Environment Agency

Evidence

Ground source heating and cooling pumps – state of play and future trends

Resource efficiency programme

Evidence Directorate

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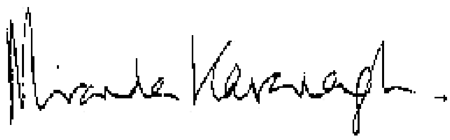

Miranda Kavanagh

Director of Evidence

Executive summary

The Environment Agency commissioned this report as part of an internal review to ensure that the Environment Agency is suitably prepared to support the future deployment of ground source heating and cooling pump systems. This report aims to assess the potential size of the market, and forms part of the wider evidence base which the Environment Agency will use to develop guidance for staff when considering applications for open loop ground source pumps. The information in this report comes from both reviewing the literature and consulting key members of the UK ground source pump industry.

The current UK ground source heating and cooling pump (GSP) market

The current UK market for ground source heating and cooling is small, but growing rapidly. In 2008 installers reported 100 percent market growth. Estimated data describing the current UK ground source pump market are shown below.

Total number of installations	8,000
Current installation rate (per annum)	4,000
Thermal capacity (MWth)	152
Energy produced (GWh)	489
Number of open loop systems	300
Number of dedicated cooling/heat and cool systems	500

The majority of installed systems are domestic scale units of 4–12kWth capacity. Stakeholders reported that households account for 75-90% of the total market; with the majority of the remaining share accounted for by commercial and public sector systems.

Cooling with GSPs

Ground source cooling systems are primarily used in large scale commercial and public buildings. Future demand for ground source cooling systems will be heavily dependent on available incentives, as well as building regulations and how buildings are constructed during this period. Construction of commercial and public sector buildings that lose less heat, coupled with increased occupancy and use of IT equipment, could increase the demand for cooling systems.

Open loop systems and the UK market

Currently, open loop systems are a relatively small sector in the overall ground source pump market. In the future, these systems will primarily be used for larger scale commercial/public buildings in urban environments.

Barriers to growth

We identify eight main barriers to growth in the ground source pump market from now until 2020. These are:

- The UK electricity distribution network – GSPs are driven by electricity, usually taken from the national grid, which for larger pumps would need to be upgraded in many instances.
- Competition with the gas distribution network – 72% of households are on the gas network and can therefore use cheaper and more conventional gas boilers.
- Thermal efficiency of UK housing stock – GSPs work best in well insulated, efficient homes.

- Capital and maintenance costs – GSPs can have higher costs associated with them than some other heating systems, particularly when retro-fitted.
- Insufficient installer network to cope with increased demand – If demand increases at such high rates, the industry may struggle to keep up
- Awareness and acceptance – consumers are not yet aware of GSPs
- Accessing the existing homes market – retro-fitting a GSP in an existing home can be disruptive and expensive.
- The carbon intensity of the UK grid – the carbon benefit of GSPs is not currently as high as it could be as the UK grid is mostly fossil-fuel based.

The first three barriers are expected to persist until 2020 and to limit the total number of systems installed in the UK. The other five barriers can, in principle, be overcome.

Future market trends

The ground source pump market is expected to grow until 2020 and no periods of stagnation are anticipated. We use this and the barriers and drivers of growth identified in this report to construct 'growth' and 'high growth' scenarios. These are summarised in the table below.

	Growth	High Growth
Total number of installations	320,000	1,200,000
Installation rate in 2019 (per annum)	40,000	400,000
Thermal capacity (MWth)	6,700	25,150
Energy produced (TWh)	21	78
Number of open loop systems	7,800	29,000
Installation rate in 2019 for open loop systems (per annum)	1,000	9,200

These estimates were sense checked against a set of UK factors and trends in European heat pump markets. The check suggests that the figures from the growth scenario are realistically attainable, whilst the high growth scenario is at the limit of what is physically achievable, but not impossible.

Geographical analysis.

London is a current hotspot for growth in the ground source heating and cooling market, particularly for private sector, open loop cooling applications. The principal reasons for this are:

- Availability of a suitable aquifer
- The impact of the Merton Rule, which requires new developments to source 10% of their energy from on site renewables
- Restricted space to use closed loop systems.

The major sandstone and chalk aquifers beneath other major UK cities provide opportunities to install open loop systems in high numbers elsewhere.

Other regions with pronounced market growth include Cornwall and the Southwest, Yorkshire and Humber and the East of England.

Regulatory context and implications for the Environment Agency.

The Environment Agency received generally positive feedback on the current process for permitting open loop pumps. However, procedures and processes will need to be streamlined and the responsible departments properly resourced in order to deal with the increase in ground source pump installations forecast in this report. Stakeholders highlighted that the Environment Agency faces the challenge of assessing and regulating the potential thermal impacts of both individual schemes and multiple schemes in close proximity, which will increasingly arise as the technology grows.

Acknowledgements

AEA and the Environment Agency would like to thank all of the industry stakeholders, listed in Appendix 1, who contributed to the project for their time and valued input to the study.

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1 Introduction, background and key conclusions

This section outlines the background to the project and gives a brief overview of each of the sections in the report. The key conclusions from this study are then outlined.

1.1 Background

The Environment Agency is conducting an internal review of its regulatory processes that relate to the deployment of renewable energy and energy efficiency technologies. As part of this review, the Environment Agency is developing guidance for its staff on the processing of ground source heating and cooling pump (GSP) permits and ensuring that it has suitable capacity and expertise to encourage and support the widespread deployment of this technology.

The review is part of the Environment Agency's work to improve its legislative processes through a modern regulatory approach, in line with the principles of Better Regulation. These principles were captured in the 2005 Hampton Report 'Reducing Administrative Burdens' and later incorporated into the UK Government Regulation Compliance Code. The objective is to improve regulations and the way they are implemented, while reducing the burden on business where practical.

The Environment Agency appointed AEA to describe the current state of the ground source pump (GSP) market in England and Wales and possible routes for its growth. AEA has conducted an extensive literature review and interviews with key members of the industry. The latter included collecting feedback from key stakeholders on the Environment Agency's current consenting process for open loop configuration GSPs. Whilst the Environment Agency's focus is England and Wales, this report considers market development at the UK level for practical reasons.

An open loop GSP system can use ground and surface water. It could potentially affect these resources and alter the temperature regime. Open loop schemes are regulated because they involve direct abstraction of groundwater and discharge of spent water (either at a higher or lower temperature). These activities are governed by national legislation enforced by the Environment Agency. Pollution caused directly, or indirectly, by a closed loop scheme also comes within the remit of the Environment Agency.

It should be noted that where stakeholders have been quoted they have been referred to by their representative organisation and not by name.[1]

1.2 Overview of report

This section gives a brief overview of each of the sections in the report.

Chapter 2 - The current UK GSP market

- Current deployment of GSP in the UK in terms of the number and capacity of current installations, year on year market growth rates and the type of systems in operation.

[1] With the exception of Rayner Mayer of the University of Reading as he is also a member of the European Heat Pump Association

- Key policies, funding and subsidy schemes, and the role of trade associations etc.

Chapter 3 - Cooling with GSPs – systems and current market penetration

- Current and future market for ground source cooling units

Chapter 4 - Open loop systems and the UK market

- Open loop systems , where they are used in the UK, and estimated current deployment
- Advantages and disadvantages of open loop systems

Chapter 5 - Barriers to growth

- Main barriers to the growth of the GSP market,
- Full potential of GSP technology in the UK and how the market will grow from now until 2020.
- Barriers specific to open loop systems is described.

Chapter 6 - Future market trends

- Overall GSP market growth (in terms of number of installations and thermal capacity), under growth and high growth scenarios, from now until 2020.
- Sense check of findings against other relevant data.

Chapter 7 - Geographical analysis

- Overview of where GSP systems are likely to be installed, stakeholders and identification of 'hot-spots' for installations.

Chapter 8 - Regulatory context

- Environment Agency's role in the GSP industry
- Feedback from stakeholders on their experiences of working with the Environment Agency and suggestions for improvement.

Chapter 9 - Implications for the Environment Agency

- Key findings and their implications for the Environment Agency.

1.3 Summary of conclusions

The current UK GSP market

- Overall numbers of GSP installations are relatively low in the UK when compared to European GSP markets. A best estimate of systems installed at the start of 2009 is 8,000. The majority of these systems are domestic units.
- The installation rate in 2008 was approximately 4,000 units.

- Year on year increases in market growth have been observed in the early stages of the market. Fifty percent growth rates are forecast for the near future.
- The thermal capacity associated with these units is unknown. Estimates vary depending on the assumptions made about the breakdown of the market into small (domestic) and large scale (commercial/public) systems. Best estimates are that this is in the region of 150 - 230 MWth of capacity.
- This capacity is approximately 8.7% of the UK's total renewable heat generation, which in turn is less than 1% of total heat demand.

Cooling with GSPs – systems and current market penetration

- Ground source cooling systems are primarily used on a commercial scale where cooling demand, associated with casual gains from occupants and IT equipment, is greater than that required for domestic housing.
- At commercial scales, ground source systems are not the market-leading technology; air source units are more widespread.
- Stakeholder feedback suggests that there are currently approximately 500 ground source cooling schemes in the UK. This may be supplemented by a small number of domestic installations, mainly at the higher end of the housing market.
- From now until 2020 demand for ground source cooling systems will be heavily dependent on the building regulations and how buildings are constructed.
- Cooling requirements are likely to increase as buildings become more thermally efficient and the trend towards more building occupants and increased IT infrastructure. This could be countered by amendments to the building regulations that stipulate both limits on heat gain and sufficient natural ventilation.

Open loop systems and the UK market:

- There are different configurations of open loop systems available. The most popular domestic type are surface water systems and a double well for larger scale systems.
- Closed loop systems are, in most cases, more straightforward to install than open loop systems.
- In some situations, mainly at a larger scale, the reduced space requirements and higher efficiencies make open loop systems a logical choice.
- We estimate that there are approximately 300 open loop systems in the UK. This is a relatively small market share. In the future, they will primarily be used in larger scale commercial/public systems in city environments.

Barriers to growth:

- Eight main barriers have been identified that will constrain the market growth of GSP systems from now to 2020. These are:
  - UK electricity distribution network
  - Competition with the gas distribution network
  - Thermal efficiency of UK housing stock
  - Capital and maintenance costs
  - Insufficient installer network to cope with increased demand
  - Awareness and acceptance
  - Accessing the existing housing stock
  - The carbon intensity of the UK grid

- The first three barriers will persist until 2020 and limit the total number of GSP systems that will be installed in the UK.
- The remaining five barriers could be overcome.
- Overall these factors have similar effects on open and closed loop system installations.

Future Market Trends:

- We constructed growth and high growth scenarios starting from the 2009 baseline. The rate of market expansion under each scenario is determined by assumptions made about market barriers and the effect of the Renewable Heat Incentive (RHI).
- The growth scenario suggests that in 2020 there will be 320,000 GSP systems installed, with an annual installation rate in 2019 of 40,000. This corresponds to 6,714 MWth of installed capacity and generation of 21 TWh;
- The high growth scenario predicts an annual installation rate that is a factor of ten higher, at 400,000 in 2019, and results in a total of 1.2m installed systems. Installed capacity would be 25,131 MWth and the estimated energy production from these units would be 78 TWh.
- A sense check against other data suggests that the growth scenario is eminently achievable. It is at the low end of other stakeholder predictions, only accounts for a small percentage of the total market share in each sector (e.g. domestic, commercial, public and industrial scale) and is within new-build and refurbishment rates.
- The sense check on the high growth scenario shows it is at the high end of what is physically achievable, but not impossible. 1.2m installations would account for 86% of all the total renewable heat projected within the RES consultation.
- The scenarios suggest that 7,750 – 29,000 new open loop systems could be installed by 2020. This represents 1,000 - 9,200 installations per year and would have serious implications for the Environment Agency, who managed the consenting process.

Geographical Analysis:

- Five areas are identified as having large number of GSP installations. These are:
  - The Southwest
  - Central London and the Southeast
  - Yorkshire and Humber
  - East of England
  - Scotland

- The principal driver behind installations differed in each 'hot spot' region, but the main drivers were associated with:
  - Coverage of the gas supply network
  - Awareness of the technology, linked to a local installer base
  - Policies, particularly the Merton Rule
  - Housing Association activity
  - Effective funding schemes.

- In the future the key factors in encouraging clusters will be:
  - Refurbishment and regeneration areas
  - New-build activity
  - House condition
  - Off gas-grid areas.

- London is a hot spot for open loop systems because of the presence of a suitable aquifer, the Merton Rule and restricted space for closed loop systems.

- There are only a finite number of open loop systems that can be accommodated in any one area. At some point the capacity of the London aquifer will be reached.

- Major aquifers (chalk and sandstone) that lie underneath other major UK cities provide opportunities for new open loop hotspots to develop.

Regulatory Context:

- Overall stakeholders reported a positive working relationship with the EA;

- Areas where regulation could be improved were:
  - Ensuring regional consistency in regulation
  - Addressing the uncertainty caused by the time limit on licenses (twelve years)
  - Assessing and regulating the potential thermal effects of both individual schemes and the interaction between multiple systems in a defined location

- More research is needed into the thermal impacts of GSPs, especially open loop systems in close proximity to each other and the long term effect of closed loop systems on ground temperature depletion. Insufficient research in this area may lead to uncertainty in the industry as to whether licences/consents could be revoked once a large number of systems are installed.

- As more GSP systems are installed, particularly larger scale commercial units and open loop systems with a wider sphere of impact, there may be a role for the Environment Agency in logging installations and mapping their areas of thermal influence. Discussions could be held with the GSHPA as to how best to address this.

- Opinions were mixed on the involvement of the Environment Agency with closed loop installations. On the one hand it was suggested that it would ensure good quality applications. Alternatively, it could slow market growth and training and technical standards may be better means of ensuring good quality installations.

2 The current UK GSP market

This section describes current GSP deployment in the UK in terms of the number and capacity of installations, year on year market growth rates and the type of systems in operation. It includes a description of factors that are relevant to the development of the UK market and will play an essential role in ensuring future industry growth, such as policies, funding and subsidy schemes, and the role of trade associations etc.

2.1 Current GSP installations

This report uses a literature review and interviews with key stakeholders in the UK GSP industry to estimate the total number of systems currently in operation.

Presently there is no organisation collecting data on UK GSP installations and, therefore, no definitive figure is available. The Ground Source Heat Pump Association (GSHPA) reported that the National Energy Foundation (NEF) is currently undertaking a project to quantify the number of installed solar thermal units. After completing this project they will seek to quantify heat pump systems and their total thermal capacity. In the future the Microgeneration Certification Scheme (now termed MCS) could be adapted to provide better quality data on installations.

It is estimated that, between 1970 and 1994, just twelve GSHP systems were installed in the UK. This is very different from the gradual development of markets in Sweden/Switzerland and the erratic, but significant, development of the markets in Germany and Austria over the same time.

Since 2000 the number of UK installations has increased rapidly. Figure 1 shows an initial slow and steady installation rate that gives way to higher levels of growth starting from 2004. (Data from the National Energy Foundation (NEF) and European Heat **Pump Association (EHPA)).**

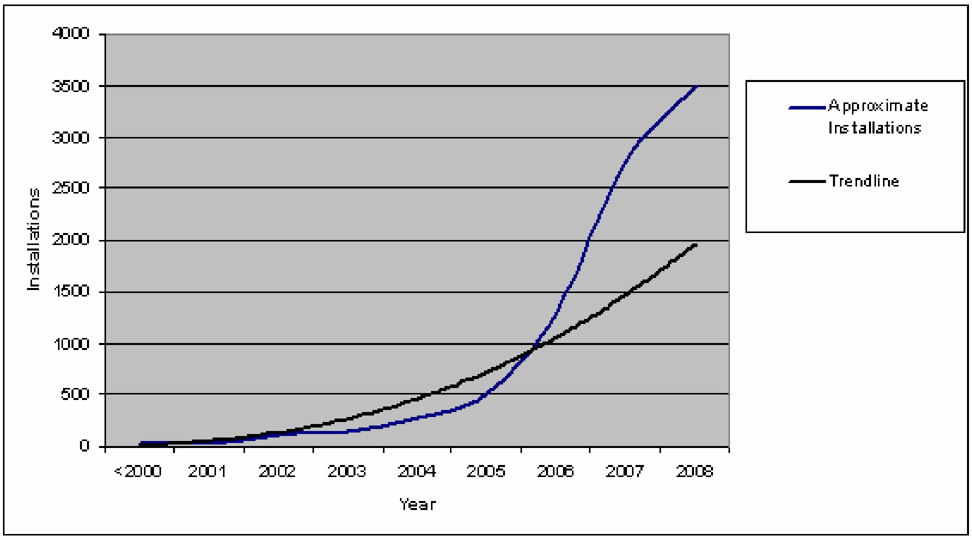

Figure 1. Estimate of GSP market growth since the year 2000 (all system types).

Stakeholders were asked to identify the likely causes of the increased growth observed from 2004 - 2006. Most agreed that it was driven by a combination of factors, including:

- The introduction of the Merton Rule in 2003, which requires new developments above a certain size to generate 10% of their energy needs from on-site renewable
- Greater consciousness of rising fuel prices
- Acceptance of GSPs as a renewable technology
- Changeover from the Clear Skies to Low Carbon Buildings Programme grant schemes
- Increased awareness of climate change issues
- Industry efforts to promote the technology
- Utility companies entering the market and driving up the numbers of domestic installations.

