LOW/ZERO CARBON

RENEWABLE ENERGY FOR UTTLESFORD

GROUND COUPLED + AIR COUPLED ENERGY

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Study undertaken for Uttlesford Futures

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4 GEOTHERMAL ENERGY + GROUND & AIR COUPLED ENERGY

SUMMARY

Geothermal energy is derived from heat within the Earth; solar energy stored in the ground (but nearer the surface) is referred to as Ground-Coupled Energy - although the latter is often referred to as geothermal. Geothermal energy is not available in Uttlesford, but Ground-Coupled Energy is available in the whole of the UK - including Uttlesford - and can provide heat, hot water and cooling energy ('coolth'); can pre-heat and pre-cool ventilation air and can be used to store energy. Low grade heat contained in ambient air can also be exploited to provide space and water heating.

Ground-coupled energy can be exploited in the following ways: -

- direct ground-coupling via earth sheltering or using an underground building
- via a ground heat exchanger, bore hole or a water source
- pre-heating or cooling of ventilation air via earth pipes or tubes
- heating and/or cooling by ground water heat pump
- heating and/or cooling via a ground collector heat pump

- **Earth Tubes** are widely used in European countries, can cool or pre-heat ventilation air and can be integrated into heat recovery and ventilation (HRV) systems and reduce cooling and heating needs thus reduce CO_2 emissions.
- **Ground-coupled 'free cooling'** has been successfully employed at the BRE Environment Office in Watford with the aim of avoiding the use of air conditioning; this approach circulates cooling water from an onsite borehole through the building. The approach could be used in Uttlesford.
- Wherever an appropriate body of water exists there will be opportunities to make use of **ground water source heat pumps**.
- The temperature of the ground throughout most of Uttlesford is such that Ground Coupled Energy can be exploited via a ground collector and a heat pump (known as a **Ground Source Heat Pump**) to warm buildings in winter and cool them in summer without emitting high levels of CO_2. If electricity to power the heat pump comes from a renewable energy source then it can be an efficient zero CO_2 method of heating and cooling.

GSHPs may be able to compete economically in rural locations where the only conventional form of heating available is that fuelled by oil or electric storage heaters.

Ball park estimates of using GSHPs to provide the space and water heating for the Uttlesford <u>non-gas</u> households indicate that they could abate an aggregated level of CO_2 emissions of the order of **9,000 tonnes/y for 20%**; **22,000 tonnes/y for 50%**, and **32,000 tonnes for 70% of the non gas households**. If it proved to be feasible for <u>all</u> of the non-gas households to use GSHPs, then they could abate around **45,600 tonnes CO_2/y**, i.e. around a **27% reduction of the <u>total</u>[1] Uttlesford domestic space and water heating related CO_2 emissions**.

If electricity from a renewable energy source is used, then GSHPs could abate of the order of **15,000 tonnes CO_2/y for 20%** of the non-gas households**; 22,000 tonnes CO_2/y for 30%**; **38,000 tonnes CO_2/y for 50%**; **53,000 tonnes CO_2/y for 70%** and **around 75,000 tonnes CO_2/y for <u>all non gas households</u>,** i.e. around a **45% reduction of the <u>total</u> Uttlesford domestic space and water heating related CO_2 emissions**.

- More recently the performance of heat pumps that extract heat from the ambient air (**Air Source Heat Pumps**) has been improved such that it is also possible to consider this form of space and water heating throughout Uttlesford.

The ball park estimates of using ASHPs indicate that they could abate of the order of **7,900 k tonnes/y for 20%** of the non gas households; **19,800 tonnes/y for 50%**, **27,700 tonnes for 70%** and **39,600 tonnesCO_2/y for all of the <u>non gas</u> households**, i.e. around a **23% reduction of the Uttlesford domestic space and water heating related CO_2 emissions**.

- Another related approach is known as **Solar-Assisted Ground Coupled Energy** or **Solar Roads**. There are a number of variants but the main principle is to use asphalt/tarmac or paved surfaces as simple unglazed 'solar collectors' in combination with Ground Coupled Energy Storage.

[1] Total includes both gas households and non-gas households.

Assuming 10% of the road area in Uttlesford were Solar Roads, the ball park estimates indicate that around **3,360 (around 12%) of Uttlesford households** could be supplied with space and water heating assuming current average demand (or around 7,000 households or around 26% of Uttlesford households if average space and water demands were reduced to 10 MWh/y by means of energy conservation). Using the Solar Road technology in the main town centre car parks would provide for around 100 to 140 households or 210 to 310 households at 10MWh/y average space and water heating demand. Utilising additional private car parks/terraces/play grounds could enhance the number of households provided for.

- The ground can also be used to inter-seasonally store energy (as heat or 'coolth') known as **Ground Coupled Energy Storage** or **Underground Thermal Energy Storage** (UTES) via ATES (**Aquifer Thermal Energy Storage**) or BTES (**Borehole Thermal Energy Storage**). Both open loop ATES and closed loop BTES systems appear to be feasible in Uttlesford and have potential to provide inter-seasonal energy storage to heat and cool large buildings or groups of households. These systems have been successfully employed in various European and North American countries and have been used in a number of UK projects.
- If suitable open spaces/roads are available adjacent to buildings that have either need for heating or cooling or have excess heat then these UTES systems and Solar Road systems have potential and could provide a means of reducing the CO_2 emissions from hard to heat/insulate old/listed buildings. These systems could also facilitate the integration of neighbourhood/large scale renewable energy sources including solar and wind energy and could also improve the viability of district scale combined heat and power systems.
- The suitability of ground soil conditions for drilling of bore holes at individual sites in Uttlesford needs to be confirmed, though no major problems are anticipated. The potential energy and CO_2 benefits of Ground-Coupled Energy should be promoted and publicised to building owners, developers, builders and housing associations.

Table G-A Summary of Ground Coupled Energy Technologies and ball park potential in Uttlesford

		Power MW	Output (GWh/y) elect	heat	CO_2 Abatement (tonnes/yr) (elect.)	(heat)	(heat+ Elect)
Ground Coupled Energy							
GSHPs							
10% of non-gas households		8.9 MWth (3MWe)		21		4560	4,560
20% of non-gas households		17.9 MWth (6MWe)		42		9120	9,120
50% of non-gas households		44.5 MWth (15MWe)		105		22,000	22,000
100% of non-gas households		89 MWth (30MWe)		210		45,600	45,600
10% of Electrically heated households		3.3 MWth (1.1MWe)		7.9		2,260	2,260
20% of Electrically heated households		6.6 MWth (2.2MWe)		15.8		4,520	4,520
50% of Electrically heated households		16.5 MWth(5.5 MWe)		39.5		11,300	11,300
100% of Electrically heated households		33 MWth (11 MWe)		79		22,600	22,600
Solar Roads							
12% of households (@21 MWh/y per HH)	10% of UF road area			70.56			
26% of households (@10 MWh/y per HH)	10% of UF road area			70.56			
Solar Road Car Parks *(conflict with SolarPV CarPorts)*							
100 to 140 housholds (21MWh/y per HH)	town centre car parks						
100 to 140 housholds (21MWh/y per HH)	town centre car parks						

CONTENTS

Definition

We can exploit energy from below ground in two principle forms. Geothermal energy and solar energy stored in the ground; the latter we will call Ground-Coupled Energy to distinguish it from true Geothermal energy. A similar form of energy to ground-coupled energy is *Surface Water-Coupled Energy*. This involves utilising solar energy stored in bodies of surface water such as ponds, lakes, rivers, streams etc.

True geothermal energy is derived from heat generated within the Earth. Its most powerful manifestation is in volcanoes and as the UK is currently a volcanic free zone, the potential exploitation of conventional geothermal energy is not a renewable energy option.

Areas of the British Isles which have granite outcrops have been researched in order to exploit Hot Dry Rocks, but the only viable parts of the England where this could be an option is in Cornwall or in the north of England. No prospects exist in Uttlesford.

The other form of true geothermal energy is known as *Geothermal Aquifer* - also known as Sedimentary Basin Aquifer. This is essentially a source of hot water found in the ground either at depth (as in Southampton) or where a hot spring produces hot water at the surface (as in the city of Bath).

However neither type of conventional Geothermal Aquifer energy sources are available in Uttlesford so no prospects exist, though there does seem to be scope to use aquifers in Uttlesford for ground coupled inter-seasonal thermal energy storage (see section on ATES).

There is another type of Geothermal Energy that might possibly have some potential in the future though it is more likely to be exploited in more favourably endowed locations before Uttlesford. This is known as variously as Universal Geothermal Energy (UGE) or 'Deep Heat Mining' (DHM) or Enhanced Geothermal Systems (EGS) and requires very deep bore-holes of 3 to 5 kilometres that potentially offer access to very deep sources of heat (in the case of Uttlesford the 5 km depth temperature is estimated to be around 100ºC - according to a European Map of Estimated Geothermal Resources at 5 km depth developed by Shell International). There are some projects operating in Germany and one is being planned in Ireland, but there are many technical uncertainties.

In contrast however Ground-Coupled Energy is potentially available in practically the whole of the UK including Uttlesford. Ground-Coupled Energy is able to provide heat, hot water, cooling energy, plus preheating and pre-cooling of ventilation air for buildings. Similarly *water coupled energy* is available in Uttlesford provided a body of water is available at the appropriate time of year.

Ambient air-coupled energy is also available everywhere and the technological improvements in heat pump technology - in part stimulated by ground source heat pump development - has made this a potentially useful form of thermal energy in the mild temperate climate of Britain when used appropriately.

The thermal capacity of many soils, ground water and aquifers enables Ground Coupled Energy Storage (also known as Underground Energy Storage) to be considered for inter-seasonal energy storage and has potential in Uttlesford for large buildings or for group/neighbourhood schemes - especially when combined with solar energy or combined heat and power schemes or as thermal energy buffer for wind energy. The ground collectors for ground source heat pumps (GSHPs) can be used for inter-seasonal thermal energy storage if using 'free-cooling' or if the heat pump is also used for cooling in the summer months.

4.1 Ground-Coupled Energy

4.1.1 Definition

During the daylight hours the sun transfers energy to the ground. Much of this is reflected and re-radiated but some is absorbed and stored as low-grade heat in the ground.

Figure 4-1 shows a map of annual average ground temperatures around the UK at a depth of 50 m (below ground level - BGL). From this, map areas in Uttlesford are likely to be suitable for some form of Ground-coupled energy exploitation with the 50m BGL temperature of 11º C.

Ground-coupled energy can be exploited in the following ways: -

- *Direct Ground-Coupling* by the use of Earth Sheltering or underground building[2]
- '*Free cooling'* via ground heat exchanger, bore hole or a water source
- *Pre-heating* or *pre-cooling* of ventilation air via *Earth Tubes* or *Pipes*
- Heating &/or cooling by *Ground Water* or *Surface Water Heat Pump*
- Heating &/or cooling by *Ground Source* or *Ground Collector Heat Pump*

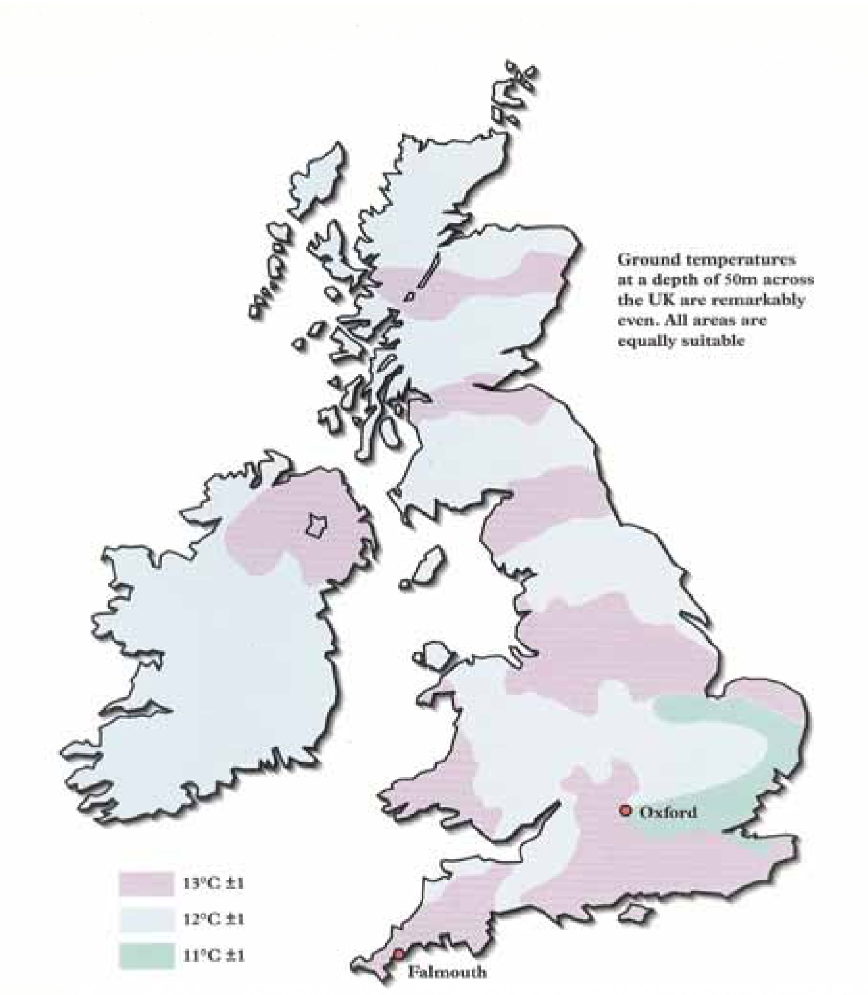

Figure 4-1: Map of ground temperatures around the UK at a depth of 50 m. (Source: Geoscience)

[2] Earth Sheltered design was described in the Section on Passive Solar Energy.

4.2 GROUND-COUPLED FREE-COOLING

This is a method of cooling buildings (usually non domestic buildings to date[3]), which usually involves taking advantage of a water source bore hole or a large body of water[4] and avoids the capital and electricity costs (and noise intrusion) of air conditioning systems.

Cool water from the water source is pumped and circulated through the building either through a radiator type circuit, ventilation system or through the structure itself through under-floor piping[5].

If a water source bore hole is not available, a ground heat exchanger similar to those used with a ground source heat pump (described later) can also be used.

Apart from the electricity[6] required for powering the circulation pump[7] this is a free method of effective cooling - hence its name. As such it can result in very large savings in electricity consumption and in abated CO_2 emissions.

The *Environment Office* (shown in **Figure 4-9**) at the Building Research Establishment at Watford has successfully employed this method of cooling and avoided the use of air conditioning by circulating cooling water from an onsite bore hole through the concrete structure.

Another example is the *Charles Cryer Studio Theatre* in a listed building in Carshalton. One of the reasons for opting for this approach was to avoid external noise from the busy main road. Water from a 50-m deep abstraction bore hole[8] (at a temperature of 10ºC) is circulated through a water-to air-heat exchanger to cool the ventilation air. Then the water is exhausted at a 20-m deep recharge bore hole (soak-away) located 40 m away from the abstraction bore hole.

There are likely to be many opportunities for this method of cooling of non-domestic buildings in Uttlesford. Developers of new non-domestic buildings with a large cooling requirement should be encouraged to consider Ground-coupled free-cooling though it will be necessary to liaise with the Environment Agency for open loop systems.

[3] Cooling has predominantly been mainly a requirement for non-domestic rather than domestic buildings though one of the potential effects of climate change is that of more frequent summer overheating so it may become more important for domestic buildings.
[4] If located near a large body of water such as a lake, stream, river, pond or a specially designed water feature then these may be able to provide a source of 'free cooling'.
[5] Using under-floor piping such as that used in under-floor heating has to be designed and controlled very carefully however as there can be a risk of condensation.
[6] Together with the cost of the borehole and installing the cooling circuit.
[7] However it is important to make sure the circulation pump uses an efficient electric motor otherwise parasitic losses may negate the free energy benefits.
[8] Exhaust water is discharged to a 375 mm dia. 20 m deep recharge bore hole and soak away located 40 m away from the abstraction bore hole.

4.3 EARTH TUBES

The heat sink capacity of sub soil may also be tapped through the use of **Earth Tubes** or **Earth Pipes**[9]. Earth Tubes have been used to cool buildings in hot climates for centuries and some examples in Persia are thought to be 5000 year old.

An Earth Tube or Earth Pipe is a tube buried in the ground to a depth of around 1.8 m or more and which has a grilled (and preferably filtered) inlet some distance away from the building and an inlet into the building's air supply. See **Figures 4-2** and **4-3**. For domestic buildings, Earth Tube diameters ranges from around 150 to 500 mm but larger buildings can have larger diameter Earth Tubes or an array of Earth Tubes.

