Case Study

July 2012

European Liability Insurance Organisation Schemes

2. Ground Source Heat Pumps

Table of Contents

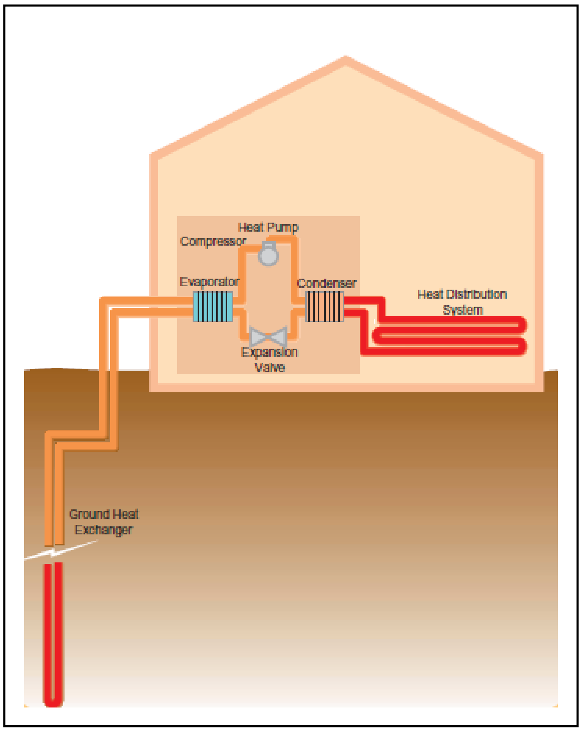
2.1 Introduction to the technology

Ground source heat pumps (GSHPs) are power generation appliances which move heat energy from the ground *up* a temperature gradient (ie. from a colder to a warmer environment), using pressurisation and phase change of a suitable fluid. In practice, for a GSHP to transfer a certain amount of energy for space heating from the earth into a building, it will use a smaller amount of energy to do so than conventional means. A full GSHP system consists of the heat pump itself, an external heat transfer loop for gathering the heat, and an internal heat distribution system.

To operate at maximum seasonal efficiency, heat pumps require as high and as constant a source temperature as possible. Air source heat pumps suffer from the fact that their source temperature tends to vary greatly and can easily fall to below 0°C in the middle of winter. Ground source heat pumps, on the other hand, gather the energy in the solar-heated ground near the surface (as opposed to deeper geothermal, volcanic, energy). At only 1-10m depth, the temperature is a constant 10-12°C throughout the year in most of the UK.

The coefficient of performance (COP)[1] of a heat pump is defined as the heat supplied into the building divided by the energy consumed by the appliance itself. (Arguably, a more useful measure for an installed system is the 'total system efficiency', ie. the heat supplied divided by the total power consumption of the entire system including pumps, fans, supplementary heating and domestic hot water - but COP is more commonly used.) For a heat pump to comply with UK building regulations its COP must be no less than 2.2. Some manufacturers claim COPs for their products as high as 3.0 or 4.0, although the most recent field trials in the UK discovered somewhat lower figures due to a combination of design and installation issues.

As at 2006 there were estimated to be around 500,000 ground source heat pumps installed worldwide.



[1] COP = energy acquired/energy applied

2.2 Available types of this technology

Basic heat pump type

Practical ground source heat pumps almost invariably consist of a compression/expansion circuit driven by a mechanical compressor powered by electricity. Gas- or waste heat-driven 'absorption' heat pumps also exist, but are not widespread in GSHP applications.

Heat transfer fluid (refrigerant)

With the progressive phasing out of chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) due to their ozone depleting potential, the heat transfer fluid (or 'refrigerant') within a mechanical heat pump unit is now most commonly a hydrofluorocarbon (HFC), notably R410A. There is also increasing interest in 'natural' refrigerants, eg. carbon dioxide (CO_2) or hydrocarbons such as propane and butane.

Heat pumps that use CO_2 can operate at high efficiencies, and the refrigerant has relatively low global warming and ozone depletion potential, low toxicity and low flammability. Hydrocarbons have similar advantages with the exception of flammability, which can be adequately managed in small, hermetically sealed units.

