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S-ER3

GROUND & WATER SOURCE HEAT PUMPS

TARGET AUDIENCE & OBJECTIVES:
This document is intended for non-experts and is a general overview of the technology with signposting to sources of further information

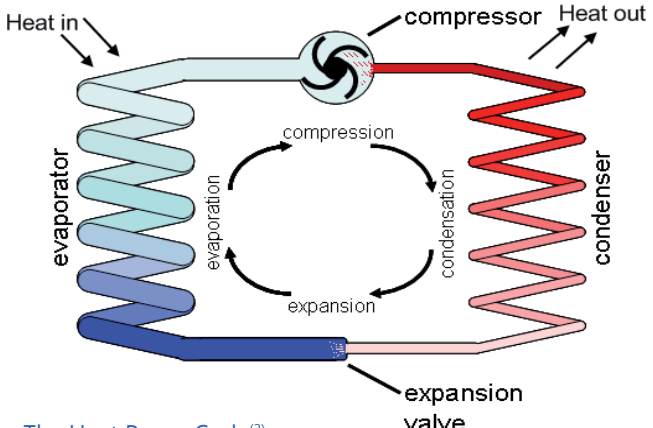
What is a heat pump and how does it work?

A heat pump is a device which moves heat energy from one place to another and from a lower to a higher temperature. (e.g. a domestic refrigerator in reverse). In heating applications, heat is removed from ambient or exhaust air, water, soil or bedrock (the source) and delivered to where it is needed (the sink). In cooling applications, the reverse happens. Heat is removed, to be discharged to the ambient air, water, soil or rock[1].

Heat pumps have the ability to deliver more energy than they consume by using a refrigeration cycle which absorbs heat from the environment and raises it to a suitable level for heating. A refrigeration cycle consists of an arrangement of heat exchangers; one that absorbs heat, the other that rejects it (see diagram below).

Low grade energy absorbed from the environment is transferred to the refrigerant (e.g. R410A) inside the absorbing stage of the heat pump (evaporator). As a result the temperature of the refrigerant rises, causing it to change from a liquid to a gaseous state. The refrigerant is then compressed, using an electrically driven compressor, reducing its volume but causing its temperature to rise signifcantly.

A second heat exchanger (condenser) then extracts the heat from the refrigerant gas and as heat is absorbed the gas condenses back into a liquid. The heat is absorbed via spontaneous heat flow and is used to heat water or air for heating or domestic hot water. After giving up its heat energy and condensing back into a liquid the refrigerant passes through an expansion valve.



The Heat Pump Cycle[2]

This creates a sudden drop in refrigerant pressure, causing it to boil and evaporate with a rapid temerature drop. This very cold gas is then channelled to the first heat exchanger where it can once again absorb energy from the environment, allowing the cycle to start anew.

Types of heat pump

There are several types of heat source available for heat pump systems:

- the ground
- water or
- air (exhaust or ambient)

This information sheet provides information on ground and water source heat pumps. Air Source heat pumps are discussed further in information sheet S-ER4.

Ground & Water Source Heat Pumps.

A Ground Source Heat Pump (GSHP) GSHP makes use of solar energy absorbed by the ground and are not a form of geothermal energy. Although commonly mis-called 'geothermal', true geothermal heat pumps require substantally deep boreholes into the earth crust 1km+. A GSHP transfers heat into or out of the earth to heat or cool buildings. The system has three main components:

- ground loop
- heat pump unit
- distribution system

Ground systems extract heat from the earth all year round via underground collectors.

Water systems extract thermal energy from water; generally ground, river or pond water and even waste heat from factory processes. Because the water source is naturally occuring both ground and water systems are often referred to as Ground Source Heat Pumps (GSHPs).

There are 4 basic ground loop configurations, shown on the following page. Selection of the most appropriate configuration is based on the required heating load of the building, available land space, ground conditions and the availability and quality of groundwater.

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The four basic ground loop configurations

Horizontal Closed Loop or Slinky

Horizontal loops require much more surface area than vertical loops and land with high moisture content is optimal as water is a better conductor of heat. Hence rural properties with large grounds which can be easily excavated are typically best suited.

