Uses water as both source and delivery mechanism for heating and cooling.

Heat Pump Efficiency

What Makes for Efficient Heat Pump Operation?

Heat pumps are most effective when changing the temperature by a small amount. If using a heat pump for a wet heating system, place the outside unit in a sunny spot and use oversized or fan assisted radiators to allow sufficient heat to be delivered at low temperature – the lower the temperature difference between heat intake and output, the higher the system efficiency.

Look for chances to use BOTH sides of the heat pump

- e.g by producing hot water using heat extracted from a cold store – this can double system efficiency

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Air Conditioning Units

- Air conditioning units (air to air) have reasonable efficiency overall but lose efficiency when it is most needed

  On the coldest days efficiency is lowest - especially when ice forms on the outdoor unit requiring de-icing for continued operation.

  Likewise there is an efficiency penalty when cooling on the hottest days as it is harder to get rid of heat to hot air than to cold air.

- Air conditioning units lack storage

  This is sub-optimal when on site generation such as solar or wind power is present as mains power must be used whenever the sun is not shining, or the wind is not blowing.

  (No thermal storage for heating or cooling beyond the thermal inertia of the building)

Air Conditioning Split System

- A typical air conditioning system
- http://portableairconditioningunitsoku.blogspot.com/2014/11/portable-air-conditioning-units-2-ton.html

Air to Water Heat Pumps

- Efficiency deteriorates in very hot or very cold conditions

  (Just like air conditioning units due to the increased temperature difference between heat source and heat sink)

- Unlike air conditioning units sanitary hot water, or chilled drinking water can be produced.

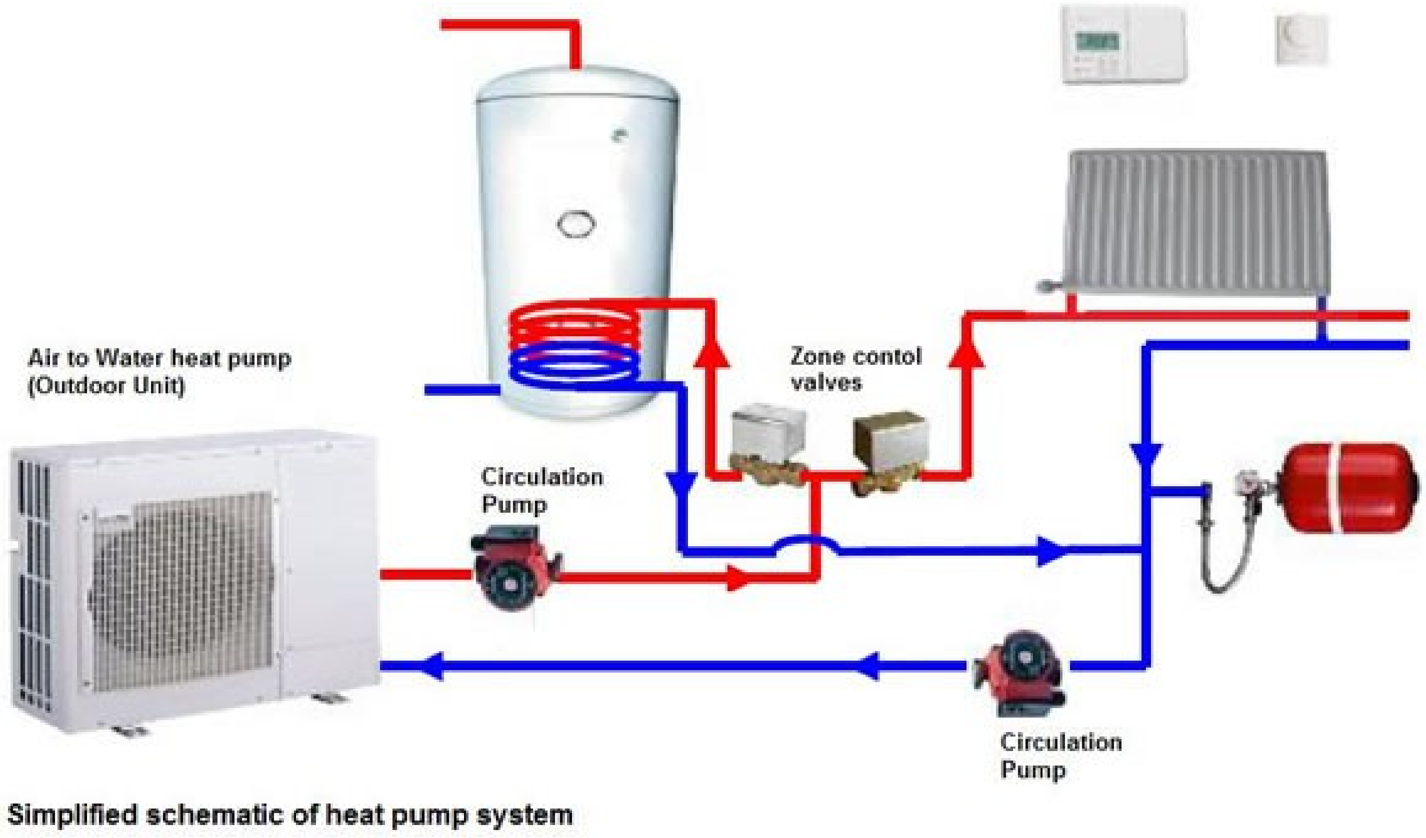
- These units can be linked to thermal stores, cost effectively saving hot water, or chilled water for when needed.

