GIR72

Heat pumps in the UK – a monitoring report

energy saving trust™

1 Introduction

Project summary

Home energy use is responsible for 27 per cent of UK carbon dioxide emissions which contribute to climate change. By following The Energy Saving Trust's best practice standards, new build and refurbished housing will be more energy efficient – reducing these emissions and saving energy, money and the environment.

This Report summarises the performance monitoring of a ground source heat pump (GSHP). The heat pump is used to supply an underfloor heating system in a large, but well-insulated, private dwelling. The heat pump maintains satisfactory comfort conditions and no significant problems have been encountered.

The running costs are estimated to be higher than for a gas condensing boiler (although mains gas is not available) and oil-fired systems, but lower than for conventional electric heating options. Carbon dioxide (CO_2) emissions were reduced compared to all alternative fuels investigated (when using standard emissions factors). The heat pump has achieved an overall coefficient of performance (CoP) of 3.16, although scope for further improvements have been identified.

The limitations of the study means that these figures cannot necessarily be applied to other types of heat pump or situations, and their energy and environmental performance should be carefully evaluated on a project by project basis. In particular, CoPs for heat pumps capable of providing cooling may be significantly lower and result in higher running costs and higher CO_2 emissions.

GSHPs are receiving increasing interest in North America and in some countries in Europe. The technology is well established with over 400,000 units (80 per cent of which are domestic) installed worldwide and about 45,000 installed annually, although most systems in the United States are of the reversible type. Very few systems have been installed in the UK.

Efficiencies for GSHPs can be high because the ground maintains a relatively stable temperature allowing the heat pump to operate close to its optimal design point. Efficiencies are inherently higher than for air source heat pumps because the air temperature varies both throughout the day and seasonally such that air temperatures, and therefore efficiencies, are lowest at times of peak heating demand.

This Report summarises the findings of a project to evaluate the energy and environmental performance of heat pumps in the UK climate. The project involved installing a GSHP in a domestic house and monitoring its performance over the first year of operation.

This Report is primarily intended for architects, designers and planners, although it does contain general information on GSHPs that may be of interest to a wider audience.

What are ground source heat pumps?

A heat pump is a device for removing heat from one place – the 'source' – and transferring it at a higher temperature to another place. The heat pump consists of a compressor, a pressure release valve, a circuit containing fluid (refrigerant), and a pump to drive the fluid around the circuit. When the fluid passes through the compressor it increases in temperature. This heat is then given off by the circuit while the pressure is maintained. When the fluid passes through the relief valve the rapid drop in pressure results in a cooling of the fluid. The fluid then absorbs heat from the surroundings before being re-compressed. In the case of domestic heating the pressurised circuit provides the heating within the dwelling. The depressurised component is external and, in the case of GSHPs, is buried in the ground (see figure 1).

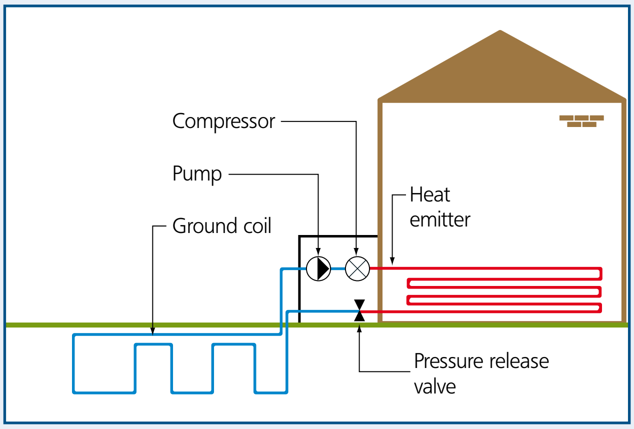

Figure 1 Components of a ground source heat pump

Heat pump efficiencies improve as the temperature differential between 'source' and demand temperature decreases, and when the system can be 'optimised' for a particular situation. The relatively stable ground temperatures moderate the differential at times of peak heat demand and provide a good basis for optimisation. They also avoid the need for defrosting cycles required by some air source heat pumps.

2 The system

The building

The building used for the project is a detached, four-bedroom, two-storey house with a linked single-storey, two-room annex. The total floor area is 288m².

The main house and the annex are constructed using part-filled cavity plinth walls, approximately 1 metre high, with timber frame construction above. Levels of insulation are high (U-values for the walls, roof and floor are 0.31, 0.25 and 0.25W/m²C respectively). For structural reasons, the house is built on a substantial concrete raft and the internal walls are dense concrete block so these elements provide substantial thermal storage. The design heat load (assuming an external temperature of -1°C) is 7.2kW for the main house and 1.46kW for the annex. The predicted total annual space and water heating requirements (using BREDEM and an average annual degree day figure of 2,263, and water consumption of 250l/day) are 20,020kWh and 5,600kWh respectively. The family occupying the house consists of two adults and two children.

The heating system

The heating system is shown diagrammatically in figure 2.

The heating system consists of a water-to-water heat pump with a rated capacity of 3.96kW at an output temperature of 45°C. It is sized to provide only 50 per cent of the design heat load so the system includes an in-line direct electric heater (3 x 2kW) to provide auxiliary heating, but for this project only 2 x 2kW heaters were connected.

The sizing is in accordance with the manufacturer's recommendations and the heat pump is expected to be able to meet over 80 per cent of the annual space-heating requirement. The next size of heat pump in the manufacturer's range (6kW capacity) would have required a three-phase supply. The heat pump (IVT Greenline 4) was imported from Sweden. IVT is the market leader in heat pumps in Sweden, where there is an established market for GSHPs.