In 2008 there were approximately 3,500 systems (figure 1). Adding a trend line to the data gives a more conservative estimate of approximately 2,000 GSP installed. This is not a reliable means of estimating future market growth as it does not take into account sudden effects on markets of external factors. For example, the release of a new subsidy for the technology or fluctuations in oil price. The latter has historically shaped development of the heat pump market in European countries.

The literature review found that the absence of methods for accurate data collection results in a wide variation in estimates of the numbers of GSP systems currently installed in the UK. Taking 2008 as the reference year, estimates for installations range from 1,500 to 4,000. The lower figure is given in the BERR 'Heat - Call for Evidence' consultation document (2008). Element Energy[2] estimates that installed numbers could range from 745-2,000, using 2007 as a reference year. These estimates are only for microgeneration (e.g. <45kWth capacity) and do not include larger scale commercial/industrial GSP systems.

Data that supports the higher figure comes from:

- ECO Heat Pumps Ltd, who commissioned market research that suggested 3,500 to 4,000 installed GSPs in 2008.[3]
- The Ground Source Heat Pump Association (GSHPA) report that by 2006 there were already 3,000 GSP installed in the UK.
- The Heat Pump Association (HPA) state that "circa 1,500 ground source heat pumps [were] installed in 2007 alone" and "based on discussions with members in the heat pump industry, the estimation of the market penetration of ground source heat pumps [in reference to the 1,500 figure quoted in the BERR 'Heat - Call for Evidence] seems low."
- The European Heat Pump Association (EHPA) states that there were 3,500 installations in the UK in 2008.[4]
- Estimates from BSRIA[5] that in 2008 there will be 3,070 systems installed.
- The HPA has estimated growth from 2009 to 2011 and predicts 6,400 units installed by the end of 2009. This assumes (a not inconceivable) 80% growth on the 2008 figure of 3,500 units.

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[2] Element Energy. The growth potential for Microgeneration in England, Wales and Scotland, Energy Saving Trust, 2008
[3] BERR. Heat call for Evidence. 2008 Available from: www.heatevidence.dialoguebydesign.net/, registration required.
[4] European Heat Pump Association. European Heat Pump Statistics. 2008.
[5] The Building Services Research and Information Association, cited in Kensa. Kensa Partner Newsletter. 2008

Stakeholders were asked to produce a best estimate for installations in 2009. Again, stakeholder opinions differed, with estimates ranging between 3,000 and 10,000 systems. However, there was a consensus that a reasonable figure, for the UK, would be around 8,000 systems, with an England & Wales figure slightly lower than this.

Since 2002 the EHPA has been collating data, collected from national associations, on various European heat pump markets, both ground and air source. This data shows (see Figure 2) that the UK currently lags behind several other nations, in terms of GSP market in relation to population size, most notably Sweden, Austria and Switzerland.

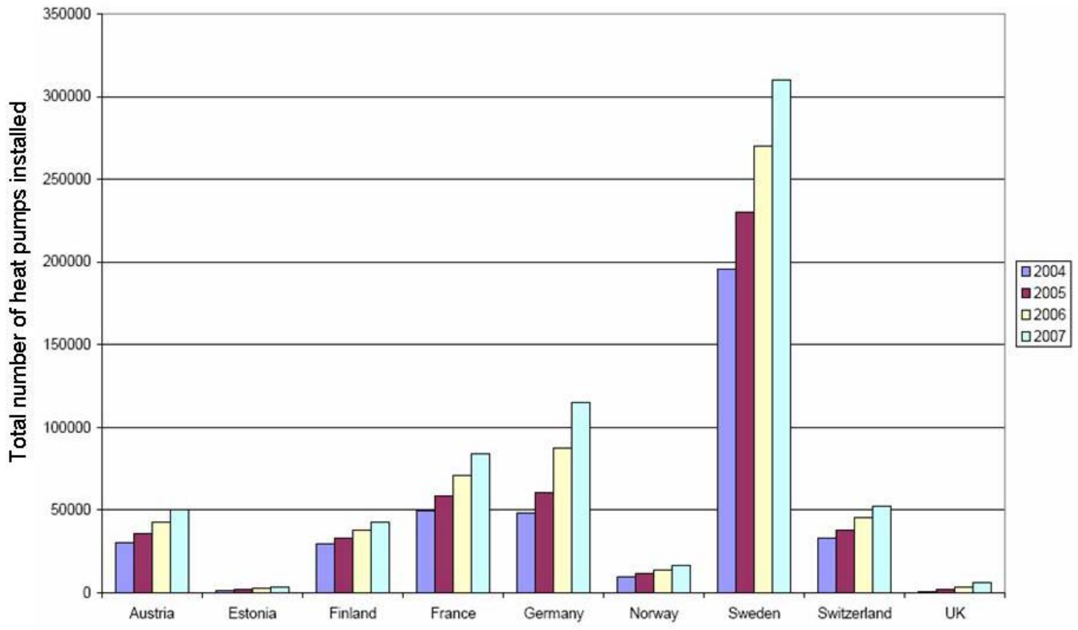

Figure 2. European GSP markets.

Clearly there is significant potential for the UK market to expand; providing the correct market conditions are present and growth stimuli are introduced. Potential GSP market expansion until 2020 is covered in section 6.

2.2 Annual growth rates

Markets for new/emerging technologies typically go through three distinct phases: emerging, growth (or scaling) and maturity. These can be outlined on an ‘S-curve’, see figure 3. An S-curve that highlights the relative market maturity of various European heat pump markets is included in Appendix 2, alongside a description of each stage of market growth.

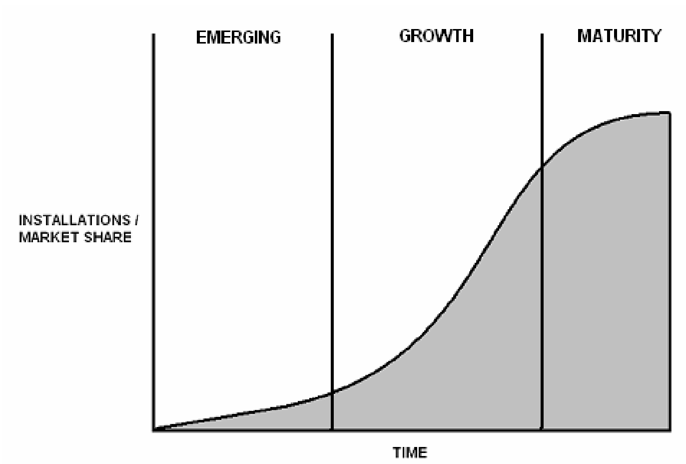

Figure 3. Technology market S-curve.

"Developing markets such as the UK see steep annual increases, albeit from a very small base number."[6] Table 1 shows estimates of annual growth rates based on the data in Figure 1 and the HPA estimates for market development in 2009 – 20011.

Table 1. Estimated annual market growth rates.

Year	Estimated Annual Growth rate from Figure 1
2000 - 2001	50%
2001 - 2002	233%
2002 - 2003	40%
2003 - 2004	96%
2004 - 2005	82%
2005 - 2006	160%
2006 - 2007	112%
2007 - 2008	27%
2008 - 2009	83%
2009 - 2010	50%
2010 - 2011	51%

Table 1 shows there was sporadic growth in the GSP market in 2001/2002 and between 2004 and 2006. High annual percentage increases reflect the low number of installations and is often seen in immature markets. The 233% increase from 2001 to 2002, for example, represents an increase from 30 to 100 units. As markets mature, and the base number of installations increase, growth rates decrease as the starting point is higher and constraints start to effect and limit annual market growth (as discussed in section 5). For example, the number of heat pump units that can be manufactured and installers that can be trained in a particular period of time can limit growth.

The Building Services Research and Information Association's (BSRIA) assessment of growth rates identifies a similar pattern, although the numbers are different. Modest annual growth of 25% and 30% in 2003/2004 and 2004/05, respectively, is followed by a 100% increase from 2005 to 2006. Subsequently, annual growth rates of approximately 50% are forecast.

[6] EHPA, 2008

It has been observed that “markets are developing at a pace that should allow the industry’s capabilities and structures to grow in step with demand.”[7] This steady year-on-year growth, in contrast to the boom and bust cycles in the early stages of the German and Austrian heat pump markets, should maintain the customer and investor confidence that is essential in the early stages of market growth for a new technology.

Figure 1 suggests that UK GSP market is in the early stages of growth , i.e. the bottom of the ‘S–curve’. While it is possible to use the S-curve model to forecast the typical development stages for a technology, assessing the length of each stage is more problematic. The key question is when will the growth in the market slow down and reach maturity? This point is determined by the maximum cost effective potential for the technology.

Market development does not always follow an ‘S’ curve and external factors can distort typical growth trends. This occurred in the early stages of development of the heat pump market in Austria, where there was an initial boom in 1980 that was stimulated by government tax reductions introduced following the second oil crisis and a 2.5 fold increase in oil prices. However, a fall in customer confidence because of large numbers of poor quality installations from untrained installers, and the removal of heat pump subsidies in 1985 (due to a drop in oil prices) caused a gradual decline in annual installations. From 1990 onwards there was an upturn in the market. Developments in Germany mirrored this trend.

Based on consultations with stakeholders, the GSHPA estimate that a steady 50% increase in the annual installation rate may be achieved as the market expands during the growth phase. This corresponds with NEF predictions, which indicate that between 2004/5 and 2005/6 there was a 60% increase in installations.[8] These levels of growth significantly exceed the 100 systems per annum suggested by Element Energy.

The annual growth rate that can be achieved is influenced by the barriers that constrain markets. Some of these are present in emerging stages, such as lack of awareness of the technology, while others arise later, such as the inability of the installer base to respond to increasing demand. Another potential constraint could be the Environment Agency’s ability to process, in a short period of time, large numbers of water abstraction and discharge consent licenses associated with open loop installations. Market barriers are described in section 5.

2.3 Current market breakdown

We have estimated that there are currently 8,000 GSPs in the UK. The total heating capacity of these units will be determined by the size and application of the units themselves. Table 2 outlines the typical heating capacity of GSP units in different applications. Note that these are only guide values.

[7] Hitchen, R. The UK Heat Pump Market. IEA Heat Pump Centre Newsletter (22/4) 2004

[8] This does not correspond to the data in Figure 1 or Table 1 because these years were the bridge between the two data sets used to construct the graph. NEF estimated 800 installations in 2006 and the EHPA estimated 1,800. Hence the average of these two figures was used as a projection.

Table 2 Typical GSP capacities.

Application	Capacity Range	Reference Values
Residential/Domestic	2-15 kWth	Small - e.g. terraced house: 5 kWth
		Large - e.g. detached house: 11 kWth
Housing Association/Council new-build multi-unit residential	20-100 kWth	Dependent on number of housing units and configuration
Commercial	50kWth –MW scale	Small - e.g. small office: 55kWth
		Large - e.g. large office: 300kWth
Public Sector	50kWth –MW scale	For offices, similar to commercial
		For Schools, bespoke depending on primary/secondary size and amenities etc
		Hospital: MW scale

The majority of heat pumps used in industrial applications such as steam production, evaporation, distillation, water treatment, injection moulding, gas processing, etc., use waste heat produced on site as a heat source. This will be at a higher temperature than is available in the ground. Therefore, the main application for GSP in industrial contexts is expected to be for space heating/cooling. Such installations are bespoke and no typical capacity can be ascribed. One respondent, Zenith International, reported that they have seen a recent increase in industrial cooling systems using an open loop, especially in food and drink industries, as popular refrigerants are being phased out.

Market data is usually presented as number of installations and references to installed capacity are limited. NEF data[9] for 2005 records approximately 500 installations amounting to approximately 3,250 kWth. This is an average capacity of 6.5kWth per installation. While there will be variation in the size of the units that make up this data, the figure indicates a market that is heavily dominated by domestic units.

Stakeholders shared this view, with most claiming that 75-90% of installations are domestic scale. A significant majority of the remainder were commercial/public units. Stakeholders agreed that recently the number of these larger scale installations has increased, but domestic scale installations still dominate. Reports on numbers of industrial GSP installations varied from none e.g. "not much seen in the way of industrial applications, nearest example would be business parks and retail" (Earth Energy), to a maximum of 1-2% of all installations.

This market breakdown shows that GSPs are not only considered a microgeneration technology (under 45kWth output). The largest scheme currently under construction in the UK is approximately 5.5MWth capacity. Installations of between 100kWth and 300kWth are becoming increasingly common.

Stakeholders also highlighted the following trends:

- Heat pumps are most effective, and pay back quickest, when installed in small well-insulated houses.
- Some respondents reported that the average size of a domestic system was 10kWth, while others reported them to be in the region of 5 kWth. This could be explained by improvements in building regulations, which mean that the size of heat pump required is getting smaller and can be as low as 4kWth.

[9] Ellis G. Ground Source Heat Pump Review and Market Penetration. In: GSHPA Launch; June 2006; Milton Keynes.

- A recent increase in volume residential installations for social housing providers who may have 50 or more houses on one site. For example, the EHPA report “increasing sales growth of larger units (20-50kW), as opportunities are developing in the social housing sector with the slowdown in private development activity”;
- Eighteen months ago the market was approximately 50% private buildings and 50% public. The economic downturn has resulted this shifting to 80% of larger scale systems being installed by the public sector, e.g. schools, colleges and libraries, etc.

It is understandable that the early stages of the UK GSP market would be dominated by residential/domestic units. The reasons for this could be:

- Larger numbers of new build homes (more suited to GSP systems) compared to commercial or public sector buildings;
- Greater difficulty in retrofitting internal heat distribution systems in larger buildings;
- Lower associated costs for small-scale domestic units that only require a horizontal ground loop rather than borehole collectors;
- Inability of commercial enterprises to justify the longer payback periods associated with GSPs compared to more conventional alternatives;
- Funding schemes, policies and initiatives are aimed at the domestic/residential sector e.g. CERT, the MCS and Code for Sustainable Homes.

Stakeholders were asked how they expected this market breakdown to alter in the period from now until 2020. The general consensus was that it would stay much the same, with domestic systems still by far the most numerous, followed by commercial and public systems, and with industrial systems representing only a tiny fraction of the market. The reasons given for this included:

- Utilities are increasingly buying into the renewables sector and they can heavily subsidise the domestic market;
- The breakdown of building stock will still be the same, e.g. there are more houses than schools;
- Greater development of community-scale residential heat pump projects.

One stakeholder stated that the domestic market is mainly driven by the utility suppliers, which are in turn led by policy and regulation. Therefore, taking away incentives and grants to suppliers would slow the domestic market. Conversely, investments in larger scale units will be based on mainly commercial factors e.g. fuel costs and security of supply. However, policies such as the Merton Rule have played an important part in stimulating this section of the market, especially as GSPs have been in a better position to benefit from the Merton Rule than other renewable technologies.

2.4 Thermal capacity and energy generation of installations

An assessment of the total installed UK capacity can be made by using the best estimate of 8,000 GSP systems installed in the UK, alongside the following assumptions.

- The average size of units are:
  - Domestic: 5 kWth
  - Commercial/public: 100 kWth
  - Industrial Scale: 1 MWth.

- The total number of installations is broken down into the following sectors:
  - domestic: 90%
  - commercial/public: 9.5%
  - industrial scale: 0.5%.

Projections for the total installed capacity are heavily dependent on these assumptions regarding the average size of units and the market breakdown, and can therefore be more variable than estimates of installed numbers.

Based on these assumptions, we estimate total thermal capacity to be 152 MWth, see Table 3.

Table 3. Estimates of current thermal capacity.

Sector	Number of Systems	Total Capacity (MWth)
Domestic	7,200	36
Commercial/Public	760	76
Industrial Scale	40	40

Table 3 shows the relative importance, in spite of their low numbers compared to the domestic GSP sector, of the energy generated by larger scale systems. An industrial scale installation has a similar output to more than 200 domestic units.

This projection can be sense checked against the known capacity installed by some UK installers. Stakeholders were less forthcoming with estimates of thermal capacity than they were with numbers of units installed. However, Geothermal International estimated that they have installed approximately 100 MWth of large scale GSP capacity in the UK and Ireland, and that they have a 50% share of the commercial market. This would put the total capacity of the commercial/public/industrial scale market at approximately 200 MWth. Adding the figure for domestic capacity (36MWth) from above gives a total market size of 236 MWth. (This includes some capacity in Ireland and Scotland, so the figure for England and Wales will be slightly lower.)

Earth Energy reported that other installers might have installed approximately 30 MWth. This would give a total figure of 166 MWth, when added to Geothermal International's market share (100 MWth) and the domestic market segment (36 MWth). The estimates in Table 3 correspond to the figure produced from Earth Energy's figures, but are below that obtained from Geothermal International's data.

To see what contribution heat pump systems might make to the UK's renewable energy targets, it is necessary to calculate the total energy delivered from these units in Megawatt Hours (MWh).

We have assumed that each unit in each sector delivers the following equivalent full load hours:

- Domestic: 1752 MWh
- Commercial/public: 3,500 MWh
- Industrial scale: 4,000 MWh

This suggests that the total energy produced by GSPs in 2009 will be approximately 489 GWh. This is compared to the totalled estimated output from GSPs in the the EU of 40,000 to 50,000 GWh.

In 2006, the total heat demand in the UK was 745 TWh (BERR, 2008). If this figure holds for 2009, then GSPs currently provide 0.06% of the UK's total heat demand. BERR data suggests that, in 2007, total UK heat generation from renewables was 3,313 GWh. If this holds for 2009, then the 289 GWh generated by GSPs would account for 8.7% of all heat generation from renewables.

