



Getting warmer: a field trial of heat pumps

The Energy Saving Trust



energy saving trust[®]

The Energy Saving Trust would like to thank our partners, who have made this field trial possible:

Government organisations

The Department of Energy and Climate Change
The North West Regional Development Agency
The Scottish Government

Manufacturers

Baxi Group
Danfoss UK
Mitsubishi Electric
NIBE Energy Systems
Worcester Bosch

Specialist heat pump contractors

Earth Energy Ltd

Energy suppliers

British Gas
EDF Energy
E.ON Engineering UK
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Technical consultants

EA Technology Ltd
Energy Monitoring Company
Gastec at CRE Ltd
The Open University

Energy Saving Trust project team:

Simon Green, Project Director
Jaryn Bradford, Project Manager



Air source heat pump

“The Department of Energy and Climate Change (DECC) is very pleased to support the Energy Saving Trust’s field trials into heat pump technology. Field trials such as these are a valuable way of establishing true performance in situ, as opposed to in the laboratory, and provide useful insights as to how performance may be improved. This is beneficial for industry, householders and the Government. DECC considers that heat pumps have an important role in achieving Government policies to reduce CO₂ emissions”

Contents

Foreword	5
Executive summary	6
Key findings	6
Further findings	6
Conclusions	7
The background	8
The field trial	8
Site selection	9
What is a heat pump?	10
The science: inside a heat pump	11
What is a heat source?	12
What is a heat sink?	14
Key findings	15
The key findings from the field trial	15
Further findings from the field trial	17
Summary	17
Conclusions	18
Advice for customers	19
Consumer checklist	20
Advice for installers	21
What's next	22
Training and standards roadmap	22
Getting warmer: areas for additional work	22

Foreword

The green market is definitely growing, as more and more consumers opt to install heat pumps and other “microgeneration” technology in their homes, helped by a number of government incentives. Until recently, despite encouragement to install these systems, there has been little data on how well the technology actually performs in real life. Instead, customers have had to rely on manufacturers’ performance claims, which are based on lab testing in ideal conditions.

The Energy Saving Trust is the UK’s leading impartial organisation helping people save energy and reduce carbon emissions. One of the key ways we do this is by providing expert insight and knowledge about energy saving. Our activity in this area includes policy research, technical testing, and consumer advice. This field trial, developed in 2008, forms part of the Energy Saving Trust’s extensive market transformation activity in the household-scale low-carbon technology sector. It follows last year’s report on our trial of domestic small-scale wind turbines, “Location, Location, Location.” Also in progress is our field trial of domestic solar water heating; the results will be published in 2011.

The Energy Saving Trust is impartial, and not tied to any particular commercial organisation or driven by political or corporate motivations. This enables us to work with a variety of industry stakeholders, who know that our findings will be without favour. We use this information to inform our advice services to the public, the industry, governments, local authorities and our other customers and stakeholders.

As a result of this field trial, we will be doing further work with trade bodies, heat pump manufacturers, the Department of Energy and Climate Change, and the Microgeneration Certification Scheme (MCS) to identify improvements to heat pump installation guidelines and installer training.

The trial will continue for another year to enable further investigation into the factors that influence heat pump performance. This will enable both the Energy Saving Trust and the wider industry to give

better advice to consumers on their heating needs, as well as improving future installations.

In keeping with the Energy Saving Trust’s work throughout Europe and the UK, the results of this first year of the trial have been peer-reviewed by leading EU heat pump experts, including the SP Technical Research Institute of Sweden, Planair (Switzerland) and Germany’s Fraunhofer Institute, as well as UK stakeholders including the Energy Technologies Institute (ETI).



Air source heat pump

Executive summary

Given the lack of data on heat pump performance in customers' homes, the Energy Saving Trust undertook the first large-scale heat pump field trial in the UK to determine how heat pumps perform in real-life conditions. The year-long field trial monitored technical performance and customer behaviour observed at 83 sites across the UK.

The findings provide valuable information about the factors that affect the success of a domestic heat pump installation. Instead of revealing outcomes along statistical grounds, or acting as a "brand-vs-brand" competition, the field trial findings provide a discussion of key points of interest to potential consumers, including:

- Measured coefficient of performance (COP) and system efficiency
- Installation practices (both system design and performance)
- Customer behaviour
- Heating patterns and average internal temperatures
- Economics

This report makes recommendations for consumers, installers, manufacturers and policy makers, and identifies areas that require additional investigation and research.

Key findings

The following key findings are also described in further detail in the report:

1. The performance values we monitored in the sample heat pumps varied widely; the best-performing systems show that well-designed and installed heat pumps can operate well in the UK.
2. The sample of ground source heat pumps had slightly higher measured system efficiencies than the air source heat pumps. The 'mid-range' ground source system efficiencies were between 2.3 and 2.5, with the highest figures above 3.0.

3. The system efficiency figures for the sample of ground source heat pumps were lower than those monitored in similar European field trials.
4. The 'mid-range' of measured system efficiencies for air source heat pumps was near 2.2 and the highest figures in excess of 3.0.
5. Heat pump performance is sensitive to installation and commissioning practices.
6. The householders in our field trial sample reported good levels of satisfaction with both space heating and hot water provision. There was no significant difference between users' satisfaction with ground and air source systems.
7. Heat pump performance can vary considerably from one installation to another and customer behaviour is a variable that was shown to impact performance.
8. Many householders said that they had difficulties understanding the instructions for operating and using their heat pump. This highlights a need for clearer and simpler customer advice.
9. A comparison between carbon emissions from heat pump installations and electric or gas heating (based on the UK government's current predictions for grid decarbonisation) shows that a well-installed heat pump can lead to carbon savings, both at present and over the lifetime of the pump.
10. The field trial shows that heat pumps have achieved reductions in heating bills for some customers – especially those whose installations are off the gas grid and are therefore replacing heating fuels such as electricity, LPG and oil.

Further findings

In a number of instances there was limited success in explaining the variation in measured performance. This finding may suggest that there are influences caused by factors that were not, or could not be, measured. An investigation of each site will be undertaken to help explain the large variation in performance, even in apparently similar installations.