This product was chosen as it had been developed by IVT as their winning entry in a Scandinavian technology procurement competition aimed at improving the efficiency and reducing the costs of heat pump heating systems. The refrigerant used is R407C, which has no ozone depletion potential (ODP) but does have a global warming potential (GWP) of 1,600 relative to CO_2 (for a 100-year time horizon).

The unit is supplied complete with the auxiliary heater and a simple controller (see figure 3). An additional time switch has been used in this installation to limit the use of the auxiliary heater to the Economy 7 tariff period.

The ground collector is a single horizontal loop of pipe (PE 32/28mm), 200m long, buried at a nominal depth of 1m. The pipe loop contains a water/antifreeze solution to prevent freezing.

Heat is delivered either to the domestic hot water (DHW) or to space heating. The DHW is heated via an exchange coil in a mains pressure cylinder (capacity 210l) which has a 3kW electric immersion heater as a back-up. This is a standard Gledhill Accolade unit, with an extra-long primary coil fitted to maximise heat transfer rates.

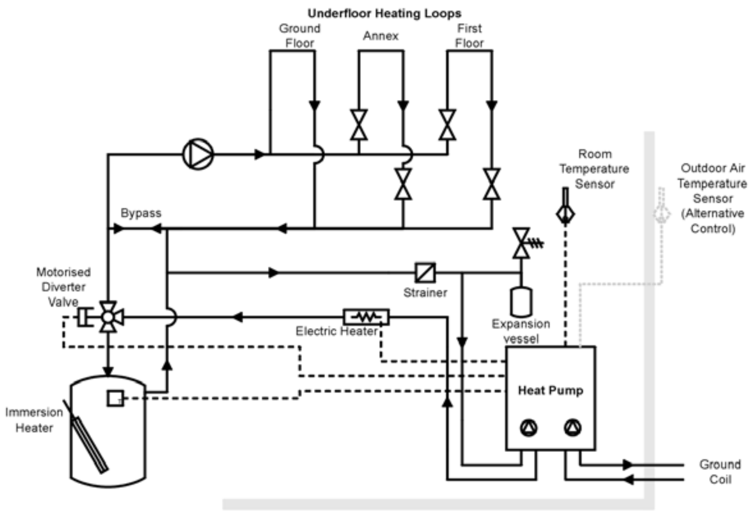

Figure 2 Diagram of the heating system

Operation of the immersion heater is mainly limited to the Economy 7 tariff period but with a boost period in the afternoon if necessary. Space heating is provided by a standard Wirsbo underfloor wet system consisting of 20mm PE piping either embedded in the floor screed (downstairs) or in suspended floors (upstairs). There are three separate loops – downstairs in the main house, upstairs in the main house, and the annex. There are motorised isolating valves on the loops to the upstairs and annex.

The heat pump output is directed via a three-way motorised valve either to DHW or underfloor heating. DHW heating takes priority and the supply of heat is controlled by a temperature sensor in the cylinder. The required temperature can be adjusted and was set to 45°C.

There are two levels of control for the space heating. If the DHW is satisfied, heat output is directed to the underfloor heating. This is controlled by an air temperature sensor in the dining room. Circulation continues in the ground floor circuit as long as the temperature sensor in the dining room is not satisfied. The isolating valves on the upstairs and annex loops only open if thermostats in the respective areas call for heat. The annex and bedrooms can only be supplied with heat when heating is being supplied to the downstairs loop.

From July 1998, the operation of the space heating system has been based on an outdoor temperature sensor instead of the temperature sensor in the dining room. The return temperature to the heat pump has been adjusted according to the curve given in figure 4. The control point was set at 4.5.

When the heat pump cannot satisfy the demand for heat the auxiliary heater comes on, but is controlled to switch in only after a time delay, which can be adjusted, from 10 minutes to two hours. The time delay was set to one hour. When the heat pump stops it cannot restart within 15 minutes.

Two wood-burning stoves can provide additional space heating, one in the living room and one in the kitchen. In practice, these stoves were used occasionally during the monitoring period, to provide amenity value or rapid space heating during extreme weather. Their contribution to the annual energy consumption for space heating was negligible.

