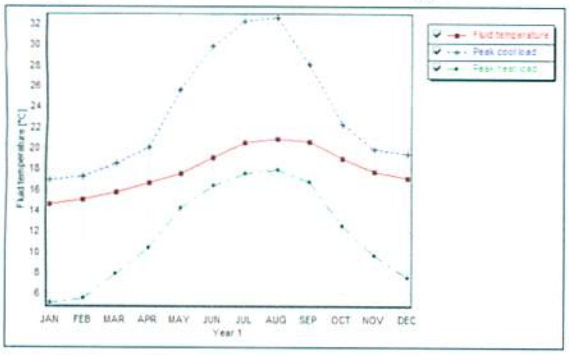
Managing and optimising GSES

Andy Howley, managing director of UK-based Ground Source Consult, explains how to maximise the efficiency of a ground-source energy system

Ground-source energy systems (GSES) are utilising a renewable resource, that much has been established. For thousands of years the ground has been warmed by the sun, the climate and the deep-earth radioactive decay to arrive at the undisturbed temperature into which the GSES taps.

From the minute a GSES is turned on, however, it extracts the energy or sends energy into the resource, thereby changing, in a matter of hours in some cases, what has taken Mother Nature eons to deliver. Creating a sustainable GSES therefore requires close management to ensure that the energy transfer does not lead to excess energy extraction, that rejection does not work faster than nature can work, and that a clear understanding is in place to make sure nature is occasionally supported.

Figure 1: year one of a GSES with heavy heat rejection imbalance. The array copes with the first year and probably the second and maybe the third



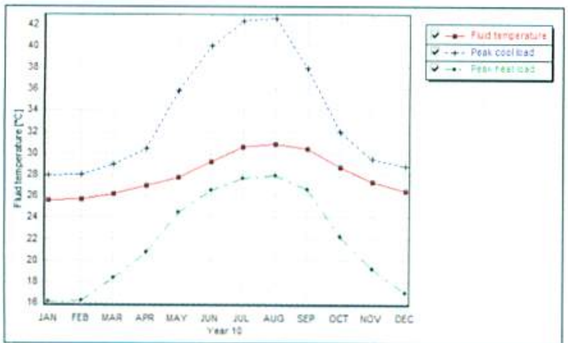


Figure 2: the same GSES at year 10 without energy management; heat build-up has resulted in mean temperatures 10°C higher

A further key consideration for GSES, as they become more prevalent, is impact on other systems nearby. All building owners, developers and system designers should be taking this into consideration today. There needs to be a shift away from designing and installing GSES that steal energy from systems we might need to install tomorrow. All too often in the past, our industry has been blighted by a lack of longer-term planning.

It is widely recognised that GSES present a substantial capital expenditure when installing a facility heating and cooling system. It is essential therefore to not only take advantage of the various incentives, run costs and energy savings that the systems offer but also, in the first instance, to optimise the initial design to deliver the best-price build for your requirements.

The key to optimising the size of the GSES is the energy flow and balance, i.e. how much heat is extracted or rejected, but just as crucially, when and how fast it is rejected or extracted, what with and to what GSES.

The ground can provide a huge thermal mass that can absorb or give up far more of its energy over a single heating or cooling period than it might be able to deliver sustainably year in year out without management of the resource. In addition, without managing the resource, delivering energy sustainably, year in year out, takes a far larger GSES; otherwise, the heat rejection or absorption will become severely limited over time, as outlined in the two graphs (Fig 1 & 2).

Key areas of a GSES

- The building and its heating and cooling requirements;
- The mechanical systems providing heating and cooling;
- The coupling of mechanical systems to GSES;
- The GSES itself.

MANAGING THE ENERGY FLOW

Firstly it is vital that the facility's energy demands are detailed and fully understood. Even on some domestic installations, carrying out hourly energy-load analysis can lead to a smaller, and thereby cheaper, GSES, and managing the demand from the facility enables the customer to take advantage of better energy tariffs. Only a detailed hourly load calculation can enable full optimisation of hybrid installations; anything else is a guess.