Ground loop configuration

The main categorisation of GSHP systems relates to the group loop configuration. There are three types of ground loop:

- Vertical (or 'borehole')
- Horizontal
- Coiled (or 'Slinky')

Vertical. Vertical loops are either copper or (more commonly) polyethylene. A closed loop is laid in a borehole between 15 and 150m deep. It may be direct expansion (DX), where the loop is an extension of the heat pump's refrigerant circuit, but is more usually indirect, where a water/antifreeze mixture circulates independently of the refrigerant and is coupled to it via a heat exchanger. Vertical loops require very little land, and achieve higher efficiencies due to the stability of the earth's temperature at greater depth. However, the drilling operation is more costly than with other configurations.

Horizontal. Simple horizontal pipework runs are laid at approximately 1m depth. As with vertical loops they are usually indirect, polyethylene pipework systems. Horizontal loops require a much larger area of land, and have to operate with a more variable earth temperature. The trench can be dug with a conventional digger rather than a specialised drilling rig, so its cost is significantly cheaper than a borehole.

Coiled (Slinky). A Slinky loop consist of a coiled pipe laid along a horizontal 1m deep trench, thereby combining some of the benefits of both vertical and horizontal configurations. Less land is required than for a purely horizontal loop, yet the complexity of drilling a borehole is avoided. Polyethylene indirect systems are once again the commonest type.

2.3 Strengths, weaknesses, opportunities and threats

This section outlines a discussion of the key drivers affecting ground source heat pumps.

Strengths

- High overall efficiency, hence low energy cost compared to other direct electric heating systems.
- Particularly suited to well-insulated developments which are off the gas grid.
- Versatile (via loop type).
- Low maintenance.
- Ideal for low-temperature distribution systems such as underfloor heating.
- Reversible – can also provide cooling in summer (although see also 'Weaknesses').

Weaknesses

- Not suitable for all ground conditions.
- Drilling cost can be significant (esp. vertical loops).
- Can be expensive in a retrofit situation.
- Low distribution temperature means that heat pumps cannot usually provide 100% of domestic hot water – a boost heater is required.
- Refrigerant leakage might contribute to global warming and ozone depletion, although this can be mitigated by choosing natural refrigerants.
- Design of low-temperature distribution systems needs care.
- The design of ground loops requires particular care and expertise if permafrost is to be avoided.
- Reversible - can also provide cooling in summer. (Whist also a strength, the general trend to reduce energy consumption is leading in some countries to legislation against active summertime cooling.)

Opportunities

- Newbuild, where building heat loads are small and diggers are likely to be on site already.
- Land scarcity and/or increasing land cost (vertical loops).
- Communal schemes, where cost of compressor and ground loop is shared between multiple occupants.
- Developments where site constraints or building designs mean that summertime cooling cannot be avoided. (System can sometimes be operated 'semi-passively', where some amount of cooling can be obtained by circulating the loop fluid through the ground without running the compressor.)

Threats

- Poor design of ground loops and internal temperature distribution systems, if it leads to underheated buildings, could cause GSHPs to become discredited.
- Further field trials may reveal lower than expected COPs and/or icing problems.
- Discouragement by national governments of active cooling.
- Advancing legislation against refrigerants in general.
- Combination of a rising electricity price and a falling gas price would conspire against the take-up of GSHPs.

2.4 Building pathology, defects, and what can go wrong

2.4.1 Invitations to complete questionnaire

An invitation to complete the online version of the Elios II questionnaire was sent to 374 individuals in the following industry sectors:

TABLE 2.1 – Invitations to complete questionnaire

Sector	***Number sent***
Insurance	64
Certification Bodies	10
Accreditation Organisations	4
Builders/Installers	55
Manufacturers	74
Trade Associations	27
Professional Institutes	19
Architects	14
Quantity Surveyors	2
Other	4
Building Inspection Services	13
Government Organisation	22
Housing Associations/Commissioner	16
Consultancies	15
Merchant/retailer	5
Unknown	30
Total	374

In total 70 respondents completed some or all of the questionnaire. This is an 18% response rate.