Piping is installed horizontally in trenches in one continuous loop or a series of parallel loops. The depth of the trenches will vary according to the design and ground characteristics, but is generally 1.5 – 2m deep. There are various horizontal loop designs including one-pipe, two-pipe, four-pipe systems. Slinky coils are common in the UK consisting of flattened coils of overlapping piping, which are spread out and laid either horizontally or vertically. Their ability to focus the area of heat transfer into a small volume reduces the length of the trenches and hence the quantity of land needed. A 10m long trench laid with a 'Slinky' coil will typically supply 1kW of heating load[4].

Vertical Closed Loop

Suitable for buildings with limited available land area, or where other loop configurations are not cost-effective.

Vertical loops are also suitable for sites with bedrock relatively close to the surface i.e. where it is impossible to install a horizontal loop.

Vertical loops require less length of piping than horizontal loops, since ground temperatures are more constant at a depth of about 6 metres (20 feet) or deeper.

Most commercial and institutional projects use 'Vertical loop' systems.

The advantage of a vertical loop system, which consists of pipe inserted into vertical bore holes, is that less space is required. Holes are spaced at around 5m intervals and their depth can vary between 15m and 150m according to the design and soil characteristics.

Well-to-Well or Open Loop

Suitable for buildings with access to a good quality supply of well water.

Open loop systems extract heat directly from the water in a "supply" well and then return it to a second well or "return well".

Open loop systems using ground water are usually more efficient than closed systems because they are better coupled with ground temperatures. Closed loop systems, in comparison, have to transfer heat across extra layers of pipe wall and dirt. However water sources with high levels of salt, chlorides or other minerals can cause premature system failure or inefficient operation.

Annual cleaning and maintenance of the heat exchanger(s) in the heat heat pump unit will be required to reduce mineral scaling. Pumping power may become an issue in installations that require deep supply wells. Approvals from the Scottish Environmental Protection Agency (SEPA) and Scottish Water are likely to be required.

Lake or Pond Closed Loop

Suitable for areas with a pond or lake nearby and poor drilling & excavation conditions, where the loop can be submerged in water, rather than in the ground.

The loop must be properly anchored to remain on the bottom of the body of water, submerged deep enough under water and protected at the shoreline to avoid being dragged away by the movement of Spring ice break-up.

The lake/pond system is an extremely specialized configuration, so it is important that an installation contractor has sufficient experience and understands all aspects of this type of installation.

Approvals from the Scottish Environmental Protection Agency (SEPA) and Scottish Water are likely to be required.

Images See reference (3)

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Space heating
Heat is distributed to either a water heating system or an air distribution system. Because GSHPs raise the temperature to around 40°C they are most suitable for underfloor heating systems, low-temperature radiators or fan coil units, which require temperatures of between 30°C and 35°C. Heat pumps operate more efficiently at low output temperatures (30-40°C). The efficiency (CoP) decreasing as the output temperature increases. Higher outputs, such as to conventional radiators requiring higher temperatures of around 60°C to 80°C can be obtained through use of the GSHP in combination with a conventional boiler or immersion heater[4].

Systems can be configured as heating only or are available as heating/cooling reversible systems. A system that can perform cooling in one part of a building and reject the heat absorbed in the process into another part of the building will have considerable energy efficiency because heat that would otherwise be wasted can be re-used. There are two types of equipment that can provide simultaneous operation typically suited to commercial applications:

Variable Refrigerant Flow (VRF): A direct expansion refrigeration system diverts hot gas from the condenser to parts of a building that require heat while cooling other parts at the same time. The installations are fully automatic and employ speed controlled compressors to match the system's output to the load demand of the building. With VRF systems, considerable savings on electrical power are available, in addition to good load demand flexibility.

Water to Air: Similar load flexibility giving simultaneous heating/cooling can be obtained using a warm water loop arrangement. Here the building is equipped with a ring main water flow and return pipe to each room, through which warm water is circulated by a central pump. Each room in turn is equipped with a small self-contained reversible heat pump unit.

The two heat exchangers in the heat pump are a combination of water and air source. Room air is passed through one, water from the ring main through the other, while the heat pump compressor circulates refrigerant through the internal pipes in the heat exchangers. A room requiring heat draws its heat source from the warm water. If cooling is required, the heat absorbed is rejected into the water circuit.

Water heating
The GSHP system alone is inadequate for directly heating hot water output. Hot water for taps needs to be stored at 60°C whereas for domestic GSHPs the maximum water storage temperature obtainable is 50°C.

A water heating strategy can be designed where the incoming water supply is preheated by the GSHP before reaching an ancillary heating source. However, it may be that an immersion heater working off off-peak electricity is more economical [4].

