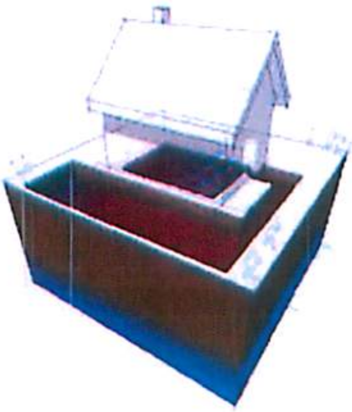
BLOWING HOT&COLD



SLAVO VALIGURSKY / SHUTTERSTOCK

The installation of cheap but inefficient and inappropriate ground source heat pumps to achieve 'simultaneous' heating and cooling must stop, declares **Andy Howley**. Here he analyses four systems to see which works best

What is simultaneous heating and cooling? Is it cooling and heating at the same time? Is it cooling and heating at the same time with the same equipment? Or, is it heating and cooling loads in the same day, week or month? GS Consult Ltd sees all manner of systems asking for simultaneous heating and cooling and there is often very little understanding of the energy flow or the associated timings of the different loads.

If we consider a conventional heating and cooling system using boilers and chillers, simultaneous heating and cooling, is quite clearly possible with two separate systems running at the same time. The boiler can provide low temperature hot water (LTHW) on demand and the chiller system can provide chilled water (CHW), again on demand, assuming the distribution system is capable. The two function independently of each other and can provide heating and cooling up to the maximum plant capacity if required, at the exact same minute of the day.

As regards heat pumps, what would a simultaneous heating and cooling system look like?

Firstly, we must define just how 'simultaneous' the load actually is, to decide which system best suits the loads. Is it simultaneous on a 'second by second' basis, or on an hourly basis? Is there a heating load in the morning and a cooling load in the afternoon? Is there a distinct heating season and a separate cooling season? All of the above have, at some time, been described as 'simultaneous' in specifications and tender documents.

However, only the first – on a 'second by second' basis – is truly a simultaneous heating and cooling load. Hourly and daily loads can be shifted to a certain degree to provide them simultaneously to a store to be used when required. Of course, using ground source systems for heating and cooling provides energy storage in the ground; the summer's heat rejection can be stored in favourable geology and used to enhance the heating performance during the winter, and vice versa in the summer.

So, in order to determine how simultaneous a load is, we need load data. Figure 1 shows an annual profile by month for a ground source heating and cooling system in Yorkshire. Although this is probably sufficient to design a simple system, does this provide sufficient information to decide which type of heat pump combination is the most carbon and operationally cost effective? Looking at the month of May, this

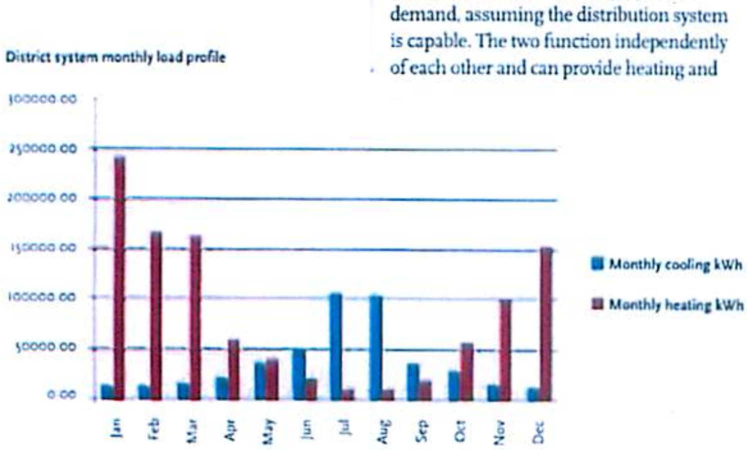


Figure 1: Annual district heating system load profile

would appear to be virtually balanced in terms of monthly load, but just how much of this occurs at the same time? This can only be determined with an hourly load profile.

If we concentrate on simultaneous heating and cooling in the true sense of the description – that is, at the exact same time – which heat pump configurations actually deliver it? And which deliver and provide carbon savings to shout about?

Of course, one can enhance the design of any system, including the first of four examples outlined below, but all of these comparisons are based on a basic system configuration, as outlined in the following schematics for comparison purposes.