2.4.2 Responses received

At the closing date of 1st October 2012, 9 responses had been received which related specifically to ground source heat pumps. This is 13% of the received questionnaires. The industry sectors of the respondents were as follows:

TABLE 2.2 – Responses

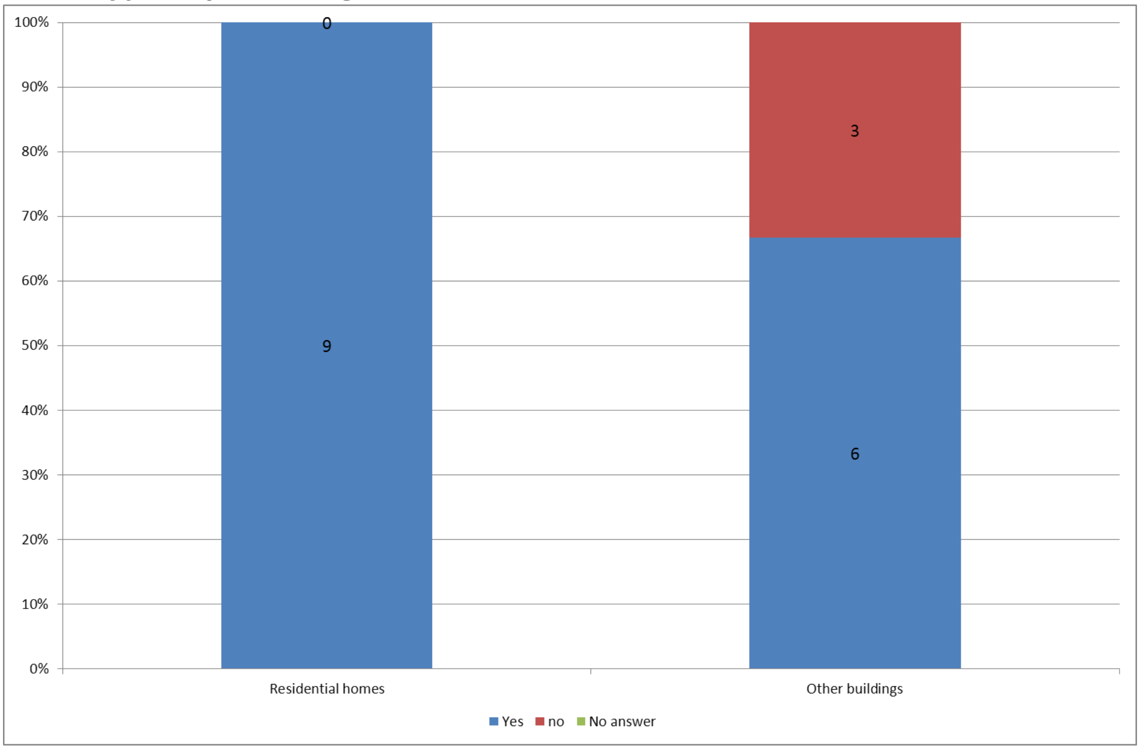
Sector	***Responses received***
Government organisation	0
Architectural practice	1
Housing organisation	4
Manufacturer	1
Retailer/merchant	1
Construction company	0
Installer	1
Building inspection service	0
Certification organisation	1
Insurance company	2
Trade association	0
Professional institution	0
Other (please specify)	2
Business in more than one sector	1
Total	***9***

6 respondents collectively claimed to have data relating to 117 installations of the technology, of which 26 (22%) were said to have experienced failures or defects.

The following graphs and charts only relate to the people who responded about this technology.