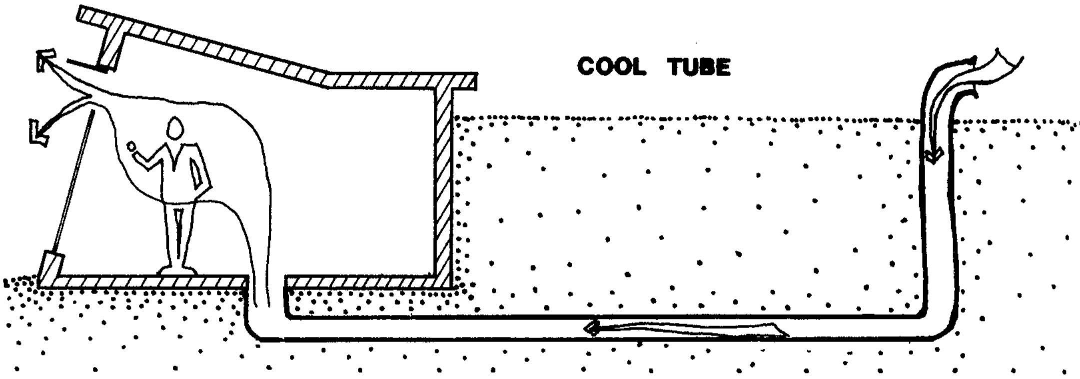

Figure 4-2: Earth Tube/Pipe operating as a Cool Tube for cooling incoming ventilation air. **(**Boyer etal. 1987)

Figure 4-3: Grilled inlet for an Earth Tube/ Pipe. (Altechnica)

[9] Also known as 'Cool Tubes', 'Earth Ducts', 'Earth-Air Exchangers' or 'Ground-to-air-exchangers'.

Such tubes may be used in winter to warm the air introduced to buildings and can be connected to mechanical ventilation and heat recovery units. In summer the tubes can be used to cool the incoming air and in this mode they are sometimes called **Cool Tubes**.

During the times of the year when the soil temperature is cooler than the air flowing through the Tubes, heat will be transferred from the warmer air to the surrounding soil. A large temperature difference may also encourage latent cooling (dehumidification) of the air stream. Generally the difference between summer outside air temperatures and soil temperatures will be greater than that between the interior air temperatures and the soil, facilitating cooling.

Earth Tubes were used in the 1970s and 80s when passive buildings began to be designed and built in North America, are an established technology in many European countries and are widely used in Germany, Austria, Switzerland and France. There have not been many examples of Earth Tubes or Pipes in the UK to date but there are examples where they are used to pre-heat or cool the incoming ventilation air including the *Energy Showcase Super Passive House* project in Herefordshire designed by Altechnica with and for Energy Advisory Associates[10]. The buildings of the *Butterfield Business Park* in Luton are an example of its use for large non-domestic buildings.

Earth Tubes can be linked to mechanical ventilation and heat recovery systems and if appropriately designed they can improve the air quality, which may have health benefits to those with respiratory ailments. In addition Earth Tubes can be employed in combination with wind catchers/cooling towers and/or solar chimneys[11].

Earth Tubes help buildings reduce the heat losses related to ventilation, which become more significant in well-insulated buildings.

Most Earth Tubes systems are custom designed but there are proprietary systems available based on polymer pipes including **Earth Tube Ring** or **Loop** systems (**Figure 4-4**) that can ring around the building a few metres away from the building's walls if ground/garden space is limited. The size and length of Earth Tubes depends on a variety of factors including soil type, depth, building volume, air change rate, but as a rough guide a house with a floor area of 100 m^2 would require an Earth Tube with a diameter of around 200 mm and a length of around 30 m which could take the form of ring around the building. Such a system could potentially raise the incoming air temperature by up to around 9º C in winter and potentially reduce the incoming temperature by up to around 14º C in summer.

Figure 4-4: Example of a proprietary Earth Tube Ring. (Source Rehau)

With appropriately sealed or continuous pipe work, Earth Tubes can be laid at or below the water table, but it is inappropriate to use them on sites that are at risk from flooding, though locating the air inlets at sufficient height above ground level will reduce the vulnerability to minor flooding.

There is likely to be scope for exploiting Earth Tubes for pre-heating or cooling domestic and non-domestic buildings (especially schools and offices) in Uttlesford. It would be more feasible when applied to new buildings when excavating machinery is likely to be on site for digging foundation trenches etc. However, it is a low CO_2 emitting technology that could be retrofitted to existing buildings - particularly those with light weight-low thermal capacity construction when appropriate adjacent land (e.g. garden, lawn, patio, playground, car park, field, playing fields or path) is available.

[10] This project was described in the section on Solar Energy.

[11] Altechnica is also researching hybrid building-integrated Earth Tube-based heating + cooling + ventilation + heat recovery systems that facilitate zero carbon performance.

It is difficult to predict the number of existing households in Uttlesford that could utilise Earth Tubes without knowing the number of households with gardens, but a large proportion of the households could exploit this technology – particularly if they are prone to overheating in the summer months which may otherwise be addressed by introducing CO_2-intensive air conditioning systems.

4.4 GROUND WATER & SURFACE WATER HEAT PUMPS

Where there is a source of water or a large body of water available (such as a spring, aquifer, lake, large pond, water source bore hole, stream, river, water, sewage or factory effluent or underground water course), a potential source of low grade heat and cooling is available.

If water is circulated through a network of pipes (or water to water heat exchangers) in contact with the water source the pipes act like a ground water heat exchanger and in the winter months, low grade heat will be transferred to the heat exchanger and during the summer months, heat is transferred from the heat exchanger to the water source.

Ground water-heat pumps are usually *open loop* systems in which ground water is abstracted at a 'well' or bore-hole at one point, passed through a heat exchanger and then exhausted at a *recharge* 'well' or bore-hole / soakaway at a different point.

Surface water-heat pumps can be *open loop* systems in which surface-water is extracted at one point, passed through a heat exchanger and then exhausted at a different point. Surface water heat pumps can also be *closed loop* systems by utilising a heat exchanger or *'pond-loop collector'* in the water or buried in the sediment of the lake or pond etc.

During the winter months, the low grade heat can be transported to a heat pump which is a device which can ‘pump’ up the temperature of a source of low grade heat to a temperature useful for space heating or hot water provision.

The Heat Pump

One common example of a *heat pump* is the basis of what makes most refrigerators operate. In the case of the refrigerator a *Compression Heat Pump* pumps the heat out of the fridge and in the process, cools its interior. This is achieved by circulating an evaporative fluid through heat exchangers located inside and outside the refrigerator. During its cycle through the circuit, the fluid evaporates at the cooler heat exchanger (known as the *evaporator*) and is then compressed by a *compressor*[12]; the fluid then condenses at the warmer heat exchanger (known as the condenser). After passing through the condenser the fluid then passes through an expansion valve and then back to the evaporator.

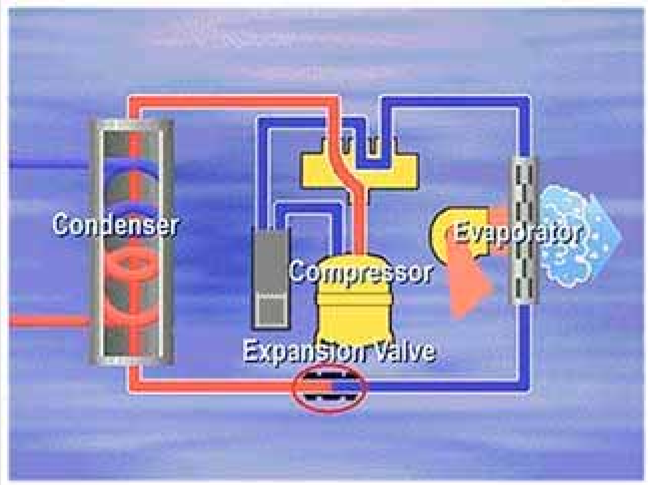

Figure 4-5: Diagram of a Compression type Heat Pump *(Alliant)*

Another form of heat pump, which requires a heat source rather than a compressor, is the *Absorption Heat Pump*. The net effect is the same and in its refrigerator form, it is often known as the *gas powered fridge* or simply *gas fridge*. These are popular when electricity is unavailable or for boats and caravans and the like. Chillers using the waste heat from a CHP unit to fuel an absorption heat pump are an established technology used in Trigen systems. Absorption heat pumps have also been powered by solar heat.

In most circumstances a *Ground Water Source Heat Pump* (GWSHP) or *Ground Source Heat Pump* (GSHP) will utilise a *Compression Heat Pump* and the low grade heated water (after being heated by being circulated through the ground water source heat exchanger) is passed through the evaporator heat exchanger. The condenser heat exchanger then imparts useful heat to the heating and hot water circuit of the building.

If the heat pump is also to be used for cooling, the heat exchangers can be switched from evaporator to condenser mode and vice versa. It has the same performance as air-conditioning but without the same level of noise or capital investment, as the same equipment can be used for both heating and cooling. It might also be possible to use the heat extracted in cooling the building to heat up domestic hot water during the summer. *Air-Source Heat Pumps* (ASHPs) which can extract useful heat from the ambient air (via a fan driven open air heat exchanger) are also becoming available for the UK climate. ASHPs are less expensive than GSHP but are generally less efficient though can be employed when GSHPs are not feasible.

The energy (usually electricity) required to power the heat pump is less than the heat energy output and this relationship is represented by the term *Coefficient of Performance* (C.O.P.) and its value is dependent on the difference in temperature between the low temperature heat source and the heat output from the condenser heat exchangers. C.O.P.s of 3 or 4 or more can be achieved with GWSHPs and GSHPs and WCHPs.

If located inside acoustic housings, heat pumps can be quiet equipment.

Heat Pump Technology is continuously being improved both in terms of more efficient compressors, refrigerants, variable speed operation and higher temperature outputs - offering further reductions in CO_2 emissions.

[12] Usually powered by electricity but can be powered by a heat engine (usually powered by gas but could include other fuels).

To exploit the low grade heat water source, a heat exchanger or heat collector needs to be in contact with the water source and installed in such a way as to be not likely to be damaged.

A flow and return pipe is then needed to transport the low-grade heat from the water source to the heat pump's evaporator heat exchanger in 'heating mode'.

In the 'cooling mode', heat is extracted from within the building and transferred to the water source. In addition to this heat pump cooling mode, when temperature differences are appropriate, the collector can be used in 'free-cooling' mode when water is simply pumped through the circuit without having to be cooled further via the heat pump.

Apart from the heat pump component, the main capital cost is the water source heat exchanger plus the flow and return pipe work. However, because the heat exchanger does not require the ground works that are needed for Ground Source Heat Pumps, Surface Water Heat Pumps tend to have a lower capital cost compared to GSHPs. If the electricity required to power the compressor and circulation pumps is generated from a renewable energy source, then it can be considered a CO_2 free method of heating.

An early experimental example of this type of heat pump (which was using the River Thames as the low-grade heat source) was used for the Royal Festival Hall at the Festival of Britain in 1951.

A more recent example of a surface water source heat pump is located at Beacon Farm in Leicestershire (it uses a large lake as its low grade heat source) and a visitor centre in the Cotswolds is using a pond loop heat exchanger connected to eight heat pumps.

The Hockerton Housing Cooperative in Nottinghamshire employs a specially constructed large lake and a surface water heat pump to provide hot water needs.

A National Trust field centre on the East Anglian coast is using a ground water heat exchanger (a coil of 25 mm diameter plastic pipe) buried a metre deep in salt marsh mud flats in the tidal creek outside the centre. Water is circulated through the piping, which is warmed twice a day by the sea-water during the periods of high tide. The heat is extracted via a heat pump to provide heat for the centre.

Opportunities exist throughout Uttlesford for ground water source and surface water source heat pumps wherever there is an appropriate body of water in close proximity. For new developments, it may also be possible to create a new water source such as a lake, or pond or water feature or to drill a water bore hole that could be used as a water source.

There is scope to retrofit such an installation for heating and cooling an existing building if an appropriate water source is available or is able to be created. It is likely to be more economically viable in rural areas when the normal heating options are propane or oil or electric radiant heating. It also has the advantage of being smoke and emission free at the point of use and the economic benefit of not needing flues or chimneys to be constructed.

4.5 GROUND SOURCE HEAT PUMPS

If a water source is not available, it is still possible take advantage of Ground-coupled energy. **Figure 4-1** shows the ground temperature distribution around the UK.

A Ground Source Heat Pump (GSHP) or Ground Collector Heat Pump[13] involves installing a horizontal or vertical 'ground heat exchanger' or 'collector' from which the heat is extracted from being in contact with the ground. It is a technology that can be applied to both domestic and non-domestic buildings and sizes range from a few kilowatts to megawatt ratings.

It can cut CO_2 emissions significantly when compared to other heating and cooling technologies and the Canadian Climate Change Programme recognises that "*There is unlikely to be a potentially larger mitigating effect on the global warming impact of buildings from any other current, market available technology than from ground source heat pumps.*" It is thought that domestic GSHPs can result in 15% lower CO_2 emissions compared with a gas condensing boiler, 40% reductions compared an oil fired boiler and 60% when compared to a conventional electric heating system.

Apart from the heat pump component, the main capital cost is the ground source heat exchanger or collector plus the flow and return pipe work. At the present time, this approach tends to be more expensive than gas fired boilers, but could be expected to achieve longer operational lifetimes and can provide energy savings. If the electricity required to power the compressor and circulation pumps is generated from a renewable energy source, then it is considered a CO_2 free method of heating.

A horizontal ground heat exchanger involves digging a trench (0.5 m to 2 m depth) and laying the plastic pipe in a horizontal 'U' (can be positioned one above the other in the same trench with backfill in between. Alternatively, one can loop a long flexible plastic pipe into a kind of flat coil (sometimes known as a spiral coil or 'slinky' coil) horizontally along its base[14] (and/or at different levels after partial filling the trench) or upright in a narrow 'cut'.

Some manufacturers have also developed *'compact ground collectors'* which have a similarity to 'flat plate' solar collectors in order to utilise less ground area

The vertical ground heat exchanger involves drilling a bore hole (between 15 m and 180 m deep) into which is installed a long 'U-tube', double 'U-tube', or a concentric co-axial vertical exchanger. If the heat demand is low enough (e.g. around 6 kW_{TH}) it might be possible to use a vertical ground collector based on a single bore hole of around 100 m depth depending on soil type, but UK houses typically often require 2 to 3 boreholes.

[13] They are also frequently described as Geothermal Heat Pumps even though strictly speaking they generally do not use geothermal energy.

[14] The Slinky coil can also be located upright along the trench.

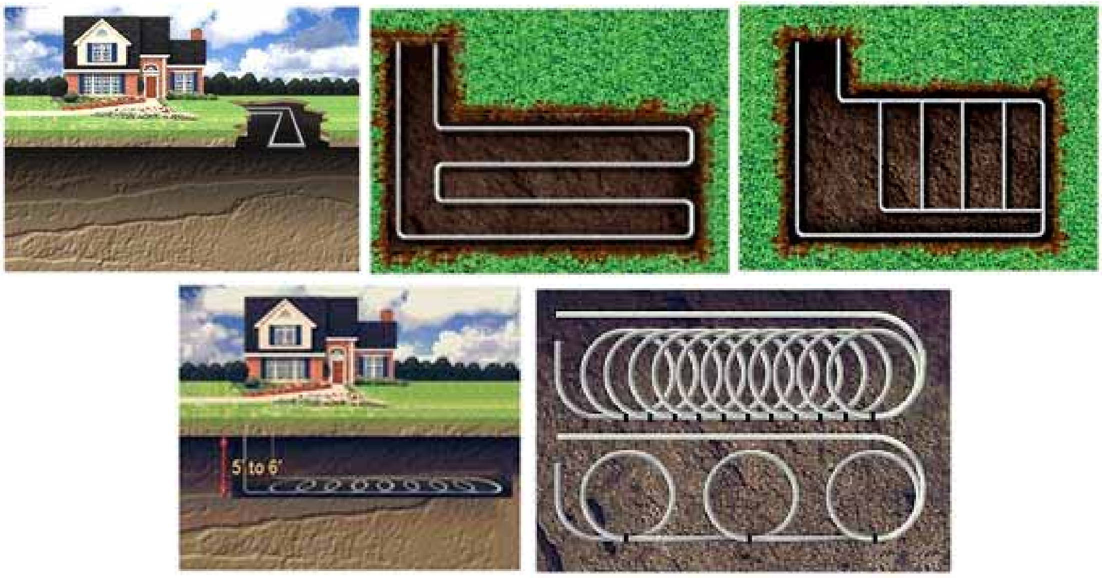

Figure 4-6: *Horizontal Ground Collector Heat Exchangers* for *Ground Source Heat Pump*. Top Middle: Plan view of a 'Series' Collector, Top Right: Plan View of 'Parallel' Collector, Bottom *'Slinky'* Coil Collector. *(Alliant)*

For small scale installations, trench based horizontal collector systems tend to be less expensive than vertical collector (bore hole) systems - mainly because it is an uncommon method of heating in the UK, so bore hole drilling costs for Vertical Ground Collectors are currently high compared to digging a trench or 'cut'.