Design & Installation Requirements.
Rural residences and new home construction sites are ideal as they have fewer physical barriers making installation more cost-effective. Retrofitting (replacing an existing heating system with GSHP technology) disrupts landscaping.

Home renovations may also be needed to install the interior components. Underfloor heating is best but low-temperature radiators may also be recommended. When retro-fitting, low temperature radiators are preferred. Any existing heat emitters will have to be checked to see that they can provide sufficient heat output, given that the Heat pump system (at say 30-35°C) will be operating at a lower temperature than the radiator system was designed for (typically 80°C flow temperature). It is likely that the existing rad's will need to be replaced.

Since ground source heat pumps produce a lower temperature heat than traditional boilers, it's essential that the building is insulated and suitably draught proofed for the heating system to be effective and to make the system cheaper and smaller. An accurate assessment of the building's likely heat loss is also important as well as considering designing a system for use with green electricity or micro-generation technologies for maximum efficiency.

In terms of the site a thorough survey should be carried out (to identify buried services etc) – and the buried loops recorded following installation. The soil type is also important as different soils have different heat transfer rates.

Performance & efficiency
The 'efficiency' of a heat pump can be measured using the Energy efficiency ratio (ERR), the seasonal energy efficiency ratio (SERR) or the Coefficient of performance (CoP). The EER is the measure of efficiency at maximum load, 35°C outside dry bulb temperature, and 27°C inside dry bulb temperature. It is measured by ratio of Btu/hour of cooling or heating load, to watts of electrical power input.

SEER is similar to EER, but is determined through averaging readings of different air conditions at the manufactures area, to represent efficiency throughout the season. It should be noted that the value won't be the same if you're installing the unit at an area with different average air conditions. However, you can ask the conditions at which the heat pumps are tested at which will normally be the same. Hence, it is accurate to select a heat pump with a higher SEER, it is also better to select heat pumps based on SEER, rather than EER. Care should be taken not to compare two heat pumps based, one based on SEER, and the other based on EER as the selection process will be flawed.

COP is defined as the cooling load, in kW, to power input at the compressor, in kW. The definition is very close to EER, but the units are different. In simple terms, a CoP of 3 means the heat pump delivers 3 units of heat energy for every 1 unit of electricity it consumes. Typical claimed manufacturers CoPs range from 2.5 to 4. The higher end of this range is for under-floor heating, because it works at a lower temperature (30-35°C) than radiators. COP values are normally used to measure efficiency of a heat pump, during design stage. It is very rarely used by consumers values for all three efficiency numbers are dependent on different criteria such as inside and outside air temperature difference, compressor's efficiency, condenser's efficiency, evaporator's efficiency, expansion device's efficiency, and fan's efficiency.

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On a very cold winter day, it takes more work to move the same amount of heat indoors than on a mild day. A ground source system will have less change in CoP than an air source one as the ground temperature from which they extract heat is more constant than the outdoor air temperature.

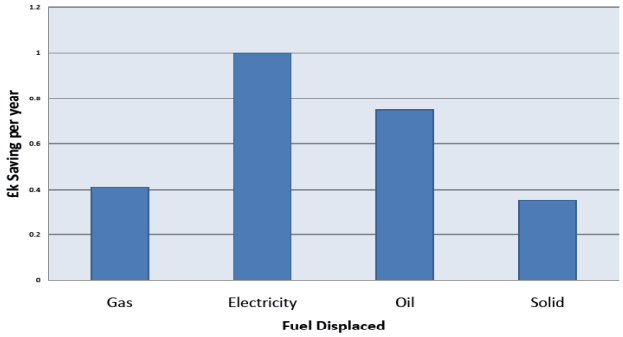
Capital Costs

A GSHP system is more expensive to install than a conventional heating and air conditioning system, but annual heating costs are predicted to be 50 to 70 per cent lower. The installed cost of a GSHP ranges from about £800-£1,200 per kW of peak heat output, excluding the cost of the distribution system. Trench systems are cheaper, so tend to be at the lower end of this range. Costs for installing a typical system suitable for a detached home range from about £6,000 to £12,000[5].

Running Costs

Running costs for a typical system suitable for a detached home (to produce heating and 50% of domestic hot water) are likely to be around £500 - £600 per year, but will depend on a number of factors - including the size of the home and how well insulated it is[5]. In a modern, well insulated house, a GSHP system can offer very high efficiency and moderate running costs. Based on current fuel prices, assuming a CoP of 3-4, a GSHP can be a cheaper form of space heating than oil, LPG and electric storage heaters.