CHART 2.3

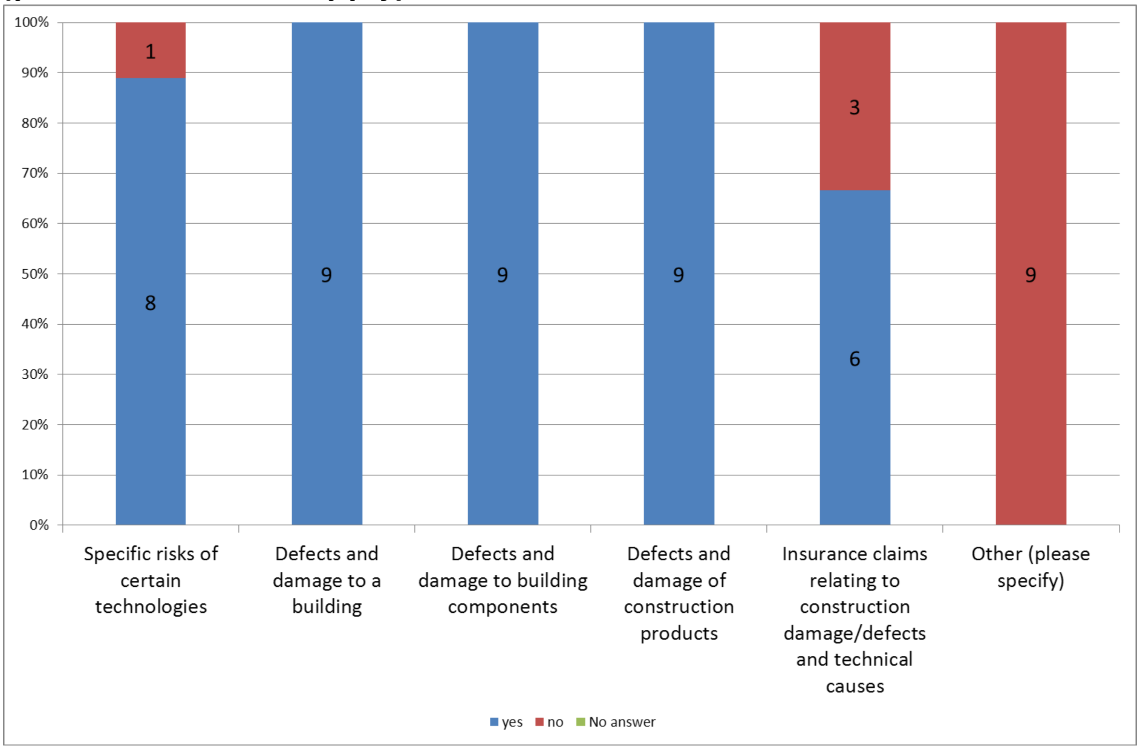
Question asked – *"Does your organisation collect or collate its own data on these types of buildings?"*



This chart shows the number of reporting organisations that collect data on each type of property. This is only for this eco-technology. Organisations may collect data on more than one type of property.