Conclusions

- 1. Heat pumps are sensitive to design and commissioning.** The field trial covered a variety of early installations, many of which failed to correctly apply the heat pump. This result emphasises the need for improved training.
- 2. Keep it simple.** There were many system configurations monitored in the field trial. In most cases, the simplest designed systems performed with higher efficiencies.
- 3. The impact of domestic hot water production on system performance is unclear.** Heat pumps can be designed to provide domestic hot water at appropriate temperatures, but more investigation is needed to determine the factors which impact system efficiency.
- 4. Heating controls for heat pump installations have to be comprehensively reviewed.** There has been a failure to explain proper control requirements to both installers and heat pump customers.
- 5. Responsibility for the installation** should be with one company, and ideally be contractually guaranteed to ensure consistency in after-sales service.
- 6. Further study** needs to be undertaken on an installation-by-installation basis, to record what has been done wrong (or well), what could be done better, and what exactly should be done in the future.

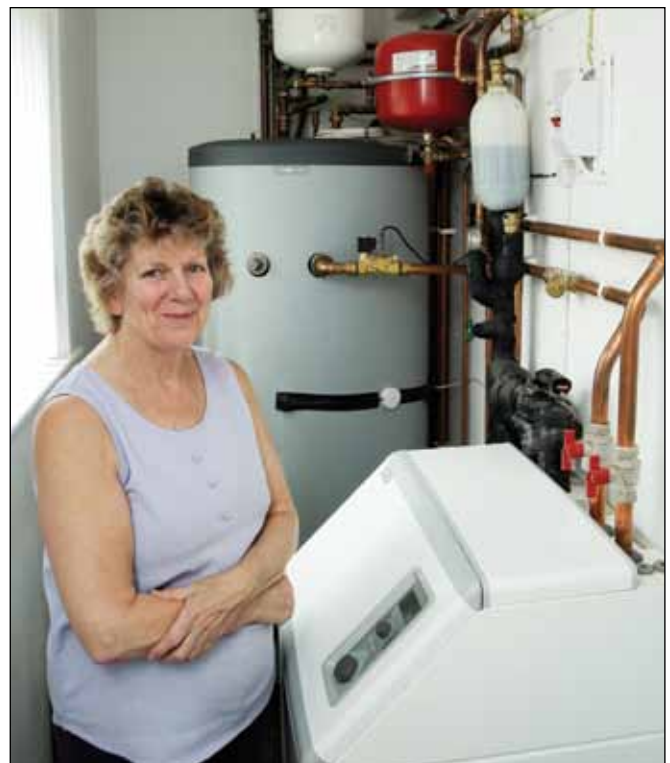
Definitions

Coefficient of performance (COP)

The amount of heat the **heat pump** produces compared to the total amount of electricity needed to run it. The higher the COP, the less electrical energy is required to deliver a given amount of heat: a high COP shows good performance, and a low COP shows poor performance.

System efficiency

The amount of heat the heat pump produces compared to the amount of electricity needed to run the **entire heating system** (including domestic hot water; supplementary heating; and pumps). This report's conclusions and recommendations are based on the measured system efficiency.



Ground source heat pump

The background

The UK has adopted the most ambitious target in Europe for reducing carbon emissions. By the year 2020 the UK is obliged to reduce greenhouse gas emissions by 34% (from 1990 emission levels). 27% of British carbon dioxide emissions come from the energy we use in our homes, so around a quarter of this 34% saving must also come from our home consumption.

“Green” micro-generation systems – including solar photovoltaic panels, solar thermal water heating, small wind turbines, micro combined heat and power, biomass heating, and heat pumps – have the potential to make a significant contribution to the UK’s energy efficiency, as well as reducing fuel bills. Even by conservative calculations, the Energy Saving Trust estimates that up to 10 million micro-generation units can be installed by 2030, which will save up to 10 megatonnes of CO₂ per year – equivalent to the CO₂ produced by around two million average homes today.

With this in mind, the government has introduced a range of initiatives to encourage consumers to invest in microgeneration. The Low Carbon Buildings Programme (LCBP); Energy Saving Scotland’s home renewables grant, and its Community and Renewable Energy Scheme (formerly Scottish Communities and Household Renewables Initiative (SCHRI)) grants; the Carbon Emissions Reduction Target (CERT); and, most recently, the proposed Renewable Heat Incentive (RHI) consultation all exist (or existed) to encourage consumers to install heat pumps and other forms of microgeneration in their homes.

Heat pump technology is relatively new to the UK market, and there has been little evidence on how well it performs in real life. This lack of independently-assessed performance information could potentially make people reluctant to invest, even with incentives in place; this, along with the need for information to back up consumer advice, prompted the Energy Saving Trust to propose a field trial to monitor the performance of a sample of heat pumps in real homes. The aim was to gather the information needed to inform existing and potential customers, policymakers, and the industry.

The field trial collected data on the performance of heat pumps in a wide-ranging sample of homes across the country, and surveyed the occupants on their experience of living with and using the heat pumps.

This publication (along with a forthcoming set of best practice guidance for the industry) is the outcome. It contains the Energy Saving Trust’s specific insights on heat pump installation and performance, customer behaviour and attitudes; and informed advice for consumers, installers, manufacturers, and the UK governments.

The field trial

The Energy Saving Trust has a well-established reputation for developing and delivering projects to monitor the in situ performance of energy-efficiency and low-carbon technologies. The objective of each project is to determine the actual performance and carbon savings when used by domestic customers. These monitoring projects help the Energy Saving Trust to understand how customers use new, innovative technologies, and to identify the potential future uptake of these technologies.

The purpose of the field trial was to gain insight into the factors that affect the performance of domestic heat pumps, including:

- Building efficiency
- User behaviour
- Types of heat source and sink
- System sizing
- Heating patterns and average internal temperatures
- Installation practices

Site selection

We monitored a representative sample of air and ground source heat pump installations in a variety of property types, focussing primarily on retrofit installations. The sample included owner-occupiers and social housing tenants.