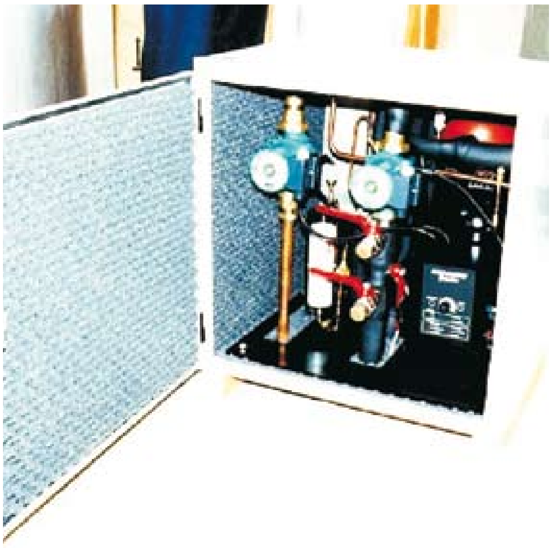

Figure 3 The heat pump prior to installation

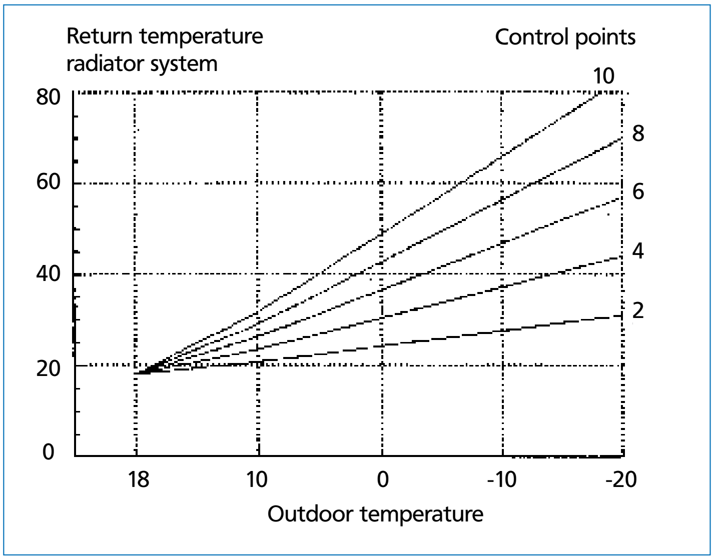

Figure 4 Outdoor temperature sensor control curve

3 Installation of the heat pump

The system was designed for installation by normal, commonly available building trades. The ground loop (figure 5) was installed by the building contractor while an excavator was on site. Roughly six hours of excavator time was required to dig the trench and backfill. The underfloor heating was installed by Wirsbo installers, terminating at three manifold pairs. The DHW cylinder and all distribution piping to hot water and heating circuits was plumbed in using plastic piping wherever possible under a standard plumbing sub-contract.

The heat pump was installed, plumbed and wired by the owner. This was to explore any installation issues, and to allow incorporation of the sensor points required for monitoring. The plumbing and wiring were straightforward to do. The heat pump was mounted in an internal understairs cupboard (maximum height 1.4m) with access from the kitchen (see figure 6). The flow and return pipes of the ground coil were led at a depth of approximately 1m below ground level through 2 x 100mm PVC-U sub-floor ducts with easy bends up through the raft floor slab into the understairs cupboard.

The heat pump was mounted on wall brackets and the connections to the ground coil were made directly into the base. Short lengths of plastic piping were incorporated in the hot loop flow and return lines, to prevent vibration from the heat pump propagating through the copper piping around the heat pump. Subsequent experience with the unit suggests that this was an unnecessary precaution.

Before commissioning, it was necessary to purge air from the ground coil and fill it with antifreeze. (The loop had previously been pressure tested to 10 bar.) Purging was performed with a submersible pump that circulated fluid through the loop with sufficient velocity to entrain air collecting in the high points of the circuit. A pressure test kit was needed to charge the loop to the necessary pressure (1 bar above operating atmospheric pressure). A specialist company with experience in installing GSHPs assisted with this task.

Installation presented no real problems but purging of air from the cold loop was more difficult than expected due to insufficient pump power. The auxiliary heater originally supplied required a three-phase supply (normal in Sweden), and a special order had to be placed to get a single-phase heater element. Even this small 4kW heat pump unit was heavy (75kg), so two people were needed to position it. In general, installation could have been easier if better documentation had been available in English.

Figure 5 200m of ground coil was used at an average depth of 1m

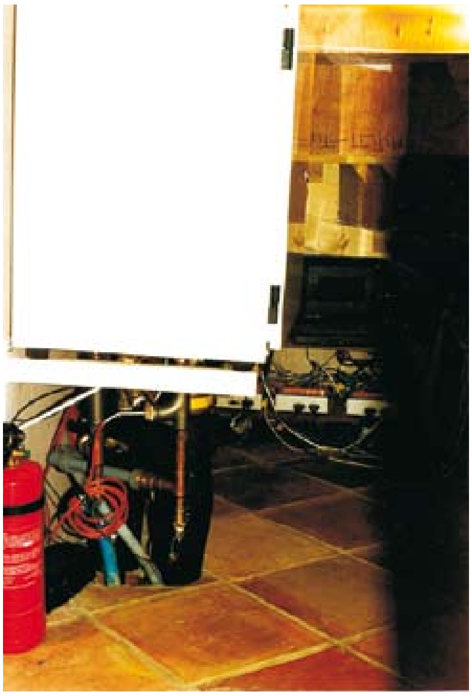

Figure 6 The heat pump was installed in an understairs cupboard

4 Monitoring and results

Monitoring

A monitoring system was set up to measure the energy output from the ground collector, the efficiency of the heat pump system, the energy it delivered to the space and hot water systems and the total energy consumed for space and water heating. In addition, temperatures at various points in the heating distribution system and the status of the pumps and valves were monitored to provide information on the detailed operation of the heating system. The temperature in the ground close to the collector coil was also monitored. To enable a qualitative assessment of comfort levels to be made, air temperatures were recorded at six positions inside the building (the kitchen, dining room, living room, main bedroom, bedroom two and the annex), and the outside air temperature was also recorded. The data-logging system was controlled using a flexible software package and both real time and summary data was recorded locally on a PC. A modem link allowed the logging system to be controlled remotely and data to be transferred so that disturbance to the occupants could be minimised. Performance data on the system was collected from 13/2/98 to 25/3/99.

The monitoring system generally operated reliably. The remote access system worked well but required that a fax machine, which was normally on the same line, be disconnected. Sometimes the logger also had to be reset. It was found from initial analysis of the data that the status monitor for the auxiliary heater had been mounted before an internal thermostat so that the run time for the auxiliary heater was overestimated. The position of the sensor was changed and the data was corrected. Detailed data was not recorded over the period from 13/8/98 to 14/10/98. Disturbance to the settings on one of the data logging boxes resulted in some of the detailed data being lost intermittently during the period 11/11/98 to 13/2/99, as the logger would not automatically restart.

Results

Energy consumption

The energy supplied for space and water heating by the heat pump, its auxiliary heater and the immersion heater over the first year of operation of the system from March 1998 to February 1999 is shown in table 1. The electricity consumed to provide this energy is also shown.

The total annual energy supplied for space heating was 15,255kWh, and domestic water heating was 3,425kWh. However, the total electricity consumed to provide the space and water heating was only 7,825kWh, as the heat pump provided 10,855kWh of 'free' energy from the ground. Use of the heat pump saved the emission of approximately 5 tonnes of CO_2 compared with conventional electric heating. The heat pump provided 91.7 per cent of the energy for space heating and 55.3 per cent of the energy for water heating.