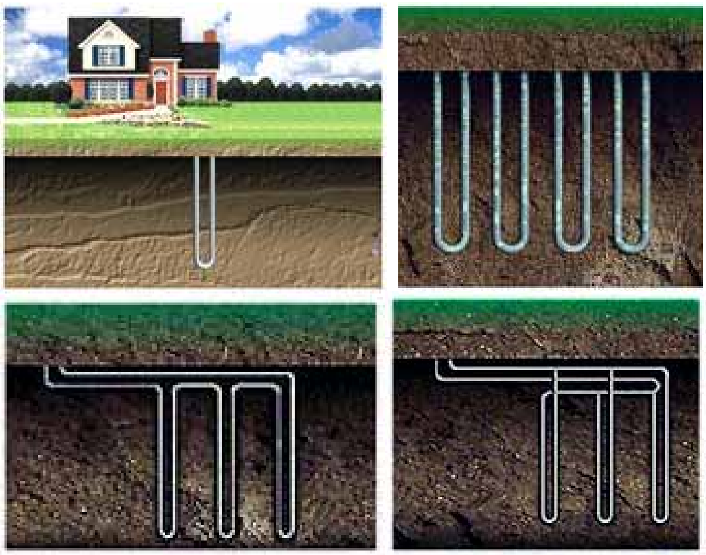

Figure 4-7: Vertical U-Tube Ground / Collector Heat Exchangers for Ground Source Heat Pump. Bottom Left: 'Series' collector, Bottom Right: 'Parallel' Collector. Note: vertical dimension shortened diagrammatically. (Alliant)

However a Vertical Ground Collector (bore hole) takes up much less land area and <u>its location is known into the future</u>. A Vertical Ground Collector is also able to reach the warmer ambient ground temperatures occurring at greater depth.

In the case of Horizontal Ground Collector (trench) based systems, care will be needed to avoid activities taking place on the land above the Horizontal Ground Collector that are likely to damage the pipes and it would normally not be possible to build on the land above the pipes without relocating or protecting them.

Circulating water through these *Ground Collector Heat Exchanger* pipes enables the ambient ground heat to be utilised. The temperature is not sufficient to provide useful heat in the winter months, so it needs to be raised to a level that permits the building to be heated and to heat domestic hot water. This is achieved by using the heat pump.

During the summer months, the water circulating through the ground collector can be used to cool the building either by direct circulation (*'Free-Cooling'*) or via the same heat pump working in a reverse 'cooling' mode. This approach has many of the advantages provided by conventional air conditioning but without the need for noisy wall or roof mounted heat exchangers and can avoid the need for and cost of extra cooling plant.

Ground source heat pumps have been widely used in North America[15], Switzerland[16] and Sweden[17] and in several other European countries but have not been widely used in the UK[18] to date though there is increasing awareness of the technology and there are now many suppliers and installers offering GSHPs. GSHPs are an established technology, over a million have been installed world-wide and they are generating increased interest as a technology for reducing primary energy consumption and CO_2 (and other) emissions. **Figure 4-8** shows a diagram of a ground source heat pump.

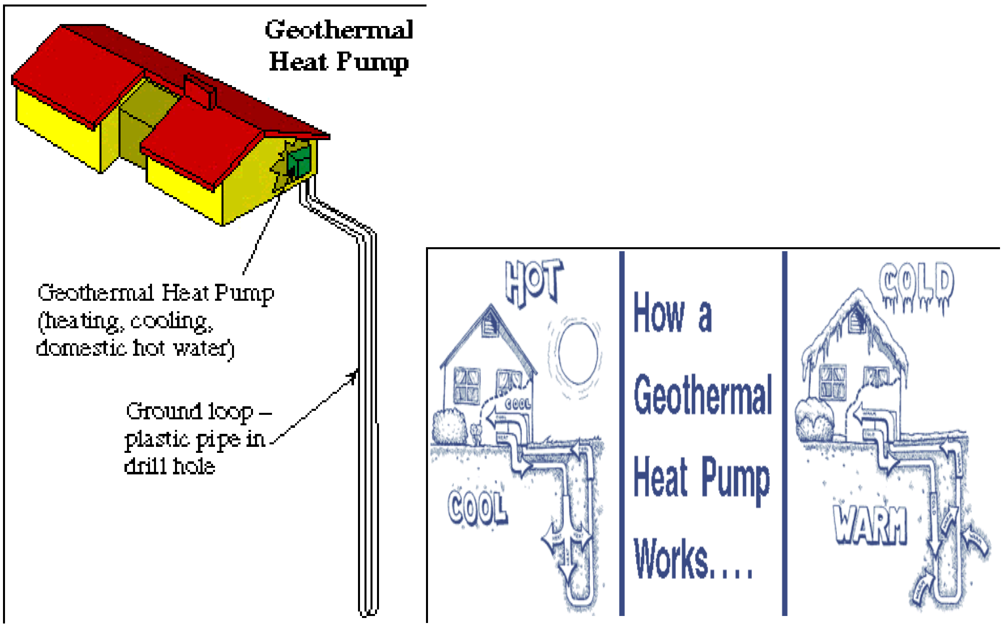

Figure 4-8: The ground source heat pump extracts useful ambient heat from below ground.

The type of space heating system employed may also influence the viability of a GSHP system. The options include radiator based central heating, under floor heating and ducted hot air heating systems. The latter two can be used for cooling and the last can be used for controlled ventilation and heat recovery.

Under floor heating also has the advantage of operating at a lower temperature (can be as low as 30°C to 45°C) compared to conventional radiators (which usually operate at 60°C and 80°C) and the lower the temperature of the space heating delivery system the more efficient and feasible is the heat pump - and the lower the running costs.

[15] Over 600,000 in North America.
[16] In Switzerland GSHP installations are growing at 10% per year.
[17] Over 230,000 in Sweden
[18] It has taken a while to develop the technology for the UK market due to the differing standards and sizes in North America and the UK and also the predominance of single phase electricity supplies compared to other European countries. There are now several systems available, which have been designed for the UK conditions and climate, overcoming these barriers.

Under-floor heating in concrete floors provides some thermal energy storage potential (from the appropriate specific heat capacity or 'thermal mass' characteristics of concrete) which has a made it an attractive option for use with off peak electricity tariffs.

Also, depending on their diameter, the under-floor heating pipes themselves (water has a much higher specific heat capacity than concrete), can provide some thermal energy storage potential when the electricity for the heat pump is provided by off peak tariff electricity or Green Tariff/Private Wire electricity (in combination with Smart Meter-Dynamic Demand Controls), or in nominally non-grid-connected applications using variable on site renewable energy sources such as a wind turbine or photovoltaic generators.

However great care is needed with under-floor heat systems with thermal storage (concrete mass or water) when used in conjunction with passive solar heating as they may not be responsive enough to take advantage of useful passive solar gains.

GSHPs are emission free at the point of use and also avoid the cost and need for a flue or chimney and thus also avoid local smoke impact.

One major advantage of a heat pump is that for every unit of electricity[19] consumed, more useful units of heat energy are produced, usually 2 to 3 times. However, a ground source heat pump can produce 3.5 to 4 times more heat energy compared to the electrical energy consumed. This reduces the CO_2 emissions compared to an electrical resistance heating system and CO_2 emission performance is comparable or superior to gas fuelled heating systems. Of course if the electricity is provided from a clean renewable energy source (either directly or via a 'green tariff' electricity company[20]) then it has the potential to be a net zero CO_2 form of heating.

Bore hole based ground source heat pump system installed costs are between about £800 and £1,500 per kW[21] of thermal power capacity and a trench based system would be between two thirds and three quarters of the bore hole based cost. As the number of installations increase, the cost should fall. In addition, if a large number of installations in a given locality can be carried out together, the bore hole costs can be reduced. In addition, maintenance costs should be low.

About 700 GSHPs have been installed in the UK. These range from installations for individual houses to several multi-bore hole non-domestic installations.

The largest installation in the UK is for a company HQ and warehouse in Croydon and consists of a 30 vertical ground loop collector GSHPs providing heating and cooling.

The largest installation in the world is for 4,000 housing units (each with its own bore hole GSHP) at a US Army base in Louisiana. This project has resulted in a 6.7 MW_E reduction in peak electrical demand and an energy reduction of 2,600 GJ/yr. An additional important benefit is that maintenance call outs have dropped from almost 90 per day in summer to almost zero.

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19 There are also primary engine powered heat pumps but they require liquid or gaseous fuels.

20 There are several options for green tariff electricity but they operate in slightly different ways.

21 Distributed heat pumps (console units) will cost more than a single central heat pump but there will probably be a trade off in the higher cost of these versus the reduction in internal distribution costs for the other systems via ductwork, radiators or underfloor installation.

4.5.1 Pile-Linked Ground Source Heat Pumps

Vertical collector GSHPs would be much less expensive if it were not for the costs involved in drilling the boreholes. One way to reduce these costs is available when pile foundations are required to support a building. In this case, it is possible to include a vertical ground collector with the pile foundation. This approach has been applied to a new building for an Oxford college.

There also so called **Precast Energy Piles** available which consist of precast reinforced concrete piles pre-installed with ground collector loops and connectors. The piles are rammed into their position at the site and the heat collection circuit subsequently connected up and filled.

4.5.2 DX Ground Source Heat Pumps

Another GSHP variant is called the Direct Expansion collector GSHP or **DX-GSHP**. This uses a refrigerant fluid in the ground collector rather than water or brine[22]. This makes for a more efficient form of ground collector, so the collector length can be reduced. However it usually requires a copper collector (for the better conductivity) so it is likely to be expensive due to the currently high costs of copper. There are some new developments in these types of heat pumps that may overcome some of the constraints and improve the COP even further.

DX-GSHPs do not require a circulation pump but can only be used for heat-only applications of heat pumps and cannot be employed for cooling.

[22] Brine refers to a mixture of water and an antifreeze compound.

4.5.3 Opportunities for Ground Source Heat Pumps in Uttlesford

As can be seen from **Figure 4-1**, the land in Uttlesford is largely in the 11ºC region of southern Britain. However ease of drilling may be affected by local subsoil conditions.

In order to ascertain the potential for GSHPs for housing within Uttlesford, estimates of annual energy consumption for space and water heating were derived by using data from the DEFRA Estimates of CO_2 Emissions estimated to be emitted in 2004 and the DTI Energy Trends 07 statistics for Uttlesford. These sources were used to derive domestic space and water heating demand and the energy consumption of gas, oil, solid fuel and Economy 7 electric heating. As the numbers of oil and solid fuel consumers was not provided, the average household space and water heating demand of these fuels has been assumed to be the same as the annual average space and water heating demand for domestic gas of 21.35 MWh/y (for the 19k domestic gas consumers in Uttlesford).

The derived distribution of Uttlesford households in terms of energy/fuel type used and space and water heating demand is shown in **Figure 4-9** and in **Table 4-1** (second column). CO_2 emissions (based CO_2 emission rates of 190 g/kWh for gas, 250 g/kWh for oil, 300 g/kWh for solid fuel and 430 g/kWh for electricity) are shown in the third column and assume boiler efficiency of 85% for gas and 80% for oil and solid fuel boilers. Electric heating is assumed to be 100% efficient.

Figure 4-9 shows the estimated average annual space and water heating demand according to derived heating energy/fuel type together with derived numbers of Uttlesford households per energy/fuel type. **Figure 4-9** and **Table 4-1** also shows the estimated annual electricity consumption to power GSHPs to deliver the estimated annual space and water heating needs based on a seasonal co-efficient of performance (COP) of 3 (higher COP values are achievable when low temperature central heating distributions are used but lower COPs may be achieved if the GSHP systems are retrofitted to radiator based central heating systems).

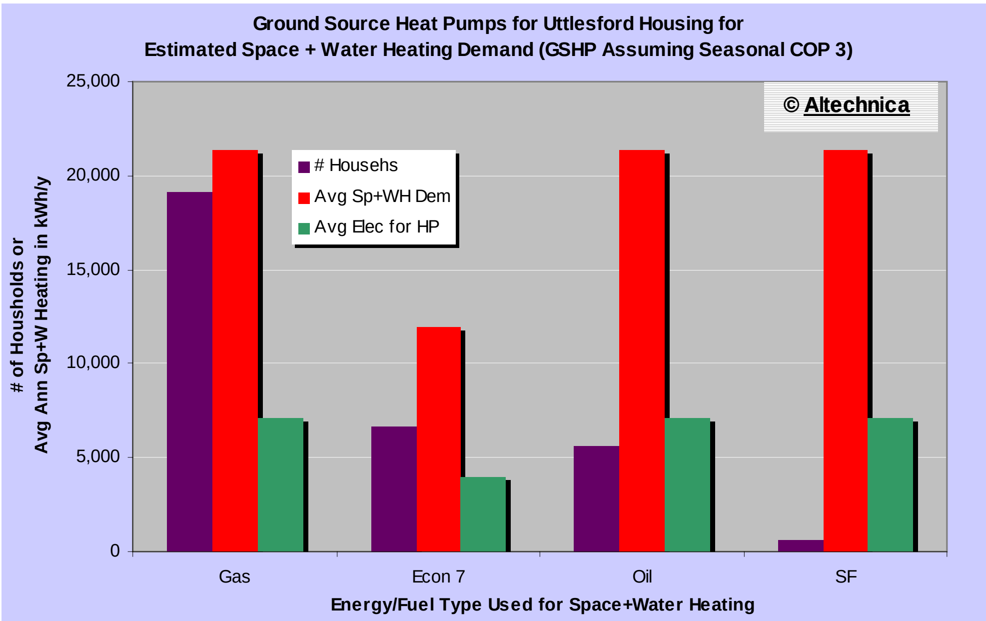

Figure 4-9: Estimated Annual Average Uttlesford Household Space & Water Heating Demand, Numbers of Households & Annual Average GSHP Electricity according to Current Energy/Fuel Type (e.g. gas, Economy 7 electricity, oil or solid fuel).

As can be seen from **Figure 4-9**, GSHPs are estimated to reduce average household energy consumption for space and water heating to 7.12 MWh/y (offsetting gas, oil and solid fuel) and to 3.96 MWh/y (offsetting Economy 7 electric heating).

In terms of the associated average annual CO_2 emissions, the picture is slightly different - as can be seen in **Table 4-1** and **Figure 4-10** which compare the CO_2 emissions from GSHPs (which are assumed to use mains electricity) with the current energy/fuel types offset.

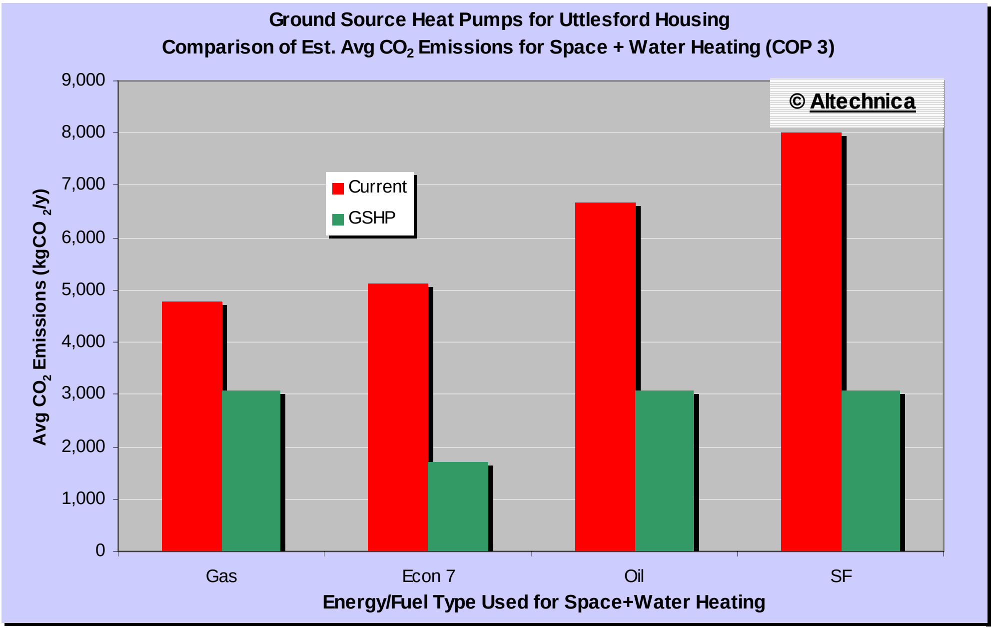

Figure 4-10: Comparison of Estimated Annual Average CO_2 emissions to deliver estimated Annual Average Uttlesford Household Space & Water Heating Demands (according to energy/fuel type). Compares CO_2 emitted from GSHPs (using mains electricity) with Current Energy/Fuel Type.

Figure 4-10 and **Table 4-1** show that the biggest difference in CO_2 emissions in these examples occurs when one displaces solid fuel heating; followed by oil and electric resistance heating (Economy 7).[23]

Figure 4-11 shows the estimated average household CO_2 emissions abatement resulting from displacing the current conventional forms of space and water heating with ground source heat pumps using main electricity.