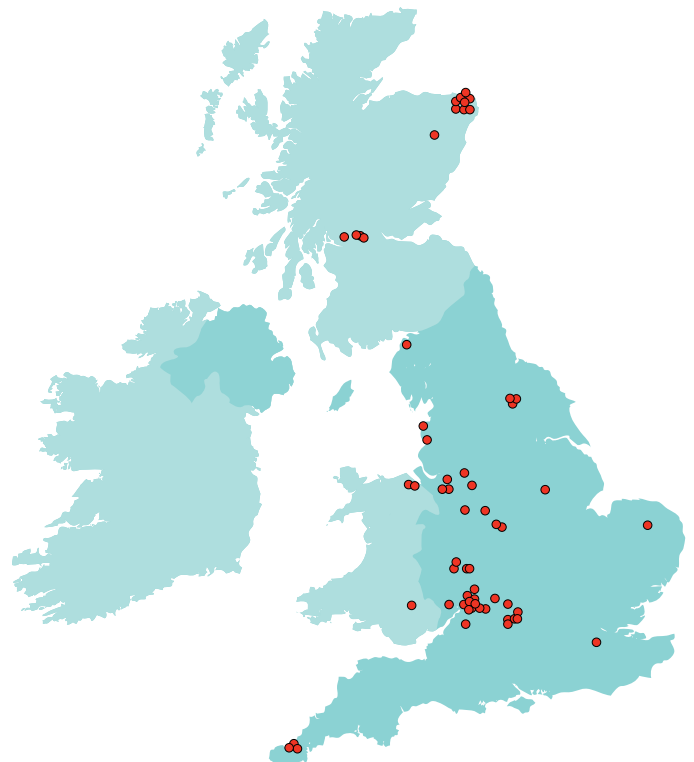
Potential trial sites were identified via a number of sources, including the project's funders and the wider heat pump industry. In 2008 the Energy Saving Trust contacted people who had installed a heat pump using the Low Carbon Building Programme (LCBP) and Scottish Communities and Householder Renewable Incentive (SCHRI) grants, inviting them to join the trial. Further sites were identified through housing associations and energy suppliers.

It should be noted that this field trial started before the Microgeneration Certification Scheme (MCS) was introduced. None of these heat pumps had been installed under the scheme; however, they were installed and accredited through MCS's predecessor, the Clear Skies programme. The field trial therefore monitored installations of products that were current as of 2008. The technology, standards, manufacturer/installer knowledge and practices continue to evolve and improve.

The first monitoring equipment was installed early in November 2008. The study monitored 83 heat pumps – including 29 air source (ASHP) and 54 ground source (GSHP) heat pumps – from 14 manufacturers, in a varied range of housing conditions. Manufacturers who are listed as partners in the field trial were *not* the sole suppliers of the heat pumps in the field trial.

The sample was chosen to be broadly representative of the market at the time of commissioning the project, and included:

- Air source and ground source heat pumps
- Heat pumps installed in private and social housing properties
- Heat pumps installed in new-build and retrofit installations
- Heat pumps providing heating only
- Heat pumps providing heating and hot water
- Heat pumps installed with different heat delivery systems: under-floor heating and/or radiators
- Grant-funded installations through LCBP and SCHRI
- Systems combined with solar water heating



A total of 83 heat pumps were monitored in the Energy Saving Trust heat pump field trial, distributed across the UK

What is a heat pump?

The heat pumps in this study serve the same purpose as a domestic boiler but, rather than burning a fuel to produce heat, they move heat from a low-temperature heat source (ambient air, for example) and “pump” it to a higher temperature where it can be used to provide central heating or produce domestic hot water.

This is the same process as in a fridge or an air-conditioning unit. In the case of a fridge, the heat energy is pumped from the interior of the fridge to the elements at the back. Removing this heat energy makes the interior of the fridge cold and the elements at the back warm. As the elements become warmer than room temperature, the heat energy (which was originally inside the fridge) is lost into the air of the room. A heat pump heating system does exactly the same thing, though on a bigger scale, and removes its

heat from a source outside the room – such as the outside air, or the ground.

In the cases of both fridge and heat pump, some additional energy must be supplied to the system to pump the heat from the low temperature to the higher temperature. There are systems that use other types of energy to achieve this – for example, gas-heated absorption fridges and heat pumps – but this study concerns only electrically-driven heat pumps.



Internal components of an air source heat pump



Internal components of a ground source heat pump integrated storage system

Definitions

Heat source

The place from which heat is taken.

Heat sink

The place where the heat is delivered to.

Coefficient of performance (COP)

The amount of heat the **heat pump** produces compared to the total amount of electricity needed to run it. The higher the COP, the less electrical energy is required to deliver a given amount of heat: a high COP shows good performance, and a low COP shows poor performance. For example, a COP of 3.0 means that for every unit of input electricity there is an output of three units of useful heat.

System efficiency

The amount of heat the heat pump produces compared to the amount of electricity needed to run the **entire heating system** (including domestic hot water; supplementary heating; and pumps). A system efficiency value of 3.0 means that for every unit of input electricity to the heating system there is an output of three units of useful heat.

The science: inside a heat pump

A heat pump works by reducing the pressure of a liquid, known in this report as a working fluid, so that it evaporates at a very low temperature. This evaporation process needs heat, which is usually sourced from the ground or the air.