BERR data from 2007 is shown in Figure 4. If the above figure of 8.7% is accurate it represents a significant change in the situation since 2007, when heat pumps (ground and air) did not even figure as a source of renewable heat.

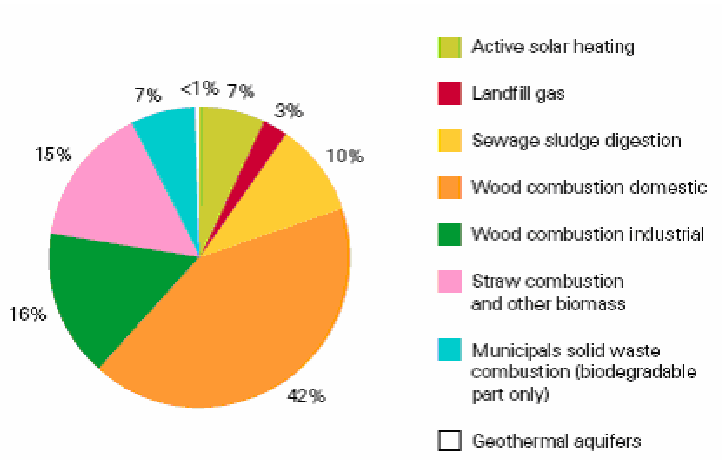

Figure 4. Renewable heat generation by technology (Dukes Report, BERR, 2007).

2.5 Government intervention in the market

Stakeholders were asked if they believed that government intervention is the key driver in growing the GSP market in the period from now to 2020. It was agreed that government policy is a key driver, but opinion was split on whether or not it was the most important.

Those that thought it was the most important stated that government must "set the lead on climate change" and show people what they can do (GSHPA). Another respondent said that government had a key role in growing the domestic GSP market, e.g. through building regulations, the Code of Sustainable Homes, and CERT funding, for example, but less of a role in encouraging growth within the market for larger scale (commercial) systems. This respondent suggested economic factors and issues such as Corporate Social Responsibility play a more significant role, although government policy, in the form of the Merton Rule, is also a driver.

Other influencing factors that were identified, included fuel cost and awareness of the technology. Of these, fuel price figured most prominently. Higher fossil fuel costs and the greater cost savings from using a heat pump system shortens the investment payback period. The price of gas was specifically mentioned as being very influential.

2.5.1 Policy perspective

The fiscal and policy environment is critical for an emerging technology, such as GSPs, and this section assesses current government policy relating to GSPs.

EU Renewable Energy Directive: In March 2007, EU heads of Government agreed that 20% of the Union's energy demand should be met from renewable sources by 2020. This target includes heat, electricity and transport. This aspiration has led to the EU Renewable Energy Directive, under which the UK is required to obtain 15% of its total energy demand from renewable sources by 2020.

The UK Renewable Energy Strategy: Published in July 2009, the Renewable Energy Strategy sets out plans for implementing the UK target. It suggests that the UK is likely to require 12% of all heat to be 'renewable' by 2020, a significant jump from the current level of 0.6%. The Strategy includes heat pumps as one of a portfolio of measures that can be used to meet the 2020 targets.

Climate Change Bill: This contains provisions that will set a legally binding target for reducing UK greenhouse gas emissions by least 80% by 2050, compared to 1990 levels, and requires Government to publish five-yearly carbon budgets.

The Low Carbon Transition Plan, the Government's plan of how they will meet the first three carbon budgets, sets our plans for 40% of electricity to come from low carbon sources by 2020. This ambition for the electricity sector in particular will benefit GSP technology by making it lower carbon, as pumps are usually powered by electricity drawn from the national grid.

Carbon Reduction Commitment (CRC): This is a mandatory cap and trade scheme to encourage cost effective carbon abatement in sectors with relatively low energy demands, such as the service sector, public sector and less energy-intensive industries. The scheme targets organisations that are currently not included in the EU ETS or Climate Change Agreements. All energy, other than transport fuels, will be covered by the scheme.

Code for Sustainable Homes: The UK government introduced the Code for Sustainable Homes to drive changes in home building practices. It sets a standard for key elements of design and construction and will become the single national standard for sustainable homes. The aim is for it to be used by home designers and builders as a guide to development and by homebuyers to assist them in their choice of home.

Government has set a target for all new homes to achieve 'zero carbon' (code 6) status by 2016 has been introduced. This necessitates the deployment of renewable heat technologies such as heat pumps.. Other similar policies, such as the 2016 zero carbon schools policy, will also lead to demand for heat pump systems.

Merton Rule: The 'Merton Rule' is a stimulus for the development of larger scale GSP units. The rule was introduced when the London Borough of Merton stipulated that new-build commercial buildings must source 10% of their energy needs from renewable sources. Similar rules have now been adopted in a multitude of regions, County Councils, City and Metropolitan Councils and other London Boroughs.

Requiring renewable technologies at the build stage of a new development is particularly beneficial to GSPs. This is when the optimal heat distribution system can be adopted and the least disruption is caused when installing the ground loop. The heat pump manufacturer Calorex recently stated that the Code for Sustainable Homes and local authority Merton Rule policies "are already having a positive impact on the uptake of heat pumps and should not be ignored.[10]"

Fuel Poverty Legislation: The Warm Homes and Energy Conservation Act has committed government to legally binding targets for eradicating fuel poverty among vulnerable pensioners, the disabled and long-term ill, in England, by 2010. All fuel poverty is meant to be eradicated by 2016-18.

GSPs can be a valuable technology in combating fuel poverty if the installation cost is borne by a housing association or covered through a grant. They are especially useful in areas that are not connected to mains gas, which are currently forced to utilise higher cost electric or heating oil systems. For example, a GSP operating at a Seasonal Performance Factor (SPF) of 3.5 will lower heating costs by a factor of 3.5 compared to direct electric systems.

Planning: In England, changes to permitted development rights for domestic renewable technologies introduced in April 2008 have lifted the requirements for planning permission for most microgeneration technologies. The General Permitted Development Order (GPDO) grants rights to carry out certain limited forms of development, without the need to apply for planning permission. This includes GSPs.

One respondent raised some concern that, with these policies in place, they should "be putting in ten times as many" heat pump systems, but this is not happening. This raises the question of how rigorously policies are implemented.

2.5.2 Funding schemes and subsidies

Funding schemes play an important role in the development of the UK GSP market and future growth could be stimulated by the introduction of subsidies for renewable heat generation. Funding schemes available for GSPs are described below.

GSP systems in England & Wales receive support through the:

- EST Low Carbon Buildings Programme (LCBP) Phase One (Householder Stream): grants are available for non-reversible closed loop systems, which utilise a borehole or trenche. A grant of up to £1,200 is available for domestic systems.
- EST Low Carbon Buildings Programme Phase Two (Community Stream): Covers the installation of microgeneration technologies in public sector buildings and charitable bodies. Grants are available for up to 50% of installation costs, with a maximum of £30,000. Phase two is administered by the BRE.

As of 2008, 727 heat pump applications were made to the Low Carbon Buildings Programme (LCBP) and 300 of these were awarded grants. Under the previous funding regime, 'Clear Skies', 600 installations were funded in three years. In Scotland, the Scottish Community & Householder Renewables Initiative (SCHRI) received 1225 heat pump applications up to September 2008, of which 687 were funded.

Historically, there has also been selected assistance from utility companies through the Energy Efficiency Commitment (EEC) scheme, such as the Powergen 'Heat Plant' scheme. This will continue, as GSPs are eligible for support under the Carbon Emissions Reduction Target (CERT), which is the replacement for EEC.

[10] Barnes T. CALOREX Response to the June 2008 Element Energy Report on the Growth Potential for Microgeneration in England, Wales and Scotland. 2008

The CERT programme began in April 2008 and will run until April 2011. It aims to deliver a lifetime saving of 42 million tonnes of carbon (MtC). CERT funding can be used to support GSP installations in a variety of social and private domestic developments and as part of heating upgrade programmes. As of 2011, CERT is due to be replaced by the Household Energy Supplier Obligation.

Government has committed to introducing a UK ‘Renewable Heat Incentive’ (RHI), which was enabled by the Energy Act 2008, and will be the main tool for promoting renewable heat and meeting Government targets. The RHI will be funded through a levy on fossil fuel providers and pay a fixed price for the generation of renewable heat,, including heat pumps.

The RHI will significantly improve the business case for heat pumps. Survey respondents were asked what they felt the impact of the RHI would be on the GSP industry in the UK. All stakeholders agreed that, if handled properly, the RHI has the potential to be “a fantastic enabler for the marketplace” (Geothermal International), which will stimulate take up of both domestic and larger scale systems. As a result, a spike in installations is expected when the RHI is introduced.

Stakeholders also recommended that the RHI also requir that buildings be thermally efficient, and that is should only encourage the take up of efficient heat pumps through specifying minimum eligible SPF and COP requirements. The current carbon intensity of the UK grid means a heat pump must be operating at high SPF to deliver carbon savings over gas boilers. Calculations of lifecycle emissions from GSPs need to factor in the projected decrease in the carbon intensity of the grid to give a realistic value.

Respondents were uncertain of the likely impact of the RHI on the GSP market because of a lack of detail on how the incentive will work, especially from 2011 when it will operate in tandem with a Household Energy Supplier Obligation. It is also not clear if it will differ between the devolved administrations and whether measures will be in place to ensure that the RHI does not encourage people to fit a GSP in buildings where it is not effective.

While subsidies can greatly increase the uptake of new technologies, changes to the subsidy regime can also damage investor confidence and can cause boom and bust cycles. This has occurred in the past in heat pump markets in Sweden and Switzerland.

2.5.3 Utility involvement

CERT funding is being used in strategic alliances between utility companies and GSP system installers to directly subsidise system costs for customers. The future of CERT funding for GSPs, in the context of the imminent introduction of the RHI, has yet to be clarified.

In European nations with more mature GSP markets than the UK, utility companies have played a strong role in the development of GSP markets. In Austria and Switzerland, GSPs are a key service offered by regional utility companies. Utility companies are just starting to become seriously involved in the UK market.

In the early 1990s, 40 domestic 1.4 & 2.5kW DX systems were installed in Scotland by Scottish Hydro-Electric. However, this was a one-off initiative. Only recently have several partnerships between energy suppliers and GSP installers/manufacturers started to emerge.

Examples include:

- Calorex, in partnership with E.ON and using CERT funding, have installed over 750 units. They aim to install 1,000 GSP systems in the social housing sector.
- Specialist heat pump distributor, Ecoliving, has accessed CERT funding through Scottish and Southern Energy (SSE).
- In April 2008, SSE agreed to invest up to £15 million in a 20% stake in Geothermal International Ltd. Geothermal International has recently formed a partnership with British Gas domestic and commercial divisions as an approved designer and installer of ground source heat pumps.
- Kensa heat pumps have established a dedicated CERT funding team, although their utility company partner is yet to be identified.

The increasing presence of large energy suppliers in the UK GSP market is an encouraging sign of growth. These partnerships partly result from the need to fulfil CERT targets, but are also recognition of the market potential for the technology within the UK.

2.6 Wider market elements

Market maturity is not just measured in numbers of installations. Other factors, described below, are also promising signs that the UK GSP market is moving from ‘emerging’ to ‘growth’ status.

Formation of Trade Associations: The UK Heat Pump Network was formed in 1999 to offer support to UK manufacturers and installers. A sub-committee has been established to investigate domestic ground source heat pumps. The national Ground Source Heat Pump Association (GSHPA) was formed in 2006.

Accreditation schemes/Quality labels: Accreditation schemes are vital in ensuring customer confidence in the quality of technologies and their installation. This is especially important with emerging technologies. For example, the Austrian, Swiss and German heat pump associations have formed the ‘D-A-CH’ heat pump quality label. This specifies achievable coefficients of performance, sets servicing standards (24hr call out service), spare part availability for ten years and gives a three-year system guarantee. The D-A-CH label is a prerequisite for various funding schemes.

In the UK, heat pumps are now included under the Microgeneration Certification Scheme, which was recently established to strengthen the microgeneration supply chain. Installers and product developers who are accredited under the scheme gain the right to use an approved installer or product mark on their products and/or literature. This third party certification scheme is intended to build consumer confidence and guarantee the quality of the products and services. Accreditation under the scheme is a prerequisite for funding from schemes such as the Low Carbon Buildings Programme.

In 2007 the British Standard ‘BS EN 15450’: Heating Systems in Buildings: Design of a heat pump heating system, was released.

Manufacturer base: There has been significant development in the UK’s heat pump manufacturing base and installer capacity in the last five years. Currently there are several prominent manufacturers in the British market (from the UK, Europe and Japan). For example, Calorex Heat Pumps Ltd, Clivet UK Ltd, Dimplex UK Ltd., Kensa Engineering, Worcester-Bosch and Viessmann UK Ltd. Thirty-three manufacturers are accredited under the MCS, giving customers a wide choice of units.

Installer base: The UK installer base is increasing in line with demand. Under the MCS sixty companies are accredited to install GSPs. Whether manufacturing and installation capacity will be a limiting factor in market growth is discussed in section 5.

2.7 Conclusion

Significant development of the UK GSP market began at the turn of the century. Since then growth rates have been high, but variable. Overall numbers are still relatively low, especially when compared to other European GSP markets. A best estimate of systems installed in 2009 is 8,000, a significant proportion of which are domestic units.

The thermal capacity associated with these units is unknown. Estimates vary depending on the assumptions made about the breakdown of the market into small (domestic) and large scale (commercial/public) systems and the average capacity of each type of system. Best estimates are that GSPs provide in the region of 150 - 230 MWth of capacity and approximately 8.7% of total UK renewable heat generation. This is less than 1% of total UK demand.

There is evidence that, given favourable legislative developments and the availability of funding for both domestic and commercial systems, the UK GSP market is entering a growth phase that will see overall installed numbers rise significantly from now until 2020. The formation of trade associations, the introduction of quality labels and the growing involvement of large-scale utility companies in the GSP market are further evidence of a maturing market.

3 Cooling with GSPs – systems and current market penetration

The calculations made in Section 2 do not specify whether the heat pumps are for heating or cooling or both. The majority of UK GSPs are heating only units. However, a proportion of systems installed will be used for both heating and cooling, and a smaller proportion still will be for cooling only. The latter are of particular interest to the Environment Agency as open loop cooling heat pump systems will discharge higher temperature water into the natural environment, which may affect local ecology and the aquifer structure.

This section outlines the applications for ground source cooling units in the market, provides a guide figure for the current number of units, and gives an overview of how the ground source cooling market may develop in the period from now until 2020. Appendix 3 includes a brief technical overview of GSP cooling.

3.1 Cooling applications

The UK GSP market is dominated by domestic systems. The prevailing UK climate does not necessitate cooling for domestic properties on the scale required in warmer climates. One stakeholder reported that “even in Southern European countries [the domestic cooling market segment] accounts for a very small proportion” of total market activity (Geothermal International). Thus, in terms of numbers of systems, the majority of UK GSPs will be domestic scale heating only units.

The general opinion of stakeholders was that domestic-scale ground source cooling systems will only be installed in a very few cases and most likely these will be niche applications in the ‘high end’ luxury housing market. When cooling is added to a scheme it is not eligible for an LCBP grant.

The UK government is not keen to see a trend towards greater domestic cooling as it increases energy demand and CO_2 emissions, even when heat pumps are used,. The Energy Saving Trust (EST) echoed this view, “EST does not want to see increased cooling in domestic housing due to the increase in demand for electricity consumption”. They advocate “passive cooling measures” instead.

Larger commercial and public buildings do require cooling, especially in the summer when high external temperatures are coupled with casual gains, increasing temperatures beyond comfortable levels. Commercial buildings may also have year-round cooling requirements in server rooms, for example. GSP systems do not, however, have a significant share of the market for commercial-scale cooling systems. Standard air conditioning units, or specifically designed air source units such as the Colt ‘Caloris’ VRF unit and Japanese reversible units, are more established. This may change though, as changes in refrigerant legislation are forcing companies to look at cooling strategies and GSPs may be utilised for process cooling in industry.

Reversible heating and cooling units are available at both domestic and commercial scales. When reversible units are installed the efficiency of the heating and cooling they provide is different. This is determined by the temperature difference between the source and sink and also by the compressor waste heat, which increases heating Coefficient of Performance (COP), but lowers cooling COP.

3.2 Number of cooling systems

Stakeholders were asked to estimate the proportion of current commercial GSP systems are also used for cooling. It was generally agreed that the majority of commercial/public scale systems are reversible heating and cooling units, and only a small proportion are heating or cooling specific. Among reversible units, the load would generally be 60/40 in favour of cooling, i.e. cooling with supplementary heating, but this varies with the specific needs of each building.

Currently there are very few ‘balanced’ schemes in reversible systems as cooling loads are generally higher than heating loads. This can result in the long-term build up of ground temperature in closed loop systems, or the aquifer in open loop systems.

Using the figures in Table 3 and assuming that 70% of commercial systems will be reversible, 30% heating only and only a few will be dedicated cooling installations, we estimate that there are currently approximately 500 cooling schemes in operation. This may be complemented by a small number of domestic installations.

American influenced companies, such as those that use American heat pump units such as Waterfurnace, are more likely to offer heating and cooling systems than Scandinavian influenced companies.