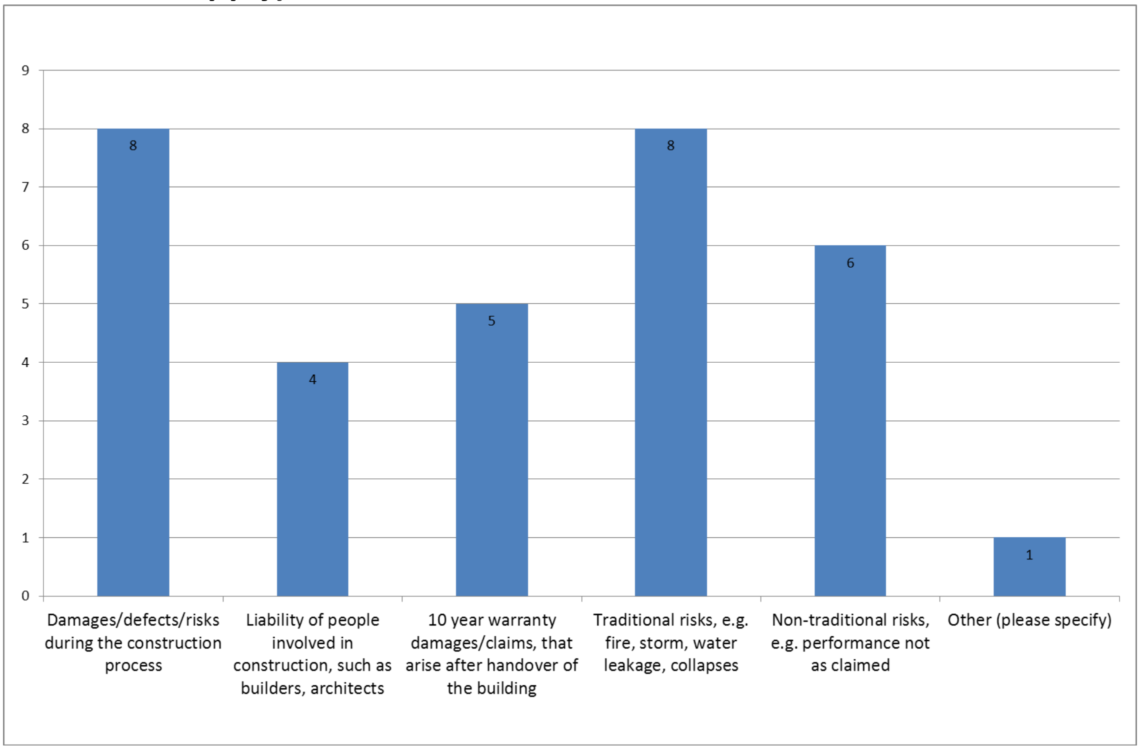
CHART 2.4

Question asked –*"Does your organisation collect its own data on these issues (please tick all that apply)?"*



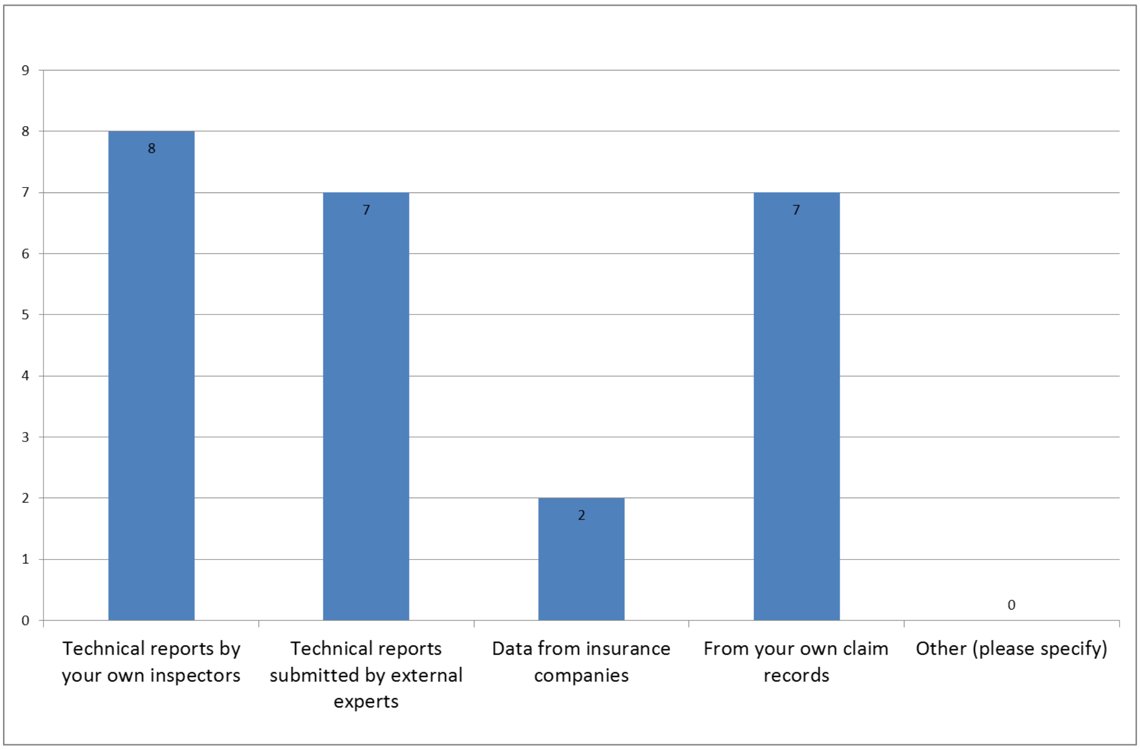
This chart shows the various reasons that the reporting organisations collect data, and the number of organisations that gave each reason. This is only for this eco-technology, and not for all 10 technologies. Organisations may collect data for more than one reason.