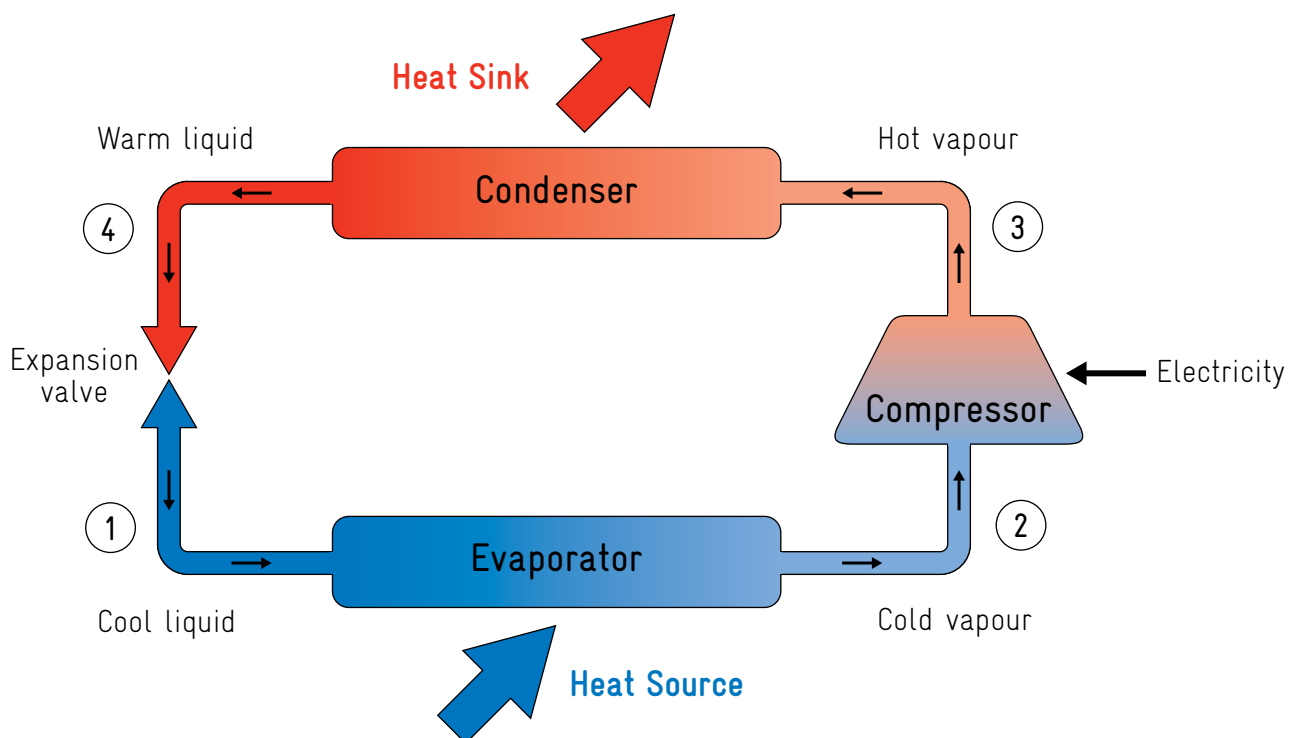
When the vapour is compressed from a low pressure to a higher pressure, its boiling point is raised, so that it wants to condense into a liquid again. In order to do this it needs to release the heat it has absorbed. The heat sink is the place the heat is transferred to; in this report, normally the central heating system and domestic hot water store.

At point (1), the working fluid is cooler than the heat source, so heat flows naturally from the heat source into the evaporator. This causes the working fluid to evaporate.

At point (2), the vapour (from the fluid) enters the compressor. The compressor, driven by an electric motor, compresses the vapour, raising its pressure and increasing the temperature.

At point (3), the high-pressure vapour enters the condenser where it condenses at a higher temperature than the heat sink; thus, heat flows naturally from the condenser to the heat sink.

At point (4), the high pressure liquid enters the expansion valve, which reduces the pressure to its original point, and the cycle is complete.



The workings of a heat pump

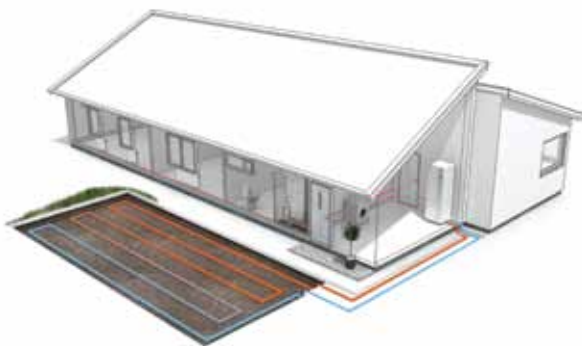
What is a heat source?

The heat source is where heat is taken from. In a fridge, it is inside the fridge; in a heat pump system it is the outside environment. Most heat pumps take heat from either the air or the ground, but water (from ponds, rivers and boreholes) can also be used.

Ground source heat pumps (GSHPs)

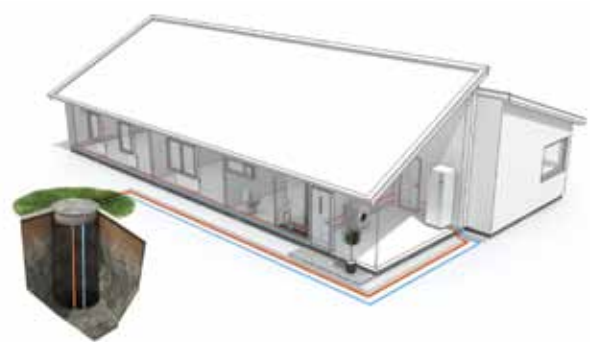
The two most common types of GSHP systems are known as horizontal (or trenched) ground loops and vertical borehole loops.

The figure below shows a ground loop made of plastic tubing laid in a shallow trench. An electrically-driven pump circulates a mixture of water and glycol through the coil, extracting heat from the ground. The size of the ground loops, whether horizontal or vertical, needs to be matched to both the peak heat demand and annual energy requirement of the property. The longer the loop, the more energy the pump is capable of producing.



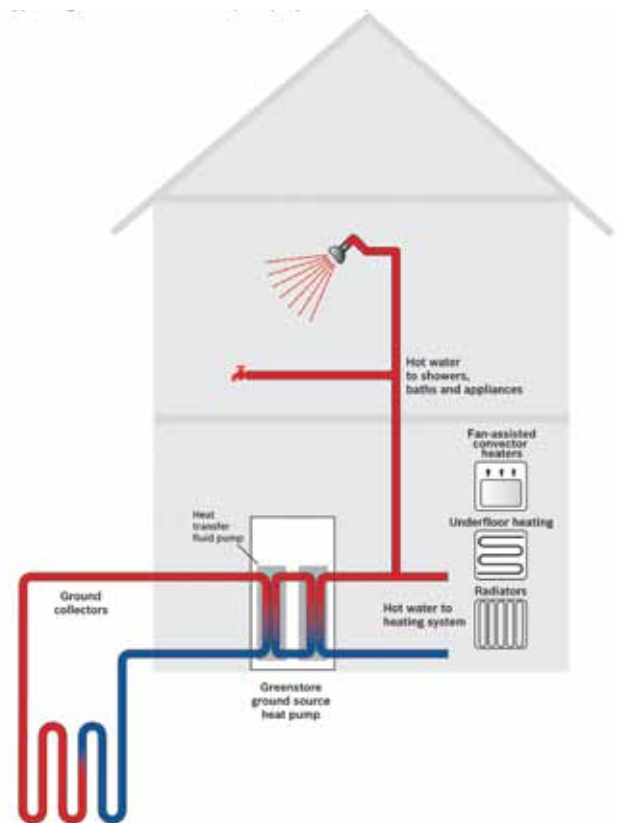
Horizontal loop

Vertical boreholes work on the same principle, but the plastic tube is arranged in a U-shape going downwards into the ground. Boreholes can be anywhere from 15 to 100 meters deep, depending on the heat demand from the house.