[23] However this distribution is partly as a result of the fact that the average Economy 7 space and water heating demand estimated is lower than the other average space heating demands and the current mix of fuels used in UK power stations. When the average space heating of Electric heating is the same as the others, the CO_2 abatement may be greatest when GSHPs are displacing electric resistance heating (assuming the solid fuel and oil boilers have good conversion efficiency).

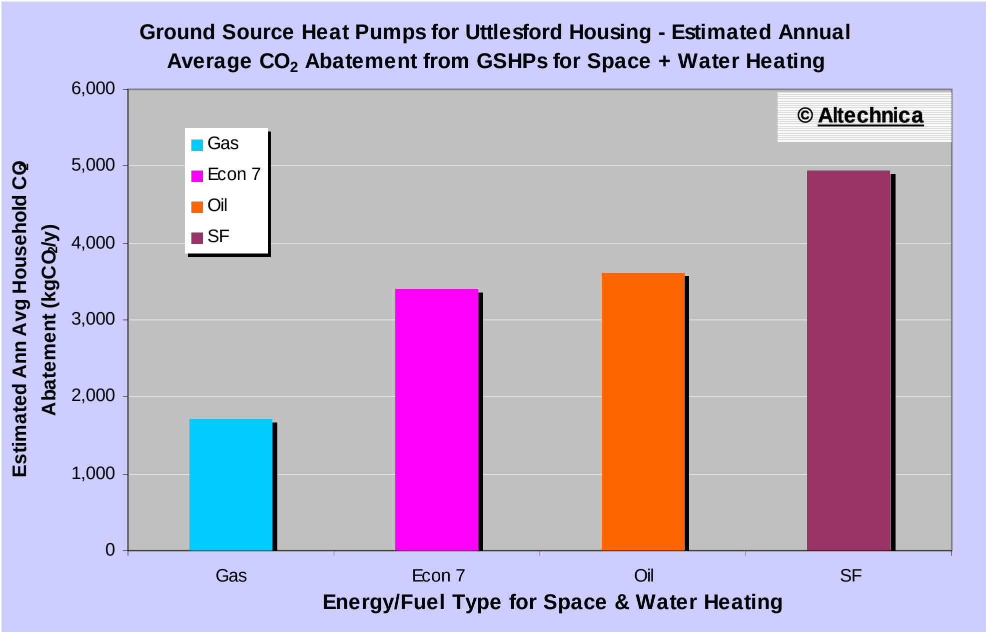

Figure 4-11: Estimated Annual average CO_2 abatement/household by GSHPs displacing space & water heating.

Figure 4-11 and **Table 4-1** show that the annual average CO_2 emissions abatement/household for the Uttlesford households ranges from 1.7 tonnes/y for gas, 3.4 tonnes/y for electric heating, 3.6 tonnes/y for oil-fired heating and 4.9 tonnes CO_2/y for solid fuel heated houses.

Figure 4-12 and **Table 4-1** shows the aggregated CO_2 abatement that is estimated to result if the current conventional forms of space and water heating were displaced by ground source heat pumps using mains electricity for between 10% and 100% of the Uttlesford households.

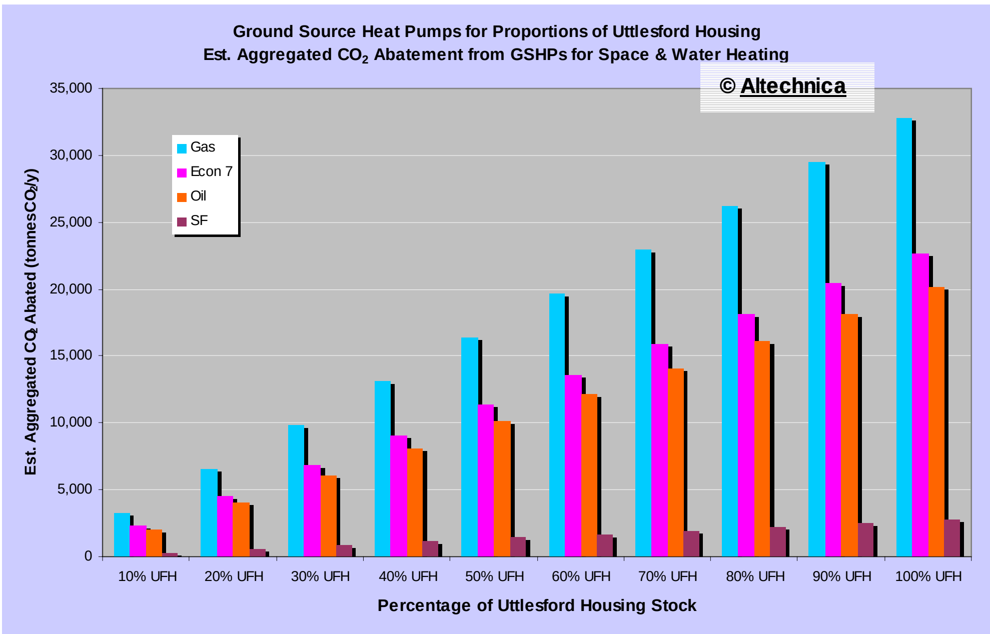

Figure 4-12: Estimated Potential Aggregated CO_2 abatement from switching space & water heating of households in Uttlesford to GSHPs powered by mains electricity.

Figure 4-12 and **Table 4-1** show that the potential aggregated CO_2 emissions that would be abated by switching the space and water heating to GSHPs would be substantial (e.g. for 100% of the households of the order of 78.4 thousand tonnes of CO_2/y - or equivalent to a reduction of CO_2 emissions of the order of 46%). However, it is unlikely that households with gas fuelled central heating systems would be willing to consider switching to a ground source heat pump (until gas prices rise or unless they wish to reduce their CO_2 emissions) and it will probably be more sensible to reduce the demand for space and water heating energy demand by introducing energy efficiency/conservation measures such as increasing insulation etc.

However in the case of non-gas heated households, the potential benefits are greater (though it will also usually make sense to carry out efficiency/conservation measures prior to giving consideration to GSHPs) as the energy/fuel costs tend to be higher and the majority of non-gas households tend to be in rural areas and are likely to have bigger gardens which can potentially accommodate the necessary ground collectors. **Figure 4-13** and **Table 4-1** therefore show the estimated aggregated annual average CO_2 abatement for Uttlesford non-gas households.

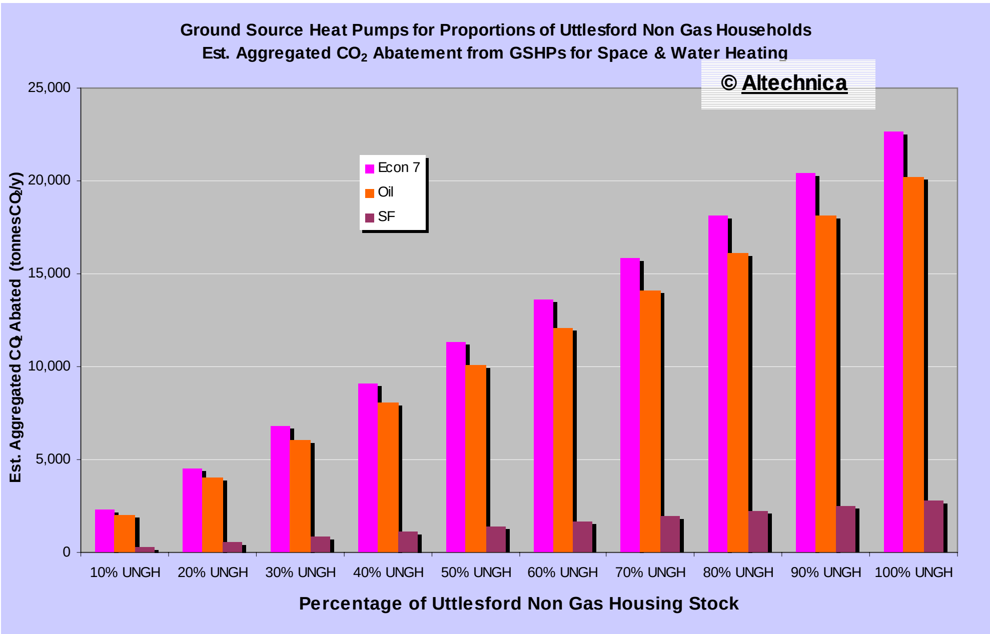

Figure 4-13: Estimated Potential Aggregated CO_2 abatement from switching space & water heating of 10 to 100% of non-gas households in Uttlesford to GSHPs powered by mains electricity.

Figure 4-13 and **Table 4-1** show that substituting GSHPs to provide the space and water heating of the non-gas households would abate an aggregated level of CO_2 emissions of the order of **9,000 tonnes/y for 20%** of the non gas households; **22,000 tonnes/y for 50%**, **32,000 tonnes for 70%** and **45.6 thousand tonnes for all of the non gas households** which would represent a **27% reduction of the Uttlesford total aggregated domestic space and water heating related CO_2 emissions**. This represents the smaller proportion of households in Uttlesford, but the use of GSHPs in these households could result in useful levels in CO_2 abatement within Uttlesford.

If the electricity used to power the GSHP is obtained via a Green Electricity Tariff/Private Wire that utilises CO_2-free or CO_2-neutral renewable energy such as electricity from wind farms[24] or community/town/village/neighbourhood-wind turbines etc, then the GSHPs are able to reduce the CO_2 emissions by an even greater degree. **Table 4-1** and **Figure 4-14** show the estimated proportional aggregated CO_2 emissions that would potentially be abated for 10% to 100% of Uttlesford households. This indicates that of the order of 33,000 tonnes CO_2/y would be abated by 20% of the Uttlesford households; 50 k tonnes CO_2/y for 30%; 83,000 tonnes CO_2/y for 50%; 117,000 tonnes CO_2/y for 70% and around 167,000 tonnes CO_2/y for all the Uttlesford households.

[24] See also wind energy section.

Figure 4-15 shows the estimated proportional aggregated CO_2 abatement for 10% to 100% of the Uttlesford Non-Gas households. This indicates that of the order of **15,000 tonnes CO_2/y** would be abated by **20% of the Uttlesford non-gas households**; **22,000 tonnes CO_2/y for 30%**; **38,000 tonnes CO_2/y for 50%**; **53,000 tonnes CO_2/y for 70%** and around **75,000 tonnes CO_2/y for <u>all non gas households</u>** - which corresponds to around a **45% reduction in CO_2 emissions of the <u>total</u> aggregated household space and water heating in Uttlesford**.

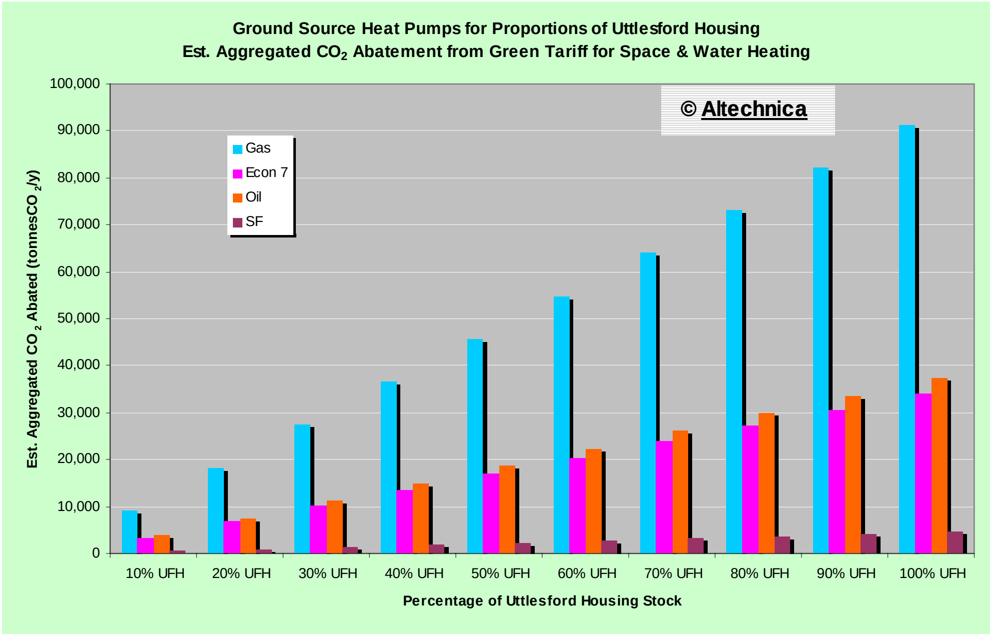

Figure 4-14: Ball park estimates of aggregated CO_2 emissions abatement from CO_2-free Green Tariff powered GSHPs for household space and water heating for 10 to 100% of Uttlesford households. Seasonal COP of 3.

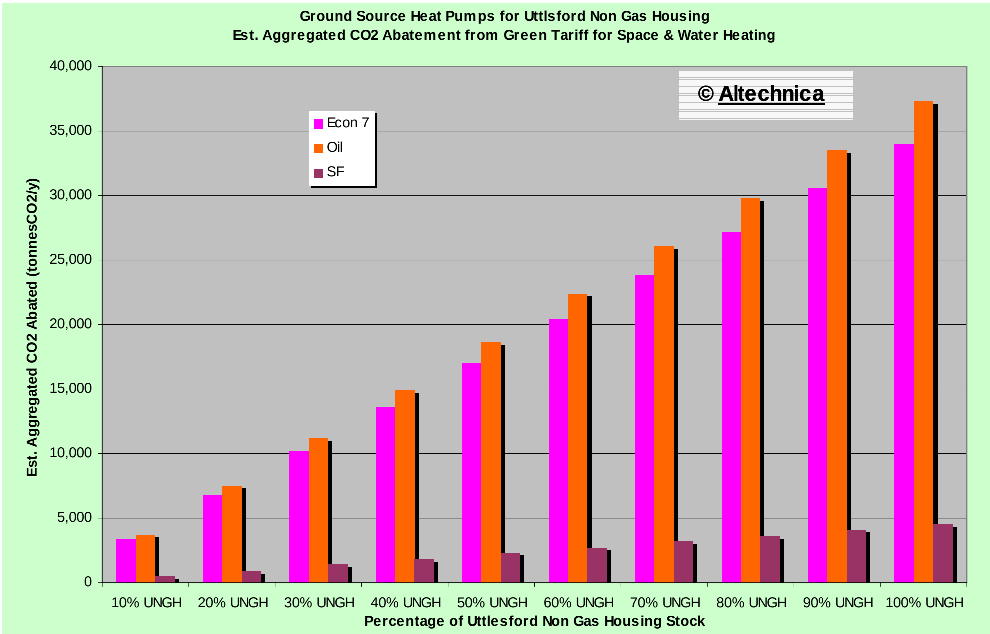

Figure 4-15: Ball park estimates of aggregated CO_2 emissions abatement from CO_2-free Green Tariff powered GSHPs for space and water heating for 10 to 100% of Uttlesford Non-Gas households. Seasonal COP of 3.

Table 4-1: Estimated Annual CO_2 emissions & abated by GSHPs to deliver estimated annual average space &water heating demands for Uttlesford Housing

GSHPs for Households in Uttlesford Provision for Space Heating & Water Heating			COP 3		Based on DEFRA Data				Renewable Green Tariff Electricity	
Energy/ Fuel Used	Derived # househ/ Energy Type	Assumed Avg Sp+WH kWh/y	Assumed Avg Sp+WH CO_2 emiss kg/y	GSHP Avg Elect (COP 3) kWh/y	GSHP Avg Sp+WH CO_2 emiss kg/y	GSHP Avg Sp+WH CO_2 abate kg/y	Aggreg CO2 abate for all Househ GSHP tCO2/y	Aggreg CO2 abate non gas Househ GSHP tCO2/y	Aggreg CO2 abate for all Househ GSHP+GT tCO2/y	Aggreg CO2 abate non gas Househ GSHP+GT tCO2/y
Gas	19,126	21,354	4,773	7,118	3,061	1,713	32,754		91,295	
Econ 7	6,643	11,901	5,117	3,967	1,706	3,412	22,663	22,663	33,994	33,994
Oil	5,586	21,354	6,673	7,118	3,061	3,612	20,179	20,179	37,277	37,277
SF	568	21,354	8,008	7,118	3,061	4,947	2,810	2,810	4,548	4,548
Totals for UF							**78,406**	**45,652**	**167,114**	**75,819**
Perc Reduction							46%	27%	99%	45%

Table 4-2: Estimated number of bore-holes and required ground area for GSHP Vertical Collectors.

GSHPs for Households in Uttlesford ***Provision for Space Heating & Water Heating***				Vertical Collectors			
				(20m/kWth)		(35m/kWth)	
Energy/ Fuel Used	Derived # househ/ Energy Type	Assumed Avg Sp+WH kWh/y	Est. Max Heat Demand kW_{TH}	GSHP # Boreholes 150m/BH #	GSHP V collectors Ground Area m^2	GSHP # Boreholes 150m/BH #	GSHP V collectors Ground Area m^2
Gas	19,126	21,354	9	2	50	3	75
Econ 7	6,643	11,901	5	1	25	2	50
Oil	5,586	21,354	9	2	50	3	75
SF	568	21,354	9	2	50	3	75

Table 4-3: Estimated number of trenches/cuts and required ground area for various types of GSHP Horizontal Collectors.