3.3 Perspectives on the 2020 market for cooling

Stakeholders were asked to comment on trends in GSP cooling units that may occur in the future. Building regulations were identified as playing an influential role. As building regulations become tighter and buildings become more thermally efficient, heat loss will be reduced. This, combined with a trend towards increased building occupants and IT infrastructure, will result in an increased requirement for cooling.

This requirement could be offset by better ventilation. Buildings that are designed to use natural ventilation will have limited cooling requirements.

Whether ground source cooling systems represent a differnt proportion of the overall GSP market in 2020 depends on how new buildings are constructed and, ultimately, on building regulations. If Government requires higher insulation levels then cooling requirements, such as limits for maximum permissible heat gain, should also be included in the building regulations. Rayner Mayer note that “If this is not done a significant proportion of commercial [ground source] heat pump units will have a cooling element”. Conversely, if building regulations are amended to include cooling requirements then cooling units will make up a smaller proportion of the market in 2020. One respondent also noted that climate change may increase future cooling demands in houses.

3.4 Conclusion

Ground source cooling systems are primarily used at the commercial scale, where a cooling demand exists as a result of buildings suffering from casual gains from occupants and IT equipment. There are very few domestic systems and these are usually in very high-end housing. At a commercial scale ground source systems are not the market leading technology, and air source units are more widespread.

Stakeholder feedback suggests that in the UK there are approximately 500 ground source systems that are used at least partially for cooling in use in commercial installations. This may be complemented by a small number of domestic installations.

Future demand for ground source cooling systems will be heavily dependent on how buildings are constructed and ultimately on building regulations. As building regulations become tighter and buildings more thermally efficient, combined with a trend towards increased building occupants and IT infrastructure, there will be an increased requirement for cooling. This could be countered by amendments to the building regulations that stipulate limits on heat gain and requirements for natural ventilation.

4 Open loop systems and the UK market

There is “considerable technical potential for open loop heat pump systems in the UK”[11] because of the presence of groundwater under a large part of the UK and the relatively high and accessible water table. Where a suitable water resource is available this can be a cost effective heat source since water can be delivered and returned using relatively inexpensive wells that occupy little ground area.

This section provides an introduction to open loop systems and where they are used in the UK. This is followed by an overview of the relative advantages and disadvantages of open loop pumps compared to closed loop, and an estimate of the numbers installed.

4.1 Key types of open loop system

Six principal permutations of open loop GSP systems are available, making use of different water sources:

- Standing column well (groundwater)
- Single well (groundwater)
- Two well (groundwater)
- River or sea (surface water)
- Pond (surface water)
- Hybrid, loops in piles and open loops (groundwater or surface water).

All these configurations extract water and pass it through a heat exchanger and then discharge into the natural environment. The discharge can be at the point of extraction or at another location. No water is actually consumed by the system, and there is no net abstraction. However, since an abstraction licence is required, installers who offer open loop units are increasingly ensuring they have the internal capacity to manage the permitting process.

Stakeholder consultation confirmed that, on a commercial scale, a double (or ‘paired’) well configuration is the most common type of open loop system installed. The advantages of this system are:

- It prevents a single point of failure occurring.
- It is the simplest system from a regulatory perspective since there are no issues of cross contamination or resource consumption.

Some early systems in London, such as the pump used in Portcullis house, were consumptive, with water extracted from the aquifer and discharged into the Thames. These systems are no longer popular as the discharge licence for consumptive systems is expensive and hard to obtain.

A practical example of an open loop system is Geothermal International’s 2005 installation at Eastbourne Terrace in London, which uses four boreholes to provide 1 MWth of heating and cooling capacity. This pump is used for heating in the winter and

[11] Curtis R., Earth Energy in the UK. 2001

cooling in the summer, balancing the annual thermal load and making it unlikely to affect groundwater temperatures in the long-term.

Open loop systems should not be confused with closed loop water based systems, where no water is extracted or re-injected. An example is the Lake Loop GSP system that Geothermal International is installing at Mansfield Hospital, in Nottinghamshire. This is thought to be the largest scheme of its type in Europe.

Further information on types of open loop systems are given in Appendix 4.

4.2 Comparative advantages and disadvantages of open loop systems

The relative advantages and disadvantages of open loop, compared to closed loop, systems are outlined in this section.

4.2.1 Advantages

The principal advantages of open loop systems are:

Efficiency: An open loop system using ground water can be more efficient than a closed loop scheme as heat is exchanged with water at ground temperature. In a closed loop system there are losses associated with heat-transfer between the liquid flowing through the tubing and the ground temperature.

Land footprint required: It can be advantageous to install open loop systems in areas where land space is at a premium and where there is insufficient area to install a bore field or horizontal ground loops. This is because a large quantity of energy can be extracted from a relatively small land footprint.

Installation cost: An open loop system, particularly at domestic scale, can be cheaper to install if a source of surface water is available.

4.2.2 Disadvantages

The principal disadvantages of open loop systems are:

Resource uncertainty: An extra element of uncertainty is added when using ground water. Firstly, a desk study must identify whether there is a suitable aquifer. A pump test must then be conducted to determine the potential energy yield, which is fundamental to the viability of a scheme. This creates uncertainty and requires up-front capital expenditure.

Design complexity: An open loop design requires an assessment of the risks at the design stage, based on the hydrogeology and thermal properties of the aquifer and adjacent rocks, and how thermal energy is transported.

This is often done using numerical groundwater modeling of the energy abstracted or re-injected into the ground by the pump. This requires specialist knowledge of heating and cooling loads and how they affect water re-injection temperatures. This process can be a complex and lengthy process, and is likely to only be worthwhile for larger installations.. Stakeholders, however, reported that greater design complexity is not a significant issue as this arises for both larger-scale closed and open loop systems.

Regulatory uncertainty: Open loop installations require abstraction licenses and discharge consents from the Environment Agency, which introduces an additional cost and uncertainty. Once issued, permits are limited to a period that is generally shorter than the design life of the system. This is typically 20 years for the heat pump unit and significantly longer for the ground loop. This is covered in more detail in Section 8.2.

Furthermore, the 2003 Water Act placed a time limit for all new abstraction licences of up to 12 years and introduced the power to revoke, without compensation, abstraction licences that are causing serious environmental damage. Discharge consents are subject to four-year reviews within this twelve-year period.

Where a Catchments Abstraction Management Strategy (CAMS) is in place, these are reviewed on a six yearly cycle and the outcome of the review may result in an amended licensing strategy for a particular catchment. The Environment Agency endeavours to give six years notice of any potential changes that may occur.

Maintenance: Over the lifetime of a GSP system a closed loop installation will require less maintenance because it is sealed and pressurised; this eliminates the possible build-up of minerals or iron deposits. Open loop units are more prone to fouling, corrosion, and scaling, and require re-lining of well screens and maintenance of the filtration unit and pump.

Thermal impact: The zone of thermal interference from open loop systems is usually >100m, which is far larger than the 6-10m zone caused by closed loop systems. This may become an issue as more systems are installed in a particular area, as thermal interference can be caused between systems.

Funding availability: The more bespoke nature of open loop systems can mean that they are not included as standard in funding mechanisms. For example, the EST Low Carbon Buildings Programme Phase One (Householder Stream) only has grants available for non-reversible closed loop systems that use a borehole or trenche. Open loop systems are also not mentioned under the ground collector options specified in the MCS.

Drilling and installation costs: Open loop systems typically have higher drilling costs as deeper boreholes of a different standard are required. However, they are not necessarily more expensive. For example, for the same cost a closed loop system may have 20 shallower boreholes compared to two deeper ones for an open system. The cost per kW for domestic open systems can also be slightly higher. Typical costs are in the region of £2000/kW for open-loop systems compared to £800/kW (slinky) to £1,200/kW (borehole) for closed-loop systems.

4.3 Outline of open loop market size

Data on the exact number of open loop systems installed in the UK is difficult to access as most sources only state the number of installations of all GSP systems and do not differentiate by system type. Reports from stakeholders indicate that open loop systems make up only a small percentage of the total market.

Stakeholders suggested that 1% of all domestic installations and 20% to 60% of commercial systems are open loop. Zenith International stated that “in the commercial/public market, 60% will be open loop, [up to] 75-80% in inner cities.” In cities that have high land values the required space between boreholes can be prohibitively expensive and thus open loop systems are favoured.

We assume that 1% of domestic and 15% of commercial systems are open loop (this is conservative, but balances the variance in stakeholder opinion). This suggests that there are approximately 200 open loop systems currently installed in the UK.

The EHPA suggest that 10% of all GSP installations in eight leading nations were water source heat pumps in 2007. Not all of these will be open loop as a significant proportion of water based heat pumps are closed loop. Assuming that half of all water based systems are closed loop, open loop systems would represent 5% of the total UK market, or approximately 400 installations.

In addition to the balance of advantages and disadvantages outlined in section 4.2, there are a number of other reasons why open loop systems make up only a small fraction of the total UK GSP market. In particular:

- Closed loop pumps do not require suitable ground or surface water and are therefore more widely applicable.
- Open loop pumps are primarily used in larger scale schemes, but the domestic market is the most developed in the UK.

4.4 Conclusion

The most popular open loop systems are surface water pumps for domestic applications and a double well for larger systems. Designing and installing an open loop system is more complex and costly than for a closed lop system, but they can usually yield higher heat outpus and have a lower land requirement. This makes them more appropriate for larger scale uses in public and commercial buildings.

Available data on open loop installations is minimal, but feedback from stakeholders suggests that open loop systems make up a relatively small fraction of the UK market. Our best estimate is that there are approximately 300 systems currently installed in the UK.

5 Barriers to growth

This section presents an analysis of the key barriers to growth in the GSP market in the UK and the relative effect these have on closed and open loop systems.

5.1 Key barriers to GSP market expansion

The eight key barriers identified in this report are described in detail in the following tables.

Barrier	UK Electricity Distribution Network
Description	Heat pump compressors are driven by an electric motor. This is an inductive load, which can cause disturbances to the electricity distribution network due to high starting currents. The UK's single-phase domestic electricity supply can only support a maximum 12kW unit without grid reinforcement. Larger systems will require a 3-phase supply. This will not be a problem for commercial and public buildings, but larger domestic properties may find this a limiting factor. Installing a larger capacity system with a single-phase supply can lead to flickering lights, voltage surges or spikes (that can effect electronic equipment) and premature main fuse failure.
Timescale of effect	Permanent limit on the application of heat pumps in larger domestic properties. Grid infrastructure will need to be evaluated in areas where large numbers of units will be installed, e.g. new-build housing developments, social housing, etc.
Mitigation potential	Ensuring domestic electricity supplies are 3-phase, as they are in several European countries, would support increased numbers of heat pump installations, but would require a prohibitively high investment. Soft/smart start systems can be fitted to remediate some of the effects of inductive start up currents.

Barrier	Competition with the gas distribution network
Description	The UK domestic heating sector remains dominated by gas-fired conventional wet central heating systems[12] because of a widespread mains gas distribution grid that serves approximately 72% of UK housing. This is compared to Austria where less than 30% of all housing is served by the gas network, and Sweden where gas only accounts for 1.5% of primary energy use. Both of these countries have mature GSP markets. As well as being widely available, natural gas is typically the cheapest heating fuel in the UK, and is considerably less expensive per kWh than alternatives such as oil, LPG, coal or electric heating, which are as a consequence principally used in areas off the gas grid. The use of gas in a high efficiency condensing boiler provides a cost effective and controllable heating option, which appeals to consumers.
Timescale of effect	Permanent barrier in areas connected to the gas network. Does not apply to the 28% of households off the gas grid, where GSPs are particularly attractive due to the limited and expensive alternatives.
Mitigation potential	Modest, as the gas network will not reduce in size. However, as UK gas reserves diminish and prices increase, electrically driven heating systems such as heat pumps will become more attractive.

[12] Energy Efficiency Best Practice Programme, Heat Pumps in the UK: Current Status and Activities, 2000

Barrier	Thermal Efficiency of UK Housing Stock
Description	The majority of housing in the UK is built with very low levels of insulation in comparison to other European countries. For example, the levels of insulation expected in the UK are much the same as those required in Sweden thirty-five years ago[13] Buildings with poor thermal performance are less suitable for GSP systems, which work best with a steady and low heat demand. This is compounded by the limitations on domestic heat pump capacity that are imposed by the electricity supply.
Timescale of effect	Limits applicability of GSPs to the existing housing stock, but this should reduce gradually with time as homes are made more thermally efficient. No effect on new-build installations, which are subject to higher standards.
Mitigation potential	Poor thermal performance of the building stock is not a problem that can be fixed overnight since new buildings, built to higher thermal performance requirements, are only a relatively small percentage of the total (approx 23 million) housing stock. In fact "86% of the 1996 housing stock will still be standing in 2050."[14] The EST field trials undertaken over 2008/09 will evaluate heat pump performance in a variety of homes with different levels of insulation, including solid walled properties.

[13] Schipper 1987 cited Guy S, Shove E. A Sociology of Energy, Buildings and the Environment, 2000
[14] Environmental Change Institute, 40 Percent Vision, 2006

Barrier	Costs
Description	The capital costs of GSP systems are usually in the region of £800 - £1,200/kW, and £1,300 - £1,500/kW for larger commercial/public. This is significantly higher than the cost per kW for an equivalent gas system and the marginal cost payback can be unacceptable to some. This is less of an issue for the public sector, which is generally able to accept longer payback periods. Stakeholders reported that, whilst costs are an issue, they have been driven down and commercial units can achieve 3-6 year paybacks (Geothermal International). As heat pumps require electricity, the ratio of gas to electricity prices also lengthens the payback period. Currently, the UK ratio is 1:3[15], which is more pronounced than, for example, in Austria/Germany with a ratio of 1:2.2. Unless this ratio is reduced, it will be hard for GSPs to compete with gas boiler systems, but this is unlikely as gas is the principal fuel used for electricity generation.
Timescale of effect	Immediate but declining with time, especially post RHI introduction in 2011.
Mitigation potential	Up front cost is a barrier to the take up of GSP technology. The introduction of the RHI will increase running cost savings and speed up payback. Coupled with capital grant and soft loan schemes this should eliminate the barrier of higher capital costs compared to fossil fuel based heating technologies. As the market develops, economies of scale should see cost premiums decrease.

[15] Price from the EU Energy Portal, as of June 2008

Barrier	Insufficient installer network to cope with increased demand
Description	Continued high annual growth rates in GSP system installations could lead to a shortage of suitably trained engineers and plumbers with the specialist knowledge and skills required to install GSPs. Suppliers of underfloor heating could also be in short supply. A shortage of drilling capacity may also act as a barrier in the future, as happened in European markets during the heat pump boom of the late 1970s/early 1980s.
Timescale of effect	The market is currently too small for this to be a major issue, but it may become a limiting factor in a fast growing market. New installation and drilling capacity will enter the market in response to demand.
Mitigation potential	Can be mitigated through training programmes, a number of which are already available from recognised providers (including NVQ and BPEC), and incentivising gas engineers to enter the heap pump industry. The GSHPA states that “It is heating engineers who are going to install systems and heating engineers don't care if they fit a gas boiler or a heat pump.” The GSHPA reports there are approximately 100,000 heating engineers in the UK. The GSHPA stated that the “drilling industry is aware of the opportunity and is trying to respond.” Geothermal International reported that many drilling contractors were at the recent ‘Ground Source Live’ conference and that they have ‘woken up’ to the potential of the market.

Barrier	Awareness & Acceptance
Description	GSP systems are a mature technology but, in the UK, there is a "lack of understanding and confidence around their use amongst both potential users and investors."[16] If the general public is not aware of the environmental and economic benefits of installing such a system, the market will be restricted to those who are environmentally conscious and keen advocates of the technology. Recent research undertaken by Element Energy (2008) showed that consumers were only willing to consider alternative 'untried' systems if they performed better and cost less than existing systems, and if more information and reassurance was made available. The report concludes that, amongst the wider general public, there was "virtually no existing knowledge about heat pumps, CHP or biomass boilers".
Timescale of effect	Currently this is an important barrier for the heat pump market. Greater public understanding of climate change issues, combined with more installations of all renewable technologies, should increase awareness and understanding. Assumed not to be an issue post-2015.
Mitigation potential	As numbers of installed systems increase, scepticism will diminish. Industry, industry associations, and Government need to launch initiatives to increase awareness of GSP systems.

[16] DEFRA, Renewable Heat and Heat from Combined Heat and Power Plants: Study & Analysis, 2004

Barrier	Accessing existing housing stock
Description	To fully realise mass market status, increasing numbers of GSPs will have to be retrofitted in existing homes, since much of today's housing stock will still be in place in fifty years time. This is a significant challenge and worldwide only Sweden has successfully penetrated the retrofit market. A domestic gas boiler is relatively small and easy to install. A ground source heat pump system is not. The disturbance associated with retro-fitting a system, which includes ground excavation for the loop and fitting the distribution system, for example, may well put off even the most ardent GSP advocate when compared to the relative ease of installing a gas boiler. Replacing a traditional condensing boiler system with a GSP system is expensive and complicated. Conventional high temperature 'wet' distribution systems (i.e. 80ºC and 70ºC flow and return temperatures) use radiators that are not compatible with heat pumps. A GSP system requires either underfloor heating, which is not usually economic for retrofitting, or oversized radiators, which cause significant disturbance and add to the project costs.
Timescale of effect:	A major barrier and challenge for the GSP sector indefinitely.
Mitigation potential	Difficult. Heat pumps are always going to be more complex to install than a gas system and will continue to require low temperature distribution systems unless there are unforeseen technical breakthroughs.

