CARBON TRUST
Making business sense of climate change

Sharing our experience

Down to earth

Lessons learned from putting ground source heat pumps into action in low carbon buildings

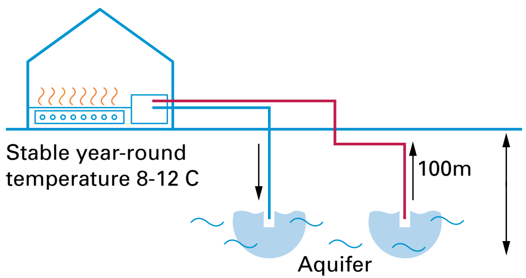
Contents

> "Interestingly, when the participants were asked whether GSHP would be the technology of choice if the project started over again, all said "Yes!""

What is a ground source heat pump?

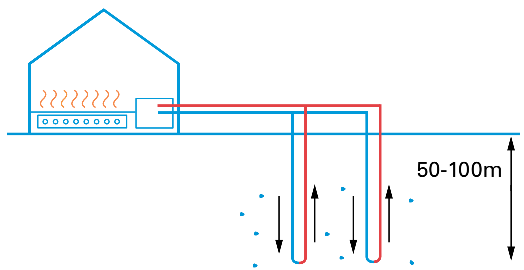
Ground source heating and cooling systems exploit the stable temperature of the ground or groundwater beneath a site and use it as a source of heating and/or cooling. We look at three types.

MENU



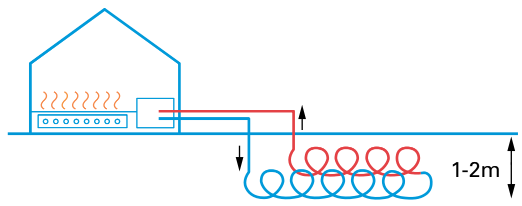
Open loop system

- Groundwater is extracted from and returned to a suitable aquifer below the site
- Output is dependant on how much water can be extracted
- More efficient than closed loop systems, so less boreholes are needed
- Generally more cost efficient than a closed loop system
- Can use cooling effect of groundwater without running a heat pump.



Closed loop vertical system

- A heat exchange fluid is circulated through pipes laid vertically in boreholes in the ground
- Can be used in most ground types in the earth or in ground water
- Output is fairly predictable
- Less efficient than an open loop system so more boreholes are required (projects showed this was by a factor of around 40)
- Generally less cost efficient than open loop systems – but up-front investigations are less.



Closed loop horizontal system

- A heat exchange fluid is circulated through pipes laid horizontally in trenches in the ground
- A large area of ground is required – larger than vertical systems
- None of the case studies referenced in this report used this system – but one considered it.

MENU

Using heat pumps

A heat pump uses electricity to raise or lower the temperature of the heat exchange fluid, but can be three or four times more efficient than conventional electric heaters.

Low temperature heating systems (or equivalent cooling systems) such as underfloor heating or chilled beams most efficiently deliver heating or cooling.

Heat pumps can be used to heat domestic hot water, however efficiency is reduced and a supplementary heating system is usually required.

Boreholes can be located almost anywhere on the site providing ground conditions permit, and there is adequate spacing between them. They can also be built or landscaped over, providing access is maintained. Space inside a plant room is required for the heat pump equipment.

Conventional systems such as gas boilers are often installed for peak heating demands and to provide a back-up system.

Well head at Edge Hill University

One of the heat pumps at Edge Hill University

The GSHP installations were predicted to contribute to average reductions in CO_2 of 25% compared to 2006 Building Regulations

> “Low carbon technology is perceived as being relatively expensive, but actually we found it to be quite cost-effective. Certainly the running costs are very cost effective, and the capital cost to us was quite modest”

David Oldham,
Director of Capital Investments, Edge Hill University

MENU

Low carbon cooling

GSHP's versatility was part of its appeal for some clients and design teams, as it is able to provide low carbon cooling as well as heating.

This proved particularly useful for St Edmundsbury Borough Council and Edge Hill University, who might otherwise have resorted to air conditioning.

Using GSHP for cooling as well as heating improves the efficiency of a system over its lifetime, because it helps keep ground temperatures constant. Hackney Academy were advised to use cooling for this very reason.

The London School of Hygiene and Tropical Medicine (LSHTM) only required cooling since the building was already connected to a district heating system. So the design team decided to use an open-loop groundwater cooling system, omitting the heat pump element.

Lessons learned

- GSHP works best as part of an integrated low carbon design.
- Good building fabric is essential to minimising heating and cooling needs.
- Upfront costs are offset by lower whole life costs.
- GSHP can make a big contribution to carbon savings in new buildings, if operated correctly.
- Using GSHP for low carbon cooling improves efficiency.

Renewable Heat Incentive (RHI)

If you install a new GSHP you could get paid for the heat generated by the installation.

This RHI tariff will significantly improve the business case for heat pumps and support their broader roll-out to meet the UK's 2020 renewable energy target.