  Energy storage / time of use discounts

- Can be set up to use “spare” on site generation from solar panels or a wind turbine so making best use of power which would otherwise be exported.

- Can be set to make best use of off peak electricity rates e.g by producing hot water at night at lower cost.

Air to Water Heat Pump

- http://www.solasave.co.uk/heat-pumps.aspx
- 

Air to Water Heat Pumps – System Description

- An air to water heat pump consists of two units
- An outside unit containing a compressor, a heat exchanger and a fan
- An inside unit consisting of a heat exchanger and a thermal store (hot or cold tank)

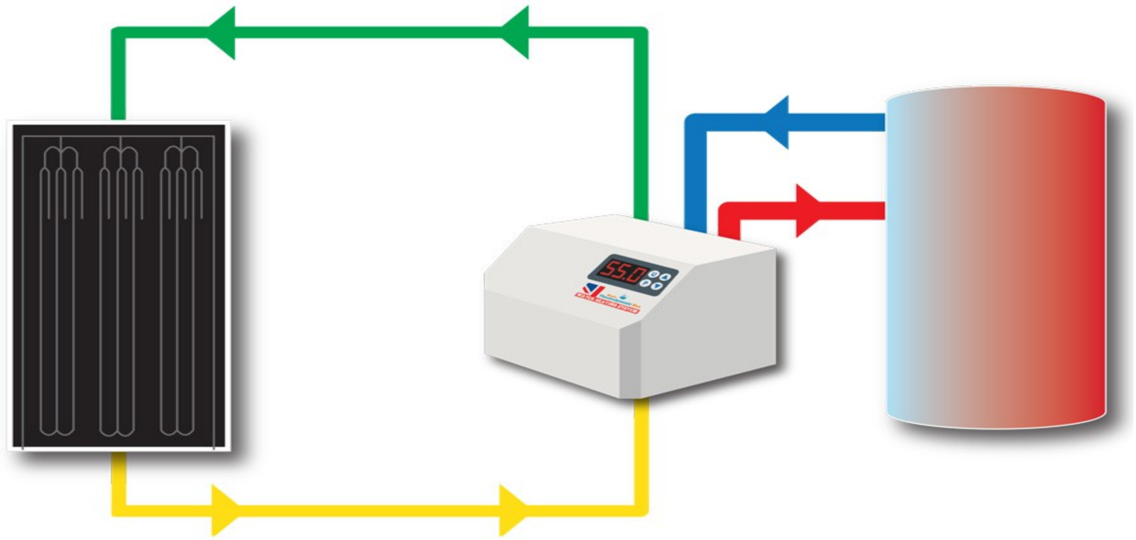
  (Occasionally these are combined in one outdoor unit)
- Heat or cool is stored in the tank and then plumbed to where heating / hot water / cooling effect is needed.
- These are ideal where there is on site solar / wind generation as heat / cool can be produced and stored whenever generation exceeds on site demand – making best use of power that would otherwise be exported – either sold at low price, or taken by the grid operator without payment.
- Qualifies for Renewable Heat Incentive