Barrier	Carbon Intensity of UK Grid
Description	The high carbon intensity of the UK electricity supply, based principally on centralised Combined Cycle Gas Turbine (CCGT) and coal fired power stations, limits the carbon savings from using a heat pump system compared to its principal competitor in the heating market; the gas boiler. A heat pump with a typical Seasonal Performance Factor (SPF) of 3.5 can deliver 1 kWh of heat at 0.15 Kg CO_2 / kWh, while a gas boiler at 90% will deliver heat at 0.228 Kg CO_2 / kWh. This is based on an average grid intensity of 0.527 Kg CO_2 /kWh. This suggests that a heat pump must achieve a minimum SPF of 2.3 to deliver carbon savings over a gas boiler, which is not always possible. When compared to direct electric heating systems, which heat pumps will often replace, the SPF values achievable with modern heat pump systems will always lead to carbon emission reductions.
Timescale of effect:	The carbon intensity of the grid is on a downward trajectory. Government targets suggest that 40% of electricity will come from low-carbon sources by 2020.
Mitigation potential	High.

5.1.1 Other barriers identified by stakeholders

- **Quality of systems/installation:** Stakeholders suggested that there was potential for unqualified ‘cowboy’ installers that could lead to a loss in customer confidence in the industry, and heat pumps in general. The absence of firm regulation for closed loop systems and a British Standard for borehole and installation design were mentioned as potential problem areas. Schemes such as the MCS were identified as solutions.

- **The Microgeneration Certification Scheme (MCS):** This may work as both a barrier and an enabler. It will be a barrier for one-off installers, for whom joining MCS is unlikely to be worthwhile. However, MCS serves to should ensure quality of installations in the domestic market and reduce the potential negative effects from ‘cowboy’ installers.

- **Competition with other technologies:** For example, an improvement in air source heat pump efficiency and reductions in the noise associated with these systems could make ground source installations considerably less attractive.

- **System specifiers:** A potential lack of Building Service Engineers with experience of dealing with ground source systems.

- **Utility involvement:** Utilities could be more supportive of the industry. For example, they could roll out specific heat pump tariffs.

- **Financial crisis:** Commercial heat pump sales have suffered because of the financial uncertainties of the current economic situation. Until this is resolved the commercial market may slow or even stagnate.

- **Loss of the Low Carbon Buildings Programme:** Phase 2 was due to close in June 2009, but closed in March 2009 because the funding had been used up.

Several stakeholders asserted that none of these barriers were insurmountable and that they would be overcome in due course. For example, in relation to skills shortages, many of the skills required to install ground source systems, such as drilling, pipe-laying, plumbing and electrical wiring, are transferable between industries. Manufacturing is also growing rapidly. Dimplex, for example, has grown from producing 10,000 systems per year to 40,000 per year in three years.

5.2 Specific open loop system barriers

The factors listed in section 5.1 will affect both open and closed loop systems. Table 4 shows how these barriers will specifically effect open loop systems.

Table 4 Barriers to Open Loop deployment.

Barrier	Relative impact compared to closed loop GSPs
UK electricity distribution network	< The majority of open loop systems will be commercial and most will therefore already have 3-phase supplies.
Carbon intensity of the grid	= Effects closed and open systems equally.
Thermal efficiency of UK housing stock	< Open loop systems will generally be larger and used in commercial and public buildings.
Competition with the gas distribution network	> Open loop systems are likely to be located in urban areas (where there is a suitable aquifer), and will therefore be in direct competition with gas.
Awareness and acceptance	> Open loop pumps are rarer and more complex than closed.
Costs	= Open loop systems will be more expensive than closed in most domestic situations. However, in optimal locations commercial installations can be cheaper than a closed loop alternative.
Accessing existing housing stock	= Equally as disruptive in terms of internal modifications, although ground works may be slightly less disruptive.
Insufficient installer network to cope with increased demand	> Open loop systems are more complex and require additional hydro-geological skills, which may restrain the market in a period of rapid growth.

Key: >: More of a concern with open loop systems

<: Less of a concern with open loop systems

=: Equal impact on both open and closed loop (ground based) systems

The principal reasons why closed loop systems may be more numerous than open loop systems were described in section 4.2. A short appraisal of these factors and whether they will continue to apply as the market expands in the period from now to 2020 follows in Table 5.

Table 5 Changes in closed loop system advantages in the period Until 2020.

Closed loop advantage	inapplicability in the period up until 2020
Larger area with suitable ground conditions	**>** Accessible groundwater at an appropriate temperature is required for open loop systems. As increasing numbers of open loop systems are installed in a particular area, the availability of suitable aquifers may decrease as the water temperature changes. One stakeholder claimed that "in Central London saturation of aquifer will be reached, as to whether this happens in the 2020 timescale is not known" (Geothermal International).
Less complexity in design	**<** More dynamic hydrological environments will continue to require greater design complexity, but it can be assumed that with increasing numbers of installations, standardised approaches and specialist open loop design software systems will be developed, as has been the case with closed loop units. A growing market may also encourage consultancies to train and develop staff in this area, particularly those already involved in groundwater issues. Therefore, it can be assumed that the impact of this will reduce with time.
Reduced regulatory requirements	**<** Increased experience in handling GSP applications within the Environment Agency should reduce the regulatory burden. Conversely, a large increase in permit applications could cause delays if the Agency is insufficiently resourced. Overall, however, we assume net reduction in effect.
Greater uniformity and inclusion in grant schemes	**=** The increasing number of open loop installations should encourage greater uniformity of systems. This will potentially lead to systems being included as standard in funding and subsidy schemes, without the need for case-by-case consideration. However, it is anticipated that the majority of open loop systems will be larger in scale and therefore bespoke in nature.
Reduced maintenance requirements	**=** Unless there are significant technological developments in filtering abstracted water it is unlikely that this factor will alter significantly. A closed system will always have reduced maintenance requirements over open systems.
Thermal interference	**>** Open loop systems will primarily be employed in cities where, at high densities, they may cause thermal interference with eachother. This will need managing.

Key: >: Increase in advantage compared to closed loop systems

<: Less of an advantage to closed loop systems

=: No change, relative advantage to closed loop systems holds

5.3 Conclusion

We have identified eight principal barriers that will constrain the market growth of GSP systems from now until 2020. Three of these - the capacity of the UK electricity distribution network, competition with the gas network, and access to existing housing stock - are expected to continue to apply until 2020 and beyond.

The remaining five - the thermal efficiency of UK housing stock, awareness and acceptance of the technology, the carbon intensity of the UK grid, marginal costs of fossil fuel alternatives, and the size of the installer network - are considered surmountable. It is likely that the ability of the installer network to cope with increasing demand will be the most significant medium term issue, whilst the rest could be addressed by 2020. The effect of these barriers is considered in the market forecasting exercise in Section 6 of this report.

Table 4 shows that these factors generally balance out in terms of how they effect open and closed loop system installations, with three of the seven impacts applying equally, three having more of an impact and two with less of an impact.

Table 5 shows that the main reasons for choosing a closed loop system over open loop will remain largely unchanged in the period to 2020. The most significant barrier - fewer locations with suitable hydrological conditions - is unlikely to change.

6 Future market trends

This section forecasts overall GSP market growth in the UK in terms of the number of installations under both a growth and high growth scenario, between now and 2020. The forecast is broken down to give an estimate of the future market size for open loop systems. The findings of this exercise are then sense checked against other relevant data (provided in the appendices).

6.1 Market forecasting

This section translates the information and perspectives on market growth from the literature review and stakeholder consultation into estimates of installed numbers of systems and their capacity in 2020.

Both of the growth scenarios assume that the market does not reach saturation and is in continuous growth from now until 2020. This is an assumption that was supported by all stakeholders. Both scenarios begin with a growth rate of 4000 units in 2008, but differ from there on. This reflects the differing opinions held by stakeholders as to the rate of growth. Kensa, for example, represented the most bullish outlook and were of the opinion that “the demand should be there the question is more as regards supply e.g. can companies ramp up production to meet demand?”

Both scenarios assume that the introduction of the RHI will cause an immediate increase in the installation rate, but has a marginally greater impact in the high growth scenario.

6.1.1 Growth scenario

The growth scenario assumes that in the early stages of the market, until 2011, 50% annual growth can be achieved. This is in line with the estimates developed in Section 2. However, as annual installed numbers increase, the cumulative impact of the following market barriers take effect:

- The prevalence of the gas distribution network and a competitive gas price.
- Difficulty in increasing installer and drilling capacity at sufficient pace to meet demand.
- Barriers in accessing the existing housing market, and the fact that the majoriting of the UK housing stock is inefficient and unsuitable for heat pump applications.
- Government policy acts as a medium stimulus to. The RHI, whilst still an enabler, places a lower value on renewable heat production and has several restrictive conditions attached that limit widespread application in the GSP market

Together, these barriers are assumed to slow market growth from 50% incrementally down to 5% from 2017 onwards, until 2020.

Figure 5 illustrates the annual installation rate and total installed systems in the UK from now until 2020, under the growth scenario.

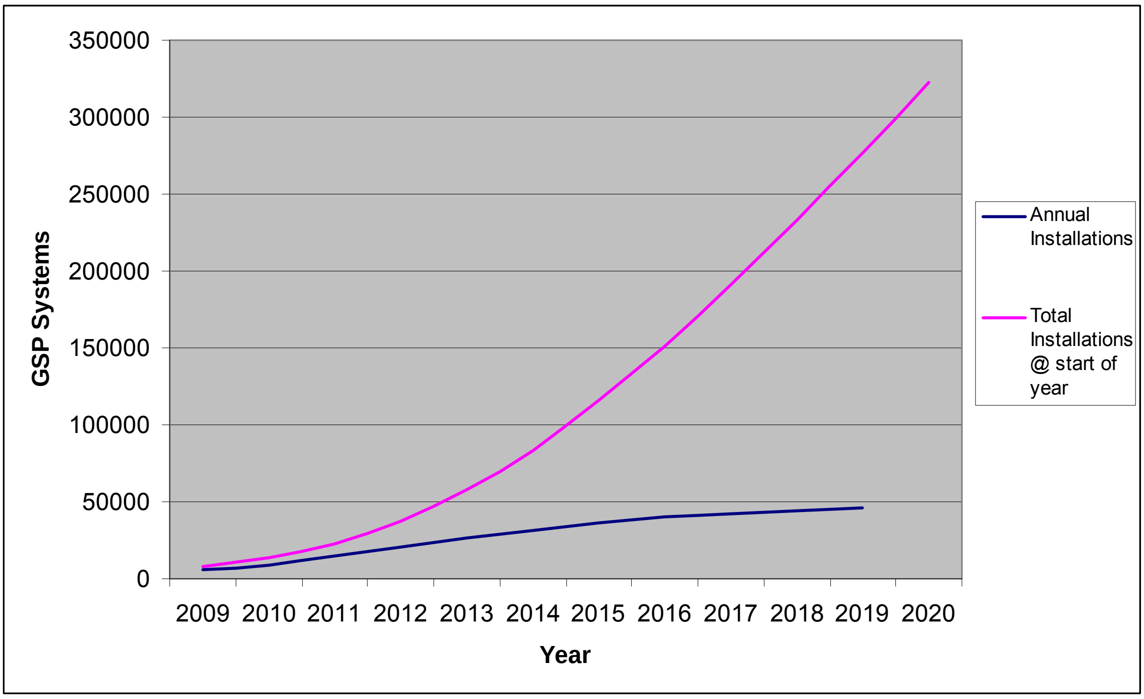

Figure 5 Growth scenario projections (UK).

It can be seen that from 2017 onwards the installation rate starts to level off at approximately 40,000 units per annum, resulting in a total of approximately 320,000 units by 2020.

6.1.2 High growth scenario

The high growth scenario assumes that all the barriers outlined in section 5 can be overcome and 50% per annum market expansion is maintained until 2020. This assumes there are perfect conditions for growth of the UK GSP industry, including continued fossil fuel price rises, enforced and effective UK government policy, growing consumer awareness and acceptance of the technology grows, and the ability of the market to respond well to growth signals.

This scenario assumes that the RHI is an efficient market enabler, placing a competitive value on heat from GSPs with no restrictive conditions attached. After an initial growth peak in 2011 and 2012, the RHI successfully maintains market growth at 50%. Rayner Mayer proposed that continuing to achieve 50% growth per annum "is highly dependent on the impact and value set for a Renewable Heat Incentive, if set at a value which can bring the payback [for a GSP system] down to five years then there will consequentially be a significant increase in annual market growth."

Earth Energy stated that, "If we are going to get near UK government targets [associated with the EU Renewable Energy Directive] we need to see this rate of growth, or even quicker in the first few years." The GSHPA echoed this, stating that, if UK government 2020 targets are going to be met, GSPs will need to be the default technology by 2016-2019.

Figure 6 - The annual installation rate and total installed systems from now until 2020, under the high growth scenario.

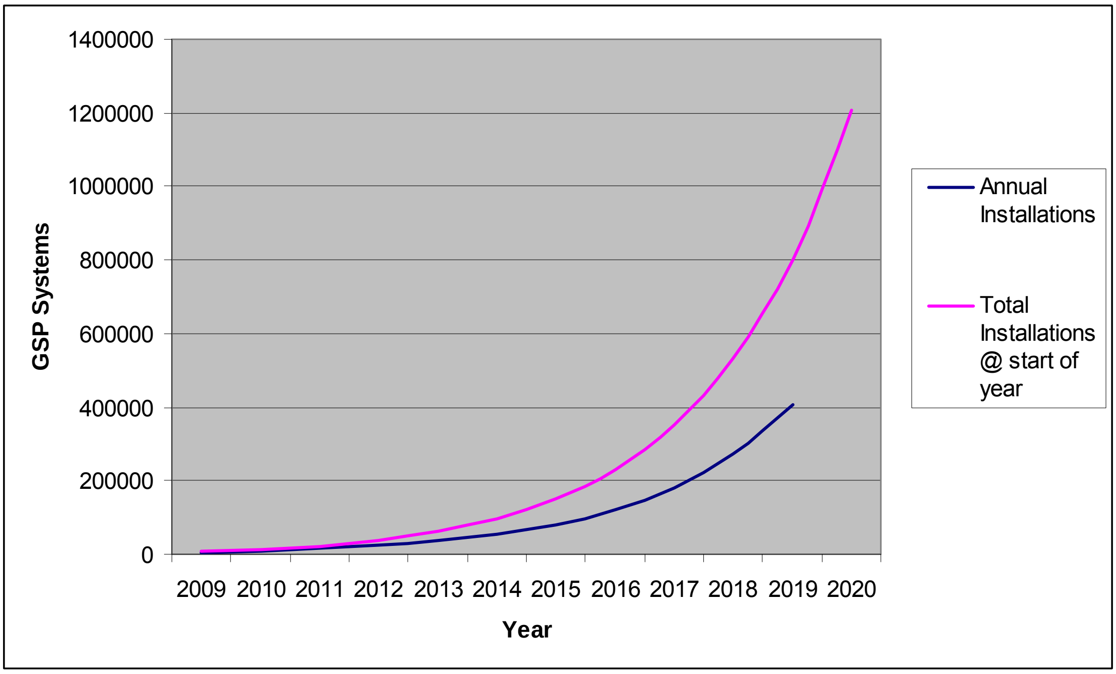

Figure 6 High Growth scenario projections (UK).

In this scenario, by 2019 the installation rate reaches approximately 400,000 units per annum, with a total of approximately 1.2m units installed by 2020. Graphs of the installation rate alone for each scenario are given in Appendix 6. Whilst these figures are high, stakeholders suggested that they are achievable. Earth Energy, for example, were of the opinion that, "The market will respond to increased demand and can do 100,000s [of heat pump] unit installations per annum."

6.1.3 Estimates of thermal capacity and energy generation

Using the base assumptions developed for the thermal capacity calculation in Section 2.4, an estimate of total thermal capacity achieved under each scenario can be calculated. The only exception is that the average size of a domestic unit has been scaled up to 7kWth, reflecting the wider use of GSHP units in larger scale domestic properties built to higher standards of thermal performance.

Using these assumptions the estimated total thermal capacity of all installed systems in 2020 is:

- Growth scenario: 6,715 MWth
- High growth scenario: 25,131 MWth.

The contribution of heat pumps to heating & cooling energy in 2020 can be estimated by applying the equivalent full load hour assumptions used in section 2.4:

- Growth scenario: 21TWh
- High growth scenario: 78 TWh.

6.1.4 Open loop market growth

Applying the assumptions made in Section 4.3, the approximate number of open loop systems under these scenarios would be:

- Growth scenario: 7,750 (2,900 Domestic, 4,850 Non-Domestic)
- High growth scenario: 29,000 (10,900 Domestic, 18,100 Non-Domestic).

6.2 Sense check of findings

To check the validity of the figures generated in section 6.1, a series of sense checks were conducted on the data. These include comparison against UK market potential and developments in other European markets, and are presented in appendices 7 and 8.

The sense check concluded that the figures under the growth scenario are eminently achievable. They are at the low-end of other stakeholder predictions and only account for a small percentage of the total market share in each sector (e.g. domestic, commercial/public and industrial scale). They are also within new-build and refurbishment rates.