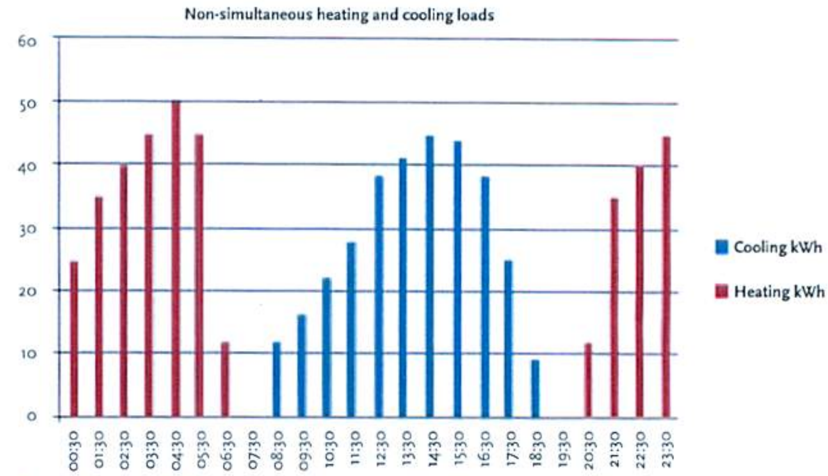


Figure 2: Morning and afternoon separate loads can be delivered by a simple reversible heat pump system

Option 1: Single refrigerant reversible heat pump

Let's first look at a single refrigerant reversible heat pump, which is a packaged unit with one or two compressors with a 'ground side' and a 'load side' fluid flow path. Heating is provided by using the ground side heat exchanger in the heat pump as an evaporator and the load side as a condenser. When cooling is required, the reversing valve changes the flow direction of the refrigerant and the ground side then becomes the condenser and the load side becomes the evaporator.

This system can only deliver either a heating load or a cooling load in its simplest form. It cannot deliver both at the same time from the heat pump. This type of system is relatively simple and is suited to a load profile that has totally separate heating and cooling loads, even if it is only hours apart (see figure 2 and 3).

In short, this set up cannot provide simultaneous heating and cooling directly from the heat pump and, quite often, the heating and cooling emitters are the same system, keeping controls relatively simple. This system is well suited to domestic or small commercial systems where control is by thermostat or even simple manual 'on demand' switching.

Option 2: Slider header systems

To use refrigerant reversible heat pumps – as many do – to provide simultaneous heating and cooling, multiple units are needed and a header configuration that can direct flow to either the CHW or LTHW systems separately. These header systems are often referred to as a sliding header, as shown in figure 4.

This system can provide 100% heating load and 100% cooling load by opening and closing two port valves in the header to divert to either the LTHW or CHW systems. However, it can only provide 50% heating and 50% cooling simultaneously with two heat pumps, and 33%/66%, for example, with three heat pumps. Either way, it cannot provide full or greater than 50/50 simultaneous heating and cooling unless additional heat pumps are used to increase the overall capacity. For example, to provide 100% heating and cooling simultaneously, 200% heat pump capacity is required. This system will also provide the load to a controlled set point for both heating and cooling loads.

> The analysis carried out in this paper can only be done with hourly loads. Anything else is futile and merely a guess