Solar Assisted Heat Pump

- A variant of air to water heat pump usually used for heat only
- Large heat exchangers in the form of black aluminium plates replace the small fan assisted heat exchanger in the outside unit. These are designed to absorb solar heat during the daylight hours.
- The remaining components are combined in a single unit consisting of heat pump and thermal store from which heat is plumbed to where it is needed.
- This variant gains efficiency by eliminating the outside fan, by increasing the heat exchanger area, by not requiring de-icing, and by absorbing solar heat whenever the sun is shining.
- Lacking an external fan, this variant is very quiet in operation.
- Installed cost is somewhere between that of standard air to water heat pump and ground source heat pump – with efficiency in heating operations averaging a little higher than either.
- RHI only available for residential hot water – not space heating or commercial

Solar Assisted Heat Pump

- From Magic Box International



Water Source Heat Pumps

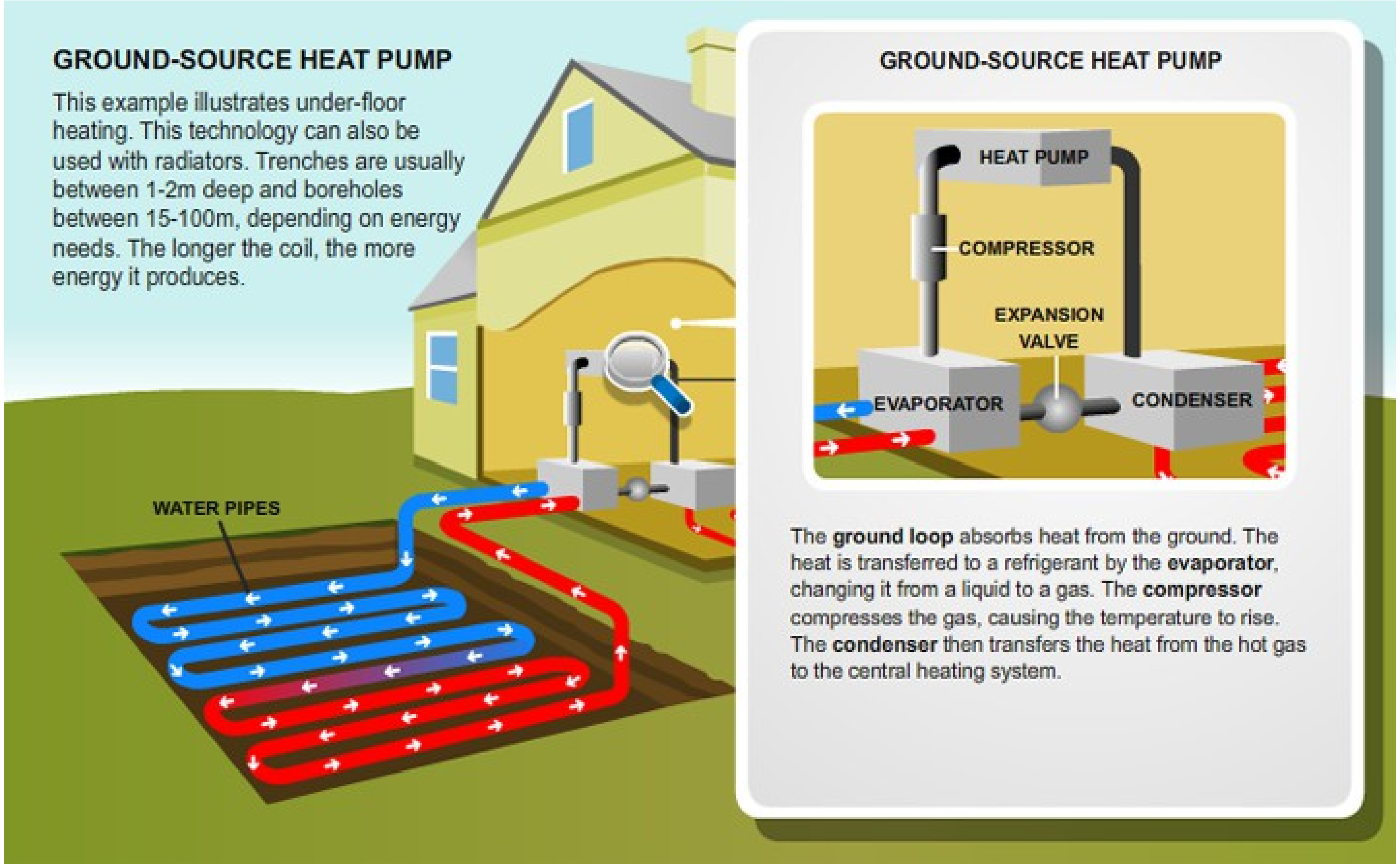
- Water or soil are used to collect or dump heat
- Typically a long coiled hose will be dropped into a lake or river, buried in a trench, or placed into a borehole (In order of increasing cost). The coiled hose forms the heat exchanger. Usually around 6 meters of trench or borehole will be needed per kW of nominal capacity.
- The remaining components are combined in a single unit consisting of heat pump and thermal store from which heat / cooling is plumbed to where it is needed.
- Due to the tendency of soil a few meters down to stay at near constant temperature year round, ground source heat pumps are more efficient than air source at delivering heat – with minimal reduction in capacity and efficiency on freezing cold days.
- Cooling can usually be delivered via the heat exchanger without running the compressor making such systems VERY efficient for summer cooling.