The sense check on the high growth scenario shows it is at the high end of what is physically achievable, but not actually impossible. The figure of 1.2 m installations is at the high end of stakeholder predictions and would account for 86% of all predicted renewable heat within the RES consultation. In terms of market share, this figure seems feasible for the domestic market when checked against the percentage share, new-build and refurbishment rates, and, to a lesser extent, for industrial scale applications. However, in the commercial/public market, GSPs would need to account for nearly 40% of all buildings.

6.3 Conclusion

Growth and high growth scenarios were constructed to determine how annual market growth rates proposed by stakeholders might correspond to actual numbers of installations, installed capacity and energy generation in 2020. The scenarios begin from the same 2009 baseline, but assume different rates of annual market expansion based on different interpretations of the impact of market barriers.

Under the growth scenario, 320,000 GSP systems are installed by 2020, with an annual installation rate of 40,000 units. This corresponds to 6,714 MWth of installed capacity and an output in the region of 21 TWh. Of these installations, 7,750 would be open loop systems, with 1000 systems installed each year.

Under the high growth scenario, the annual installation rate is a factor of ten higher, at 400,000 in 2019, with a total of 1.2m installed systems by 2020. This equates to an installed capacity of 25,131 MWth and an estimated output of 78 TWh. Of these installations, 29,000 would be open loop systems, with 9,200 systems installed each year.

Note that this analysis gives an estimate of the range in which the market may develop. However, this is a basic forecasting exercise and there can be no means to accurately predict the true nature of the industry in 11 years time.

7 Geographical analysis

To provide the Environment Agency with an overview of where GSP systems are likely to be installed, stakeholders were asked to identify any current installation 'hot-spots' and any that are likely to evolve by 2020. This section reports their feedback in relation to the market in general, and to open loop systems in particular.

7.1 Current market

A key driver for the Environment Agency's commissioning of this study was to identify any areas that are currently exhibiting high levels of GSP installations. There is little information on this topic in the literature, so stakeholder opinion forms the core input for this section.

The areas that currently have high levels of GSP installations and the proposed reasons for this are, shown in the table below.

Table 6 Current GSP deployment 'hotspots'.

Region(s) / Area(s)	Explanation
The Southwest	Key industry members such as Kensa and Earth Energy Ltd are based in this region. Therefore, there is a relatively high level of awareness of GSP technology in the area, especially at a domestic level. The South West is known as the 'green peninsula' and has higher than average numbers of all renewable technologies. Many parts of the area have limited access to the gas supply network.
London and the Southeast	This was identified as a hotspot for commercial scale systems, with the focus of development in central London. This has principally been driven by the Merton Rule, which has been in place there the longest.
Yorkshire and Humber	Heat pump systems accounted for 10% of all LCBP funding, equivalent to approximately £2m. Yorkshire and Humber was one of the biggest areas for grant awards. In Yorkshire, Harrogate and Doncaster are active in using GSPs in housing association schemes.
East of England	LCBP grant awards highlight Norfolk as an area of potential because of limited access to mains gas.
Scotland	Due to a superior funding scheme for GSP technology. The SCHRI was identified as a "good stimulus to the market" by the GSHPA and more effective than equivalent English funding schemes in stimulating the market.
Scottish Islands	The Islands do not have access to mains gas supplies and hence have good potential for GSP systems.

Per capita installations are higher in Scotland than in England and Wales and this offers an insight into how future hotspots could develop. Wales and Scotland have marketplaces that are principally driven by domestic installations and are only now starting to get more commercial/public scale installations (with more success in this respect in Scotland than Wales).

The split in the market between public and private sector installations differs by region. For example, the majority of GSP systems in London are in the private sector, which is not eligible for LCBP grants. This means London does not show up as a hotspot in regional splits of LCBP funding.

A recent trend is for a rise in demand for large numbers of GSP systems, particularly in areas off the gas grid for, for example, large scale switchovers of systems in multiple homes by social housing providers. This is expected to be a main market driver for clustering of installations. In the long term, clustering is likely to be in areas of new build activity.

The general opinion of stakeholders was that, with the exception of the regions above, installations are scattered. EST stated “from our access to the LCBP grant data, we do note a geographic spread [of installations] all across the country.” This is another potential barrier for a fledgling industry as it reduces the installer’s profit margin per installation because of increased travel and time spent per installation. For this reason, it is expected that as the market grows the major players will open more regional offices. This trend has already begun.

7.1.1 Open loop systems

An open loop system requires access to a suitable aquifer. The fact that the Merton Rule originated in London, where there is limited space available for closed loop systems but access to a suitable (chalk) aquifer, has resulted in a hotspot for open loop installations in the capital. This aquifer is particularly accessible and of a well understood fissure flow type. Some of the early systems in London were consumptive i.e. extracting from groundwater and discharging into the Thames, as the water level of the aquifer has dropped these have become less popular.

Where a significant number of open loop systems will be installed in a particular area, there is a clear need for both planning and regulation to ensure their sustainability in terms of their impacts on the aquifer. The effect on the GSP industry of revoking/non-issue of licences, where serious implications from over-use of the aquifer have been identified, will need to be considered.

7.2 2020 Market

This section presents stakeholder feedback on what may cause higher levels of GSP installations in certain areas as the market grows to 2020. Where possible it provides examples of where these areas might be. A geographical perspective on the 2020 market is developed.

Table 7 Geographical growth drivers.

Geographical Growth Driver	Explanation
Refurbishment and Regeneration Areas	Regeneration areas are an opportunity for the GSP market. Stakeholders particularly mentioned projects in East Anglia and Liverpool, as well as the Schools for the Future programme.
Off Gas Areas	There is a higher potential for GSP in rural areas that are off the gas grid.
Climate	As the market grows there may be proportionally more installations towards the north of the country, as there is in Scotland, where housing has a higher heating demand. Where the number of equivalent full load hours is higher the higher operational efficiency of a heat pump means the system will pay back quicker.
House Condition	While heat pumps are particularly effective in well-insulated homes, they are also applicable to poorly constructed ones. Houses which suffer from condensation dampness are suitable for fitting a GSHP system, as the need to both heat and ventilate will make the lower running costs of a GSHP system attractive.
New Build Activity	The build stage is ideal for installing a GSP as it minimises cost and disruption. Clusters of new-build activity should also represent hotspots of GSP installations.

7.2.1 Open loop systems

It is possible that with time some areas will become less pronounced GSP installation hot spots. As the wider GSP market grows installations in London may slow down as capacity is reached. Capacity is defined by the number of systems that can be installed without interference effects between schemes. This effects both open and closed loop schemes, but is considerably more pronounced for open loop as they have a much wider zone of thermal effect. If too many systems are in close proximity, short-circuiting may arise, for example bridging can occur between two boreholes in one scheme or between two adjacent systems. Groundwater may also become overheated, since these installations are cooling dominated.

The UK has two major chalk and sandstone aquifers that run in two bands from the Northeast to the Southwest of England. Both are suitable for open loop systems. Anywhere along these aquifers should be suitable, although suitability needs to be assessed on a case by case basis via a pump test.

The chalk aquifer covers London, East Anglia, Colchester, etc ,and the sandstone aquifer covers Birmingham, Leeds, Manchester, Liverpool and Newcastle. Most major cities have some access to a suitable aquifer, providing the opportunity for open loop systems to become more widespread.

There is potential for considerable development of open source systems on the sandstone aquifers of the North and West of England, and in the Coventry region based on coalfield aquifers. It was noted that in London the water is low in minerals, but in sandstone aquifers there is a higher mineral content that could cause maintenance problems.

7.3 Conclusion

Currently five areas have high levels of GSP installations. The drivers behind differences in regional market penetration are:

- Coverage of gas supply network
- Awareness of the technology, linked to a local installer base
- Policies, particularly the Merton Rule
- Housing Association activity
- Effective funding schemes

The principal drivers behind installations differed between regions. The market segmentation is also different. In some areas most systems are domestic, whilst in others they are commercial/public scale. In London the private sector is leading the way, while in Yorkshire and Humber the public sector is dominant. Beyond the identified hot spots it is assumed the remainder of installations are scattered.

Looking forward to the 2020 market, the key factors in encouraging clusters were:

- Refurbishment & regeneration areas
- New-build activity
- Housing condition
- Off-gas grid areas.

Where these factors, or combinations of these factors, are present, there should be an increase in clusters of GSP installations as 2020 approaches.

London was identified as a hot spot for open loop systems. This is because of the combination of a suitable aquifer, the Merton Rule and restricted space for closed loop collectors. Only a finite number of open loop systems can be accommodated in a particular area and at some point the capacity of the London aquifer will be reached. As there are major aquifers underneath other major UK cities, there is the possibility that open loop hotspots will appear in new locations.

8 Regulatory context

This section provides a brief overview of the Environment Agency's role in the GSP industry, in relation to closed and open loop systems. It reports stakeholders' experiences of working with the Environment Agency and suggests how regulation of this technology could be improved.

8.1 The Environment Agency's role

8.1.1 General responsibilities

The Environment Agency's Groundwater Protection: Policy and Practice" (GP3) document states that the Environment Act (1995) requires the Environment Agency to: "contribute to the objective of achieving sustainable development." The Environment Agency must support the responsible development of low carbon energy technologies, such as well-designed GSP systems, provided that they have no unacceptable adverse impact on the environment.

The Environment Agency has an obligation to facilitate the use of groundwater for heating and cooling purposes, provided that this use is sustainable and does not result in deterioration in the water environment. This is why the Environment Agency insists that a well-designed open loop GSP scheme requires input from a professional hydrogeologist and/or groundwater engineer.

Some Brownfield sites may fall under the Contaminated Land (England) Regulations 2006 and any action that may potentially cause pollution to a water body will result in enforcement action by the Environment Agency.

8.1.2 Responsibilities relating to closed loop systems

Currently most closed loop GSP systems do not require any form of licence or permit from the Environment Agency. However, closed loop systems or heat exchangers that are installed in surface watercourses may require a 'Flood Defence Consent' from the Environment Agency.

Whilst the Environment Agency does not regulate closed loop systems, it is keen to influence the sector to ensure responsible installation of GSP systems by encouraging adherence to codes of good practice. In exceptional circumstances, such as very large closed loop schemes or schemes that may pose a risk, the Environment Agency reserves the right to exert its influence, either directly or via the planning process.

8.1.3 Responsibilities relating to open loop systems

The operation of open loop GSP schemes is tightly regulated by the Environment Agency's abstraction licence and discharge consent requirements. The installation and operation of an open loop GSP scheme will normally require prior permission from the Environment Agency, in the form of consent to drill and conduct a pump test, an abstraction licence and discharge consent.

Open loop systems that involve the abstraction of groundwater (or surface water) for heating and cooling purposes require an abstraction licence from the Environment Agency, unless the quantity abstracted is very small (less than 20 m^3/day in any 24 hour period). Before any drilling commences, a Water Resources Act (1991) Section 32(3) Application must be submitted to the Environment Agency.

The return of thermally 'spent' water to surface water or an aquifer is regulated via discharge consents, issued by the Environment Agency. The 'spent' water may be discharged to a sewer, drain, surface water (river or lake), sea or back to an aquifer via a re-injection well. In most cases a permit will be required for this discharge, either from a utility company or from the Environment Agency.

8.2 Feedback regarding the regulatory process

Overall stakeholders described their dealings with the Environment Agency as positive, noting that the Environment Agency had been co-operative and helpful despite the challenges that arise when regulating a new industry and working in what was described as a 'guidance vacuum'. The Environment Agency has acknowledged the expertise within the industry, which has been appreciated.

Stakeholders would like clarification from the Environment Agency regarding the consents process for open loop systems and GSP issues as outlined below.

Consistency: Stakeholders asked for a more consistent regulatory framework. Several noted some inconsistency in interpretation by the Environment Agency when determining applications for abstraction licences and discharge consents in different regions. This required a new relationship to be built each time and additional time spent working with Environment Agency staff to resolve any issues. It was noted that regional offices have been taking the lead on guidance from the more experienced London office (see section 7), which is welcomed.

It was suggested that a centralised approach would help and that the application process be modified so that a single department processes applications, rather than different departments managing abstraction licences and discharge consents. These concerns may be addressed through the establishment of the National Permitting Centre, a new centralised body within the Environment Agency responsible for processing all applications.

Licences & consents: One stakeholder noted that there is an element of uncertainty associated with the regulatory process because of the twelve-year time limit on licences and situations, although not involving GSHP schemes, where licences have been issued and later revoked. The uncertainty arises because investment in a heat pump system is usually based on a twenty-year plus timescale and not the twelve-year period of a licence. This regulatory risk may deter investors.

Although not a specific concern it was noted that abstraction licences are issued on a first come first served basis. In 'hotspots' for open loop systems this could lead to strategic applications for licences to ensure that a licence is available once the go-ahead for a project is given. One stakeholder stated that they "advise clients to make an application as early as possible" (Zenith International).

Some clarification from the Environment Agency on the key regulatory differences between surface water and borehole open loop systems would also be welcomed.

Thermal assessment of GSP installations: The consensus among stakeholders was that the potential thermal impacts of open loop systems should be given more consideration in the regulatory process. This should have a particular focus on interference between systems and how thermal impacts effect the environment. Specific areas where greater clarification could be given regarding thermal impacts are:

- Clear guidance on what can and cannot be done with regards to temperature impacts. The set temperature levels at present appear arbitrary.
- There is a concern that heat pumps could contribute to the 'urban heat island' effect which is already a problem in London. Geothermal is not thought to be a primary cause at present, but could be in the future with an increase in the number of installations.
- The zone of influence for closed and open loop pumps and the implications if this extends past the boundaries of the site.
- Real examples of heat balanced schemes.

The GSHPA aim to take an active lead in monitoring numbers of GSP installations, but there are currently no plans in place to monitor the location of installations. This could be important in identifying where thermal impacts may occur, especially at a larger scale and with open loop systems, which will have a wider thermal influence. Stakeholders did not propose a particular role for the Environment Agency in this respect.

With regards to 'balanced schemes', where heating and cooling are provided in equal measure, it was noted that the Environment Agency would like to see these installations but has no powers to encourage them. In reality, achieving balanced schemes is not always as simple as moving 'heat' and 'cool' from building to building and UK land ownership laws don't facilitate this approach. It may be possible to balance heating and cooling loads in, for example, a shopping centre, where some areas will be heated and others cooled, but, in most cases the cooling and heating load will be the same in each building. Sophisticated systems, such as Underground Thermal Aquifer Storage (UTAS), are under development, which will allow interseasonal storage of 'heat' and 'cool' for use when required.

Zenith International stated they would like to see licensing of the thermal aspects of GSP schemes (open and closed loop) in a regulatory framework like the Catchment Abstraction Management Strategies (CAMS). Instead of a water balancing calculation a similar balancing approach could be used for thermal loads.

Regulation of closed loop applications: Opinions differed as to whether there should be increased regulation of closed loop heat pump systems. Stakeholders reported they interacted with the Environment Agency on closed loop systems when:

- List one substances are used, such as refrigerants
- Working on Brownfield sites, where drilling can spread contamination.

The Groundwater Regulations (1998) prohibit the discharge of List one substances and allows permits to discharge List two substances only under set conditions. The Contaminated Land (England) Regulations 2006 make it an offence to pollute a water body from contaminated land.

One respondent called for increased regulation of closed loop system installation, design and monitoring. This could be for systems over a certain threshold capacity, as it would not be required for domestic schemes. The principal aim of increased regulation would be to keep 'cowboy' operators out of the industry and preserve customer confidence. This is a pertinent issue; one installer noted that knowledge of best practice can be very poor even amongst members of the industry.

The majority of respondents, however, did not wish to see regulation of closed loop systems. Some stakeholders reported that a simple courtesy call, or short meeting, has been sufficient to discuss the issues and the appropriate measures to take. It was agreed that ensuring good quality installations is important, but it was thought that providing technical guidelines for installers and investing in training are a better means to ensure good quality installations than increased regulation. In some cases increased regulation would inhibit, rather than open up, the market for GSPs.

Additional guidance was requested on:

- When the Environment Agency becomes involved in closed loop applications and when installers need to make contact.
- The effects of long-term temperature depletion in the ground from closed loop borehole systems.
- When an EIA is needed for closed loop systems in surface water.

8.3 Conclusion

The Environment Agency's role in the GSP industry primarily relates to permitting abstraction and discharge for open loop systems. Overall, stakeholders reported a positive working relationship with the Environment Agency. They highlighted areas where the regulatory landscape could be improved, including ensuring regional consistency in regulation, reducing uncertainty caused by the granting of time limited licences, and assessing and regulating the potential thermal effects of both individual schemes and the interaction between multiple systems in a particular location.

Opinions were mixed over whether the Environment Agency should become more involved with closed loop installations. On the one hand it was suggested this was a means of ensuring a good quality of applications. On the other hand it was thought this could slow market growth and that training and technical standards were a better means of ensuring high quality installations.

9 Implications for the Environment Agency

This section describes the implications for the Environment Agency of the findings made in this report.

The current size of the market for GSPs is small, but high levels of market growth appear set to continue. Even if the barriers to market growth identified here significantly impede growth, the number of systems installed by 2020 will still be significantly higher than at present. If these barriers have relatively minor effects, then GSPs could become a mass market technology. The prevailing legislative environment and favourable policies and subsidy schemes support the view that significant growth will be achieved.

A good proportion of these installations will be domestic scale closed loop systems and not of primary concern to the Environment Agency. However, expansion should occur in all segments of the market and the Environment Agency may wish to consider its current staff resources in abstraction and discharge permitting, and how to streamline processes and procedures to ensure that the regulatory process does not cause undue delay in system installation. The use of time-limited licences could be reviewed to see how the uncertainty for heat pump investers can be reduced.