It is marginally more expensive than mains gas to run but that is on current gas prices, which are set to rise. Also, all fossil fuel boilers need regular servicing and maintenance. If grid electricity is used for the compressor and pump, then an economy 7 or 10 tariff usually gives the lowest running costs depending on how and when the system is used. A comparison of savings achieved is shown below:



Source [5].Savings above assume ground source heat pump installed in a detached property and provides up to 50% of domestic hot water as well as 100% of space heating

Payback: The payback period varies greatly as systems are customized to individual buildings.

Factors influencing payback include the following.

- New building vs. retrofit (existing).
- Capital cost of the GSHP system.
- Size and energy efficiency of the building and the age/ type of heating/cooling system the GSHP is replacing.
- In addition, premium system options may be selected for comfort reasons which increase the total cost of the system relative to a conventional heating system.

To calculate payback, you will need:

A GSHP system capital cost;

B base system installed cost (e.g. electric or natural gas);

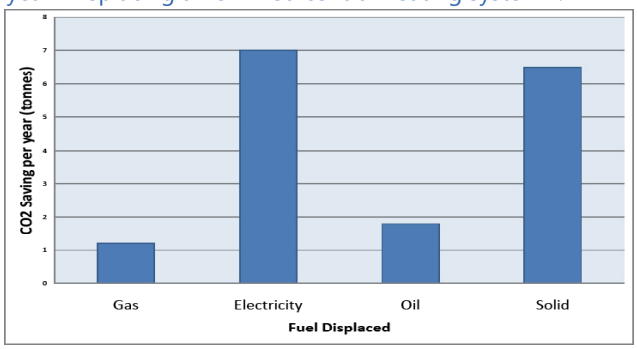
C annual energy savings as a result from switching to a GSHP system (obtained from your GSHPl contractor).

Simple payback formula: Payback in years = (A – B) / C.

Typical paybacks in the UK have been shown to be around 10 years when the fuel displaced is electric or oil. paybacks for gas will be higher.

Carbon Savings

Savings can be considerable - up to 1.8 tonnes of CO_2 per year if replacing an oil-fired central heating system[5].



Savings above assume ground source heat pump installed in a detached property and provides up to 50% of domestic hot water as well as 100% of space heating.[5]

To reduce CO_2 emissions further, consideration should be given to installing solar electricity or some other form of renewable electricity generating system to power the compressor and pump.

Summary

GSHPs are efficient heating and cooling systems with long life expectancies. They are reliable in a variety of climates with more than one million units in operation worldwide[3]. However they are not a renewable technology as electricity drives the heat pump. If they are also used to heat hot water, an ancillary electrical immersion is required. This means that to demonstrate significant carbon savings they need to be combined with microgeneration technologies or with green electricity tariffs. Furthermore manufacturers' claims of CoPs (Coefficient of Performance) of 3-5 are not generally being realised in practice, where CoPs of 2-3 are more common.

Another issue is that refrigerants are present in GSHP systems and so present the threat of HCFCs and toxicity. However, new types and blends of refrigerant (some using CO_2) with minimal negative impacts are emerging[4].

Pay back and life cycle costs are key in the owner's view of GSHPs. Where no ''piped gas" is available the alternate high grade heat source is oil where boiler efficiency is improving with condensing versions now available making the added costs of GSHP systems hard to justify on economic grounds alone, especially for retrofits. However grant assistance, & reduced maintenance costs are helping to make them more attractive.