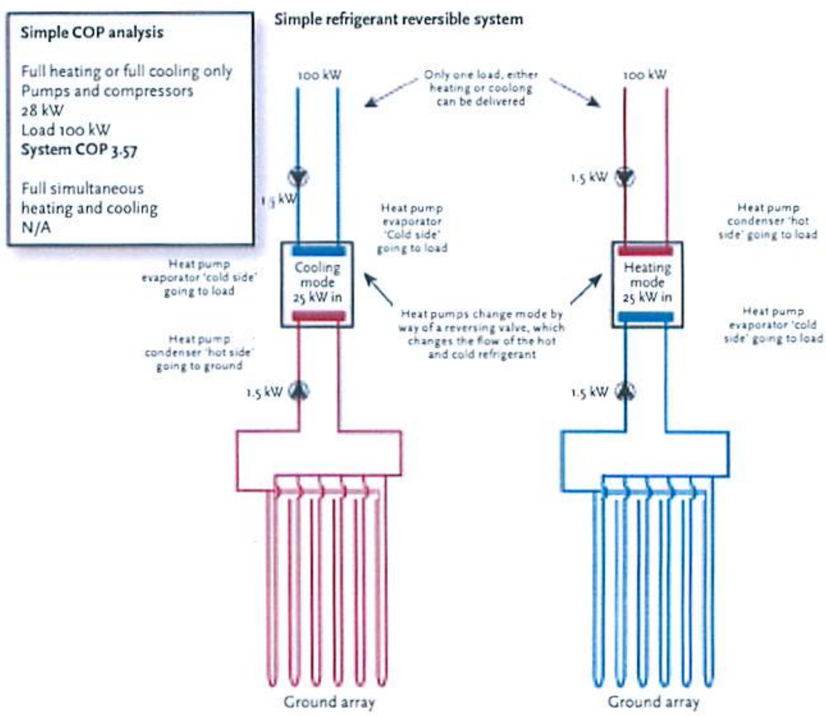
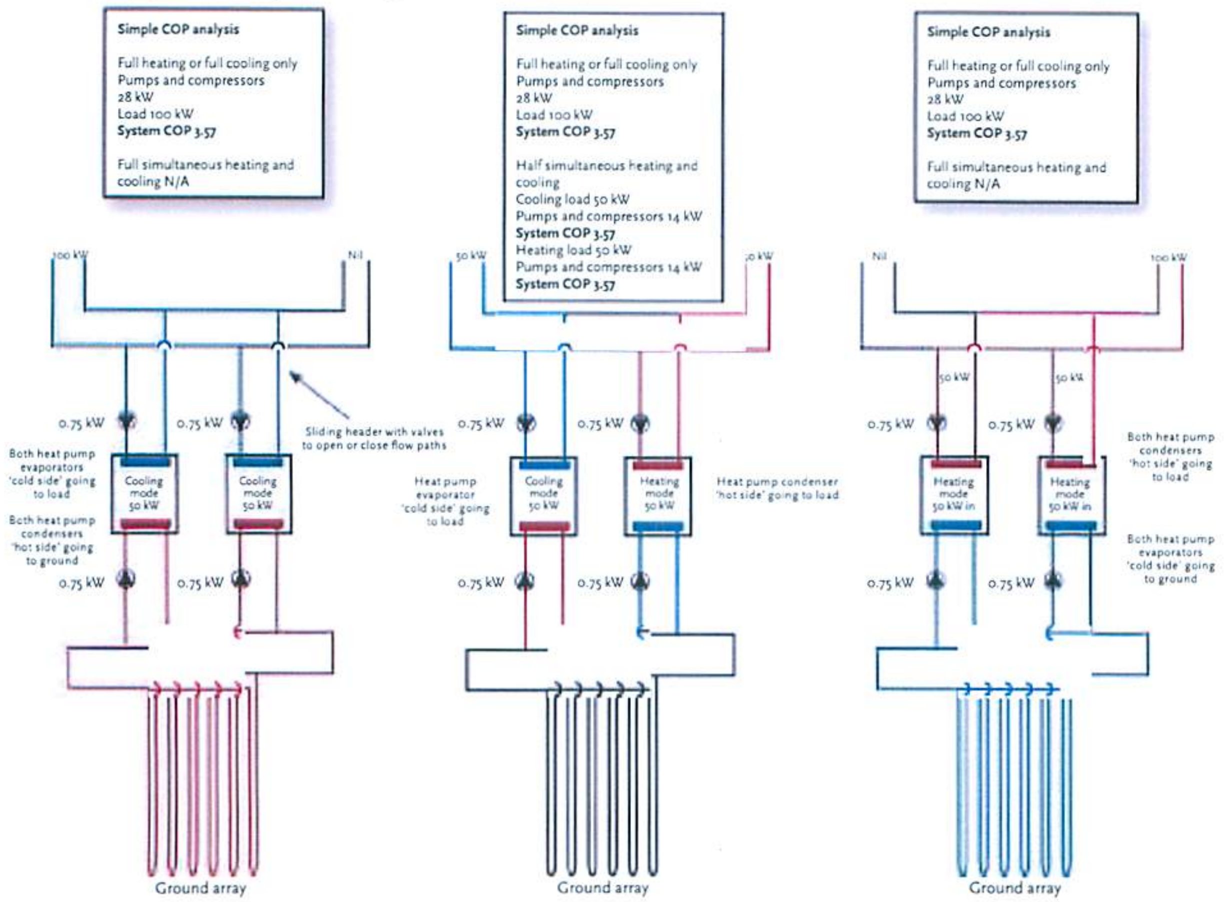