Cooling is a significant proportion of the larger scale commercial/public segment of the market. The Environment Agency may wish to consider the potential impacts on the ground, groundwater and surface water of heat rejected from building cooling. Cooling loads are set to increase as a result of reduced heat losses specified in the building regulations combined with higher numbers of building occupants and increases in IT equipment.

Hotspots of GSP activity exist and the Environment Agency may wish to investigate the effects on the natural environment of multiple GSP systems in a particular area, such as long-term heat depletion or build up in the ground. The situation in London demonstrates that the ability of open loop systems to extract a significant volume of heat from a relatively small site footprint can lead to installation hotspots in cities above a suitable aquifer.

Industry feedback highlighted concerns about potential thermal effects from multiple systems in a particular location; both in terms of overall changes in the temperature regime of the ground/aquifer and the effects of systems on each other. The latter is especially an issue for open loop systems.

Further research was suggested to identify any potential impacts from both closed and open loop systems, especially in areas with a high density of systems. Once this has been conducted, permitting and planning processes could be tailored to fit the findings. This would be preferable to impacts being discovered at a later date and the consequential uncertainty associated with revoking of licences and consents.

As more GSP systems are installed, particularly larger scale commercial units and open loop systems with wider spheres of influence, there may be a future role for the Environment Agency in logging installations and mapping their areas of thermal influence. Discussions could be held with the GSHPA to decide how best to go about this.

The national permitting centre should go a long way to resolving the issue of inconsistency between regions, but a further review of how best to ensure a consistent approach to open loop system regulation might be worthwhile.

Finally, the Environment Agency may wish to consider its position and responsibilities regarding the regulation of closed loop systems. They should consider how best to ensure there are no environmental impacts from the installation of more numerous and larger systems, without introducing additional barriers to market growth. The industry would value clarification of exactly where the Environment Agency is, and is not, involved with closed loop installations.

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Personal Communication with the stakeholder consultation respondents listed in Appendix 1.

List of abbreviations

Below is a selected list of abbreviations that appear in the report:

COP: Co-efficient of Performance, the steady state efficiency of a heat pump unit at defined design conditions

EHPA: European Heat Pump Association

EST: Energy Saving Trust

GSP: Ground sourced pump system, for the provision of heating, cooling or both.

GSHPA: Ground Source Heat Pump Association

GWh: Gigawatt-Hour

kWth: Kilowatt thermal, used to describe the thermal heating/cooling capacity of a heat pump unit, one thousandth of a MWth

LCBP: Low Carbon Buildings Programme, a grant scheme

MCS: An accreditation scheme for installers. Previously the Microgeneration Certification Scheme, now termed MCS

MWth: Megawatt thermal, used to describe the thermal heating/cooling capacity of a heat pump unit

MWh: Megawatt-Hour, unit of energy

RHI: Renewable Heat Incentive, a proposed subsidy scheme for renewable heat

SPF: The efficiency of a heat pump over a prolonged period of time i.e. the heating season

TWh: Terawatt-Hour, unit of energy

Appendices

Appendix 1: Organisations contacted as part of stakeholder consultation

Appendix 2: European market maturity S-curve

Appendix 3: Cooling technical overview

Appendix 4: Open loop system diagrams and overview

Appendix 5: Other GSP barriers

Appendix 6: Annual installation graphs under the growth and high growth scenarios

Appendix 7: Growth scenario(s): UK sense checks

Appendix 8: Growth scenario(s): European market sense checks

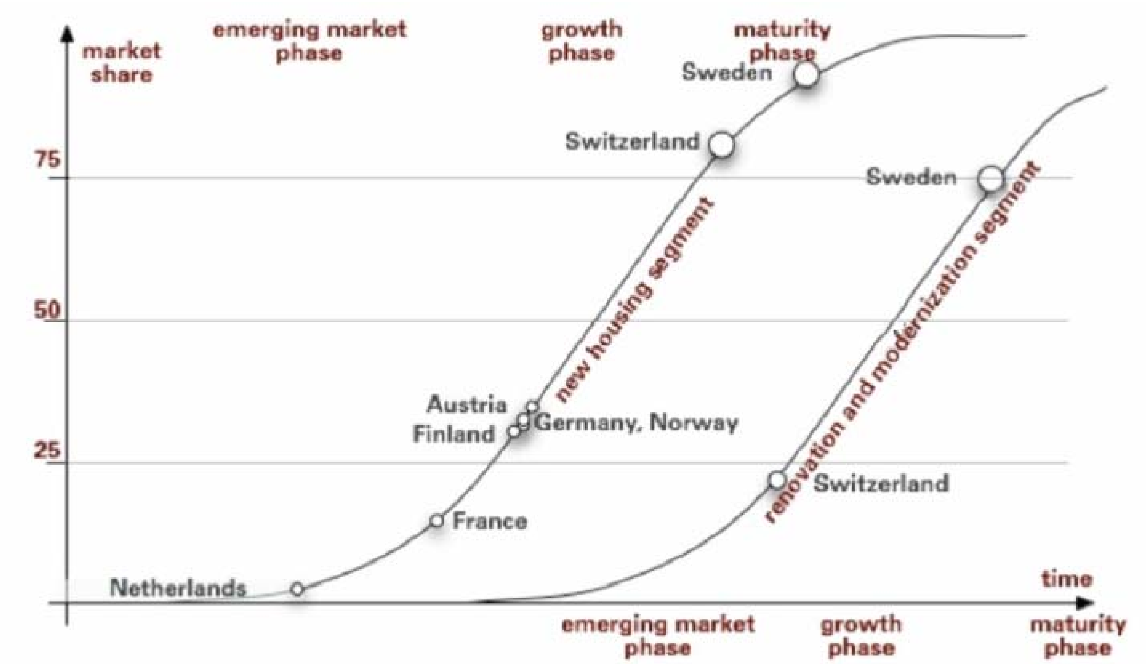
Appendix 1 Organisations contacted as part of stakeholder consultation

Contributors to the stakeholder consultation exercise are listed below:

Organisation	Role in Market	Name of Respondent
Geothermal International	Installer	Chris Davidson
Reading University/EHPA	Academia/Trade Association	Rayner Mayer
Earth Energy	Installer	Brian Kennelly
Zenith International	Open Loop Consultant	Mark Mulcahy
GSHPA	Trade Association	David Matthews
Kensa	Manufacturer and installer	John Barker Brown
Energy Saving Trust	Advisory	Jaryn Bradford/Rob Lewis

AEA and the Environment Agency would like to thank the above for their time and valued input to the study.

Appendix 2 European market maturity S-curve



Market status for selected EU countries in 2007 (EHPA, 2008).

There are three key market stages that characterise the development of a new technology such as heat pumps:

Emerging: During an emerging stage the technology is evolving to meet emerging needs, which have arisen in this case as a result of climate change policy stimulating low carbon heating and rising fossil fuel prices. Some technologies may be brought to market while still undergoing research and development optimisation. This is not the case with heat pumps, which have a long, circa 20 year, operational history in Europe. Each application may involve innovative and original thought, and precedents are few. At the emerging stage it is difficult to price systems accurately. For customers, it is unusual for systems provided at this stage to be cost competitive with more established technologies and for this reason they tend to be cost sensitive.

Growth: The growth stage emerges once the new technology becomes entrenched and more firms start offering related units, e.g. manufacturing heat pumps, or services, e.g. drilling/installation. Revenues increase and the technology becomes profitable. As profits rise more service providers enter the market and the overall demand for the technology increases too. For firms that were early entrants, this can be an extremely profitable phase as there will be a steady flow of projects. There will be a higher level of public awareness and public acceptance of the technology as the growth stage progresses.

Maturity: Maturity is reached once a critical mass of customers and service providers are active. Revenues plateau as sales growth slows and then levels off. Competition on price becomes more pronounced as more and more firms reach the point where they can offer a good quality service.

Appendix 3 Cooling technical overview

Cooling can be performed with a GSP by two methods, reversible operation and direct cooling (also referred to as natural cooling). In the former the heat pump function is reversed, while in the latter the ground loop, which can be closed or open, absorbs energy from the heating circuit and transfers it outside.

Direct cooling works because in summer the ground and groundwater temperature is generally lower than that inside buildings and thus can be used for cooling. To use direct cooling additional equipment will be required, including an additional heat exchanger, a three-way valve and a circulation pump. The heat pump compressor is turned off and a circulation pump drives a secondary circuit. This removes the energy from the in-house distribution system, e.g. underfloor, via a heat exchanger to the water loop in the ground where the heat is lost. This is a very energy efficient form of cooling as the only power required is that needed to drive the circulation pumps (COP of 15-20 achievable).

Reversible heat pumps operate best with a hybrid air (cooling)/water (heating) distribution system. In the UK water based distribution systems dominate e.g. low temperature radiators or, for new-build properties with GSPs, underfloor heating. Radiators are particularly unsuitable for cooling a room because of the small summer temperature differences and the relatively small surface area for heat transfer from the room to the radiator. Furthermore, heat rises and most radiators are situated at the base of a wall. Consequently, a heat and cool unit will usually have two distribution systems, water based for heating and air based for cooling.

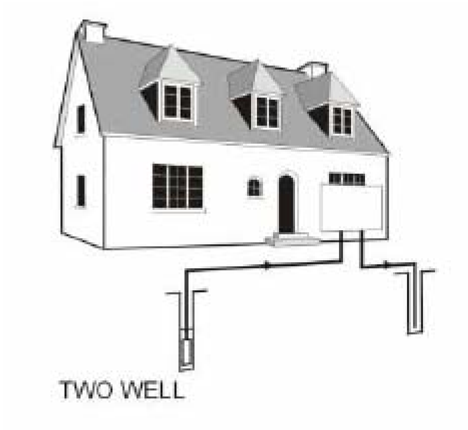
Reversible units do exist, but it is a common misconception that all heat pump systems are capable of operating in reverse to provide both heating and cooling capacity. The majority of those installed in the UK are specially designed heating units. Reversible units differ from standard heat pump units because:

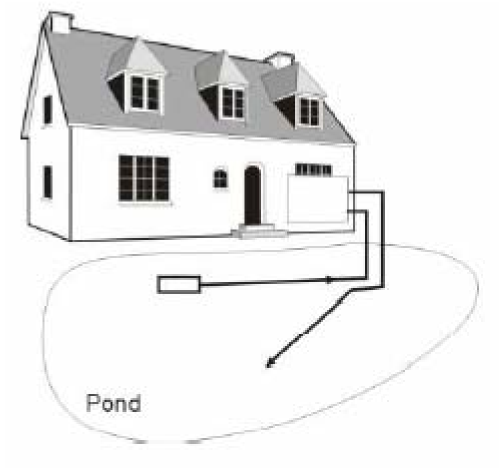
- Additional surface area is required for the indoor coil to prevent excessively high condensing temperatures.
- For an air distribution system, sufficient airflow will be required to ensure adequate condensing of the refrigerant.
- The compressor will need to be specifically designed to operate all year and under different pressures/conditions.
- Auxiliary heating may well be required in certain conditions.

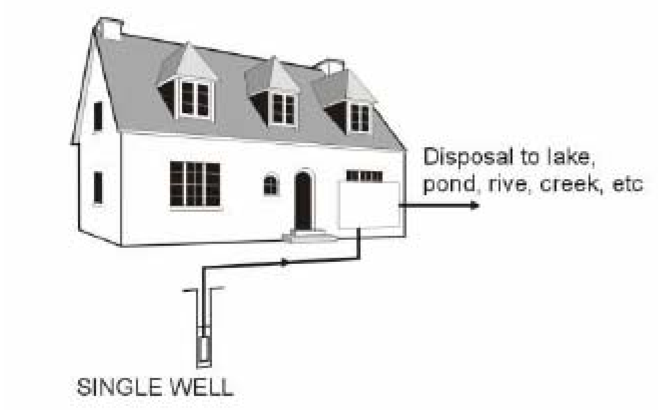
The cooling capacity of a reversible heat pump does not match its heating capacity. This is because the heat generated during compression is useful for heating, but it lowers the COP in cooling mode.

There are heat pump systems available that are specifically designed to offer cooling and heating services. In the USA and southern European Countries (Spain/Italy) these systems are widespread. The vast majority of these systems do not use the ground as a heat source/sink, but the air. In Northern European markets, such as Germany and the UK, heating only GSP units are more popular.

Appendix 4 Open loop system diagrams and overview







Key types and applications for open loop systems in the UK:

Water well systems: An abstraction and rejection pair (or pairs) of water wells is installed as the source. The water is piped into the plant room and through a heat exchanger where heat is either taken from, or added to, the water. The water is then returned to the ground, chemically unaltered. Open loop water well systems are best suited for larger projects and, provided sufficient water is available, size of project can be undertaken. There is a risk element to water well drilling as that water yields cannot be guaranteed. This risk is borne by the developer, who will usually conduct detailed hydro-geological studies to quantify the risk. These systems are most suited to larger scale commercial or public projects in urban areas.

The Groundwater Association has reported growing numbers of open loop GSPs that use multiple pairs of abstraction and injection boreholes and involve significant groundwater abstraction and re-injection rates. As these schemes become more common and potentially closer together, there are technical and regulatory challenges that must be met if the successful and sustainable use of this technology is to continue to grow.

Surface water systems: Where surface water is available and a closed loop is not possible, surface water can be used as the source and taken through a system of heat exchangers similar to that described above. Filtration is the main issue with these systems, and can constitute a significant maintenance requirement. These systems are most suited to medium to large-scale projects.

Hybrid systems – loops in piles and open loop: A typical piling layout is not capable of meeting 100% of the building heating and cooling loads. The addition of open loop wells to cover peak periods is a potential solution. Working together the two systems can provide much larger heating and cooling loads for the building than the two systems in isolation. These systems are most suited to large new buildings with piles, located in built up areas.

Most open loop systems are used for larger GSP installations. This is because open loop system design is highly complex and systems all have bespoke design requirements that are dependent on the local conditions. If there is adequate ground or surface water supply and means of disposal, then an open loop system can be used very effectively. However, if there is no access to suitable ground or surface water resources, an open loop system cannot be installed.

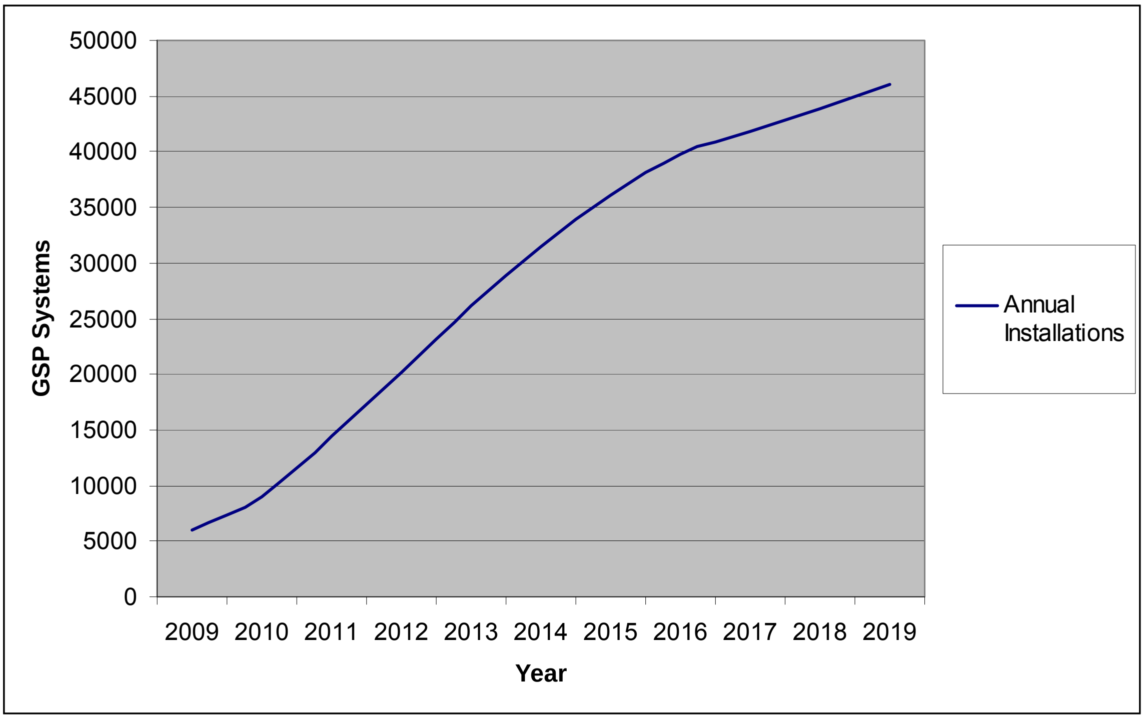
Appendix 5 Other GSP barriers

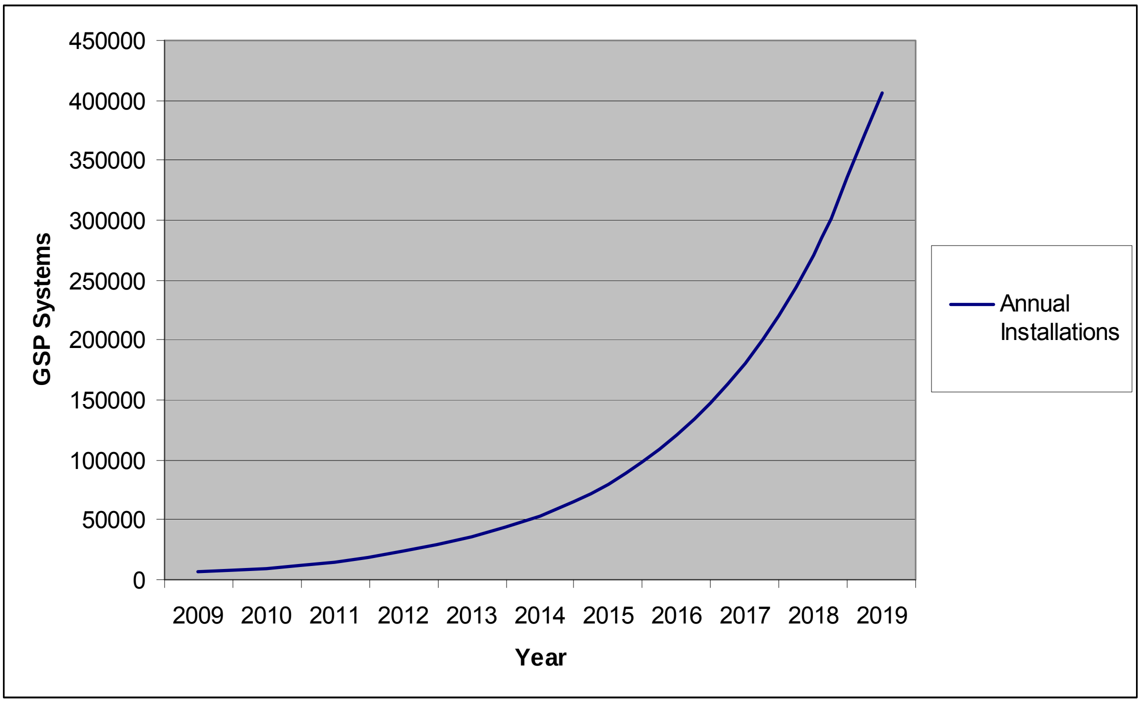
In addition to the eight principal barriers described in section 5, the following potential barriers have also been identified from the literature:

- **Highly variable UK geology:** This will add complexity to borehole installations, but is not considered a significant constraining factor.
- **UK 'Maritime' climate:** The UK has a more moderate 'maritime' climate than that found in Scandinavia and Central Europe. It has mild and moist conditions during winter, rather than the more severe low temperatures found in the latter two areas. The mild climate can be a hindrance to heat pump use in that at night/during the day it is acceptable to turn off the heating. This means that in the morning, or on return from work, the building must be heated quickly and a demand peak occurs; this fast response is far better suited to a boiler than heat pump. This situation is exacerbated where underfloor heating is used because of its higher thermal mass and slower response.
- **Legionnaires legislation:** In the UK, preventative measures against Legionnaires' disease require that stored hot water for commercial buildings be constantly above 60°C, even though it is not actually used at the tap at this temperature. (*Legionella* cannot survive in constant temperatures above this value). A heat pump can supply water at the temperature it is needed (up to 55°C), but to boost it to over 60°C would lower system efficiency, possibly requiring an immersion boost. Domestic systems only require the temperature to be above 60°C once a week.
- **State of the art in the technology:** The ability to achieve good efficiencies at higher distribution temperatures would open the door to easier retrofitting of heat pumps because existing standard high temperature radiator systems could then be modified.

Appendix 6 Annual installation graphs under the growth and high growth scenarios

The graphs below show the annual installation numbers for the growth (above) and high growth (below) scenarios.





Appendix 7 Growth scenarios: UK sense checks

This section compares the results of section 6.1 against other sources of data to check their robustness.

Comparison against other stakeholder opinions: How do the figures developed in section 6.1 compare with predictions made by other stakeholders in the industry? The following projections of the maximum potential for heat pumps were obtained by reviewing the literature and from information from industry stakeholders.

Projected installations by 2020.

Source	Projection
GSHPA	At least 200,000 systems installed per annum, with between 1 and 7 million systems installed by 2020, with 50% penetration in commercial buildings. From stakeholder consultation the GSHPA stated that "100,000's of units per annum is achievable, and we are preparing the supply chain to make installing these numbers possible."
Geothermal International	300,000 systems in total.
Reading University (Rayner Mayer)	1m systems in total.
BERR	If renewable heat accounts for 11% of overall heat demand, this could result in approximately 100,000 householders using heat pump technology.
DTI	'The potential for Micro-generation' (2005) suggests that 28,000 heat pumps will be installed by 2012.
BSRIA	15,600 GSPs installed by 2012.
Calorex	With the adoption of a renewable heat incentive subsidy over 850,000 heat pumps (all types) could be installed by 2020.
Bouma JWJ[17]	"In the UK an achievable sales target would be 15,000 heat pump systems per year", with GSHP systems accounting for a significant proportion of these systems.
Renewables Advisory Board (RAB)	Estimates for GSPs in 2020 range from 615,000 (bottom up) to 950,000 (top down).
EST	EST corporate strategy is to have 500,000 microgeneration technologies by 2014/15. Heat pumps are part of this mix, but EST does not want to "pick winners."

It is not possible to predict the exact number of GSP installations by 2020, as demonstrated by the range in estimates given above (from 100,000 to 7m installations). The estimates made in section 6.1, from 320,000 to 1.2m units, are in line with predictions made by other organisations. With the exception of the 7m figure proposed

[17] Achieving Domestic Kyoto Targets with Building Heat Pumps in the UK, 2002

by the GSHPA, the 1.2m installations forecast (from the high growth scenario) is at the high end of predictions.

Sense check outcome: valid

Comparison against total size of each market sector: Heat, in all its forms, is expected to account for 635 TWh of energy demand in 2020 (BERR, 2008). The table below outlines the sectors in which it is used.

Total thermal energy demand by market sector.

Sector	% Of Total Demand[18]	Heat Demand (TWh)	% Served by Gas[19]
Domestic	54	342.9	86%
Commercial/ Public	16	101.6	72.3%
Industrial	30	190.5	30%

Reviewing the figures produced for each sector in the analysis in 6.1, the proportion of this energy demand that would be accounted for by GSPs is a follows.

GSP contribution percentages to each market sector.

Sector	Growth Scenario (TWh)	High Growth Scenario (TWh)	% Of Total Sector Demand	% Of Non-Gas Sector Demand
Domestic	4	13	1.1% / 3.8%	8.3% / 27.1%
Commercial/ Public	11	40	10.8% / 39.4%	39% / >100%
Industrial Scale	6	24	3.1% / 12.6%	4.5% / 18%

Applying our assumptions regarding the average size of systems and the capacity factor to the energy demand per sector allows estimates to be made of how total heat demand equates to the figures generated in the growth and high growth scenarios. This is shown in the following table.

[18] Obtained from RES consultation (BERR 2008), the % breakdown is as of 2005, so this includes an assumption that the demand for heat in 2020 will have broadly the same split in each sector as 2005

GSP contribution units in each market sector.

Sector	Total Units	Units Served by GSPs 2020 'Growth' scenario (number)	Units Served by GSPs 2020 'High Growth' scenario (number)
Domestic	27,959,883	290,572	1,087,394
Commercial / Public	290,286	30,671	114,780
Industrial Scale[20]	47,625	1614	6041

In the domestic and industrial scale markets, the numbers of heat pump installations predicted by the growth and high growth scenarios are not 'impossible' i.e. above total demand figures. However, while the domestic market figures seem robust, the 'high growth' figures for commercial/public and industrial sectors are ambitious.

Sense check outcome: broadly valid

Comparison against total renewable heat: In the Government's RES consultation it is stated that 14.2% of total heat demand could be met by renewables in 2020. This equates to 90.17 TWh. The 'Barriers To Renewable Heat Part 1: Supply Side' report produced for BERR (Enviros, 2008) describes a scenario where renewables account for 14.1% of total heat demand and heat pumps (ground and air) account for 38% of this figure, at 29 TWh. The table below outlines how the growth projections made in section 6.1 correspond to these figures.

Renewable heat cross check.

Growth Scenario	% Of All Renewable Heat against RES figure	Comparison against Enviros Figure
Growth	23%	+ 6.5 TWh
High Growth	86%	+ 63.5 TWh

The figures produced from both the growth and high growth scenarios are within the total renewable energy production figures produced by BERR for 2020. Although, at 86%, the high growth scenario assumes a contribution from GSPs that would dwarf that of biomass, solar thermal and ASHP combined. For comparison, the BERR RES consultation (2008) suggests that all types of heat pumps could, together, account for 11 TWh of energy production per annum in 2020. The Enviros figure is below that proposed for energy contributed by GSPs under both the growth and high growth scenarios, significantly so in the latter case.

Sense check outcome: growth scenario valid, but high growth is highly ambitious

[19] AEA acquired industry knowledge
[20] Within growth forecasting this sector is assumed to include hospitals, although strictly public sector, and other large MW scale applications

Comparison against Housing Market: A significant proportion of all GSPs installed in 2020 will be in domestic properties. Annual domestic installation ranges from 41,500 to 365,000 according to the scenario. These can be sense checked by assessing the total potential size of the domestic new-build and retrofit market.

New build: New build properties are ideal for heat pump units and will form a large percentage of annual system installations. In this respect the heat pump market is strongly linked to new-build construction activity. The UK government has a target of 185,000 new homes constructed per annum. Since the turn of the century, construction has fluctuated around this figure, as outlined in the table below.

New home completions per annum.

Year	Homes completed in Great Britain[21]	Homes completed in England
2000/01	165,290	133,518
2001/02	161,854	129,992
2002/03	169,611	137,977
2003/04	175,914	143,958
2004/05	191,011	155,893
2005/06	196,307	163,398

However, the current economic climate has resulted in a turbulent time for the construction sector. Comparisons of current activity with historical figures should be treated with caution as the construction industry responds to near-paralysis of the housing market via a sharp slowdown in house building programmes.

The number of housing completions is likely to be well below the government's targets for house building over the next five years. The Centre for Economic and Business Research (CEBR) reports a sharp fall in house building, with fewer completions forecast for 2008, 2009 and 2010 - 141,000, 134,000 and 139,000 new-builds per annum, respectively. This may slow the growth of the GSP industry. The figures are well below projections made in the industry. For example "new-build houses in the UK number approximately 400,000 per year with 80,000 off the gas network (Hitchen R. The UK Heat Pump Market, 2004)." However, there is scope for the market to make a sustained recovery in the period from now until 2020.

Taking a 2008 build rate of approx 140,000 homes per annum and factoring in that the UK has a widespread mains gas distribution grid serving approximately 72% of UK housing and most urban areas, then approximately 39,000 homes per annum could be off the gas grid and prime candidates for GSP systems. However, the majority of house building programmes may be focused in urban areas that have existing gas network connections.

39,000 off-gas grid new build homes per year is compared to the growth scenario, which suggests that 41,500 pumps will be installed each year. This suggests it is eminently achievable. Comparing this figure, for off gas new-build properties, with the 41,500 figure from the growth scenario, indicates that this is eminently achievable. The 365,000 installations per annum from the high growth scenario would require a

[21] Figures obtained from Communities & Local Government (CLG)

significant additional contribution from both domestic properties on the gas network and the existing housing stock.

Existing homes: Obtaining data to assess the potential size of the retrofit market, i.e. the number of homes renovated per annum and rate of boiler replacement, is more problematic than assessing the number of new builds per annum. Estimates include:

- An annual refurbishment rate (major home renovation including a new heating system) of 1m units (Nordman, R., IEA Heat Pump Centre). Assuming that the gas network covers 72% of housing stock, 280,000 homes off the gas network will be refurbished per annum and may be suitable for heat pumps.
- An estimated 4.42 million houses in the UK are located off the gas network and 1.3 million of these utilise electric heating systems. If the heating systems in these 1.3 million houses require replacement every 20 years, this alone provides a potential heat pump market of 65,000 per year (DEFRA, 2004. Renewable Heat and Heat from Combined Heat and Power Plants: Study & Analysis).
- The UK government's Heat and Energy Saving Strategy (HESS) proposes that 7m homes will be targeted for an energy upgrade over the next 10 years. This equates to 700,000 per annum, 196,000 of which may be situated off the gas grid.

Geothermal International reported that "new build and sensible retrofit, such as gutting buildings, will characterise the commercial market, while for domestic installations there is a need to gain access to the retrofit market to keep growth increasing at current rates." Earth Energy added that further penetration of the retrofit market should be expected, currently "of the 1,500 social housing [GSP] installations at present about 1,200 would be retrofit." Rayner Mayer also advocated that "of heat pumps sold in 2020 the biggest market will be retrofit for social housing, in all retrofit could account for 75% of the market"

Adding the 2008 build rate figure to the HESS refurbishment pledge gives a potential market of 840,000 domestic installations per annum where GSP installations may be suitable. When compared to this number, the 365,000 figure from the high growth scenario seems plausible. RAB estimate that there are 1.5 million boiler replacements per annum; this is another example of the scale of the potential retrofit market for GSPs in the UK.

Sense check outcome: valid

Appendix 8 Growth scenarios: European market sense checks

More mature GSP markets found in other European Countries offer valuable insight into whether the assumptions made in the growth scenarios in 6.1 are acceptable. A high level review of market growth in Austria, Germany, Sweden and Switzerland was conducted and analysed against the following criteria.

% growth rates: “The long winter in 2005/6 in combination with further increases in energy prices and considerable media attention to climate change resulted in a 120% growth of sales in the heat pump market in Germany in 2006” (EHPA, 2008). This put a strain on production and drilling capacity, and the level of installations was consolidated the year after and growth slowed because of an unfavourable change to the VAT regime, introduced in Jan 2007. This suggests that the percentage levels of annual growth predicted for the UK in Section 6.1 (a maximum of 60% for the growth scenario and 65% for the high growth scenario) are achievable.

Germany the annual growth rates in the period 1996 – 2005 i.e. before the 120% jump, were as follows:

Historical GSP market growth rates in Germany (1997 - 2005).

Year	1997	1998	1999	2000	2001	2002	2003	2004	2005
GSP Growth Rate	30%	36%	8%	21%	30%	0%	5%	36%	37%

The growth scenarios explored in this report would mean that the UK needs to avoid periods of growth slowing and stagnation like those in Germany in 1999 and 2002-3. This issue is discussed below.

Ability to sustain year on year growth: From the first introduction of heat pumps in the late 1970s/early 1980s the market growth in Germany and Austria reached a peak and then declined. This can be attributed to a drop in the price of oil and a loss of consumer confidence. The latter was caused by an insufficient installer base, which led to poor quality installations and installation of heat pump units still undergoing development. In Austria the removal of subsidies in the mid 1980’s was also a factor in the decline in market growth.

These problems were rectified and both countries have seen steady growth since the early 1990’s. This has also been the case in Switzerland. Over the period 1997 - 2007 the Austrian and Swiss heat pump markets showed constant year on year growth. In 2007 the Swiss heat pump market held a 73% share of all new-build property heating systems. In Sweden the market grew continuously from 1997 until 2006, when there was a drop in sales. During stakeholder consultation it was reported “that in North America the market for commercial units is a good example [for the UK] since it keeps on doubling in size” (Rayner Mayer).

This demonstrates that year on year growth can be sustained over a prolonged period. This has been the case in the emerging period of the UK market (2000 – 2005) and will need to be continued through the growth phase, until 2020, to make a significant contribution to the UK’s fulfilment of its renewable energy and carbon reduction targets.

Years before market maturity: After first becoming popular in the early 1980s, heat pump units in Sweden have seen stable and sustainable growth. There was some stagnation from the mid eighties to early 1990's, when sales were stunted slightly by lower energy prices and some quality issues. A spike in sales during 1990 can be attributed to a VAT charge on heat pumps and energy, which was introduced in 1991.

Sweden is the most developed heat pump market in Europe and has reached maturity in the single family-housing sector. This market hit a peak in 2006, with annual installations of approximately 16,000. The installation rate dropped by 30% in 2007 and a further reduction was anticipated for 2008. There is still growth in larger scale unit sales. This represents a period of approximately 25 years before segments of the market reached maturity and this in a country with a population of less than 10 million. By comparison it would seem feasible that market growth in the UK, with a population in excess of 60 million, could be sustained from now until 2020.

One caveat to this example is that Sweden is the one European nation to have succeeded in fully unlocking the potential in the existing housing stock; more than 75% of all heat pumps sold are retrofitted into buildings. Sustaining the annual market growth rates of the high growth scenario will require significant penetration of the retrofit market in the UK.

Total installed numbers after long term market development: The UK market for heat pumps first exhibited serious growth from 2000. The market will effectively be 20 years old in 2020. Since the early 1990's the markets in Austria, Germany, Sweden and Switzerland have been experiencing steady growth. The approximate market size in 2007 for these countries was:

- Sweden: 300,000 units
- Germany: 100,000 units
- Switzerland: 50,000 units.

The size of the Swedish market suggests that achieving a high number of UK installations by 2020 is possible. These figures result from the high per capita number of installations found in Austria (pop: 8.2m approx) and Switzerland (pop: 7.5m approx). In Germany, with a population greater than the UK (pop: >80m) and a more mature GSP market, the total market in 2007 was smaller than that predicted for the UK in 2020, despite a prolonged period of market development. Therefore, for the UK to achieve the numbers predicted by either growth scenario, higher levels of annual growth will have to be achieved in the UK than in Germany.

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