Water Source Heat Pumps 2

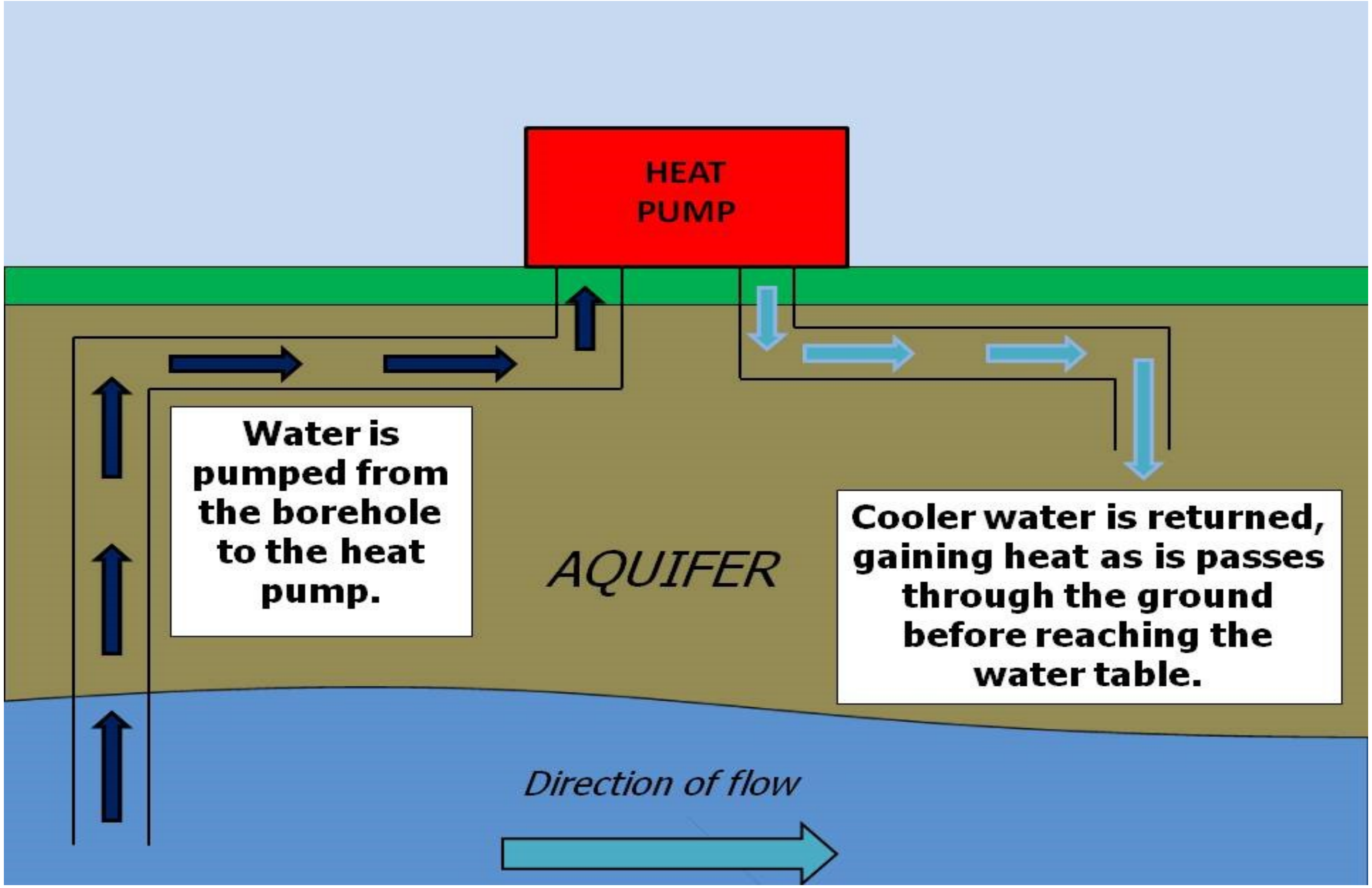
- Water source heat pumps generally maintain their efficiency in all conditions.
- These units are un-obtrusive – with nothing to be seen outside the building and very low noise levels.
- Typically, less space is needed indoors than for conventional HVAC equipment.
- Costs CAN be high for borehole based systems, especially for small systems such as individual houses, and when not installed as original equipment at the time of construction.
- Note – The system described is closed cycle with anti-freeze constantly cycled through a closed loop.
- Qualify for RHI payments