Table 1 Energy supplied and electricity consumed for space and water heating – March 1998 to February 1999, with predicted consumption in parentheses

	Energy supplied (kWh)			Electricity consumed (kWh)
	Space heating	Domestic hot water	Total	Total
Heat pump	13,985	1,895	15,880	5,025
Auxiliary heater	1,270	_	1,270	1,270
Immersion heater	_	1,530	1,530	1,530
Total	15,255 (20,020)	3,425 (5,600)	18,680	7,825

The energy consumption for space and water heating is lower than predicted. The difference in the energy required for space heating is probably due to differences in the weather conditions. The period monitored was warmer than the average year. The degree day total was 1,899, which was 16 per cent lower than the 10-year average of 2,263 used to predict the energy consumption for space heating. The amount of energy required will also be affected by solar gains.

Domestic water consumption is extremely variable. The estimate of the energy consumption for water heating was based on:

- A daily usage of 250 litres.
- A constant mains supply temperature of 8°C.
- A constant output temperature of 50°C.

No measurements of water consumption were taken but, as three members of the household are away from the house for most of the day, the actual consumption figure could be expected to be lower than that predicted. Also, in practice, the mains supply temperature will not be constant.

Figure 7 shows the daily energy output from the heat pump for space and water heating (for all dates where detailed data was available). Figure 8 shows the daily total energy consumption for space and water heating.

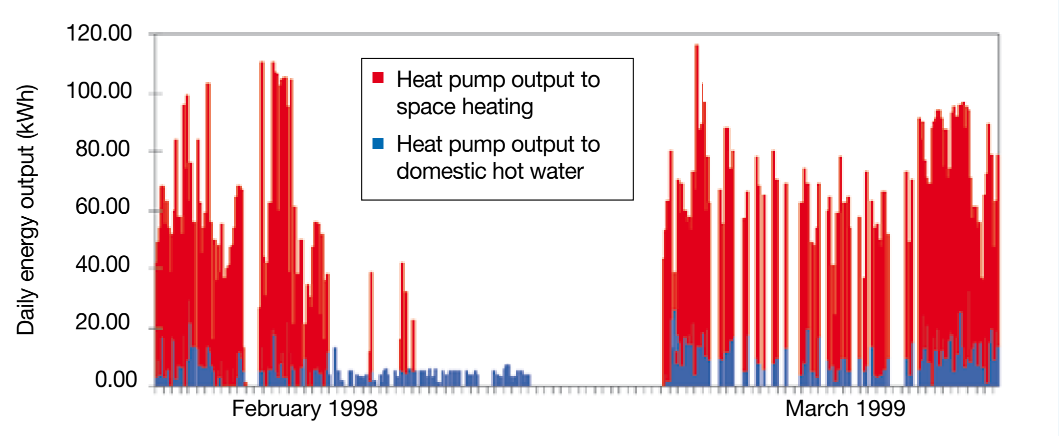

Figure 7 Heat pump daily total energy output (kWh)

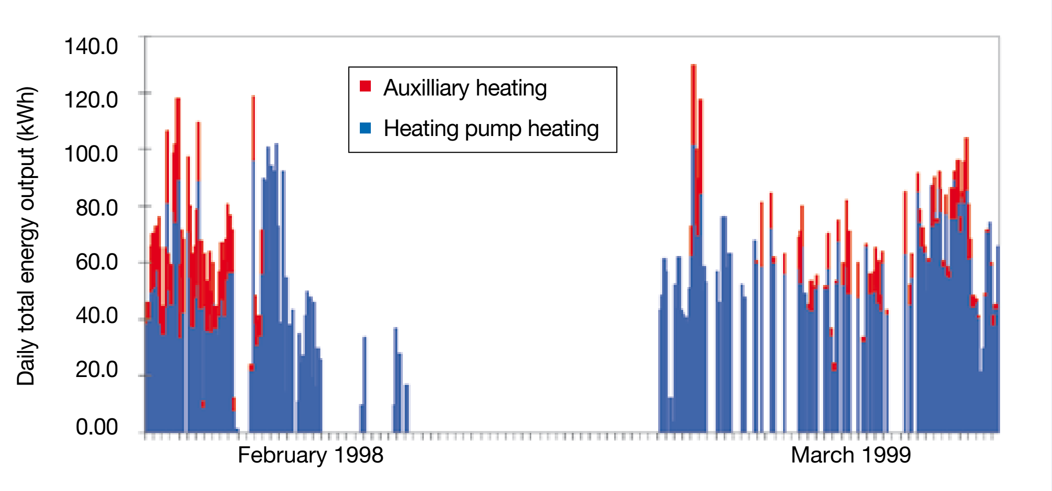

Figure 8 Daily total space heating (kWh)

Heat pump system performance

The overall performance factor of the heat pump system was 3.16, i.e. the overall efficiency was 316 per cent. This was calculated as the total energy output to the space and water heating distribution system (including some contribution from a distribution pump sited inside the heat pump) divided by the total electrical energy consumed by the compressor and the circulating pumps for the ground coil and the distribution pump in the heat pump system. The average heat pump system efficiency over the heating season (taken as November to April) was 3.31 compared to an average system efficiency of 2.5 over the summer months, when the heat pump was providing predominately water heating. The highest daily performance factor recorded was 3.72.

Detailed analysis of the results, however, showed that the difference in system efficiency between winter and summer was largely due to the fact that the heat pump includes a small (86.7W) distribution pump that runs continuously, i.e. even when the heat pump is not supplying heat. This was factory set, presumably to prevent the possibility of the heat pump operating with no flow over the condensing coil.