Borehole, or vertical ground loop

Ground source heat pumps, once installed, are unobtrusive. As the ground maintains a more constant temperature than the air, GSHPs are not prone, like ASHPs, to fluctuations in efficiency in colder weather. However, installing the ground loop can be expensive, and sizing it depends on geological factors – a real issue in the UK, where local geology varies widely across locations.



A typical ground source heat pump system layout

Air source heat pumps (ASHPs)



Air source heat pump

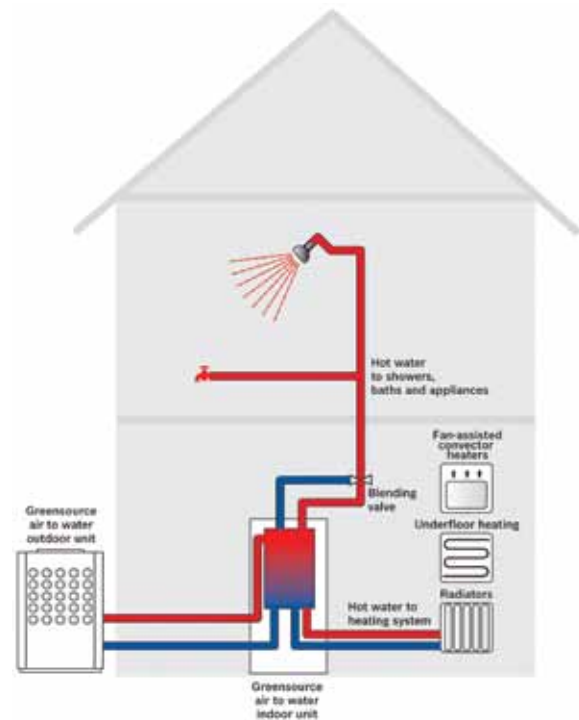
Most ASHPs are sited just outside the property. An electrically-driven fan draws air across the evaporator, cooling the air stream and supplying heat to the heat pump. Below about 7°C, ice may form on the evaporator as the air is cooled, restricting the air-flow and impairing performance. For this reason ASHPs always include a defrost cycle. A common defrosting method is to extract heat from the heat sink (the house or hot water tank) and re-supply it to the evaporator to melt the ice – in effect, operating the heat pump in reverse, so that the evaporator becomes the condenser and the condenser the evaporator. While this is happening, not only is heat being taken from the house, but no heat is being sent to the house, which may temporarily lower the heat pump's COP.

Exhaust air heat pumps

Another potential heat source is air from the house, extracted by an exhaust air heat pump (see below). Exhaust air systems have the advantage that their heat source has a fairly constant temperature of around 20°C, but they need to be carefully designed to balance with the ventilation requirements of the house. They are usually only suitable for well-insulated houses.



Exhaust air heat pump



A typical air to water heat pump system layout

What is a heat sink?

A heat sink is the place the heat is delivered to. In our fridge model, this is the kitchen. In a domestic heating system it is the house, where it can supply both central heating and hot water.

Although the field trial shows that the performance of a heat pump can be affected by the difference in temperature between heat source and heat sink, there is no clear correlation of this in the findings.

Central heating

Methods of providing central heating with a heat pump vary according to the property and its existing heating system. Most existing properties in the UK, as well as some new-build homes, have central heating systems with radiators.

Heat pumps can also be installed with under-floor heating; this is more common in new properties, but older houses can be retrofitted with it as well. Because under-floor heating works with water at 30° to 40°C – as opposed to between 50° and 60°C in radiators – it is considered a more energy-efficient option.

Standard radiators are the cheapest option, and most retrofitted heat pump systems use them. Radiators require higher-temperature water, which would tend to make the heat pump work harder and thus achieve a lower COP and system efficiency. Heat pumps installed with radiators could still be an energy-efficient option for central heating, especially compared to traditional electric or coal-fired heating. “Oversized” radiators can also be used successfully if designed and installed appropriately.

This field trial monitored both under-floor and radiator systems. Although there are no enhanced (fanned) radiators in the trial, the extension to the project planned for 2010 to 2011 may include them.

A number of manufacturers offer air-to-air systems, in which air acts as both heat source (outdoor air) and heat sink (indoor air). The air can be released into the

sink at only a few degrees above required room temperature, which can increase the energy efficiency of these systems. They are usually split, with an external unit (compressor) and an internal unit for warm air distribution. The drawback is that an internal unit may be necessary in every room, which can be expensive. These installations are not yet common in the UK.

Domestic hot water

Most heat pump installations will be designed to produce domestic hot water at temperatures between 50 and 55°C. Good practice assumes that heat pumps should be sized to meet the total space and water heating needs of the home.

The general advice in the UK is that hot water stored in a cylinder should be kept above, or periodically rise to, 60°C, to avoid the danger of Legionella bacteria. This temperature is sometimes achieved with the help of an electric immersion heater, but some heat pumps are capable of delivering the 60 degree temperatures required without the use of immersion heating.

Some of the working fluids in common use produce lower COPs when operating at such high temperatures. For this reason some manufacturers offer heat pumps only for central heating, with electric immersion heating of a hot water cylinder.

Further investigation of domestic hot water production efficiencies will be undertaken in the second year of the field trial.

Key findings

This field trial is the first in the UK to monitor how heat pumps perform in real conditions in actual homes. The 83 sites we monitored yielded a wide spectrum of performance results, even in installations that seemed similar. Some installations performed as well as heat pumps studied in European field trials, but many failed to meet these levels.