Many of the tools available to manage a GSES are in fact standard items of plant and equipment that will often be seen on systems as 'back-up' anyway. Components such as dry coolers, adiabatic coolers, boilers and air chillers and heat-recovery systems can all be used to manage the GSES.

Add to this the options of using together more than one type of GSES, such as open-loop and closed-loop boreholes, as well as pavement heat rejection, pavement heat extraction, ponds, lakes, fountains, the sea, rivers, sewage discharge, solar thermal, snow and ice melt, process energy and combined heat and power, and suddenly there is a whole range of additional options that can be used to manage a GSES, with all manner of additional benefits to the project.

For example, a ground array can be allowed to absorb a lot of rejected heat all summer long; the energy can be used all winter for improved heating performance, and then using a DAC, excess energy can be stripped out in spring. To do this effectively, however, requires control algorithms specifically developed for the actual building, based on the building's loads.

With the hourly building loads programmed into the control system, the hybrid GSES can be designed to extract just the right amount of energy using the correct components at the correct time of the day, week, month or year to 'reset' the GSES. The control system is not finished there, however, as it then learns each year to predict what and when it modifies the following year, thus continually optimising the system performance (Fig 3).

Alternative options are found in facilities where there may be a high through-flow of effluent. This provides a great opportunity to use the effluent and its stored energy, or to reject excess to the effluent to rebalance a GSES. An effluent system can be used to provide additional energy sources to minimise the GSES system requirements. In many cases, through-flow of effluent is very predictable – sometimes more so than the buildings' energy loads themselves. This predictability enables a designer to use these sources almost on demand.

GROUND CONDITIONS

When the detailed energy loads of the building are known, alternative sources can be used to load-shift or to peak-load lop or to rebalance a GSES. To ensure that the hybrid works and works well (and in fact any ground-source system beyond purely domestic or very small commercial schemes), a far greater understanding of the ground conditions, geology, hydrogeology and thermal properties of the ground is required.

Detailed feasibilities must be completed to reap the benefits and to optimise a system. Aside from access, site conditions, services and building needs etc, this feasibility must include details of the geology, hydrogeology, barriers to construction and the thermal properties of the ground.

For example, groundwater movement through a closed-loop borehole GSES has both positive and negative implications for the design. If the intention is to create a thermal store, groundwater movement simply takes it away. If there is a large load imbalance, groundwater movement can enable the GSES to maintain stability by mobilising the excess energy off site. However, where has it gone? Is it now impacting next door?

Field work such as a test borehole and thermal response test (TRT) for closed-loop borehole systems should be part and parcel of feasibility and early design work. If this type of testing is not carried out in the early stages of a project and the results used to help direct the design, the system is unlikely to be optimised and, at best, unnecessary costs may be incurred; at worst, the system will not be fit for purpose.

Geology is hugely variable. Consider for a moment London Clay in the general London Basin area. To start with, London Clay has five very distinct layers within it that may not be easily distinguished simply from drilling cuttings (Fig 4).

The uppermost section of London Clay is the Claygate Member and comprises silts, sands and clays. Unit D which underlies the Claygate Member comprises again silts, sands and clays and is quite variable in its own right with increasing sand content to the west. Unit C, however, being fairly thick at times, is in fact predominantly clay. Unit B is again partly sandy clay but not all that thick, and Unit A, also known sometimes as the Basement Beds, is again a sandy horizon but not a great thickness.

The variations are only in the London area. This clay stretches from the Dorchester area in the south west to Felixstowe in Suffolk and down to Canterbury in Kent.

GEOTHERMAL DATA

So, what information is available and being used by designers for the thermal properties of this particular clay? The data contained in the British Geological Survey's (BGS) publication 'Catalogue of geothermal data for the land area of the United Kingdom' (Rollin 1987) outlines thermal conductivity for these strata as being a lofty 2.45 watts per metre kelvin (W/mk) with an error of just 0.07. But, the report also quite clearly clarifies that this value is derived from just five samples. The report also comes with a specific passage about the fact the publication data for some boreholes may not give a reasonably good guide.