The energy used to operate this pump could be reduced if it was controlled to operate only when the heat pump was supplying heat. The improvement in efficiency would be greatest in summer when the heat pump is only operating for a short period each day. If this pump were controlled to operate only when the heat pump is operating, it is estimated that the overall annual performance factor of the heat pump system would be 3.43, and that the average system efficiencies for the period November to March and April to September would be 3.42 and 3.44 respectively. Under these conditions, it is predicted that there would only be a small variation in the efficiency of the heat pump system between summer and winter. This is explained by the fact that although the output temperature required for domestic water heating is higher than that required for space heating, the ground temperatures are significantly higher in the summer than in the winter (see page 9).

The performance of the heat pump is inversely proportional to the difference between the condensation temperature and the evaporation temperature (the temperature lift).

Figure 9 shows the output of the heat pump for a range of output (condensation) temperatures. These are stable operating conditions, but not true steady state conditions. At output temperatures greater than 40°C, the heat pump was providing heating to the domestic hot water. The scatter in the points is largely due to variations in the source temperatures (range 0.2°C to 4.3°C). These results indicate that the system performance meets and possibly exceeds the specified rating for the heat pump of 3.7kW at an output temperature of 45°C.

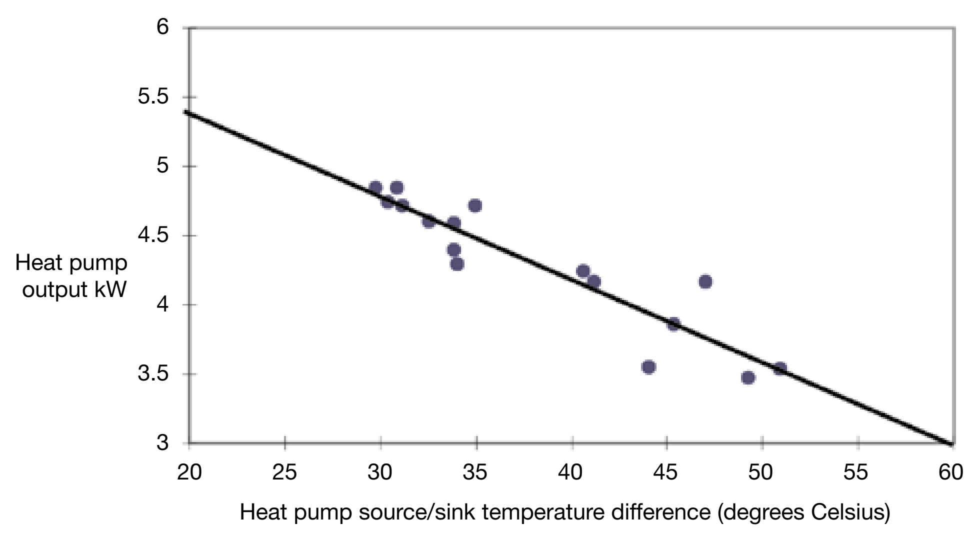

Figure 9 Heat pump output (kW) versus average output temperature

Two different control mechanisms for the supply of energy from the heat pump for space heating were tested. From March until July 1998, the supply of energy from the heat pump to the space heating system was controlled by a thermostat mounted in the dining-room. From August 1998, an alternative control using an outside air temperature sensor was used. This resulted in the heat pump operating more continuously in cold weather and in considerably less use of the auxiliary heater. The amount the auxiliary heater is used has a large effect on the economics of the system. Using the outdoor air temperature sensor results in the return temperature being adjusted for changes in the outdoor temperature and good prediction of the heating requirement. Very stable internal temperatures were maintained. Figure 10 shows the daily total space heating from the heat pump and the auxiliary heater for the two heating control systems. The same period of the year has been compared. The period in 1998 was using the room temperature sensor in the dining room and the period in 1999 shows the performance using an outdoor air temperature sensor.

The operating conditions were not identical, but the average 24-hour temperatures for the two periods were quite similar at 9.26°C and 9.02°C respectively.

Figures 11 and 12 show daily system temperatures for a sample day in each period and the periods of operation of the auxiliary heater and the immersion heater.

Performance of the ground collector

The flow rate in the ground coil is 0.23l/s. The heat collection rate varies from approximately 19W to 27W per metre length of collector coil. In winter, the ground coil typically operates with a temperature differential of about 5°C (i.e. a flow temperature from the ground of 2°C to 3°C and a return temperature to the ground coil of -1°C to -2°C). Icing up of the return pipework immediately below the heat pump can be quite severe. The ground coil temperatures are considerably higher in summer when, for water heating, the temperature differential is similar but flow and return temperatures are typically 11°C and 6°C respectively. When the heat pump starts, the flow and return temperatures stabilise very quickly. Even over sustained periods of continuous operation the temperatures remained stable. The ground coil appears adequately sized and could possibly be oversized.

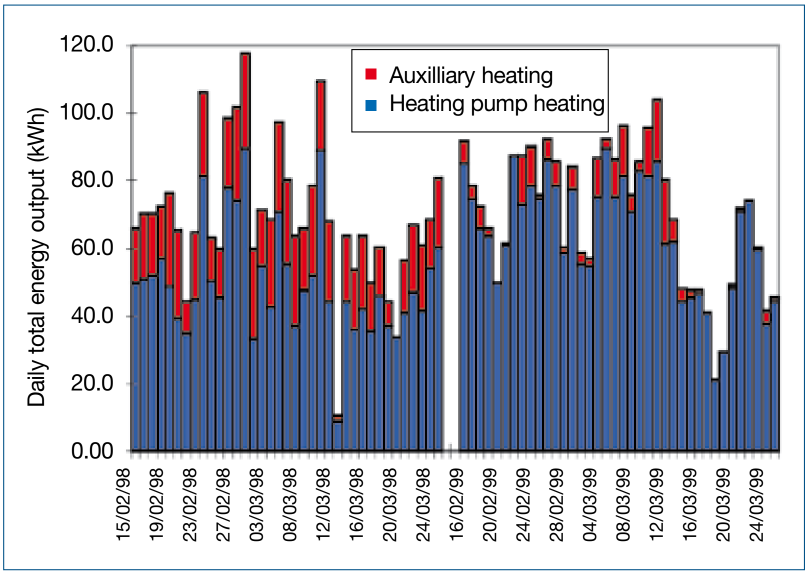

Figure 10 Daily total space heating for different control regimes (kWh)