GSHPs for Households in Uttlesford ***Provision for Space Heating & Water Heating***				Horizontal Flat Collectors		Horizontal Flat Collectors		Horizontal Upright Collectors		Horizontal Upright Slinky Collectors		Horizontal Compact Collectors	
				(50m/kWth)	1.5m deep trench	(65m/kWth)	1.5m deep trench	(80m/kWth)	2.1m deep cuts	(10m/kWth)	2m deep cuts	(2.5Mod/kWth)	3m deep cuts
Energy/ Fuel Used	Derived # househ/ Energy Type	Assumed Avg Sp+WH kWh/y	Max Heat Demand kW_{TH}	GSHP Space + WH 4 Pipe/Trench 10 m L Trenches # Trenches	GSHP Space + WH H collectors Ground Area m^2	GSHP Space + WH 4 Pipe/Trench 10 m L Trenches # Trenches	GSHP Space + WH H collectors Ground Area m^2	GSHP Space + WH 4 Pipe/Cut 10 m L Trenches # Cuts	GSHP Space + WH H collectors Ground Area m^2	GSHP Space + WH # Cuts 10 m L Cuts #	GSHP Space + WH H UR Slinky Ground Area m^2	GSHP Space + WH 1.5mW x 3mH 10.8 m L Cuts # Cuts	GSHP Space + WH H UR CompColl Ground Area m^2
Gas	19,126	21,354	9	12	294	15	383	18	360	3	450	3.8	203
Econ 7	6,643	11,901	5	7	164	9	214	10	200	2	250	2.1	113
Oil	5,586	21,354	9	12	294	15	383	18	360	3	450	3.8	203
SF	568	21,354	9	12	294	15	383	18	360	3	450	3.8	203

For GSHPs to be able to be used will require sufficient ground or garden area being available adjacent to the building to be heated (or cooled). In order to explore the likely amounts of ground required the numbers of collectors and ground collection areas were calculated for vertical (borehole-based) collectors (assuming a maximum depth of 150 m[25]) and a number of horizontal collector variants including horizontal flat collectors (with the collector laid flat-wise at different depths in a 1.5 m deep x 600 mm wide trench); horizontal upright collectors with the collectors positioned horizontally in uptight planes in 300mm wide x 2.1 m deep 'cuts'; horizontal upright 'slinky' type collectors laid in 2 m deep x 300 mm wide cuts; and horizontal upright compact collectors (which resemble unglazed solar collectors) laid in 3 m deep x 300 mm wide cuts.

The actual size of ground collectors will depend on the soil and ground conditions and types of soils, but **Table 4-2** and **Figure 4-16** shows the estimated ball park ground area requirements and numbers of boreholes for vertical collectors to deliver the average household space and water heating requirements - according to East Anglia *10-Year Degree-Days*.

As can be seen from **Table 4-2** and **Figure 4-16**, vertical collectors to deliver the average space and water heating demand range from 1 to 3 bore-holes and 25m² to 75 m² of ground area.

Table 4-3 and **Figure 4-16** shows the estimated ball park ground area requirements and numbers of trenches/cuts for a range of types of horizontal collectors needed to deliver the average household space and water heating requirements.

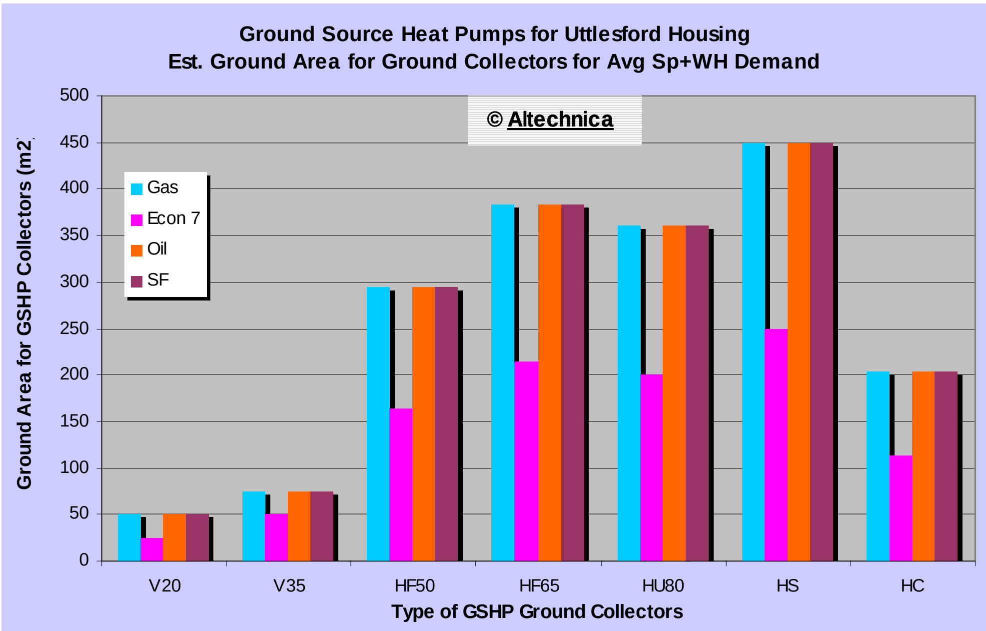

Figure 4-16: Ball Park Estimates of required ground area for vertical and horizontal GSHP Ground Collectors. V20 = 20m/kW$_{TH}$ vertical collector; V35 = 35m/kW$_{TH}$ vertical collector; HF50 = 50m/kW$_{TH}$ horizontal flat collector; HF65 = 65m/kW$_{TH}$ horizontal flat collector; HU80 = 80m/kW$_{TH}$ horizontal upright collector; HS = Horizontal upright 'Slinky'; HC = Horizontal compact collector.

As can be seen from **Table 4-3** and **Figure 4-16**, the ground area needed for the horizontal collectors to deliver the average space water heating demand ranges from 113 m² to 203 m² for the HC collectors, 164 m² to 383 m² for horizontal flat collectors, 200 m² to 360 m² for horizontal upright collectors and 250 m² to 450 m² for horizontal upright 'slinky' collectors.

[25] With appropriate drilling equipment it may be possible to drill 180 m deep bore-holes.

Clearly one of the main limitations to the potential uptake of GSHPs is likely to be the available ground or garden area that can be used to locate the ground collectors. Information on garden sizes for houses in Uttlesford was unavailable, but the aggregate land area used for 'domestic gardens' is given in the Census statistics and dividing this by the number of dwellings in Uttlesford yields an average garden size of the order of 650 m^2. This is larger than the largest average ground collector area requirements, so in principle there is potential to utilise GSHPs throughout Uttlesford - assuming the houses with the biggest gardens also correspond to the houses with the largest demand for space and water heating - though in general the (more expensive[26]) vertical collectors have the smallest impact on ground area.

These ground area estimates are based on the space and water heating energy requirements derived from current energy consumption data. The ground area size requirements could be reduced proportionately according to reductions in demand so it makes good sense to carry out substantial energy efficiency/conservation improvements to make a GSHP more feasible. E.g. reducing the space and water heating demand by 50% will also reduce the ground area by 50% (or potentially more in the case of vertical collectors or in the case of horizontal collectors in long gardens).

However when the houses involved are considered to be difficult to insulate and provided there is sufficient ground area available, the use of GSHPs may be one of the few methods of reducing the CO_2 emissions from this portion of the housing stock.

4.5.4 Monoenergetic & Bivalent GSHPs

The above GSHPs are assumed to be 'Monovalent' which essentially means a GSHP is assumed to provide all of the space and water heating demand. However, another means by which the ground area required can be reduced is to consider the GSHP as so-called 'Monoenergetic' or 'Bivalent' schemes in which the GSHP is not the sole source of heat. This means that the ground collectors are not sized in order to provide all of the peak demand but a proportion of it and a back up heating source provides a top up. This could be a pre-existing boiler or wood stove (Bivalent systems) or electric boiler or immersion heater (Monoenergetic). The Mononergtic/Bivalent GSHP approaches reduce the capital cost of the ground works and collectors (as well as reducing the ground area) but do not necessarily greatly reduce the CO_2 emissions abated if the system is appropriately sized.

In order to explore the effect on ground area requirements, the estimated annual energy requirements for hot water (e.g. 2000kWh/y on the basis of the SAP calculation recommendations for houses with 100 m^2 of floor area) was subtracted from the estimated average demand and the GSHPs were sized accordingly.

Figure 4-17 shows the resulting ground area requirements for the range of horizontal collectors for providing both space heating only (right hand side of the chart) and compares the horizontal collector sizes for space and water heating (on the left hand side of the chart).

[26] The main cost of vertical collectors is the cost of drilling the boreholes, but these can be reduced substantially if a group of bore-holes are required in the same locality/neighbourhood. So some means of co-ordination of the drilling of GSHP bore-holes may help to reduce the costs.

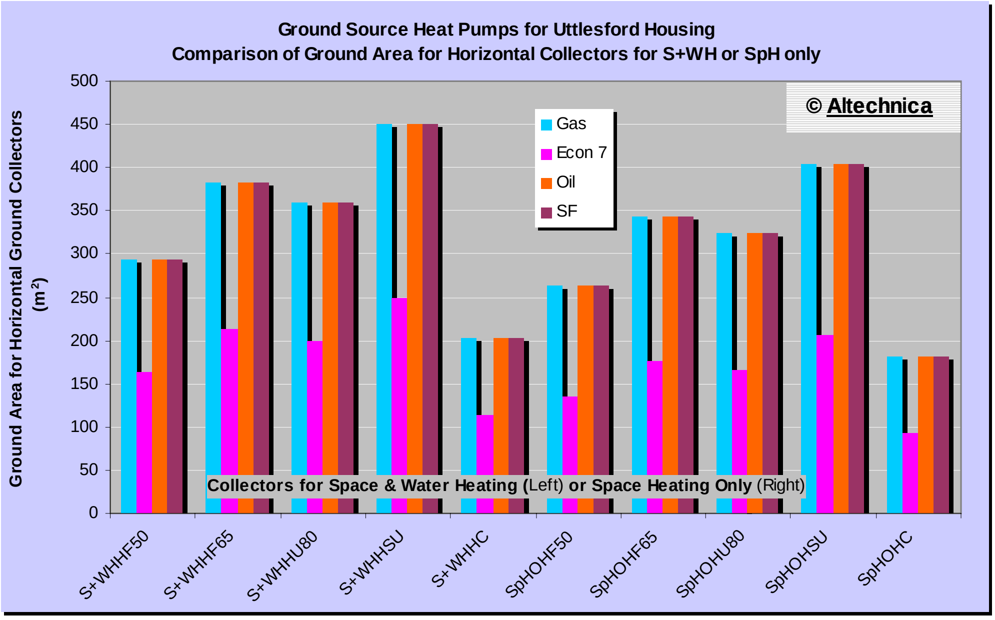

Figure 4-17: Ball Park Estimates of required ground area for horizontal GSHP Ground Collectors showing ground area requirements when providing the estimated average space and water heating (S+WH) needs (left) & when the GSHPs are sized to provide only the estimated space heating (SpH) demand.

Figure 4-17 shows that switching from a GSHP sized to deliver space and water heating to one which delivers only space heating can have a noticeable impact on the ground area requirements for the system. In the case of the horizontal flat collectors, the ground area size range reduces down to 136 to 344 m^2 (from 164 to 383 m^2); for the horizontal upright collectors the ground area reduces down to 166 to 324 m^2 (from 200 to 360 m^2); horizontal upright slinky is reduced down to 207 to 404 m^2 (from 250 to 450 m^2); and the horizontal compact collector size is reduced down to 93 to 182 m^2 (from 113 to203 m^2).

There is likely to be substantial potential for Bivalent GSHPs for the Uttlesford housing and whilst the main potential is likely to be mainly for the non-gas housing, there may be scope to include GSHPs in combination with gas fuelled heating as a means of reducing gas consumption (and CO_2 emissions[27]) or reducing reliance on gas.

However the economics may discourage this approach unless upgrading/replacement of the heating system and or boiler is imminent (or if there is also likely to be a need for space cooling). In which case there may be some merit in sizing the GSHP such that it would ultimately be able to deliver the future space and water heating requirements in Monovalent mode (sized assuming the house has received an insulated upgrade), but it would be operating in Bivalent mode with the existing boiler until the insulated upgrade is completed. This approach would require forward planning and assumes that the householder is intending to remain at the same house into the future. However it would reduce CO_2 emissions and would avoid the risk of over-sizing the GSHP as well as reduce the capital costs involved without foreclosing the benefits of energy efficiency/conservation measures.

If the GSHP system incorporates a controllable thermal store[28] (hot water cylinder sized to contribute to space heating), then the electricity consumed can be at the lower priced Economy Seven tariff rates substantially reducing the running costs.

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[27] Particularly when using CO_2-free Green Tariff or Private Wire electricity to power the heat pumps.

[28] An important means of managing variable renewable energy in the future is likely to utilise thermal stores with 'smart meters' that permit the 'Dynamic Demand Controlled' heat store to be 'heated up' during periods of excess electricity availability.

In the case of new housing in Uttlesford, the opportunities for incorporating GSHPs should be substantial as the required insulation standards reduce the space heating demand such that they can be efficiently supplied by GSHPs, the space heat distribution systems can be designed to be low temperature (which improves the COP and can be either underfloor heating, low temperature radiators or air based/controlled HRV systems) with much reduced ground area requirements needing a much smaller installation and the costs of any related trenching or bore-holes are much reduced as the relevant equipment is likely to be on site anyway. If the project involves piling, then it would also be possible to incorporate ground collector heat exchangers with the piles. This approach has been successfully employed in Austria and in a number of buildings in the UK including a college in Oxford.

There is also substantial potential for utilising GSHPs for both heating and cooling of both new and existing non-domestic buildings in Uttlesford. GSHPs could serve particularly schools, offices, sheltered accommodation, leisure centres and various public buildings. The energy savings and cuts in CO_2 emissions per GSHP will be even greater as the system would be offsetting air conditioning electricity as well as heating energy.

Grants are currently available under the Low Carbon Buildings Programme towards the capital cost of GSHPs (for heating but not cooling) and a number of electricity/energy supply companies offer various support schemes for accredited GSHPs and GSHP equipment is subjected to reduced rates of VAT. GSHPs are also eligible for capital tax allowances.

It still makes sense to apply energy efficiency measures to reduce heating or cooling demand, which would reduce the capital expenditure for the GSHP and reduce the energy consumption and emissions still further.

4.6 Air Source Heat Pumps

In addition to exploiting the low grade heat stored in the ground, it is also possible to use heat pumps to utilise low grade heat contained in the ambient air surrounding the building.

As a result of solar radiation, rain, and heat emitted from the ground or surrounding objects the ambient air also contains useful low grade heat.

This low grade heat can be utilised by means of Air Source Heat Pumps (ASHPs) (**Figure 4-18**) which consist of an air heat exchanger usually located outside the building though can be located within a building if the air can be ducted to the heat pump heat exchanger.

Air Source Heat Pumps are either air to air or air to water devices. The former have been used most widely overseas, but air to water heat pumps are available in the UK from a number of manufacturers and many GSHP installers also offer Air Source Heat Pumps. Air to air heat pumps can be incorporated into warm air heating systems or HRV (Heat Recovery & Ventilation) systems particularly when there is a need for cooling. Air to water heat pumps are well suited to underfloor heating systems but can be used for radiator based heating systems (preferably using larger low temperature radiators for best efficiency) and a number of ASHPs can also supply hot water.

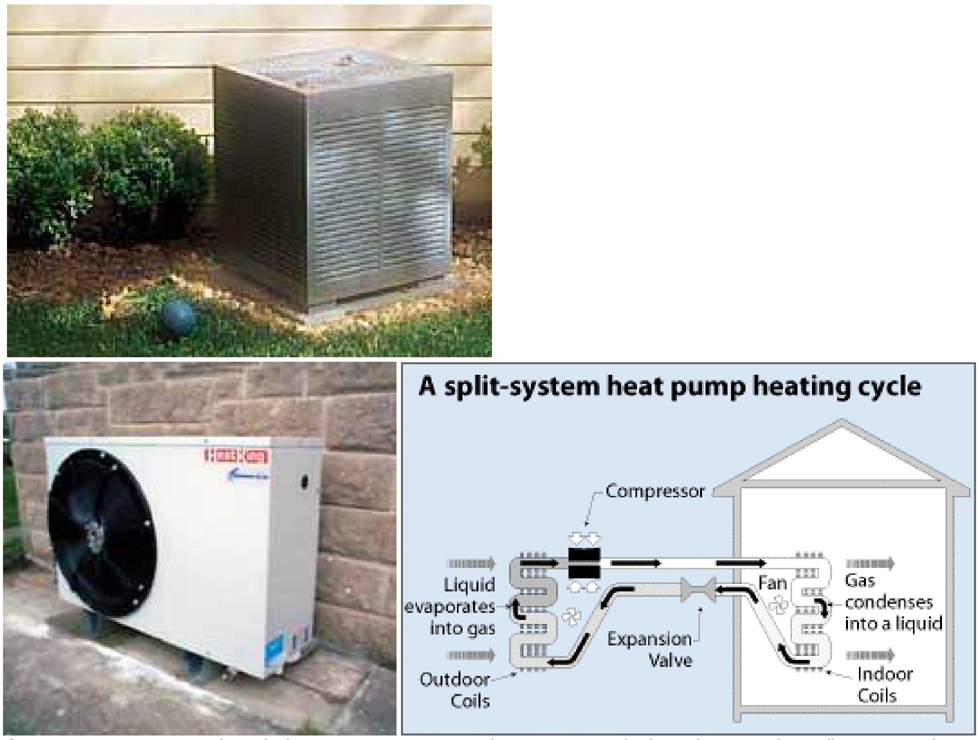

Figure 4-18: Two examples of Air Source Heat Pumps (Source Heat King) & Diagram of a Split System Air Source Heat Pump (Source: EERE)

The evaporator heat exchanger or coil for the ASHP is located outside and requires a fan to blow the ambient air across it in order to extract the low grade heat.