- For more information visit the **Department of Energy and Climate Change website**

Feasibility and outline design

Detail design

Desktop studies
Cost: £1,000 approx; time: 3 weeks

The British Geological Survey (BGS) provides desktop survey services. These reports are based on geological data and models, so will only give a designer a rough indication of what to expect from your site.

Water feature survey
Cost: varies; time: 2-4 weeks

The performance of nearby boreholes may give a more detailed picture of how much ground water may be available on a site. Bear in mind there can be variations within localities and even on the same site.

Engage GSHP supplier/contractor.

Test borehole drilling
Cost: £13,000 (closed loop), £80,000 (open loop); time: lead in – 2 months, drilling – up to 1 week, analysis – 2-3 weeks

A test borehole is the best way of determining ground conditions, but all boreholes on the site may not have the same performance. Environment Agency approval is required.

Case study: Desktop only
A desktop study confirmed that there was not a great deal of local information available about the ground conditions at RHS Garden Harlow Carr. A closed loop system was therefore chosen as no ground water is needed, and output can be predicted fairly reliably.

Case study: Comparing locations
The LSHTM found that the ground water yields of boreholes in nearby locations weren't indicative of the actual yields in practice.

Case study: Actual yields
Some projects, such as St Edmundsbury Borough Council, found the yields of their boreholes were better than tests predicted. Whereas Greenhouse in Leeds found the yields of the four different boreholes on their site varied to a significant extent.

Assessing ground condition

The diagram above shows the stages of the fact-finding process. Each stage offers a more detailed level of information, reducing the risk of making the wrong choices.

MENU

		Bramall Learning Centre	City Academy, Hackney	Edge Hill University
Constraints		Small, well-insulated building (700m^2) with low heat demand	Large heat demand, 11,000m^2 building	Large heat demand in a 9,000m^2 building
		Unknown ground and water conditions	Suitable aquifer not available	Very productive aquifer
		Good ground space	Good ground space on sports pitch	–
Solution		**Five vertical closed loop boreholes**	**51 vertical closed loop boreholes 8m apart – using a large area**	**Two open loop boreholes – one extracting and one discharging water – with excess capacity to share with adjacent buildings**

Technology choices

Technology choice was influenced by:

- ground space available
- building characteristics
- likely ground conditions
- groundwater presence.

Three examples are shown above.

Lessons learned

- Desktop studies give an indication of what to expect from your site.
- Test boreholes may be expensive but they reduce risk and can be reused in the final installation.
- Ask for a fixed price for borehole drilling.
- Estimate the maximum and minimum number of boreholes needed.
- If an aquifer is available, consider an open loop system.
- Allow for a slightly reduced average CoP in operation in a feasibility assessment.

MENU

MENU

Design, procurement and installation

Finding experienced delivery partners, fostering good relationships and setting up collaborative work practices are all essential to project success.

Building successful teams

Experience

Contractor experience was given as a defining factor for success.

Citu was grateful that its construction contractors for Greenhouse were up-front about their limited experience. It bridged the knowledge gap by asking the building services consultant to design to a higher level of detail – an approach that worked well.

Having identified a lack of GSHP experience within the design team, Edge Hill University engaged the supplier of the system specifically to add expertise, ensuring the success of the project.

Collaboration

The way contracts are managed can make a difference.

Citu shared the feasibility 'cost risk' among the team, resulting in a successful project.

Early involvement

Engaging contractors early allows them to inform the design.

At Edge Hill University, early engagement meant the M&E designer and the GSHP sub-contractor finalised the system design together:

- opportunities to optimise and extend the system were identified
- the architect had time to make changes to the plant room
- costs were better controlled.

A large number of parties can be involved in the design of ground source systems, which can lead to gaps in construction packages and confusion over overall responsibility when things go wrong. It therefore pays to ensure responsibilities are clearly defined.

> "During testing they discovered one of the boreholes was blocked. All the equipment had to be brought back and another borehole drilled. But because it was in the external works, it didn't delay overall completion"

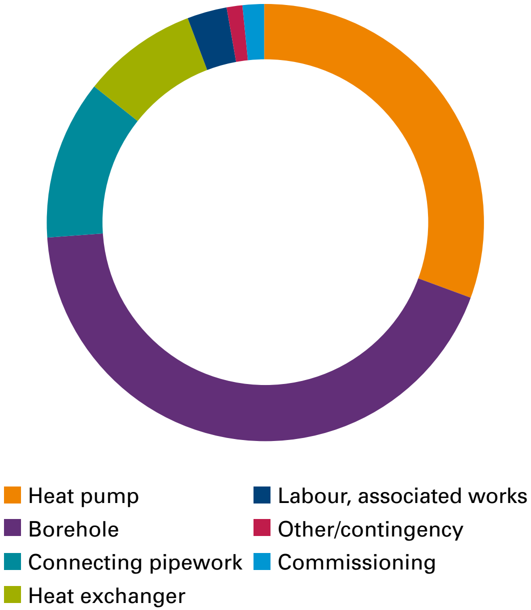
Howard Hammond, Project Manager, City of Stoke-on-Trent

Maintenance and monitoring

Contractors can offer valuable advice about running and maintenance from the earliest stages – ensuring that you end up with a simple, well-monitored and efficient system.