The major difference between the UK and European field trial findings is that the UK has particularly old and inefficient housing stock. The British climate also tends to be cold and damp, rather than very cold and dry like Scandinavia. But as well as these predictable factors, heat pump performance is affected by the existing heating systems in UK homes, the attitudes and behaviour of heat pump users, and the quality of installations. The heat pump market is more mature in the rest of Europe, and installers have more experience. The fact that heat pumps have been shown to work effectively in Europe suggests that the technology has the potential to provide good carbon savings in the UK.

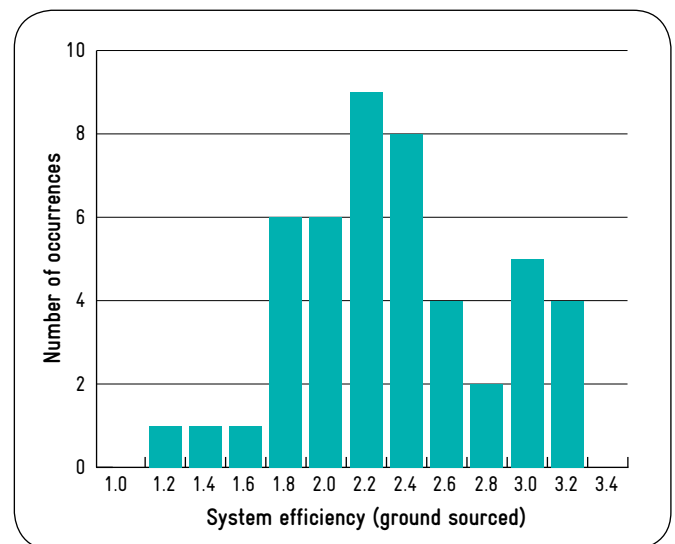
Although every home is unique, it has been shown that a well-performing heat pump can produce a COP and system efficiency ratio of at least 3.0. This means that for every input unit of electricity there is a useful output of three equivalent heat energy units. These best-performing installations should give consumers confidence that heat pumps can provide good levels of internal heating, lower carbon emissions, and reduce fuel bills when installed properly. Approximately 13% of all sites in the trial achieved system efficiencies in excess of 3.0.

The worst-performing sites we monitored illustrate the need for customers to be vigilant when purchasing a heat pump, to be sure that they are buying the best system for their property and their lifestyle. Manufacturers and installers should also take care to ensure that heat pumps are specified and installed properly.

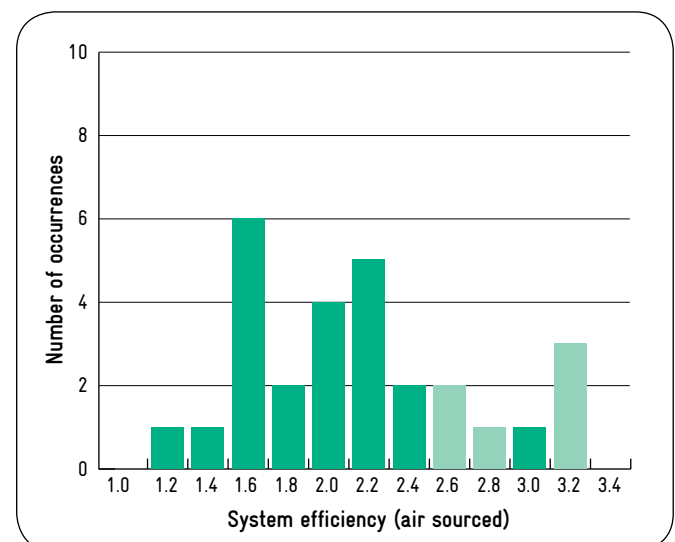
The heat pump industry also needs to ensure that future installations are carried out in accordance with an agreed set of norms and standards. Installers need to be aware that they play an important role in educating customers on the best way to control their system.

The following section discusses the key findings in more detail.

The key findings from the field trial



Distribution of measured system efficiencies (GSHP)



Distribution of measured system efficiencies (ASHP)
Shaded bars denote estimated efficiencies

Measured coefficient of performance (COP) and system efficiency

1. The performance values we monitored in the sample heat pumps varied widely, as shown in the table below. The best-performing systems show that well-designed and installed heat pumps can operate well in the UK, and that the technology has real potential to help the UK meet its carbon reduction targets.

	Heat pump COP		System efficiency	
	Air source	Ground source	Air source	Ground source
Range	1.2 - 3.3	1.3 - 3.6	1.2 - 3.2 ¹	1.3 - 3.3

2. The sample of **ground source** heat pumps had slightly higher measured system efficiencies than the air source heat pumps. The 'mid-range' ground source system efficiencies were between 2.3 and 2.5, with the highest figures reaching over 3.0.
3. The system efficiency figures for the sample of **ground source** heat pumps were lower than those monitored in similar European field trials.
4. The 'mid-range' of measured system efficiencies for **air source** heat pumps was near 2.2 and the highest figures were above 3.0. The sample of air source heat pumps performed comparably with other European studies

Installation practices

5. Heat pump performance is sensitive to installation and commissioning practices. A thorough review of installation guidelines and training should be undertaken.

User perceptions and behaviour

6. Heat pump performance can vary considerably from one installation to another and customer behaviour is a variable that was shown to impact performance.
7. The householders in our field trial sample reported, overall, good levels of satisfaction with both space heating and hot water provision. There was no significant difference between users' satisfaction with ground and air source systems.
8. Many householders said that they had difficulties understanding the instructions for operating and using their heat pump. This highlights a need for clearer and simpler customer advice.
9. A comparison between carbon emissions from heat pump installations and electric or gas heating (based on the UK government's current predictions for grid decarbonisation) shows that a well-installed heat pump can lead to carbon savings, both at present and over the lifetime of the pump.

Economics:

10. The field trial shows that heat pumps have achieved reductions in heating bills for some customers – especially those whose installations are off the gas grid and are therefore replacing heating fuels such as electricity, LPG and oil.

¹ Please note that it was not possible to directly measure system efficiency at seven of the ASHP installations. The system efficiency at these sites has been estimated as denoted by the shaded base in the chart of distribution of measured system efficiencies (ASHP).

Further findings from the field trial

As well as the key findings above, the field trial has revealed some secondary findings which will also help us to understand what factors determine heat pump performance.