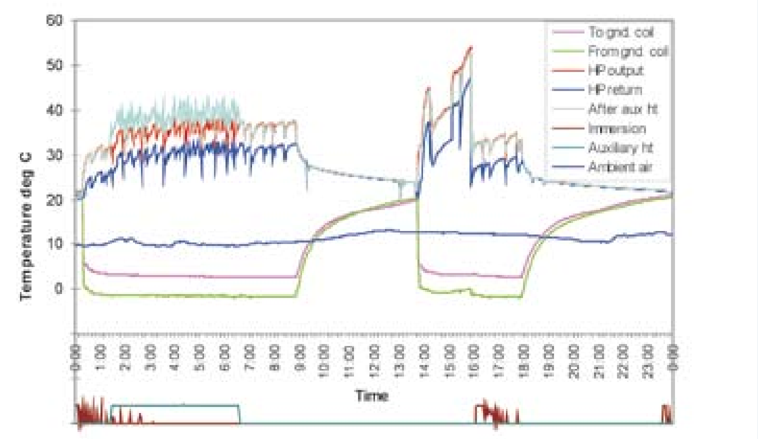

Figure 11 Heating system temperatures 17/3/98

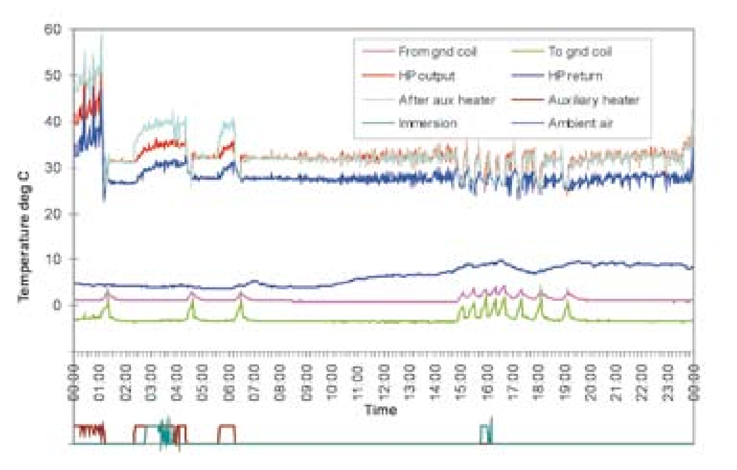

Figure 12 Heating system temperatures 8/3/99

Comfort conditions

Acceptable conditions appear to have been maintained with daily average indoor air temperatures of between and 18°C and 23°C consistently maintained during the heating season (figure 13). Some problems with poor airtightness, however, have been reported which can cause draughts with certain wind directions. The thermostats in the dining room, spare bedroom, and annex appear to control the temperatures well in the three zones of the building. The thermostats for the upstairs and annex loops, however, appear to switch in repeatedly for very short periods at times and this needs to be investigated. The annex appears to maintain a lower temperature (by approximately 3°C) than the main house when not heated, due to its higher perimeter/area ratio.

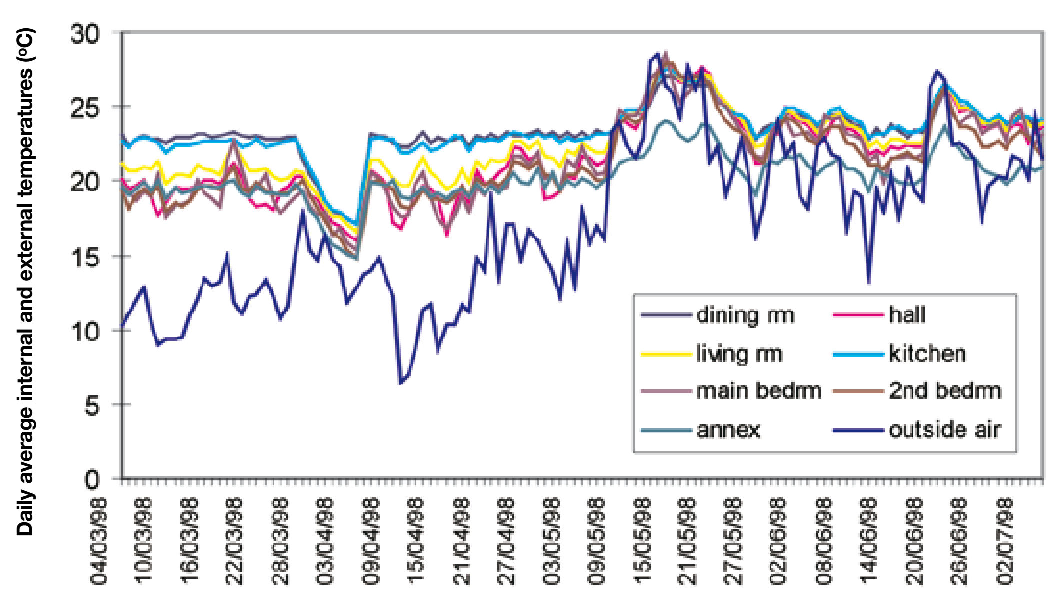

Figure 13 Daily average internal and external temperatures

5 Economics

Capital costs

The total installed cost for the GSHP system, excluding the underfloor heating system and the hot water cylinder, was £1,800 (£450 per kW capacity). A breakdown of these costs is given in table 2. The total cost includes an allowance for plumbing and wiring the heat pump, although this was done by the owner.