The seasonal performance of ASHPs is more variable than GSHPs because the temperature of ambient air varies much more than ground temperature. However because of the mild temperate climate of the British Isles the average winter air temperature tends to be about 5 degree C, so ASHPs can be successfully employed in the UK and in Uttlesford.

As there are no ground works involved, ASHPs have a much lower capital cost compared to GSHPs, though because of the generally lower winter time COPs, the running costs tend to be higher. They do rely on a fan to blow the ambient air across the outside heat exchanger so need to be properly mounted and acoustically shielded to avoid noise intrusion, but provided the system is installed correctly there should be minimal noise and should be no more noisy than a good quality fridge. The main use for ASHPs for domestic purposes is for space heating and hot water provision and in this mode they can help to reduce CO_2 emissions for those uses. Air source heat pumps can also be used for cooling and there is some concern that, given the current promotion of air conditioners, they could be used as summer air conditioners (though probably more efficient than conventional domestic air conditioners) and in this situation they could potentially increase CO_2 emissions, so they do need to be used appropriately. GSHP systems can also be used for cooling (either non heat pump 'free-cooling' or heat pump cooling) but unlike the ASHPs the extracted heat is not 'dumped' into the surrounding ambient air[29] but stored in the ground and so can 'help' the winter performance of the GSHPs by 'recharging' the ground with extra heat.

Historically ASHPs were problematic, especially at low temperatures, but there have been considerable improvements in performance mainly attributable to newer refrigerants, more efficient compressors and inverter based variable speed drives (VSD)[30].

One of the problems that used to be experienced with ASHPs was that of frosting up of the outside heat exchanger at freezing temperatures. This required heating elements to defrost the exchanger - which reduced the efficiency and performance at these temperatures. Modern ASHPs can be utilised all year round with ambient temperatures between -25 ºC and + 35 ºC.

ASHPs are either 'Split Systems' - in which one coil or heat exchanger is indoors and one is outdoors - or 'Packaged Systems' in which both coils/exchangers and fan are located outdoors.

[29] There are some types of ASHPs that can use the extracted heat to heat up hot water which helps to mitigate this potential disadvantage of ASHPs.

[30] Also known as VRV (Variable Refrigerant Volume) and VRF (Variable Refrigerant Flow).

4.6.1 Opportunities for Air Source Heat Pumps in Uttlesford

Estimates of the potential for ASHPs for housing within Uttlesford was based on the same annual energy consumption for space and water heating values as those that were used for estimating the potential yields for GSHPs.

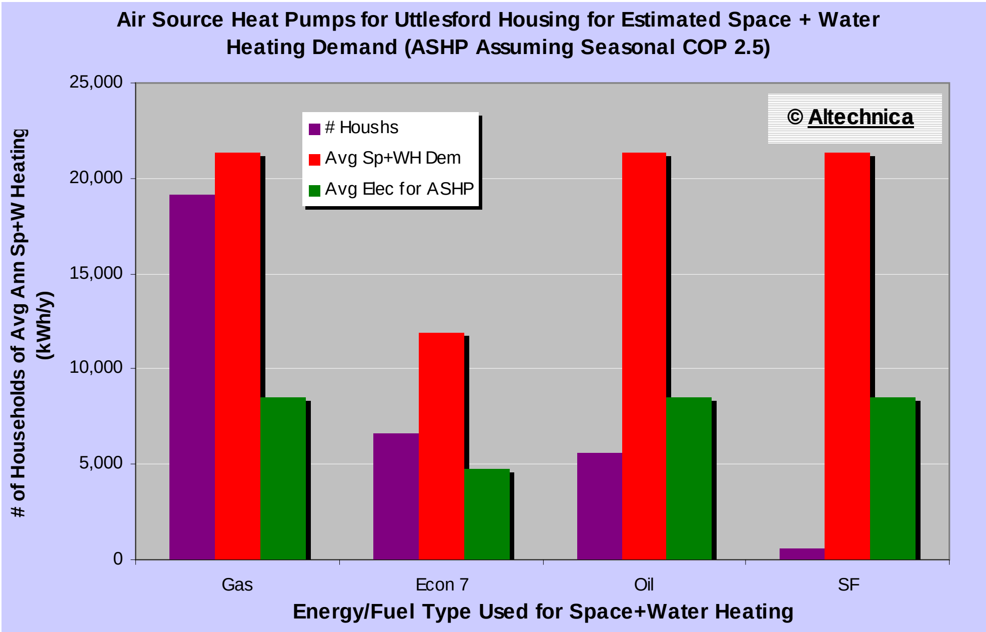

Figure 4-19: Estimated Annual Average Uttlesford Household Space & Water Heating Demand, Numbers of Households/energy type & Annual Average ASHP Electricity according to Current Energy/Fuel Type offset (e.g. gas, Economy 7 electricity, oil or solid fuel).

Figure 4-19 shows the estimated average annual space and water heating demand according to the derived heating energy/fuel type together with derived numbers of Uttlesford households per energy/fuel type. **Figure 4-19** also shows the estimated annual electricity consumption to power ASHPs to deliver the estimated annual space and water heating needs based on a seasonal co-efficient of performance (COP) of 2.5. Higher COP values are achievable when low temperature central heating distributions are used but lower COPs may be achieved if the ASHP systems are retrofitted to radiator based central heating systems.

As can be seen from **Figure 4-19**, ASHPs are estimated to reduce average household energy consumption for space and water heating from 21.3 MWh/y to 8.54 MWh/y (for gas, oil and solid fuel) and from 11.9 MWh/y to 4.76 MWh/y (for Economy 7 electric heating).

Figure 4-20 compares the CO_2 emissions from ASHPs (which are assumed to use mains electricity) with the current energy/fuel types.

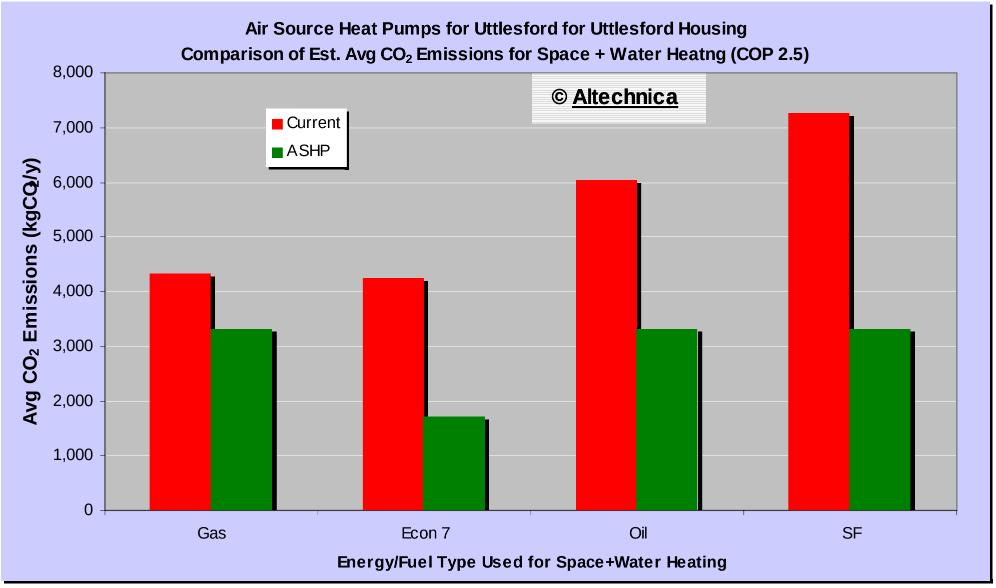

Figure 4-29: Comparison of Estimated Annual Average CO_2 emissions to deliver estimated Annual Average Uttlesford Household Space & Water Heating Demands (according to energy/fuel type offset). Compares CO_2 emitted from ASHPs (using mains electricity) with Current Energy/Fuel Type.

Figure 4-29, and **Figure 4-30** show that the biggest difference in CO_2 emissions (emitted to provide average space and water heating demands) in these examples occurs when one displaces solid fuel heating followed by oil and electric resistance heating (Economy 7).[31]

Figure 4-30 shows the estimated average household CO_2 abatement resulting from displacing the current conventional forms of space and water heating with air source heat pumps using main electricity.

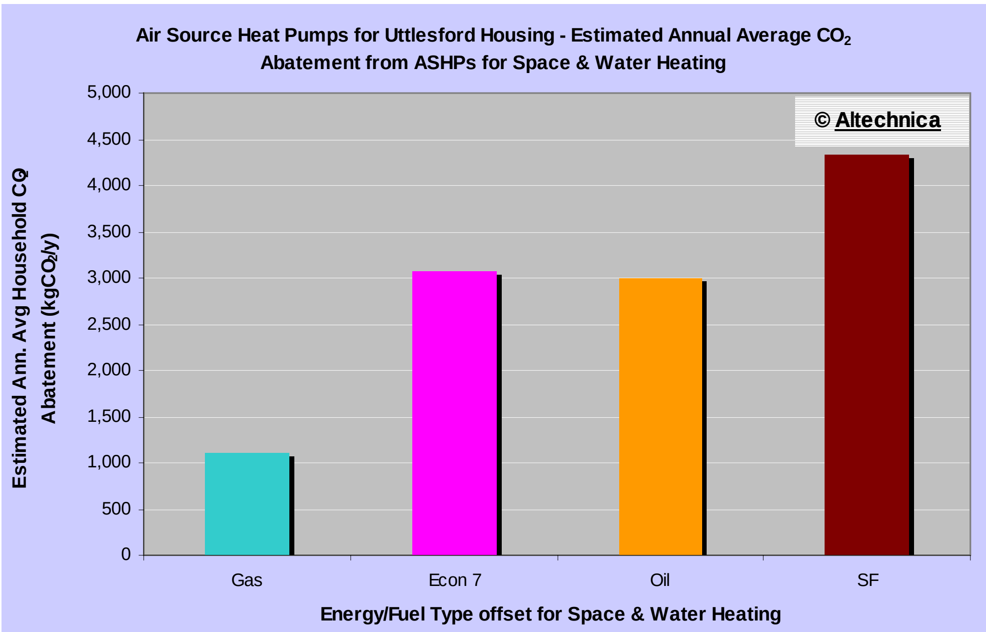

Figure 4-30: Estimated annual average CO_2 abatement/household from ASHPs displacing space & water heating.

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[31] However this distribution is partly as a result of the fact that the average Economy 7 space and water heating demand estimated is lower than the other average space heating demands and the mix of fuels used in UK power stations. When the average space heating of Electric heating is the same as the others, the CO_2 abatement may be greatest when GSHPs are displacing electric resistance heating (assuming the solid fuel and oil boilers have good conversion efficiencies).

Figure 4-30 shows that the annual average CO_2 emissions abatement/household for the Uttlesford households based on these assumptions ranges from 1.1 tonnes for gas, 3.07 tonnes for electric heating, 3 tonnes for oil-fired heating and 4.3 tonnes CO_2/y for solid fuel heated houses.

Figure 4-31 shows the aggregated CO_2 abatement that is estimated for air source heat pumps (using mains electricity) for between 10% and 100% of the Uttlesford households.

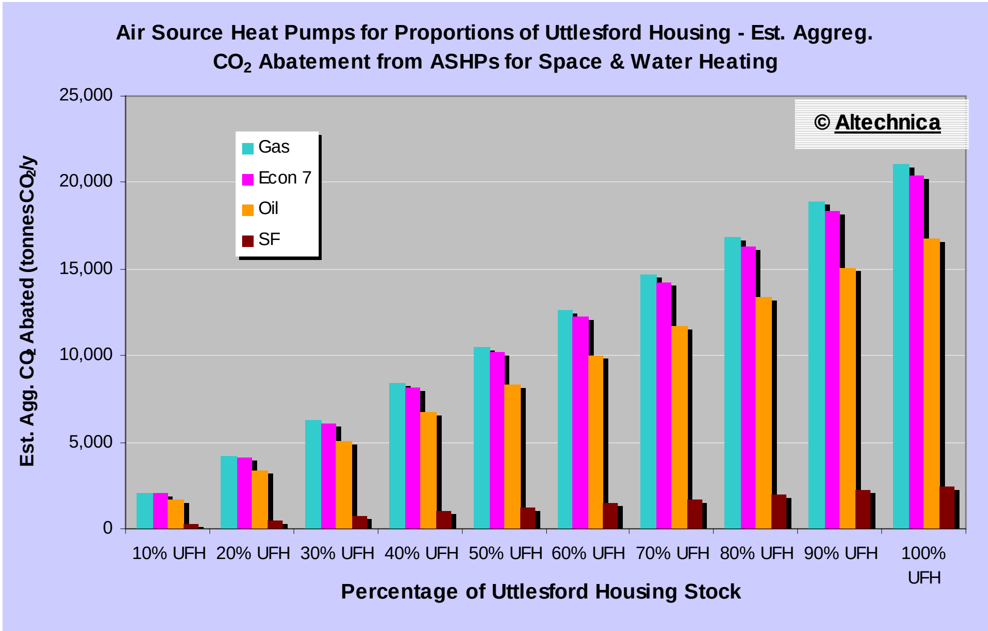

Figure 4-31: Estimated Potential Aggregated CO_2 abatement from switching space & water heating of households in Uttlesford to ASHPs powered by mains electricity.

Figure 4-31 shows that the potential aggregated CO_2 emissions that would be abated by switching the space and water heating to ASHPs (e.g. for 100% of the households of the order of 60 thousand tonnes of CO_2/y or equivalent to a reduction of CO_2 emissions of the order of 36%).

However in the case of non gas heated households the potential benefits are greater (though it will also usually make sense to carry out efficiency/conservation measures prior to giving consideration to ASHPs) as the energy/fuel costs tend to be higher. **Figure 4-32** shows the estimated aggregated annual average CO_2 abatement for Uttlesford non-gas households.

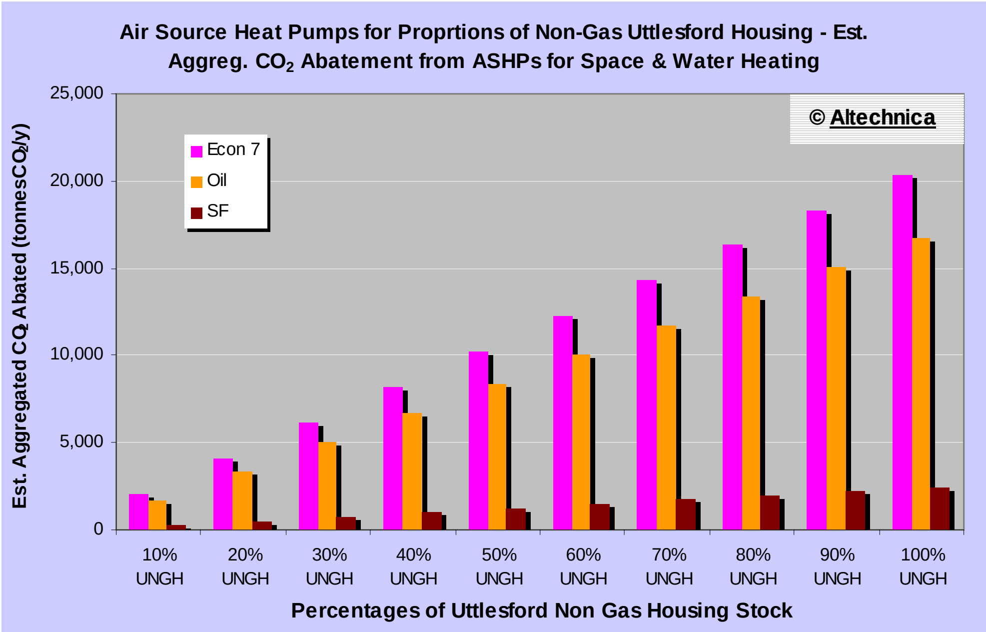

Figure 4-32: Estimated Potential Aggregated CO_2 abatement from switching space & water heating of 10 to 100% of non-gas households in Uttlesford to ASHPs powered by mains electricity.