Figure 3: A simple refrigerant reversible heat pump system in heating and cooling

Figure 4: Complex refrigerant reversible system with sliding header



These inappropriate systems are not 'value engineered' for the operator. They are, however, a much easier and cheaper option for an inexperienced and unqualified installer

The main drawback with this system is that it must use one compressor to provide the heating and one to provide the cooling. As a result it is a comparably inefficient means of providing simultaneous heating and cooling. It also requires pumping to deliver fluid to both sides of all the heat pumps in operation, creating an increased 'parasitic' input pumping power. We have seen claims that the coefficient of performance (COP) of the heat pumps operating together can be added together for an overall system COP, but this is an incorrect methodology for calculating COPs, as can be seen in the COP calculation in Figure 4.

So, this system can provide simultaneous heating and cooling, but not efficiently in terms of input energy or pumping power. It is best suited to providing separate heating and cooling loads that do not occur simultaneously or, if there are some simultaneous loads, these are not regular throughout the year (as circled in figure 5) and the lower system efficiency is tolerable for these short durations in return for a relatively simple system.

Heat pumps – regardless of type and/or operation – have a hot and a cold side by virtue of the evaporator and condenser operation. An efficient means of providing simultaneous heating and cooling is by the use of both sides of a heat pump, or multiple heat pumps.

Option 3: Simple refrigerant reversible system

Figure 6 is a simple schematic using three port valves to switch between the ground array and the load on both the evaporator and the condenser. This does truly provide simultaneous heating and cooling at 100% of the units' capacity.

A further advantage of this system is the ability to use thermal storage to increase the amount of load that can be generated simultaneously. With previous example systems, there is no point in providing thermal storage because there is no real increase in efficiency. However, with the evaporator/condenser both providing load, a morning heating load can be used to charge a thermal store with chilled water ready for the afternoon cooling, and the store is depleted or used as needed prior to, or in conjunction with, bringing on the

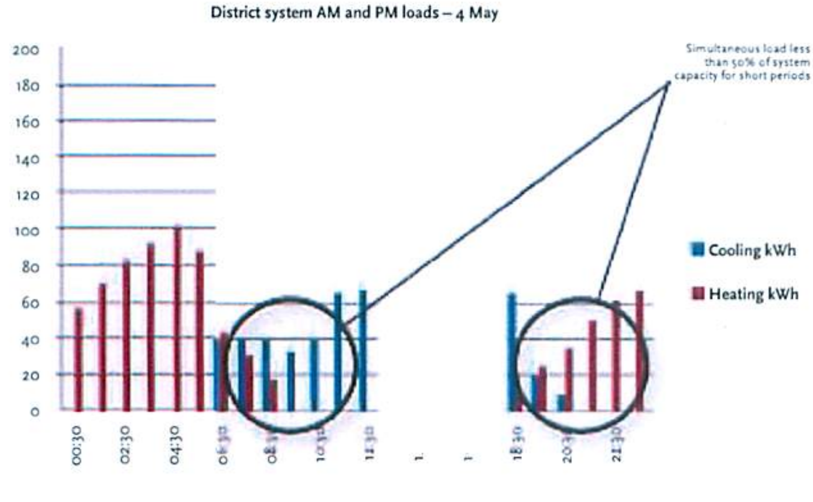


Figure 5: Morning and afternoon loads with small periods of simultaneous loads

heat pumps. The same then occurs during the cooling cycle in the afternoon, where the following morning's heating can be generated during the afternoon cooling process (see figure 7).

Effectively, load shifting generates as much energy as possible simultaneously, thereby hugely increasing overall system efficiency. Use the morning heat load to charge a thermal store and release this to augment or provide the afternoon cooling and vice versa.

The drawback of this system, however, is that the hydraulics of the heat pump may need to be separated from the LTHW and CHW systems as, by virtue of the three port valves, the fluids from the ground array will pass to the LTHW and CHW. If there is a thermal transfer fluid requiring antifreeze to protect the evaporator, this fluid will be present in both the LTHW and CHW systems. This is an added installation and maintenance cost.