Ground Source Heat Pump

- https://ukhomeimprovementnews.wordpress.com/2014/12/01/benefits-of-ground-source-heat-pumps/



Open Cycle Ground Source Heat Pump

- http://www.hdgeothermal.co.uk/technology/
- 

Open Cycle Ground Source Heat Pumps

- For larger systems e.g commercial / institutional buildings.

  2 boreholes are drilled into an aquifer, some distance apart. Water is extracted from 1 borehole, used as a heat source / heat sink, then pumped back into the aquifer using the second well, so no net water extraction. (The wells are separated so the return water has minimal impact on the temperature of the extracted water). Very large systems may use more than 2 boreholes.

- Boreholes in the South and Midlands can often support flow rates up to 1000m3 per day, and capable of supporting thermal loads – heating or cooling of several hundred kW.
- Open cycle becomes increasingly cost effective as capacity increases – especially for hundreds of kW.
- **An open source heat pump requires an water abstraction licence from the environment agency – even where there is no net extraction.**

Gas Engine Heat Pump

- Gas engine heat pumps operate on the same compression cycle as electrically driven heat pumps.
- Mechanically driven by a mains / LPG powered engine
- Exhaust gas heat is captured for additional efficiency
- Cost of producing heat is around 1/3 that of an electrically driven heat pump assuming not generated on site.
- May include a small electrical generator running off the same shaft as the heat pump – this covers the electrical loads of circulating pumps etc.
- Cost effective for large systems, less so for small residential systems due to engine servicing costs
- Not currently qualified for RHI

Gas Engine Heat Pump

- https://aegischp.com/product/yanmar-ghp-systems/

Renewable Heat Incentive (RHI)

- Compliant heat pumps systems are eligible for RHI payments for useful heat produced.
- Each qualifying kWh of heat produced receives a payment – similar to a feed in tariff (FIT). Note :-The FIT closed in April 2019, unlike RHI which remains open to the end of March 2021 non domestic, and and a year later for residential.
- There are two schemes, Residential for single dwellings, and Commercial RHI for commercial or shared systems.
- Grant funded systems DO NOT qualify so best use funds from other sources such as loans for this component of any project.
- Both the hardware, and the installer MUST be Microgeneration Certification Scheme Qualified for RHI to be paid.
- Rate set at registration 7 years residential, 20 years commercial RPI linked
- Note:- RHI for solar assisted heat pumps only applies to domestic hot water.

Commercial RHI Rates per kWh of Heat

- Tier 1 applies to a limited number of full load hours, above this Tier 2 applies. Systems designed to allow cooling do not qualify.