- The wide-ranging performance values can be attributed to a number of observed factors, namely the system design and installation and the customers' use of controls.
- Efficiencies for domestic hot water production were lower than expected in a number of cases, mainly in systems producing domestic hot water in the summer.
- Control systems were generally too complicated for the householders to understand. Some householders found it difficult to control the ambient room temperature.
- Many systems appeared to be installed incorrectly.
- Often there was no single contractor responsible for the installation, which might involve a ground works contractor, a plumber, a heat pump installer and an electrician. This meant that there was often no single point of responsibility or any liability for the eventual performance of the whole installation.
- Running costs are one of the main negative factors affecting user satisfaction. Dissatisfaction may be related to the substantial increases in fuel costs which occurred just before and during the project; however such feedback is subjective. There were many more dissatisfied social housing residents (42%) than private householders (13%).

Summary

These findings and observations lead to some simple conclusions:

1. **Heat pumps are sensitive to design and commissioning.** The field trial covered a variety of early installations, many of which failed to apply the heat pump correctly. This result emphasises the need for improved training.
2. **Keep it simple.** There were many system configurations monitored in the field trial. In most cases, the simplest designed systems performed with higher efficiencies.
3. **The impact of domestic hot water production on system performance is unclear.** Heat pumps can be designed to provide domestic hot water at appropriate temperatures, but more investigation is required to determine the factors which impact system efficiency.
4. **Heating controls for heat pump installations have to be comprehensively reviewed.** There has been a failure to explain proper control requirements to both installers and heat pump customers.
5. **Responsibility for the installation** should be with one company, and ideally be contractually guaranteed to ensure consistency in after-sales service.
6. **Further study** needs to be undertaken on an installation-by-installation basis, to record what has been done wrong (or correctly), what could be done better, and what exactly should be done in the future.

Conclusions

Results of the field trial show that well-designed and well-installed heat pump systems can perform well in the UK. Among the 83 sites we monitored, there were good, average, and poor performing sites. This variation in performance has been influenced by a number of factors, including system design (sizing of the pump, and type and size of heat source and heat sink), system installation, and customer behaviour.

Attempts to explain the variation in performance using statistical methods have given only partial answers and unclear trends. More insight has been gained when individual sites were considered as case studies. When a site has been looked at in isolation, reasons for the good, average, or poor performance can usually be found.

In order to get the best performance from a heat pump, it is essential that installation and system design meet the heat demand of the building. The Energy Saving Trust is actively working with relevant stakeholders, including the trade associations, heat pump manufacturers, the Department of Energy and Climate Change, the Scottish Government, and the Microgeneration Certification Scheme (MCS), to identify improvements to heat pump installation guidelines and installer training.

This field trial has highlighted the need for improved consumer advice regarding the appropriate use of system controls, and choice of the appropriate electricity tariff. Customers should take an active part of the installation process so they gain a good understanding of how to operate the system. This is particularly important for social housing residents as tenants, who may not have been involved in choosing the technology or commissioning the installation.

Findings from the field trial show that heat pumps have a real potential to reduce carbon emissions, compared with other traditional domestic heating systems (such as electric storage heating). The potential for carbon savings on a site-by-site basis will increase over time as the grid is decarbonised.

The field trial has identified a number of useful additional benefits to be gained by a second year of monitoring to investigate performance in more detail at a number of sites. Therefore, it has been agreed to extend the field trial through June 2011 to undertake additional site measurements, analysis of data, and study of customer behaviour.

In the meantime, the Energy Saving Trust will continue to provide impartial advice to customers who are interested in purchasing a heat pump. Customers are encouraged to visit the Energy Saving Trust's website (www.est.org.uk) or phone our advice line (**0800 512 012**) to speak to a local advisor.



Installers must work with customers to ensure that they understand how to use the controls

Advice for customers

The information gained from this field trial makes it possible for the Energy Saving Trust to give much more accurate and targeted advice to people who are considering whether to install a heat pump.

Results from the first year of research suggest that heat pumps can both perform well and save on CO₂ emissions in many property types. We particularly recommend considering a heat pump if your home is one of the approximately five million properties that are off-gas, or for a new-build property.

Phase one of the field trial shows that there is potential for more widespread use, but the second year of study is needed to give a clearer picture of that potential in actual conditions across the UK housing stock.

The main considerations in choosing an air source or a ground source heat pump are installation costs; the amount of space available (ground source heat pumps require land for a ground loop or a borehole) and for air source heat pumps, proximity to neighbouring properties. The Energy Saving Trust strongly recommends that you use an installer certified through the Microgeneration Certified Scheme (MCS), which is currently the most robust installer standard in the UK.

A heat pump with a mid-range efficiency can be expected to use only a third of the energy of an average existing gas boiler (78% efficient) or oil boiler (82% efficient) to produce the same amount of heat. A heat pump draws on a small amount of electricity to power it, which is more carbon-intensive than gas and oil. Taking these factors into account, and based on Government projections for grid electricity carbon factors, a heat pump installed in 2010 produces 9% less carbon dioxide than an average gas boiler and 28% less than an average oil boiler do per unit of heat. The potential for carbon savings will increase in future under the UK Government's plan to decarbonise the electricity grid.

Although every home is unique, a well-performing heat pump should typically produce a system efficiency ratio above 3.0 – comparable to heat pump installations monitored in European field trials.

Assuming a mid-range system efficiency, at current electricity prices a ground source heat pump will provide a payback on the marginal installation costs compared with direct electric heating in 18 years. This payback period increases to 29 and 47 years when compared with new oil and gas boilers, respectively. At current electricity prices an air source heat pump will provide a payback on the marginal installation costs compared with direct electric heating in 10 years. This payback period increases to 16 and 31 years when compared with new oil and gas boilers, respectively. The difference in payback is due to differences in capital costs of different heating technologies and fuel prices. If energy prices increase, as is being predicted; the Renewable Heat Incentive (RHI) is enacted; and as heat pumps become cheaper due to wider adoption and economies of scale, payback periods could become shorter.

The government has recently proposed the RHI to provide a subsidy payment to heat pump users. The RHI is still under formal consultation, but on the proposed figures a ground source heat pump could be expected to pay back installation costs in around eight years, and air source heat pump in around five years.