Figure 4-32 shows that substituting ASHPs to provide the space and water heating of the non-gas households would abate of the order of **7,900 tonnes/y for 20%** of the non gas households; **19.800 tonnes/y for 50%**, **27.7 k tonnes for 70%** and **39,600 tonnesCO_2/y for all of the non gas households** which would represent a **23% reduction of the Uttlesford total aggregated domestic space and water heating related CO_2 emissions**.

If the electricity used to power the ASHP is obtained via a Green Electricity Tariff/Private Wire that utilises CO_2-free or CO_2-neutral renewable energy such as electricity, then the ASHPs are able to reduce the CO_2 emissions by an even greater degree. **Figure 4-33** shows the estimated proportional aggregated CO_2 emissions that would potentially be abated for 10% to 100% of Uttlesford households. This indicates that of the order of 33 k tonnes CO_2/y would be abated by 20% of the Uttlesford households; 50 k tonnes CO_2/y for 30%; 83 k tonnes CO_2/y for 50%; 117 k tonnes CO_2/y for 70% and around 167,000 tonnes CO_2/y for all the Uttlesford households.

Figure 4-34 shows the estimated proportional aggregated CO_2 abatement for 10% to 100% of the Uttlesford non-gas households. This indicates that of the order of **15.000 tonnes CO_2/y** would be abated by **20% of the Uttlesford non-gas households**; **22 k tonnes CO_2/y for 30%**; **38,000 tonnes CO_2/y for 50%**; **53,000 tonnes CO_2/y for 70%** and around **75,000 tonnes CO_2/y for all non gas households** - which corresponds to around a **45% reduction in CO_2 emissions for the total aggregated household space and water heating in Uttlesford**.

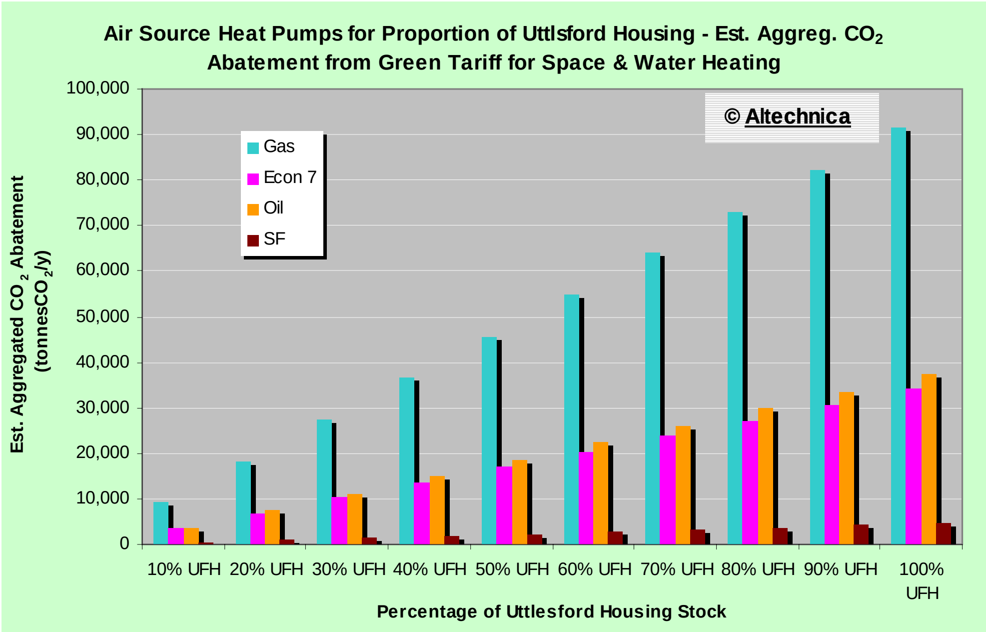

Figure 4-33: Ball park estimates of aggregated CO_2 emissions abatement from CO_2-free Green Tariff Powered ASHPs for household space and water heating for 10 to 100% of Uttlesford households. Seasonal COP of 2.5.

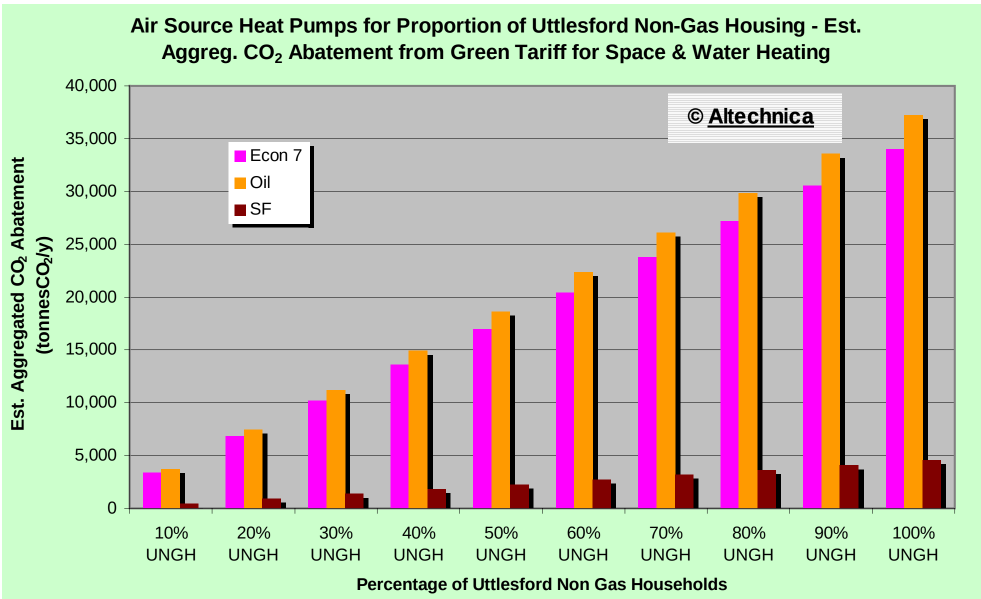

Figure 4-34: Ball park estimates of aggregated CO_2 emissions abatement from CO_2-free Green Tariff Powered ASHPs for space and water heating for 10 to 100% of Uttlesford Non Gas households. Seasonal COP of 3.

There is considerable potential for the use of ASHPs for domestic buildings in Uttlesford, particularly the non-gas buildings with little adjacent ground available for use with GSHPs. ASHPs could also have a role to play in reducing the CO_2 emissions of listed buildings though unless the space and water heating demand is low, ASHPs are likely to be operating in Monoenergetic or Bivalent mode as in general ASHPs tend not to have rated outputs above around $10kW_{TH}$ - though 100 kW_{TH} installations have been carried out.

If the ASHP householders also sign up to CO_2-neutral Green Tariff electricity or join a CO_2-neutral Private Wire scheme, considerable CO_2 emissions savings could be achieved in the Uttlesford housing stock.

It will be preferable to include ASHPs as part of energy efficient upgrades to get the best performance from ASHPs and to reduce the likelihood of their being used as 'air-conditioning' as this could potentially neutralise the CO_2 emissions abated in heating mode.

Compact ASHP based water heaters are also becoming available and these could have substantial potential in Uttlesford, particularly where it is difficult to consider solar water heating systems but they could also be packaged with solar water heating systems and provide the low carbon back-up heat source.

4.7 '*Solar Road*' Technology or Solar-Assisted Ground Coupled Energy

A Ground-Coupled Energy technology - which is strictly a form of solar energy utilisation - is being investigated in the Netherlands, Germany, Switzerland. USA and in the UK. This is an inter-seasonal technology that consists of embedding pipes in a road and water or a brine mixture is circulated through them, which then warms up during the summer months and provides a source of heat. In the Dutch climate, one kilometre of road is predicted to be able to heat about 100 houses[32].

A second benefit claimed for this concept is that it can reduce the temperature-induced wear on the structural performance of roads and extend the life of the road surface.

There are two main types of these asphalt based 'Solar-Assisted Ground Coupled Energy Systems'.

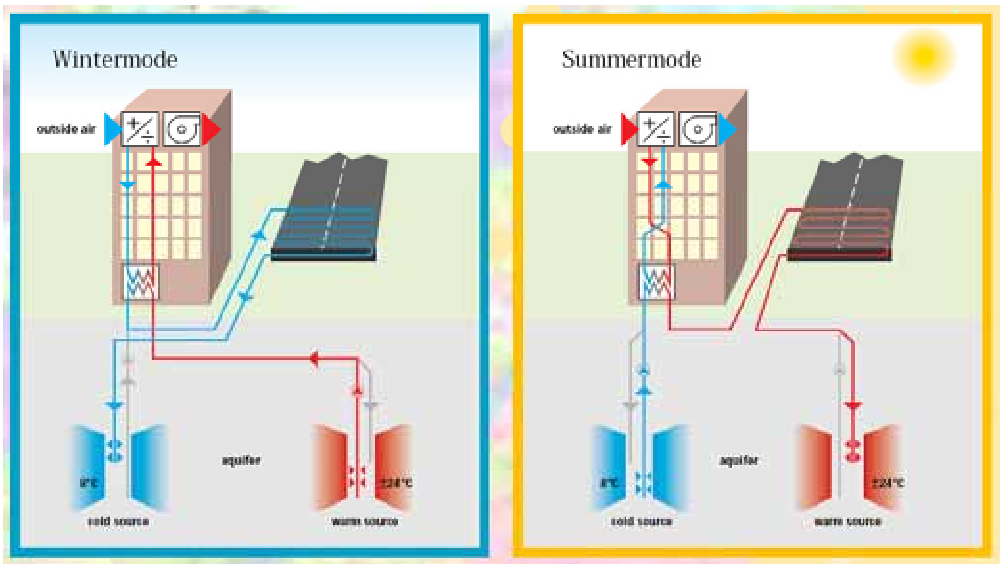

Figure 4-35: Diagram of the *Road Energy System* using roads for solar-assisted ground coupled energy.
Source: Ooms

One system known as the *Road Energy System* (**Figure 4-35** and **4-36**) uses two aquifer heat stores (one to store heat and the other to store 'coolth'), solar heat is collected from the roads in the summer months and stored in the heat store. In the summer, heat is also extracted from buildings and also stored in the aquifer heat store and coolth is transferred to the buildings. In the winter, heat is taken from the heat store to provide heat (with heat pumps as necessary) for the buildings and during freezing weather heat is also circulated through the road surface to prevent ice building up and then transferred to the coolth store. This latter feature has clear safety benefits and if appropriately designed can potentially avoid/minimise the 'salting or roads' which has environmental and cost saving benefits.

[32] This assumed 7,000 kWh/yr. per house.

Figure 4-36: Exampl;es of the *Road Energy System* + interseasonal energy storage. Heating 70 'care houses' (left) and keeping a Dutch road ice free using the roads as solar collectors (right) . Source Ooms

Road Energy Systems have been installed in a number of projects in the Netherlands, including various building complexes heated and cooled by 2200 m² of roads, car parks and pavement; an office heated and cooled by a 450 m² car park; a bridge in Rotterdam maintained ice free with 10000 m² of collectors/exchangers; 70 'care houses' heated by 850 m² of adjacent road (**Figure 4-36**), a Belgian apartment building heated and cooled by 700 m² of adjacent road; and an office in Scotland heated by a 500 m² car park.

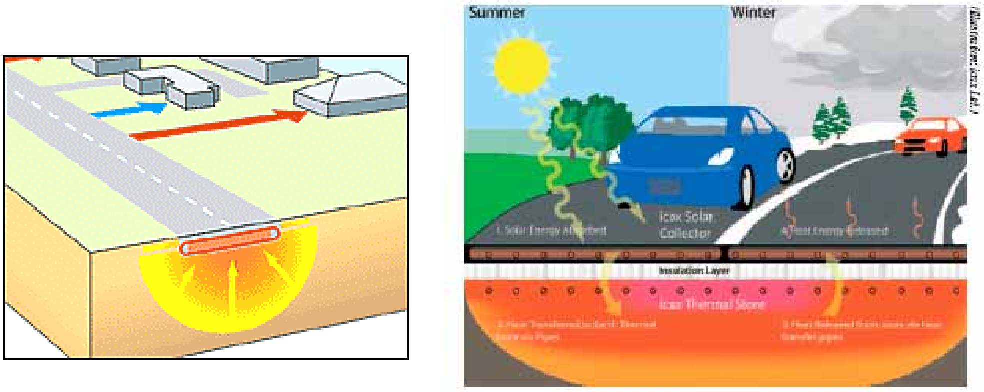

Figure 4-37: The ICAX IHT sandwich type systm for using roads for solar-assisted ground coupled energy. Source ICAX

The other main asphalt based Solar-Assisted Ground Coupled Energy System is a British development (ICAX) based on a sandwich form of construction for the road or car park/play ground (**Figure 4-37** and **4-38**). The lowest layer of the 'sandwich' is an inter-seasonal heat store, which uses the thermal storage capacity of the ground below the road. Insulation forms the next layer up of the sandwich and the top layer is the 'solar collector' embedded within the asphalt covering of the road.

Figure 4-38: The ICAX IHT sandwich type systm for using a playground for solar-assisted ground coupled energy for heating a school in Hertfordshire. Source ICAX Ltd

The sandwich based IHT[33] system from ICAX Ltd has been installed on a stretch of motorway services on the M1 motorway (**Figure 4-37**) and performance has been encouraging. It has also recently been installed in a school in Hertfordshire (**Figure 4-38**) in which the school play ground acts as the solar-ground coupled collector and the heat store is located under the school building in this case. When heat is required for the school it is transferred to the heat distribution system or via heat pumps depending on temperature required. Because the heat source for the heat pump is kept warm in the heat store, the heat pumps can achieve higher COPs than conventional GSHPs thus reducing the electricity consumption, running costs and the CO_2 emissions.

4.7.1 Opportunities for Asphalt-Based Solar-Assisted Ground Coupled Energy Systems (ASAGES) in Uttlesford

The aggregated road area provided in the January 2005 Land Use Statistics for Uttlesford indicate some 7.84 million square metres of road surface.

If we assume an overall solar collection efficiency of 10%, and if 10% of the Uttlesford road area was converted to Solar-Assisted Ground Coupled Energy Systems, then the ball-park estimates indicate that we could expect that some 3,360 (around 12%) of the Uttlesford households could be supplied with space and water heating based on the assumed current average annual demand of 21 MWh/y. If the average annual space and water heating demand was reduced to 10 MWh/y, then using 10% of the Uttlesford road area would supply some 7,000 households or around 26% of Uttlesford households. These ball park estimates would need to be confirmed, but the energy delivered will result in lower CO_2 emissions compared to GSHPs as COPs greater than 3 should be achievable.

To see how many households could be heated by the current town centre car parks in Uttlesford if they were installed with ASAGESs, ball park estimates were made using the

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[33] 'Inter-seasonal Heat Transfer' (IHT)

above approach and (depending on the car parking density[34]) which indicate that we could expect that between 100 and 140[35] of the Uttlesford households could be supplied with space and water heating based on the assumed current average annual demand of 21 MWh/y. If the average annual space and water heating demand was reduced to 10 MWh/y, then the town centre car parks might be able to supply between 210 and 310 households. Other private car parks/paved areas/terraces/play grounds could also potentially be employed for this purpose.

If these estimates are correct, then this road/car park based technology would seem to have promise in Uttlesford as it offers potential to complement conventional GSHPs and ASHPs and offers scope for group scale schemes and economies of scale benefits. Subject to highways authorities being amenable, ASGESs would also appear to offer a potential means of reducing the CO_2 emissions for difficult to heat buildings or Listed Buildings within Uttlesford that are located adjacent to appropriate roads etc.

This technology appears to have proven viable in the Netherlands, so it would seem to have potential in Uttlesford, at least as an alternative form of solar water heating. Large car park areas could potentially provide useful amounts of hot water. Such heat sources could be used to improve the performance of heat pump technology.

4.8 ATES & BTES Ground Coupled Energy Storage

Ground Coupled Energy Storage also known as Underground Thermal Energy Storage (UTES) and based on Aquifer Thermal Energy Storage (ATES) or Borehole Thermal Energy Storage (BTES) are also able to take advantage of the thermal capacity of aquifers, ground water or the ground to achieve effective inter-seasonal thermal energy storage for heat or 'coolth' for cooling and heating of large buildings or groups of buildings.

These systems enable buildings to be cooled without air conditioning/chillers and some have apparently achieved a 75% reduction in electricity bills and with a claimed five year pay back on investment. In the summer time, the UTES systems can take coolth out of the coolth store and transfer into the buildings. Heat is also removed from buildings in the summer time and is then stored in the UTES heat store for retrieval to heat the building in the winter (with or without heat pumps depending on temperature needs).