GROUND & WATER SOURCE HEAT PUMPS

SIGNPOSTING

GENERAL HEAT PUMPS

TITLE	DESCRIPTION	LINKS
Heat Pump Centre	Examples of Heat Pump Applications	http://www.heatpumpcentre.org/Publications/Case_Studies.asp
The Heat Pump Association (HPA)	The UK's leading authority on the use and benefits of heat pump technology and includes many of the country's leading manufacturers of heat pumps, components and associated equipment. Influences legislation & co-ordinates technical and market research into areas of mutual interest.	http://www.heatpumps.org.uk/
The Renewable Energy Centre	General Guidance on Ground and Air Source Heating	http://www.therenewableenergycentre.co.uk/ground-and-air-source-heating/
Renewable Energy Association (REA)	Trade association open to all companies supportive of the UK renewable energy industry. Guidance on heat Pumps	http://www.r-e-a.net/heat/heat-pumps
Carbon Trust: Policy Frameworks for renewables	This report examines the case for renewable energy both in the near-term and the long-term in the light of the Energy Review	www.carbontrust.co.uk/Publications/publicationdetail.htm?productid=CTC610&metaNoCache=1
Carbon Trust: CTV010: Renewable energy sources technology overview	Introduces the main sources of renewable energy and helps readers to assess whether using renewable energy is a viable option for their business.	http://www.carbontrust.co.uk/publications/publicationdetail?productid=CTV010
UK Heat Pump Network	UK Information Network for Heat Pumps provides information of benefit to manufacturers, suppliers, importers, utilities, researchers, architects and consultants/specifiers.	http://www.heatpumpnet.org.uk/
HVCA Good practice Guide TR/30.	Looks at different applications of Heat Pump technology and provides generic installation requirements for a range of renewable energy systems.	https://shop.welplan.co.uk/catalog/product_info.php/cPath/52/products_id/312
HPA Facts about heat Pumps	Some questions and answers outlining the essential facts.	http://www.heatpumps.org.uk/FactsAboutHeatPumpsPF.htm
Energy Efficiency Partnership for Homes: UK Heat Pump Guidance	Guidance developed from a study commissioned by the Hard to Treat group of the Energy Efficiency Partnership for Homes to help inform Local Authorities, Housing Associations, architects and developers about the use of heat pumps in the UK. Includes an explanation of heat pumps, their advantages and disadvantages, the different types of heat pumps and how & where they are most effective.	http://www.eeph.org.uk/uploads/documents/partnership/Heat%20Pumps%20Guide%20May%2005.pdf
Heating and Cooling With a Heat Pump	The Heating and Cooling series is published by the EnerGuide team at Natural Resources Canada's Office of Energy Efficiency.	http://oee.nrcan-rncan.gc.ca/publications/infosource/pub/home/heating-heat-pump/booklet.pdf

GROUND & WATER SOURCE HEAT PUMPS

TITLE	DESCRIPTION	LINKS
BERR	BERR Guidance on Geothermal Energy	http://www.berr.gov.uk/energy/sources/renewables/explained/geothermal/page17506.html
BSRIA Guide TN 18/99 Ground source heat pumps - a technology review	Provides a detailed literature- based review of GSHP technology and looks in separate chapters at applications of the technology, applicable standards and regulations, financial and other benefits and the current market.	https://infonet.bsria.co.uk/books-downloads/details/?p=1&i=66771&pa=s&k=heat+pumps&anc=5
Energy Saving Trust	Ground source heat pump Information	http://www.energysavingtrust.org.uk/Generate-your-own-energy/Ground-source-heat-pumps