Heat pumps also have the potential to provide significant carbon savings at present and over the lifetime of an installation. For example, if all five million off-gas properties were installed with a heat pump in 2010, it could save 10 million tonnes of CO₂ and £2 billion on fuel bills per year.

Consumer checklist

The Energy Saving Trust advises householders to be rigorous in their research before purchasing a heat pump. This checklist also suggests questions that customers should ask installers before purchasing a heat pump.

When you should consider a heat pump

- In a well-insulated existing property off the gas network. Heat pumps have the potential to reduce running costs compared with oil, direct electric, LPG, or coal, and can provide substantial carbon savings over the lifetime of the installation.
- In new-build properties

How to get the best performance from a heat pump

- Make sure that your home is as well insulated as possible (with cavity and loft insulation) before installing a heat pump.
- Install the heat pump with low temperature under-floor heating or properly sized radiators.
- Insist upon understandable, user-friendly controls.

What to expect from a heat pump

- Since heat pumps provide a lower temperature heating than boilers, radiators will feel warm rather than hot.
- A house with radiators may heat up more slowly.
- The heat pump will run for longer hours than a conventional boiler, but if properly controlled it will switch on and off with the heating requirements of the house.
- A properly sized and installed heat pump should be able to provide all of a household's domestic hot water, but many systems are installed with a supplemental electric immersion heater.

What to expect from a heat pump installer

Potential customers need to ask the right questions when choosing a heat pump, as with any other heating technology. Proper installation is essential to achieve the best performance from a heat pump.

1. Ask the installer to explain how he or she has determined the appropriate type and size of heat pump for your property. The installer should explain how the heat demand of your property was calculated.
2. Make sure the installer explains how the heat pump will work with your existing heating system (including radiators and hot water supply).
3. Ask for guidance to operate the heat pump system controls.
4. Ask how often you should run the heat pump.

Finally, the Energy Saving Trust recommends that householders speak to one of our advisors before installing a heat pump. Additionally, customers should speak to MCS accredited installers and manufacturers to determine whether a heat pump is a viable option.

Advice for installers

As well as monitoring equipment and surveying householders, this field trial has reviewed relevant installation standards in the UK and Europe. The guidance set out in those standards, combined with feedback from customers in this field trial, suggests that installers should follow these “top tips” when engaging with customers to install heat pumps.

The Energy Saving Trust will produce further comprehensive technical guidance for both ASHP and GSHP installations in Autumn 2010.

How installers should approach their next installation design

1. Keep it simple. The field trial findings categorically show that the simplest system designs achieve the best efficiencies.
2. Keep controls simple. Controls need to be appropriate for the installation, but it is vital that the customer can understand how to use them properly.
3. System sizing is key. Ensure that the system is sized correctly to meet the property’s central heating demand.
4. Be transparent with customers. Discuss system running costs and the likely performance customers should expect as honestly and frankly as possible, so they understand what to expect.
5. Be realistic. Advise your customers about the need for any supplementary heating.
6. Be aware of the margin of error. If a heat pump is installed even slightly wrong, the outcome for the householder may be very wrong.
7. Manage your subcontractors rigorously to ensure that their work is appropriate for your heat pump. Installers need to take overall responsibility and supervise each stage of the installation.



Sizing and positioning a heat pump are critical to running efficiency

What's next

Training and standards roadmap

In the UK there are a number of standards and guidelines for heat pumps and installers.

The MCS product standard, MCS 007, sets out guidelines for product certification. The MCS installer standard, MIS 3005, sets out guidelines for the supply, design, installation, and commissioning of heat pump systems. MCS certification is a prerequisite for access to grants and incentives through the Low Carbon Buildings Programme (LCBP), and has been suggested as a prerequisite for the proposed Renewable Heat Incentive (RHI).

As well as these standards there are a number of guidelines that promote good practice in heat pump installation, including *Technical Report 30 (TR 30): Guide to Good Practice – Heat Pumps*, and the Energy Saving Trust publication *Domestic Ground Source Heat Pumps: Design and installation of closed-loop systems (CE82)*.

We recommend that the trade and government agree a roadmap outlining changes to product and installation standards, within six months. To this end, we will participate in a working group of leading industry players to make recommendations as to how the UK can achieve the needed improvements.

In autumn 2010 we will publish an updated version of CE82, which provides guidance for installers of GHSP installations, and will also develop a similar set of guidelines for ASHP. We view these documents as vital to support the success of heat pumps in the UK.

We are actively working with the MCS and the heat pump industry to improve the availability of training for heat pump installers, including skills-based training courses. Heat pump standards in North America and Europe contain much guidance that can help the UK market. For example, Denmark and Sweden have EU quality assurance certification schemes for sizing, installation and installers. The Energy Saving Trust will work with the UK government and industry to re-assess appropriate training for installers.

This ongoing work is crucial to the success of heat pumps in the UK, and the achievement of the carbon savings they can provide.

Getting warmer: areas for additional work

The Energy Saving Trust's heat pump field trial gives the industry some very useful information about how heat pumps are performing in the UK when installed in actual customers' homes.

It also shows that additional research is necessary to explain the reasons for the wide-ranging performance observed across the sample. For this reason, a second year of the study has been planned, during which we will continue to monitor the participating sites, and thoroughly investigate various factors.

This will allow the field trial to bring into focus exactly what makes a high performing heat pump retrofit installation, and to ensure that this becomes standard practice. The work proposed for the second year will allow the Energy Saving Trust to investigate and modify installations, to identify exactly what makes an installation perform well and, conversely, what practices should be avoided. These measures are in line with similar field trials in Europe which have run for a number of years.

Extension of the heat pump field trial will help us to provide the best possible advice to customers. Building on the results from the first year of the study, this further research will enable us to give potential customers a more precise understanding of how heat pumps perform in real homes, allowing them to make the most informed decision regarding the purchase of a heat pump. Ultimately it should mean that more people decide to opt for the option of microgeneration.

The Energy Saving Trust is the UK's leading impartial organisation helping people save energy and reduce carbon emissions. We do this by providing expert insight and knowledge about energy saving, supporting people to take action, helping local authorities and communities to save energy and providing quality assurance for goods, services and installers.



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Energy Saving Trust, 21 Dartmouth Street, London SW1H 9BP
Tel 020 7222 0101 Fax 0845 120 7789
energysavingtrust.org.uk

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