A further drawback is the control strategy required to operate such a system. Generally, the heat pumps can only deliver one load to a controlled set point. For example, if the system is cooling dominant at a certain point in time, the heat pumps are programmed to deliver the load to a set point in cooling. The heating then provided by the condenser is effectively 'uncontrolled', in that the heat pump is not delivering this load to a particular set point. The building management system (BMS) must therefore identify how best to deliver this load and when, using the three port

Simple COP analysis	Full simultaneous heating and cooling
Full heating or full cooling only	Pumps and compressors 28 kW
Pumps and compressors 28 kW	Load 200 kW
Load 100 kW	**System COP 7.14**
System COP 3.57	

Simultaneous capabilities using three port valves

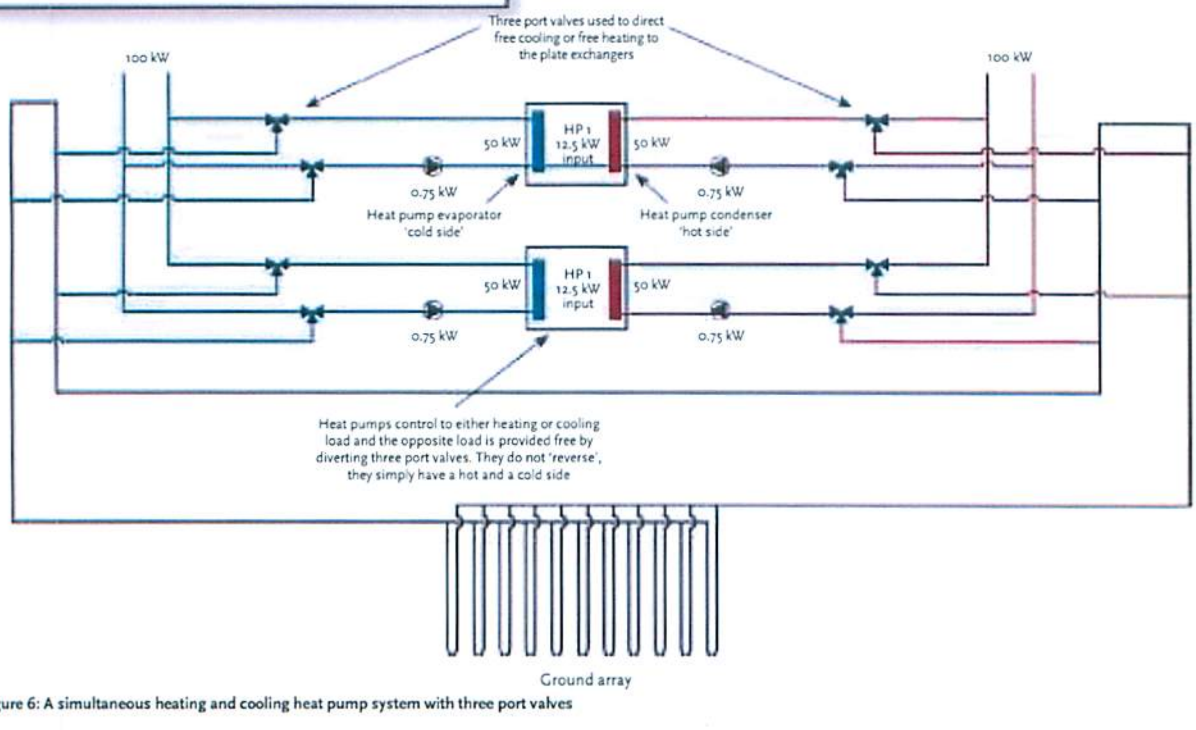


Figure 6: A simultaneous heating and cooling heat pump system with three port valves