Energy Saving Trust	Energy Saving Trust factsheet on Ground Source Heat Pumps	http://www.energysavingtrust.org.uk/uploads/documents/myhome/Groundsource%20Factsheet%205%20final.pdf
Renewable Energy Association (REA)	Trade association open to all companies supportive of the UK renewable energy industry. Guidance on Geothermal	http://www.r-e-a.net/heat/geothermal-heat
Energy Saving Trust Case Study	Ground source heat pumps Case Study: When Dr Lawn decided to build a three bedroom house he wanted to make it as sustainable as possible, so one of the things he did was install a ground source heat pump.	http://www.energysavingtrust.org.uk/content/download/1494/10221/version/1/file/cs_mr_lawn_ground_source_heat_pump.pdf
GreenSpec	Information on Ground Source Heat Pumps	http://www.greenspec.co.uk/html/energy/GSHP.html
GreenSpec	Energy Efficiency Best Practice in Housing: Domestic Ground Source Heat Pumps: Design and installation of closed-loop systems	http://www.greenspec.co.uk/documents/energy/GSHP1.pdf
Ground Source Heat Pump Association (GSHPA)	Aims to share best practice and develop and disseminate industry approved technical standards & to represent the Ground Source Heating & Cooling industry, engaging with government and other bodies to influence relevant policymaking.	http://www.gshp.org.uk/
Low Carbon Buildings Programme	Ground source heat pump information	http://www.lowcarbonbuildings.org.uk/micro/ground/
The International Ground Source Heat Pump Association (IGSHPA)	Non-profit, member driven organization established in 1987 to advance geothermal heat pump (GHP) technology on local,state, national and international levels.	http://www.igshpa.okstate.edu/
What you'll need and where to get it.	Telegraph article on GSHP's	http://www.telegraph.co.uk/earth/3297938/What-youll-need-and-where-to-get-it.html
Heat Pump Association Data Sheet.	Ground to Water Heat Pumps.	http://www.heatpumps.org.uk/PdfFiles/Heat_Pump_Ground_to_Water_Data_Sheet_No.2.pdf
Domestic Ground Source Heat Pumps: Design and installation of closed-loop systems (CE82/GPG339)	Aimed at both specifiers and users, this guide details the types of systems, how to achieve an integrated system, how to maximise efficiency, capital and running costs as well as 'dos and don'ts'.	http://www.energysavingtrust.org.uk/business/Global-Data/Publications/Domestic-Ground-Source-Heat-Pumps-Design-and-installation-of-closed-loop-systems-CE82-GPG339
Heat Pumps in the UK - a monitoring report (GIR72)	This report for architects and developers summarises the findings of a project to install a heat pump in a private dwelling, including capital and running cost assessment. Publication date: March 2000.	http://www.energysavingtrust.org.uk/business/Global-Data/Publications/Heat-Pumps-in-the-UK-a-monitoring-report-GIR72
European Renewable Energy Council: Geothermal Energy.	The EREC acts as a forum for exchange of information and discussion on issues related to renewables as well as to represent the European RES industry & research community.	http://www.erec.org/renewableenergysources/geothermal-energy.html
Engineering Systems Solutions: Why Water Source Heat Pump Systems Are So Efficient.	This issue of Engineering System Solutions provides a basic overview of why water source heat pumps are so efficient and how steady improvements have made the system fundamentally better.	http://www.mcquay.com/mcquaybiz/literature/lit_systems/engnews/1002.pdf