MENU

Figure 3 ***Breakdown of costs – St Edmundsbury Borough Council***



Cost control

Early planning always pays

Projects in which the design was completed before construction began received more accurate quotes from contractors and were generally more in control of final costs.

Early design = early quotations = better cost control

Consider the cost of ancillary items

Disparity between tender costs and final costs is often down to overlooked ancillary items. *Figure 3* shows a cost breakdown where ancillary items make up more than 25% of the total budget.

Edge Hill asked for quotations on an 'open book' basis, making it possible to compare estimates and spot whether any ancillary items had been overlooked in budgeting.

Managing complexity

The integration of GSHPs with heating and cooling systems that also include gas boilers or chillers was a common issue in many projects. We found that it can be difficult to control and prioritise different heating or cooling sources; each working at different temperatures.

Poor control can reduce the efficiency of heat pumps and increase the running cost of the overall system. A simple system design is preferable and the designer needs to provide a clear description of how the heat pump interacts with the controls for the whole heating system. This is even more important where the system provides both heating and hot water.

MENU

Managing construction

Managing the quality of construction is key to success. Some recurring themes came up:

- locating boreholes away from other site activities helps avoid programme disruption
- 'clean' drilling methods can cut clean-up and soil removal costs
- marking boreholes prevents damage from other site activities
- without good quality lining to the correct depth, boreholes can collapse
- ensure safety equipment is installed and fully commissioned before testing the system. On one project, expensive parts were damaged by unauthorised testing by inexperienced contractors.

Contractual responsibilities and interfaces need careful consideration to ensure the success of systems

Borehole drilling for Bramall Learning Centre at RHS Garden Harlow Carr

Lessons learned

- Team experience matters and outside expertise can be used to bridge knowledge gaps.
- Engaging contractors early enhances design outcomes and controls cost.
- System design should be simple with controls carefully integrated.
- Ensure costing includes all ancilliary items.
- Careful consideration of borehole construction and quality control is vital for success.
- Contractual responsibilities need careful consideration.

MENU

Project summaries

	The City Academy, Hackney, London	St Edmundsbury Borough Council, Suffolk	Royal Horticultural Society, North Yorkshire	Citu, Greenhouse, West Yorkshire	London School of Hygiene & Tropical Medicine	Stoke Local Service Centre, Staffordshire	Edge Hill University, Lancashire
Description of project	New build academy	Four-storey new office	New Bramall Learning Centre	Major refurbishment for 172 apartments and commercial	Grade 2 listed refurbishment	New build extension	Two buildings for the Faculty of Health
Floor area	11,217m²	6,430m²	703m²	11,500m²	2,105m²	1,314m²	7,069m² + 2,065m²
Heating capacity	200kW	463kW	22kW	645kW heating 586kW hot water	Cooling only	90kW	380kW
% Annual heating & hot water	53% heating	100% heating	90% heating 40% hot water	100% heating 85% hot water		100% heating	30% heating
Cooling capacity	57kW	430kW	Free cooling	570kW	200kW	None	525kW
% Annual cooling		89.5% cooling		100% cooling	53% cooling		100% cooling
Total cost	£465,000	£435,000	£71,000	£1.3m	£650,000	£149,000	£575,000
No. of boreholes	51	4	4	4	4	16	2
Open/closed loop	Closed	Open	Closed	Open	Open direct cooling	Closed	Open
Distance between boreholes	8m	~ 70m	10m	~ 80m	~ 10m	7m	180m

CTG036

The Carbon Trust is a not-for-profit company with the mission to accelerate the move to a low carbon economy. We provide specialist support to business and the public sector to help cut carbon emissions, save energy and commercialise low carbon technologies. By stimulating low carbon action we contribute to key UK goals of lower carbon emissions, the development of low carbon businesses, increased energy security and associated jobs.

We help to cut carbon emissions now by:

- providing specialist advice and finance to help organisations cut carbon
- setting standards for carbon reduction.

We reduce potential future carbon emissions by:

- opening markets for low carbon technologies
- leading industry collaborations to commercialise technologies
- investing in early-stage low carbon companies.

www.carbontrust.co.uk
0800 085 2005

The Carbon Trust receives funding from Government including the Department of Energy and Climate Change, the Department for Transport, the Scottish Government, the Welsh Assembly Government and Invest Northern Ireland.

The Carbon Trust is a company limited by guarantee and registered in England and Wales under Company number 4190230 with its Registered Office at: 6th Floor, 5 New Street Square, London EC4A 3BF.

Printed on 80% recycled paper containing a minimum of 60% de-inked waste fibre.

Published in the UK: March 2011.

CARBON TRUST
Making business sense of climate change