There was no mains gas supply available to the property, so these costs can be compared with the costs for an alternative oil-fired heating system, which it was estimated would have cost about £1,280. A breakdown of these costs is given in table 3.

Based on costs at the time of installation, the GSHP system was thus approximately £500 more than an equivalent oil-fired boiler system.

Table 2 Capital costs for the GSHP system

Item	Price details	Price paid (£)
Heat pump and ancillaries		
Heat pump (including controls)	Export (SEK 14,400 @ 13 SEK/£)	1,108
Auxiliary heater (including controls)	Export (SEK 2,750)	212
Sensors and extra time switch	Trade (small trader)	31
32 A electrical supply	Marginal cost estimate	25
Installation	Extra for cold loop connection	30
Hot water system		
DHW	Extra cost over standard Gledhill Accolade (est)	50
Controls and safety features	Standard requirements (supplied with the above)	
Cold loop		
Ground pipe (200m)	Trade (small trader	120
Ducts (2 x long radius 110mm)	Trade (approx)	30
Blinding sand	Trade (approx)	50
Anti-freeze (30 l Fernox)	Trade (small trader)	66
Installation (6 hours excavator @ £13)	Marginal cost estimate	78
Hot loop	No additional costs	
Total		1,800

Running costs

In order to allow comparison with other fuels, standardised fuel prices have been used in this Report as given below. The annual running costs for space and water heating, assuming these figures, are estimated to be £419 (4,307kWh at the off-peak tariff, 3,518kWh at the on-peak tariff).

The use of the GSHP resulted in a saving of 10,855kWh of energy. If this energy had been supplied as electricity (at an efficiency of 100 per cent), it would have cost an additional £870 or £730 (assuming 25 per cent could be supplied at the off-peak rate). It is unlikely in practice that electricity would be used to heat an underfloor wet system.

If electric storage heating had been used, and all the energy for space and water heating could have been provided at the off-peak rate, the running cost would still have been more than for the heat pump system at £545.

A summary of the costs of the GSHP system compared with alternative systems is given in table 4. System running costs are compared with both the type of oil boiler available when the system was installed and a newer oil boiler (the performance of standard oil boilers improved significantly in 1998) and also a condensing gas boiler. Standard figures for the seasonal efficiencies of the boilers and fuel prices, taken from the Government's Standard Assessment Procedure for Energy Rating of Dwellings (SAP 1998), have been assumed.

Fuel prices

In order to overcome the effect of fuel cost fluctuations over time and across regions, all the fuel prices are three-year averages taken from the Government's Standard Assessment Procedure (SAP 1998).

These fuel prices are as follows (p/kWh).

- Electricity
  - on-peak – 8.04 (standing charge not heating dependent)
  - off-peak – 2.84 (standing charge £14 per year).
- Oil – 1.43 (no standing charge).
- Gas – 1.49 (standing charge £36 per year).

Table 3 Capital costs for an oil-fired heating system

Item	Price details	Price paid (£)
Boiler and ancillaries		
Boiler	Trade (small trader)	660
Controller	Typical	60
Flue lining and flue installation	Marginal cost estimate	180
Installation	Extra for kitchen housing	45
Oil tank and feed		
Ground pipe (30m)	Estimate	20
Tank (210gall)	Trade (small trader)	180
Foundation	Estimate	120
Installation (1 hour JCB @ £13)	Marginal cost estimate	13
Total		1,278

The calculated running costs do not include annual servicing. Both gas-fired and oil-fired systems are likely to have higher annual servicing costs than those for the heat pump system. The only maintenance recommended for the heat pump system is to clean the filter annually and to check the sight glass inside the heat pump regularly (about every three months). If maintenance were required, however, there is no agent for IVT in Britain and work would need to be carried out by a suitable local firm. Replacement parts would need to be obtained from Sweden.

The lifetime of the heat pump system is expected to be in excess of 20 years. The most important component (and therefore the most expensive to replace) is the compressor which is hermetically sealed and expected to have a lifetime of 15-20 years. The ground coil should last longer (coils in the US are being guaranteed for up to 50 years). Despite this, the heat pump was only supplied with a two-year guarantee.

Potential Cost Reductions

The controller supplied with the heat pump was not designed to optimise operation with an Economy 7 type tariff structure. There is potential to improve the operation of the system by scheduling more of the space and water heating duty during the reduced tariff period. This would require a more sophisticated controller, but could achieve substantial savings in running cost without a noticeable reduction in comfort level. An improved controller could also allow easier override of normal operating mode, e.g. a setback mode during unoccupied periods or overnight.

The heat pump unit has not been optimised for minimum manufacturing cost. It is likely that unit costs could be brought down as production volumes increase and economies of scale are exploited.

Table 4 Costs and CO_2 emissions of the ground source system compared with alternatives

System	Capital cost installed (£)	Energy consumed (kWh)	Annual running cost[1] (£)	Annual CO_2 emissions[4] ($kgCO_2$)
Ground source heat pump	1,800	7,825	420	3,600
All electric[2] (efficiency 100 per cent)		18,680	545 – 1,100	8,590
Regular oil-fired boiler, pre 1998 (efficiency 70 per cent)[3]	1,280	26,686	380	7,210
Regular oil-fired boiler, 1998 or later (efficiency 79 per cent)[3]		23,646	340	6,390
Gas-fired condensing boiler (efficiency 85 per cent)		21,976	365	4,260

Notes

1. Annual running costs are calculated using the fuel prices from SAP 1998 (see page 12, opposite). Assumed costs do not include annual servicing.
2. The low cost assumes all energy supplied at Economy 7 off peak; high cost assumes all water heating and 30 per cent of space heating as off-peak rate.
3. Default values from SAP 1998 adjusted for underfloor heating.
4. Assumed CO_2 emission: oil 0.27kg/kWh; gas 0.194kg/kWh; electricity 0.46kg/kWh.