CHART 2.5
Question asked – *"What kind of damages/defects do the data refer to (please tick all that apply)?"*



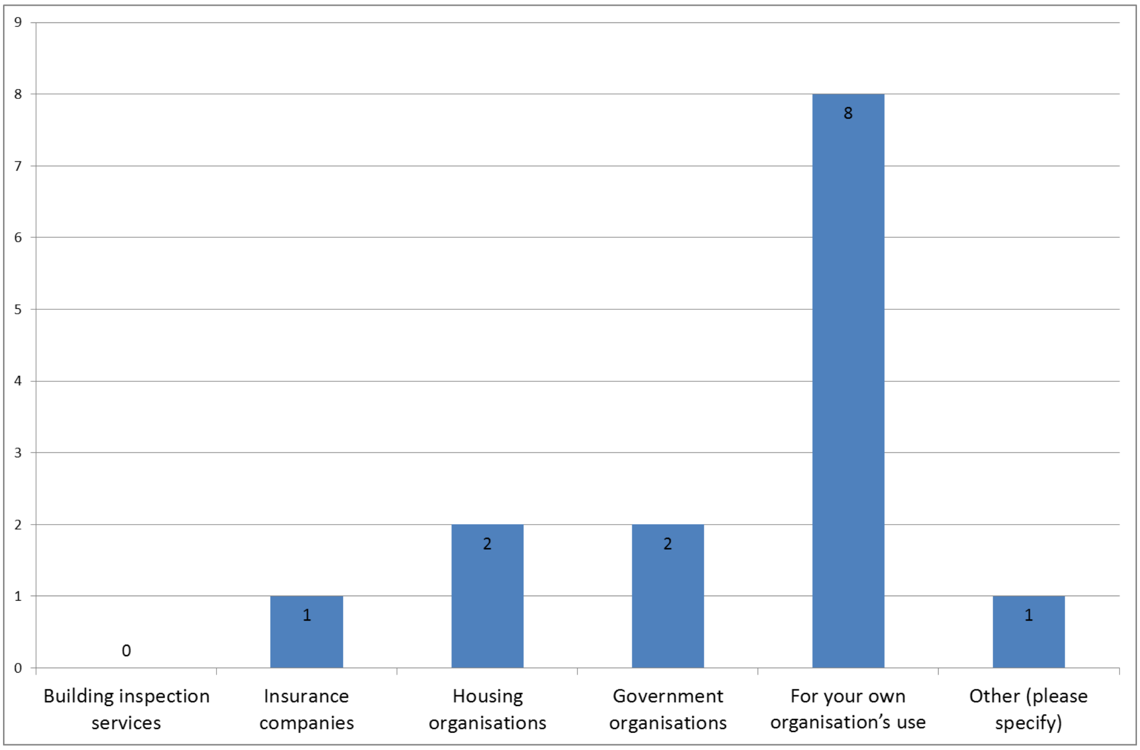
This chart shows the number of organisations that reported each kind of damage on which they collect data. Each column represents a different type of damage. This is only for this specific eco-technology, not overall. Organisations may collect data for more than one reason.

CHART 2.6
Question asked – *"How do you collect the data (please tick all that apply) ?"*



This chart shows the method by which each organisation collects data; each column represents a different method of data collection. This is only for this eco-technology, not overall. Organisations may collect data for more than one reason.

CHART 2.7
Question asked "*For whom do you collect the data (please tick all that apply)?*"



This chart shows the number and type of organisations that reported that they collect data about this eco-technology. Organisations may collect data for more than one type of organisation.