Such systems have also been employed for large scale inter-seasonal solar schemes in Scandinavia. When used with district scale combined heat and power schemes they can improve the viability of such schemes as they can then generate electricity during the most profitable periods and are no longer tied to follow heat demand which can limit the effectiveness of CHP systems without thermal energy storage. Such systems can also be used to absorb excess energy from wind turbines

ATES systems use natural water saturated and permeable underground layers (aquifers) as a thermal storage medium. **Figure 4-39** shows a diagram of an ATES system.

[34] Information on land area allocated for the car parks was not available, so the number car parking bays per car park was used to infer car park land area using the AJ Metric Handbook parking bay guidance - which indicates between 18 m^2/car and 26 m^2/car (both including a 6.1 m wide clear zone) depending on car park layout.
[35] These estimates have not included improvements in COP, so it is likely that many more households could be supplied if that was taken into account.

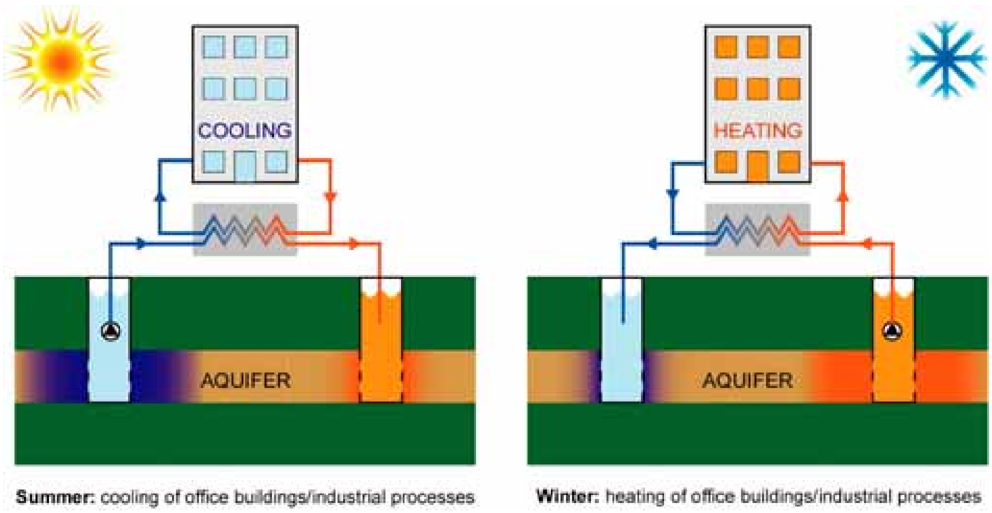

Figure 4-39: Diagram of Aquifer Thermal Energy Storage system (Source IF Tech Ltd)

ATES systems can also provide a means of *Heat Exchange* as older buildings with a net heat demand can use the heat rejected from buildings with a net heat excess. In the heat mode ATES systems improve the COP of heat pumps because of the raised source temperature for the heat pump.

ATES systems have been used in a number of European countries including Germany and the Netherlands and has been used in a number of building projects in the UK including an industrial campus in Cheshire, London Zoo and in London.

For ATES to be feasible depends on ground conditions and accessibility of aquifers. IF Tech Ltd have assessed the UK and produced a map showing ATES feasibility and a part of this is shown in **Figure 4-40.**

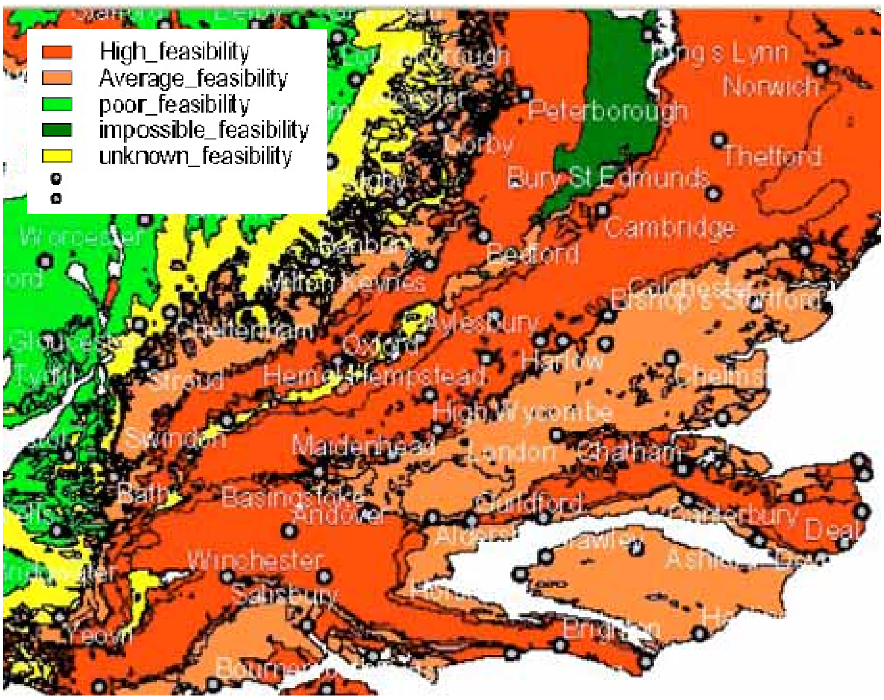

Figure 4-40: Aquifer Thermal Energy Storage (ATES) Map Including Uttlesford (Source IF Tech Ltd)

As can be seen from **Figure 4-40**, the northern part of Uttlesford is located in the High Feasibility zone and the southern part in the Average Feasibility Zone. Whilst local inspection would be needed to confirm, there would appear to be scope to consider the application of ATES systems within most of Uttlesford.

BTES (Borehole Thermal Energy Storage) systems are a closed loop (ATES are open loop systems) which can be employed when ATES systems are not feasible. BTES systems are usually designed as a radial, circular array of boreholes containing U-tube pipes similar to those used as vertical collectors for GSHPs. **Figure 4-41** shows a BTES used to provide inter-seasonal thermal energy storage for a solar community on Alberta Canada for 52 homes.

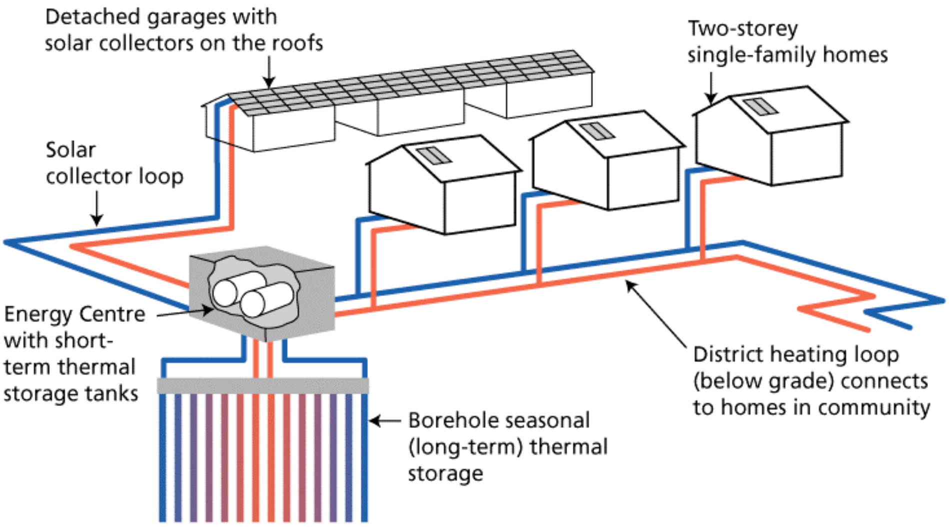

Figure 4-41: BTES used for inter-seasonal storage for 52 homes in Drakes Landing Solar Community in Canada (Source Drakes Landing Community)

In the heating season, the heat stored in the outer part of the BTES array is used to heat buildings - with or without a heat pump depending on delivery temperature required. The cooled water is returned to the centre of the array. When cooling is required, coolth is extracted from the centre of the array and heat from the building is stored in the outer part of the array.

There could be scope to utilise UTES (both ATES and BTES) systems in Uttlesford and they could have potential for reducing the CO_2 emissions from old buildings/listed buildings that are difficult to heat or insulate. To evaluate the potential would require a more detailed survey of potential sites, proximity of buildings needing heat or coolth, proximity of sources of excess heat and opportunities for inter-seasonal capture of neighbourhood scale renewable energy sources.

These appear to be very promising and invisible technologies which seem likely to have potential at the appropriate scale.

4.9 Ground-Coupled Energy & Air Coupled Energy Conclusions

Ground Coupled Energy is an under-rated and underused renewable energy resource in the UK yet it has substantial potential in Uttlesford for providing a low CO_2 based source of heating and cooling.

- ***Ground coupled free cooling***

Ground coupled free cooling is a low CO_2 emissions form of cooling that may provide a viable alternative when passive solar cooling is not feasible.

- ***Earth Tubes***

There could be scope for utilising Earth Tubes to provide cooling and pre-heating of ventilation air and they may be incorporated into HRV systems. If appropriately designed, Earth Tubes can improve air quality with potential benefits for those with respiratory ailments. These systems are best suited to new well insulated buildings when ground works are being undertaken but can be retrofitted to existing buildings when adjacent ground is available.

- ***Ground Source Heat Pumps***

Perhaps the biggest potential for utilising ground coupled energy is the use of ground source heat pumps(GSHPs). The capital investment required for heat-only GSHPs is higher than for comparable heating systems (they can be 2 to 3 times the cost of a condensing gas boiler), but GSHPs can achieve some of the highest reductions in CO_2 emissions for heating. Compared to conventional heating systems, GSHPs are likely to require much less maintenance and servicing. Therefore, organisations with large maintenance costs may find that, when these factors are taken into account in lifecycle costings, investment in GSHPs may be justified on economic grounds as well as for helping to reduce CO_2 emissions.

When GSHPs are able to provide both heating and cooling from the same equipment, the economic viability is improved by avoiding the additional capital investment that would be required for two sets of equipment.

GSHPs may be able to compete economically in rural locations where the only conventional form of heating available is that fuelled by oil or electric storage heaters. A GSHP also avoids the capital costs of a flue/chimney and oil storage tank.

Ball park estimates of using GSHPs (seasonal COP of 3.0) to provide the space and water heating for the Uttlesford non-gas households indicate that they could abate an aggregated level of CO_2 emissions of the order of **9,000 tonnes/y for 20%**; **22,000 tonnes/y for 50%**, and **32,000 tonnes for 70% of the non gas households**. Whilst it is unlikely to be feasible for all of the non-gas households to use GSHPs, if it did prove to be so then they could abate around **45,600 tonnes CO_2/y** which would represent a **27% reduction of the total[36] Uttlesford aggregated domestic space and water heating related CO_2 emissions**. This represents the smaller proportion of households in Uttlesford, but the use of GSHPs in these households could result in useful levels in CO_2 abatement within Uttlesford.

If electricity from a renewable energy source is used then GSHPs provide a Zero CO_2 form of space heating, hot water provision and cooling.

[36] Total includes both gas households and non-gas households.

The ball park estimates using CO_2-free/CO_2-neutral renewable electricity powered GSHPs indicate that they could abate of the order of **15,000 tonnes CO_2/y for 20%** of the non-gas households**; 22,000 tonnes CO_2/y for 30%**; **38,000 tonnes CO_2/y for 50%**; **53,000 tonnes CO_2/y for 70%** and **around 75,000 tonnes CO_2/y for <u>all non gas households</u>** - which corresponds to around a **45% reduction of the <u>total</u> Uttlesford aggregated domestic space and water heating related CO_2 emissions**.

If combined with heat stores, a GSHP-Heat store combination provides an effective means of storing energy from a variable renewable energy source such as wind energy. Wide scale implementation of 'Smart Dynamic Demand Controlled Heat Stores' could facilitate a larger proportion of variable renewable energy sources to supply electricity into the electricity supply network/grid, than would otherwise be feasible and increase the CO_2 emissions abated.

In the case of Ground Source Heat Pumps with vertical ground collectors, high efficiencies can be achieved, but the cost of drilling the bore hole is more expensive. If Ground Source Heat Pumps can be installed in larger numbers in the UK, then competition may start to reduce the costs as has happened in North America and Sweden.

- ***Air Source Heat Pumps***

Air Source Heat Pumps are now becoming available that are suited to the relatively mild climate of the British Isles and can provide domestic space and water heating needs. Air source heat pumps have a lower capital cost compared to GSHPs but higher running costs but can also be used when there is insufficient ground or garden available to consider using GSHPs and can also be used in flats and apartments above ground level.

The ball park estimates using of using ASHPs (seasonal COP of 2.5) indicate that they could abate of the order of **7,900 tonnes CO_2/y** for 20% of the non gas households; **19,800 tonnes CO_2/y** for 50%, **27,700 tonnes CO_2/y** for 70% and **39,600 tonnesCO_2/y** for all of the <u>non gas</u> households which would represent a **23% reduction** of the Uttlesford aggregated domestic space and water heating related CO_2 emissions. This represents the smaller proportion of households in Uttlesford, but the use of ASHPs in these households could result in useful levels of CO_2 abatement within Uttlesford.

- ***Underfloor Heating***

Under-floor heating systems are becoming more popular in the UK and GSHPs and ASHPs are ideally suited to this type of heating, so one can expect to see an increase in this combination if the trend continues.

- ***Solar Road - Ground Coupled Energy Storage***

A more recent development of using roads or other asphalt or paved areas as 'solar collectors' with inter-seasonal ground coupled energy storage also appears to have potential, and should improve the performance of heat pumps and reduce CO_2 emissions further compared to GSHPs. These technologies would seem to have potential for use when garden based GSHPs are not feasible and may have a role to play in reducing the CO_2 emissions for hard to heat/insulate old/listed buildings. Using 10% of the aggregated road area in Uttlesford, ball park estimates indicate that around **3,360 (around 12%) of Uttlesford households** could be supplied with space and water heating at the estimated current average demands (or around 7,000 households or around 26% of Uttlesford households if average space and water demands were reduced to 10 MWh/y by implementing energy efficiency/conservation measures).

These *solar road* technologies can also be applied to car parks or other asphalt/paved areas and if the town centre car parks in Uttlesford were able to be used then the ball park estimates indicate they could potentially provide average space and water heating for between 100 and 140 households or between 210 and 310 households at 10MWh/y average space and water heating demand. Utilising additional private car parks/terraces/play grounds could enhance the number of households provided for.

- ***UTES Ground Coupled Energy Storage***

Ground coupled energy storage utilising Underground Thermal Energy Storage (UTES) utilising either ATES (Aquifer Thermal Energy Storage) or BTES (Borehole Thermal Energy Storage) has potential to provide inter-seasonal energy storage to heat and cool large buildings or groups of households. These systems have been successfully employed in various European and North American countries and also have been used in a number of UK projects.

If suitable open spaces are available adjacent to buildings that have either need or have excess heat then these UTES systems would seem to have potential in Uttlesford and could provide a means to reduce the CO_2 emissions from hard to heat/insulate old/listed buildings but also facilitate the integration of neighbourhood/large scale renewable energy sources including solar and wind energy but could also improve the viability of district scale combined heat and power systems.

- ***Ground coupled energy + storage and air coupled energy***

Ground coupled energy and storage and air coupled energy can play a useful role in reducing the energy consumption and related CO_2 emissions within Uttlesford, though to achieve the potential will require careful planning and promotion of the technologies within the district.

4.10 Ground-Coupled Energy + Air Coupled Energy Recommendations

Confirm that subsoil conditions in Uttlesford are satisfactory for the drilling of bore holes for ground-coupled heating and/or cooling.

Consider the practicality of installing clusters of bore hole GSHPs within a locality to reduce cost of drilling.

Explore the viability of utilising existing water sources as low temperature heat and cooling sources for adjacent communities or buildings.

Promote and publicise the potential energy and CO_2 saving benefits of Ground-Coupled Energy to building owners, developers, builders, electricians, plumbers, and housing associations.

Promote and publicise the potential energy and CO_2 saving benefits of Air Source Heat Pumps (ASHPs) to building owners, developers, builders, electricians, plumbers, and housing associations. At the same time the appropriate use of ASHPs should be promoted so as to discourage their use as air conditioners without other measures to reduce over heating being considered.

Publicise the availability of capital allowances for Ground-Coupled Energy equipment to reduce Climate Change Levy costs.

Promote and publicise the potential energy and CO_2 saving benefits of Solar Road based Ground-Coupled Energy and Ground Couple Energy Storage Systems to building owners, developers, builders, electricians, plumbers, and housing associations.

Liaise with highway authorities and car park owners with regards to utilising Solar Road based Ground-Coupled Energy.

Make contact with drilling companies in or around Uttlesford to raise awareness and take advantage of their local experience of soil and ground conditions within the District.

Review schools without access to gas in order to explore the potential for retrofitting Ground-coupled energy provision using UTES systems.

Review Uttlesford DC buildings to explore possibilities for Ground-coupled/Air Coupled energy.

Encourage Essex CC to review their buildings within Uttlesford to explore possibilities for Ground-coupled/Air Coupled energy provision.


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