6 Conclusions

Over its first year of operation, the GSHP system has provided 91.7 per cent of the total heating requirement of the building and 55.3 per cent of the domestic water heating requirement, although only sized to meet half the design heating load. The heat pump has operated reliably and its performance appears to be at least as good as its specification. The system has a measured annual performance factor of 3.16. The occupants are pleased with the comfort levels achieved and find the system quiet and unobtrusive. The heat pump is mounted in a cupboard under the stairs and does not reduce the useful space in the house, and there are no visible signs of the installation externally (no flue, vents, etc.).

The GSHP system is responsible for lower CO_2 emissions than alternative heating systems (the emission figures for an all-electric system, and oil- or gas-fired boilers are given in table 4). For example, compared with a gas condensing boiler, the heat pump system resulted in 15 per cent lower CO_2 emissions (assuming a CO_2 emission factor for electricity of 0.46kg/kWh). When compared with a new oil-fired boiler system or an all-electric system, the emissions of CO_2 are cut by over 40 per cent and nearly 60 per cent respectively.

Annual fuel costs, based on the fuel prices given in SAP 1998, are about 10 per cent higher than those for a gas condensing boiler and about 20 per cent higher than for a new regular oil boiler, but servicing costs are likely to be lower. Running costs are substantially cheaper than for an all-electric heating system.

At present, suitable products are not readily available in the UK, so the heat pump had to be imported. This had some drawbacks, e.g. limited documentation in English and possible difficulty in obtaining spare parts.

The controller supplied with the heat pump was not designed for use with an Economy 7 type tariff structure. There is, however, potential to improve the operation of the system by scheduling more of the space and water heating duty during the reduced tariff period.

The performance of the heat pump system could also be improved by eliminating unnecessary running of the integral distribution pump. It is estimated that reducing the running time of this pump, which currently runs virtually continuously, would increase the overall performance factor to 3.43. This would improve both the economics and the environmental performance of the system.

More generally, there is still potential for improvement in the performance of heat pumps, and seasonal efficiencies for GSHPs of 4.0[1] are already being achieved. It is also likely that unit costs will fall as production volumes increase. By comparison, there is little scope to further improve the efficiency of gas- or oil-fired boilers.

Figure 14 Rear view of the property

Implications of heat pumps in the UK

This monitoring study has provided valuable data and experiences on a number of aspects of using heat pumps for domestic heating. However, it needs to be stressed that the study was limited in its scope and it may not always be possible to replicate the results in other situations. In particular, there are many different types of heat pumps so the advantages and disadvantages for each type and the running costs and environmental performance may vary considerably. For example, heat pumps designed for heating only will tend to have significantly better CoPs than 'reversible' heat pumps, i.e. heat pumps that can provide heating and cooling which are usually optimised for cooling.

Heat pumps and CO_2 emissions

Whenever fossil fuels are burnt, either in a domestic boiler or at a power station, CO_2 is emitted into the atmosphere. The CO_2 emissions for oil or gas heating are relatively constant, but the emission factor for electricity can vary considerably depending on the generation mix at any given time. As this is very difficult to predict, the 'average' emission factor for electricity is generally used. This is currently 0.46kg/kWh and it is this figure that is used in this Report.

The true environmental impact of any increased use of heat pumps will, therefore, be dependent not only on the amount of electricity used but also the demand profile. The older coal-fired power stations, which are used predominantly at peak-demand periods such as early evening in winter, have particularly high emission factors of around 0.8kg/kWh. Consequently, any changes which increase or decrease the use of these power stations will have a significantly different environmental impact in practice, compared with the general assessment used in this Report.

Summer cooling

Heat pump technology can be used for heating only (as in this study), or for cooling only, or be 'reversible' and used for heating and cooling depending on the demand. Reversible heat pumps generally have lower CoPs than heating-only heat pumps. They will, therefore, result in higher running costs and emissions and are not recommended as an energy-efficient heating option.

Summary

'Heating-only' heat pumps are a viable form of heating and should, therefore, be considered along with other heating options, especially when utilising low CO_2 electricity generation. However, the relative energy and environmental benefits of heat pumps will vary significantly in different situations and should be considered carefully on a project by project basis.

References

[1] Van de Ven H. 'Ground-source heat pump systems – An international review'. IEA Heat Pump Centre Newsletter Vol. 17 No 1 Heat Pump Centre Sittard 1999, 19 January 2000 14:36

Further information

The Energy Saving Trust sets energy efficiency standards that go beyond building regulations for use in the design, construction and refurbishment of homes. These standards provide an integrated package of measures covering fabric, ventilation, heating, lighting and hot water systems for all aspects of new build and renovation. Free resources including best practice guides, training seminars, technical advice and online tools, are available to help meet these standards. The following publications may also be of interest:

Domestic Ground Source Heat Pumps: Design and installation of closed-loop systems (CE82/GPG339)

New and renewable energy technologies for existing housing (CE102)

This Report is based on material produced as part of a collaborative project between BRECSU, Contech Design, BSRIA, Southern Electric and Geoscience Ltd for the Energy Saving Trust.
The Essentials. An Introduction to heat pumps.

To obtain these publications or for more information, call 0845 120 7799, email bestpractice@est.org.uk or visit www.est.org.uk/housingbuildings

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