2.4.3 Summary of responses about databases

About their database:

- 5 have a database, 1 did not respond;
- 3 provided a date when data collection started –
  - 2 in 1990
  - 1 in 1998;
- 5 carry out statistical analysis of the data;

About data publication:

- 5 make data available on the web;
- 3 in newsletters;
- 5 in other publications;

About the availability of data, of these 8 respondents:

- 6 publish summary data only;
- 2 publish raw data in any form;
- 2 publish raw data, even anonymously;

1 comment was passed, as follows:

- *"Confidential to ourselves and the providers - used to inform various services and policy"*

Finally, note that this question was answered in general about all 10 eco-technologies and may not apply to the specific technology.

2.4.4 Reasons for failures and defects

The reported reasons for the failures and defects were as follows:

TABLE 2.8

Reason for failure/defect	Number	% of total
Requirement management		
Change in client's requirements	0	0.0%
Misunderstanding of the effectiveness of the technology	12	10.3%
Poor project management	1	0.9%
Inaccurate engineering or architectural data	0	0.0%
Delivery		
Late delivery	1	0.9%
Storage issues	1	0.9%
Awkward packaging	0	0.0%
Poor transport of product	0	0.0%
Installation		
Incorrect design for installation	16	13.7%
Incorrect installation documentation	0	0.0%
Failure in installation	1	0.9%
Commissioning failure	1	0.9%
Operational failure		
Product failure once installed	2	1.7%
Incorrect user documentation	1	0.9%
Misuse of product by end-user	1	0.9%
Performance not as claimed	21	18.9%
Other		
No other reasons were given for failure		
Total		

Note that an installation may have had more than one reason to fail.

2.4.5 Failures/defects commentary

The respondents offered the following general comments and suggestions on the ways in which the failures and defects might be avoided in future:

TABLE 2.9

Reason for failure/defect	Commentary
Requirement management	
Change in client's requirements	Sometimes the client (or the municipality) changes an open source system to a ground converter, with another yield. *<Author's note: we take this to mean that an open loop system is changed to a closed loop system, with corresponding loss of efficiency.>*
Misunderstanding of the effectiveness of the technology	Better product information - not from manufacturer Ground types not suitable Theory is different from practice. During the design phase the B-factor (yield factor of the pump) is changed; an open source has a much higher yield than a ground converter. *<See (a) above>*
Poor project management	The choice for the system in a building plan with several dwellings is often made by the contractor after he has the contract. Then the choice and the execution of the system is often mainly based on lowest price.
Inaccurate engineering or architectural data	
Delivery	
Late delivery	
Storage issues	cylinder was far larger than anticipated - if known at design stage then storage could have been increased
Awkward packaging	
Poor transport of product	

Installation	
Incorrect design for installation	ground types not suitable Marginal incorrect design to suit geology, inadequate pre site investigation into geology; poor air tightness and insulation of existing home; wrong electrical tariff
Incorrect installation documentation	
Failure in installation	poor installation and commissioning, too many teams involved in installation
Commissioning failure	poor installation and commissioning, too many teams involved in installation
Operational failure	
Product failure once installed	leak from ground loop / loss of pressure, pump failures, failure to re set after power cut
Incorrect user documentation	guidance too complex to understand easily
Misuse of product by end-user	much better training prior to occupation and then regular checks that end-user understands heating not knowing how to maintain users not knowing how to operate to optimum / not reading guidance / complicated controls / not all easily accessible
Performance not as claimed	electrical back up heat source operating above stated levels running costs higher than expected
Other (specified)	

1 general comment was passed:

- Penwith HA (part of the DCH Group) was the first housing association to install ground source heat pumps in both new build and retrofit. A great deal of care was taken in both cases to procure and install systems that would perform well. The lack of issues identified above is not meant to suggest that all installations were perfect in every respect, but overall the installations have been very effective.

2.4.6 Key findings

In summary:

- Most failures were reported to be in the areas of
  - initial design
  - performance in practice
  - unsuitable ground type.
- Many of the negative comments regarding failures in-use came from a single respondent who had clearly had a bad experience.

Lessons:

- Comments confirm the importance of careful and correct system design.