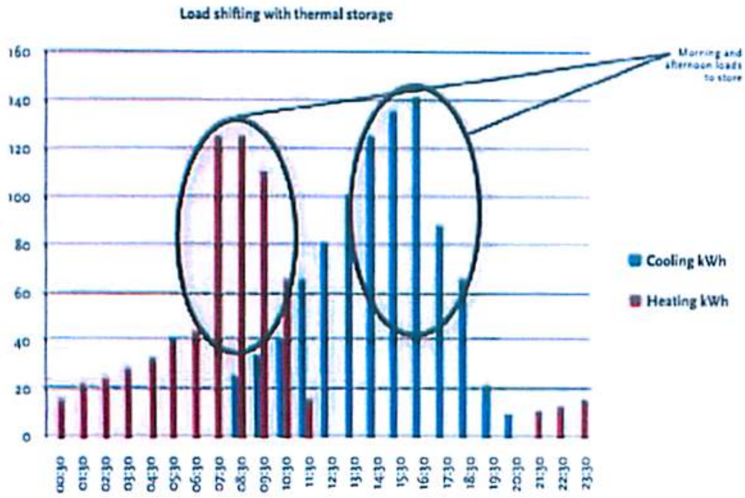


Figure 7: A load profile that warrants thermal storage to provide as much load simultaneously as possible

valves. Again, using a thermal store is a good way of using this uncontrolled load.

Option 4: Six-pipe heat pump with heat recovery

The final example is of a six-pipe heat pump with heat recovery (see figure 8).

Importantly, internal to the heat pump, the load is apportioned to either the CHW system, LTHW system or the ground array. The BMS merely calls for either the LTHW, CHW, or both loads and the heat pump delivers both loads to set points.

Simple COP analysis

Full heating or full cooling only
Pumps and compressors 28 kW
Load 100 kW
System COP 3.57

Full simultaneous heating and cooling
Pumps and compressors 28 kW
Load 200 kW
System COP 7.14

Part simultaneous heating and cooling
Pumps and compressors 29.5 kW
Load 200 kW
System COP 6.78

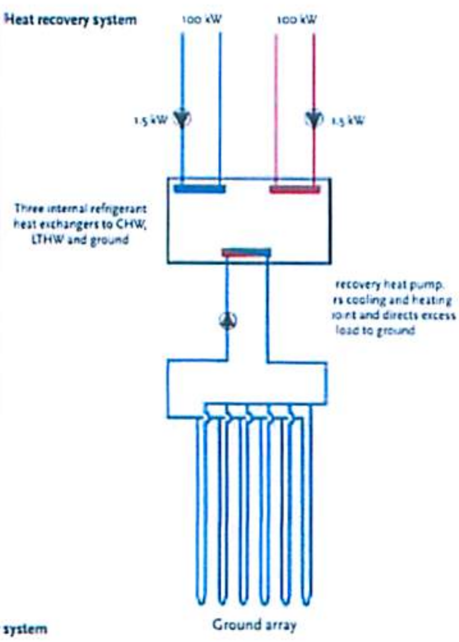


Figure 8: A six pipe heat recovery system

The thermal store option can still be used with this type of system to again load shift from one part of a day to another, to further enhance the efficiency of the overall system.

In true and simplistic efficiency terms, this may not quite reach the levels of a three-port valve system. However, the very simple pipe work – and controls – plus the ability to maintain two set points as opposed to one, provide compelling reasons to accept this slight drop in performance of the overall system over what is a very simple option.

Conclusions

The analysis carried out in this paper can only be done with hourly loads. Anything else is futile and merely a guess.

Hourly loads must be provided for even the most simple types of systems and this must quickly become commonplace.

Option one cannot provide the simultaneous loads.

Option two can only provide the simultaneous loads inefficiently; this system is cheap to install but expensive to run.

Option three can provide truly simultaneous heating and cooling with the efficiency of only using one compressor, or bank of compressors, to do it and thermal storage can further enhance the system efficiency.

Option four can do all of the same things as system three, but is less complex in terms of controls and piping, and isolates the LTHW and CHW from the ground array fluids. Options three and four present by far the most efficient systems for simultaneous heating and cooling, on both lifecycle and carbon savings, beat option two hands down. It's simple – the initial cost to the operator of these inferior systems appears low. However these inappropriate systems are not 'value engineered' for the operator. They are, however, a much easier and cheaper option for an inexperienced and unqualified installer.

The practice of installing cheap but inefficient and inappropriate systems must stop. Production of hourly loads for even relatively simple systems must become the norm and be carried out very early in the overall building concept and design process. It is our job to help clients understand that the cheapest to install may actually prove to be a very expensive on-going mistake. **CJ**

Andy Howley is a certified geo-exchange designer (CGD) And also the technical director of Ground Source Consult. www.gscltd.co.uk