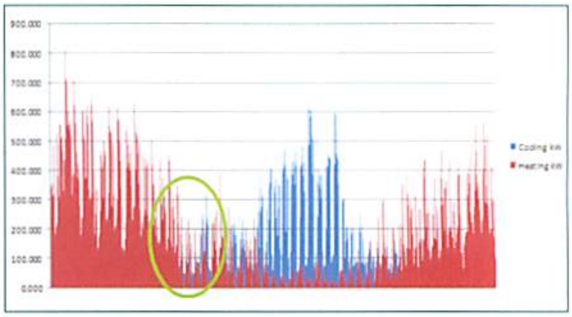


Figure 3: look for periods in the load profile that allow load stripping from the ground array

A further BGS publication provides a value of 1.89W/mk for the same lithology. So, which one is correct? Both of them are correct based on the samples (where taken from samples) they came from. Are they correct to be used for design at a specific site or location? Only if the samples came from that site or location, and even then, the samples would have to have been long enough to cover the entire borehole.

> "The difference that accurate energy load calculations can make to the energy efficiency for both domestic and large commercial and district energy systems is dramatic"

Would anyone expect five samples taken, tested and referenced in published data to be totally representative of a stratum stretching literally hundreds of miles, with several different strata layers and thickness that varies from a few centimetres to hundreds of metres?

Designers have in the past relied on published data. As useful as the basic data is for outline design and, in many cases small domestic systems, everyone would acknowledge that data is only as good as the samples from whence it came. Published data is usually a small select set of samples from which the numbers are produced.

UNDERSTANDING THE DATA

Sticking with London Clay: Ground Source Consult has a ►

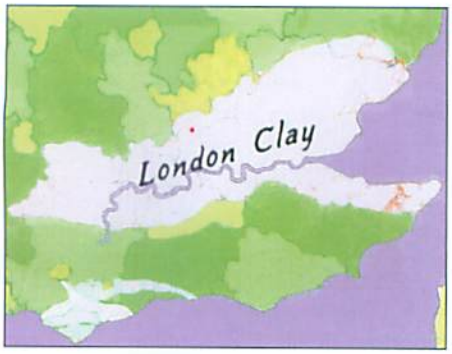


Figure 4: London Clay in the general London Basin area

whole array of results for boreholes we have encountered from the in-situ TRTs carried out in and around London, including boreholes that also pass through Woolwich and Reading Beds, river gravels and chalk.

Not once have we seen a thermal conductivity (TC) value of 2.45W/mk. This is a value being used, however, for design of boreholes and thermal pile systems in London with no consideration as to whether the published data is representative of the site being developed.

Before using anything, one should understand what it is and what it does. This is the same for published data. Understand what the data is and understand the impact of using it; above all, once beyond outline feasibility, use TRT data from the site itself.

With an understanding of the ground conditions, hydrogeology, thermal properties, the types of GSES, the building requirements and the mechanical systems, and the way it delivers load and of course the loads themselves, a tailor-made optimised GSES and mechanical system can be designed and implemented.

The difference that accurate energy-load calculations can make to the energy efficiency for both domestic and large commercial and district energy systems is dramatic, and it is unlikely that a GSES will work to its optimum potential without this sort of detailed analysis. In some cases, the size of a GSES can easily be halved using a hybrid system.

With the appropriate information, we should not be looking at GSES to heat and cool buildings, but looking at a GSES as a tool for storing and moving energy from one place to another. In this way we would fully maximise the efficiency of the equipment that is providing the heating and cooling to the building.

Background

Andy Howley and his brother Iain have been involved in the drilling industry since they took over their father's business many years ago. They have been designing, building and managing installations of GSES for 20 years.

Andy is a highly qualified commercial ground-source energy designer in the UK with Certified Geoexchange Designer (CGD) status.