Water/Ground-source heat pumps	Ground-source heat pumps & Water-source heat pumps	All capacities Tier 1	9.36
		All capacities Tier 2	2.79
Air-source heat pumps (commissioned on or after 4 December 2013)	Air-source heat pumps	All capacities	2.69
Deep geothermal (commissioned on or after 4 December 2013)	Deep geothermal	All capacities	5.38
All solar collectors	Solar collectors	Less than 200 kWth	10.75

Residential RHI Rates

- Residential RHI lasts 7 years with RPI link

Applications submitted	Biomass boilers and stoves (p/kWh)	Air source heat pumps (p/kWh)	Ground source heat pumps (p/kWh)	Solar thermal (p/kWh)
01/01/2018 - 31/03/2018	6.54p	10.18p	19.86p	20.06p
01/04/2018 - 30/06/2018	6.74p	10.49p	20.46p	20.66p
01/07/2018 - 30/09/2018	6.74p	10.49p	20.46p	20.66p
01/10/2018 - 30/12/2018	If any new tariff changes are to be made due to degression, the announcement by BEIS would be made by 1 August 2018.			

Heat Pump Indicative Costs 1

- Air to Water Heat Pumps
- £200 to £300 per kW heat pump cost at >10 kW for quality product. Also needs a heat store, radiators and installation. (Underfloor heating or fan assisted radiators are recommended to allow a heating water temperature of around 37 to 40 centigrade for optimum efficiency). Perhaps £7,000 to £10,000 for 10 to 15 kW installed.
- Ground Source Heat Pumps
- Similar to slightly higher hardware cost for the heat pump, and radiators / underfloor heating equipment, however there is an additional cost of several thousands for borehole drilling and hardware for the borehole. Perhaps £15,000 to £20,000 for 10 to 15 kW installed.
- RHI covers a substantial proportion of the electricity cost for the first 20 years of operation – especially with on site solar power generation.

Heat Pump Indicative Costs

- Open Cycle Ground Source heat Pump
- For large commercial systems – shopping centres, large office blocks, district heating etc. significant economies of scale kick in as the borehole drilling cost does not rise in proportion to capacity. Such systems may only be a little more expensive in capital costs than air source heat pumps, with lack of noise, space saving, and higher annual average coefficient of performance (efficiency) more than making up for the extra capital cost.
- Note:- In all cases, buildings need a heating system so with a major refurbishment, or new build, or when the existing system is obsolete, it would be reasonable to consider only the ADDITIONAL costs when calculating payback periods.

Payback time – Air to Water

- Air to water heat pumps
- Assuming 15 kW system, £15,000 cost of which £5,000 is additional.
- RHI 2.69p/kWh for 20,000 kWh
- RHI Payments £538 per annum inflation adjusted
- Payback time just under 10 years for the incremental cost - indicative
- Running costs substantially lower than resistive heating or oil fired boilers – especially if a substantial portion of the electricity used is solar generated on site

Payback time Ground Source

- Air to water heat pumps
- Assuming 15 kW system, £20,000 cost of which £10,000 is additional.
- RHI 9.63p/kWh (Tier 1) for 20,000 kWh
- RHI Payments £1,963 per annum inflation adjusted
- Payback time just over 5 years for the incremental cost – indicative
- Running costs substantially lower than resistive heating or oil fired boilers – slightly lower than air source heat pumps.

Solar Power

- Larger systems can be installed for around £800 to £1,000 per kW – possibly less
- Yield per kW range from around 700 to 1000 kWh per annum – depends on location and orientation
- Annual value assuming 70% used on site at 15p/kWh £73.50 to £105 per kW per annum
- Approx 7 to 10 year payback
- In special cases where the panels are integrated into structures such as car ports, acoustic screens etc, the incremental cost of solar above that of a similar structure with glass is possibly £200 to £300
- **Special inverters can integrate on site batteries, and solar boosted electric vehicle chargers into the system(a good option for using spare solar power).**

Thermal Stores

- Traditional thermal stores are tanks which use water / water antifreeze mixtures and warm up or cool down as heat or cold is stored
- An alternative option is to store heat or cold as a phase change e.g solid to liquid wax for storing heat, or water to ice for cold storage.
- Advantages include – heat or cold stored at a constant temperature unlike a hot water tank which can deliver lukewarm water as it discharges (whilst wax is melting or ice is forming a lot of heat is stored / discharged before the temperature changes)
- Physically smaller – about ¼ the size for similar kWh capacity all of which is useable
- Lower heat losses through reduced convective, radiative, and conductive losses
- Disadvantage – somewhat higher capital cost (£1,250 retail for a phase change heat store of 70 litre equivalent)

Thermal Stores

- From Sunamp – Phase change heat store can also serve as a heat interface unit in district heating
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