GROUND & WATER SOURCE HEAT PUMPS

SIGNPOSTING

MANUFACTURERS & INSTALLERS. Please note the SCC does in no way endorse or recommend any manufacturer or installer. If you feel your company should be listed here please contact enquiries@scocon.org.

TITLE	DESCRIPTION	LINKS
Green Book Live	Find certified products	www.greenbooklive.com/page.jsp?id=131
Low carbon Building Programme	Find an Installer	www.lowcarbonbuildings.org.uk/info/installers/find/installerfind
Microgeneration Certification Scheme	The Microgeneration Certification Scheme (MCS) is an independent scheme that certifies microgeneration products and installers in accordance with consistent standards. It is designed to evaluate microgeneration products and installers against robust criteria providing greater protection for consumers.	http://www.microgenerationcertification.org/
Baxi	The Baxi GeofloTM ground source heat pumps are single phase units suitable for domestic properties and available in outputs ranging from 4kW to 20kW.	http://www.baxi.co.uk/products/groundsource.htm
Danfoss Heat Pumps	"Danfoss Heat Pumps UK Limited is a leading Supplier of Air Source & Ground Source Heat Pumps. Expertise within the Heat Pump Sector includes: Ground Source & Air Source Heat Pump Technology, Advice about Air Source & Ground Source Heat Pumps, Specification of Heat Pumps, The Manufacture of Heat Pumps, Installation of Ground Source Heat Pumps, Financial assistance including Grants for Air & Ground Source Heat Pumps."	http://www.ecoheatpumps.co.uk/?gclid=CL3K6PL_45kCFQ0FZgodIzwPQg
Dimplex	Dimplex is a well established company, with hundreds of products dedicated to energy efficient heating solutions. Their line-up covers heat pumps and solar thermal water heating; commercial heating and air curtains; water heating; award winning electric fires and suites; portable heaters, towel rails and domestic raditors and panel heaters for all around the home.	http://www.dimplex.co.uk/products/renewable_solutions/index.htm
Earth Energy	"EarthEnergy Limited is a UKgeothermal company specialising in the design and installation of Ground Source Heat Pump systems for building heating and cooling, jointly owned by the GeoScience Group and Renewable Energy Systems (RES) a subsidiary of Sir Robert McAlpine. EarthEnergy offers a full turnkey design and construction service for Ground Source Heat Pump Systems and undertakes initial feasibility analysis and thermal testing of ground conditions., feasibility Studies, Thermal Conductivity Testing, Ground Modelling & Turnkey Design and Installation."	http://www.earthenergy.co.uk/
Eartheat	Provide and install Heatpump powered heating systems, a cost effective and environmentally friendly solution to space and water heating	http://www.eartheat.com/
Ecovision Systems.	Ecovision is an approved Low Carbon Buildings Programme Installer. Service incorporates the design, installation and commissioning of a range of renewable and sustainable technologies, including Ground Source Heat Pumps, Air Source Heat Pumps, Solar Water Heating and Wet Underfloor Heating.	http://www.ecovisionsystems.co.uk/
Geowarmth Heat Pumps	Geowarmth Heat Pumps is a designer, supplier and accredited installer of ground source and air source heat pump systems. The Geowarmth team has a successful track record in residential, community and commercial schemes, including closed loop in trenches, boreholes, ponds and open loop systems.	http://www.geowarmth.co.uk/content/view/13/27/
ICE Energy	Ice Energy is the leading Ground Source Heat Pump company with more installations and sales than any other UK company. Ice Energy can offer a £1500 financial contribution to all domestic ground source heat pump installations. This is a genuine contribution and not a "cash back" after paying a higher initial price.	http://www.iceenergy.co.uk/
Invisible Heating Systems	Complete heating and cooling systems, including underfloor heating, heat pumps, solar panels & Wind energy - fully integratable, yet offering the customer the choice to select individual elements to suit their own requirements. Working closely with partners and suppliers in Austria, Holland and Germany to develop high quality systems that are both energy and cost-efficient.	http://www.invisibleheating.co.uk/ground-source-heat-pumps-g.asp
McQuay International	McQuay offers a complete line of water source heat pump systems for boiler/tower (water loop) and geothermal (ground loop or ground source) applications.	http://www.mcquay.com/McQuay/ProductInformation/WSHP/WSHPpage
NIBE	NIBE Energy Systems Limited is a subsidiary of NIBE Heating with its headquarters in Markaryd in Sweden. NIBE is one of Europe's leading manufacturers in the domestic heating sector.	http://www.nibe.co.uk/
Worcester Bosch - GSHP	British company, dedicated to energy efficiency, and committed to developing and manufacturing energy efficient heating and hot water solutions for the home. Manufacturers of Ground and Air Source heat Pumps	http://www.worcester-bosch.co.uk/homeowner/products
Future Utilities	Future Utilities specialises in the design, specification, supply and installation of microgeneration technologies for domestic and commercial applications.	http://www.futureutilities.co.uk/

SOURCES OF FUNDING

TITLE	DESCRIPTION	LINKS
Low Carbon Building Programme	Grants for renewables	www.lowcarbonbuildings.org.uk/home/
SCHRI	The Scottish Community Householder Renewables Initiative (SCHRI) provides grants for properties in Scotland. Funded by Scottish Government and managed by the Energy Saving Trust. Grants are available for solar water heating, solar photovoltaics, small scale wind and hydro systems, ground source heat pumps and biomass.	www.energysavingtrust.org.uk/scotland/Scotland/Scottish-Community-and-Householder-Renewables-Initiative-SCHRI
ECA	Enhanced Capital Allowances (ECAs) enable a business to claim 100% first-year capital allowances on their spending on qualifying plant and machinery	http://www.eca.gov.uk/
Carbon Trust Technology information leaflet:	Heat pump equipment: A guide to equipment eligible for Enhanced Capital Allowances	http://www.carbontrust.co.uk/Publications/publicationdetail.htm?productid=ECA761&metaNoCache=1
The Renewable Energy Centre	Information on Grants and Sources of Funding	http://www.therenewableenergycentre.co.uk/grants/#anchor1

REFERENCES

No.	DESCRIPTION	LINKS
1	UK Heat Pump Network FAQ	http://www.heatpumpnet.org.uk/
2	Diracdelta: Science and Engineering Encyclopedia	http://www.diracdelta.co.uk/science/source/h/e/heat%20pump/image001.gif
3	Manintoba Hydro: Ground loop Configurations	http://www.hydro.mb.ca/earthpower/configurations.shtml
4	Green Spec; Ground Source Heat Pumps (GSHP)	http://www.greenspec.co.uk/html/energy/GSHP.html
5	Energy Savings Trust: Ground source heat pumps	http://www.energysavingtrust.org.uk/Generate-your-own-energy/Ground-source-heat-pumps