



<b>Title</b>	Geothermal energy in small countries - laying the foundations for innovative development
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<b>Publication date</b>	2011-09-04
<b>Publication information</b>	Hemmingway, Phil, and Michael (Michael M.) Long. "Geothermal Energy in Small Countries - Laying the Foundations for Innovative Development." World Federation of Engineering Organizations, 2011.
<b>Conference details</b>	Fourth World Engineers Convention: Engineers Power the World – Facing the Global Energy Challenge, Geneva, Switzerland, 4-9 September 2011
<b>Publisher</b>	World Federation of Engineering Organizations
<b>Item record/more information</b>	<a href="http://hdl.handle.net/10197/3693">http://hdl.handle.net/10197/3693</a>

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## Geothermal Energy In Small Countries - Laying The Foundations For Innovative Development

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**Abstract:** Creation of an environment in which shallow geothermal energy can thrive will require a coherent approach and a high level of collaboration with professionals from countries that have developed technical expertise in the area. Implementation of regulations, standards and guidelines adapted from best practice in countries such as Switzerland, Germany and Sweden, in addition to understanding the mistakes and successes made by these countries, with respect to the development of their geothermal industries, will help small countries such as Ireland to develop a well-regulated market for the technology. This paper outlines and addresses some of the technical, regulatory and certification issues faced particularly by small countries in their efforts to develop a shallow geothermal energy industry, provides examples of best practice with regard to development in countries with established geothermal energy industries and presents proposed solutions to these issues / barriers using the existing situation in Ireland by way of example.

**Keywords:** Geothermal Energy; Ground Source Energy

### Introduction

Shallow geothermal energy (or ground source energy as it is more commonly referred to in Europe) is considered to be a mature form of renewable energy technology in countries such as Switzerland, Germany and Sweden. In contrast, the technology may be thought of as being in its infancy in many countries in Europe. In many cases this has led to a situation where implementation of a suitable technical, economic and regulatory framework to exploit this very promising renewable energy technology has proven and continues to prove difficult. Development of the industry from its existing early stages to a situation where it is cost-competitive with established renewable energy technologies will be particularly difficult for many small countries such as Ireland, where lack of the required technical expertise and complicated legislative and regulatory systems act as barriers to progress.

The barriers outlined above are compounded by the fact that Ireland has no established pedigree with regard to geothermal energy installations and as such consultants and contractors lack the required specialist engineering and technical ability to install these systems [1]. This has led to a scenario where some installations have encountered significant installation and post-installation issues or completely failed – resulting in a situation

where public confidence in the technology is low. Instances where specialist international consultants & contractors have been employed to carry out feasibility studies and installation of systems remain relatively rare due to the comparatively inexpensive option of installing conventional oil or gas systems and because technical experience relating alternative forms of renewable energy technologies (such as wind, solar & biomass) is relatively advanced in Ireland. High dependence on imported energy in many small or peripheral countries, increasing energy prices, price volatility and further research in the area applied to localised geological conditions should act as mechanisms to deliver increased confidence and competence in the industry in the coming years [2].

The previous two paragraphs briefly outline some of the primary reasons why shallow geothermal energy has not been extensively exploited in Ireland. However, proponents of ground source energy technologies must recognise the opportunity that this offers to develop the industry in a responsible and sustainable manner. We now have the opportunity to examine the precedent set by some of our European neighbours who continue to develop and refine environmental, technical, economic and regulatory mechanisms for the GSHP (ground source heat pump) industry in their respective countries. Formulation of a coherent strategy, which considers the requirements of the industry in the short, medium and long term, will require a comprehensive review of standards, policy documents and relevant literature published in other jurisdictions. In addition, viewpoints of professionals across a broad spectrum of professional disciplines (thermal energy experts, geologists, hydro-geologists, geotechnical engineers, mechanical engineers, academics, policy makers etc.) need to be sought and considered. The following sections of this paper outline and discuss some of the considerations which require deliberation and provide suggested solutions to some of the issues which require action in the short-term.

## **1. Ground heat ownership**

Definition of an allowable distance between neighbouring BHE (Borehole Heat Exchanger) systems will form an essential component of any future regulations / guidance documents for the GSHP industry in Ireland and must be given careful consideration. A clear definition of ‘who owns what’ with regard to sub-surface heat resources will establish confidence that the design and installation of a one-off system will not be later compromised by potential BHE systems on neighbouring sites.

A brief review of regulations in Germany and Sweden (two GSHP industry leading European countries) demonstrates significant definitional disparities between the specified minimum required distances between neighbouring systems. German regulations state that neighbouring systems must be separated by a minimum distance of 3 to 6 m while Swedish regulations state a minimum distance requirement can be as much as 20 m. This emphasises the necessity for Ireland to adopt a scientifically rigorous approach to development of ‘ground heat ownership’ regulations, ensuring that any minimum distance requirement is suited to Irish geological and climatic conditions.

## **2. Ground energy balance (Heat as a pollutant)**

Excessive heating or cooling of aestifers (an aestifer may be defined as a body of soil or rock bearing heat) leads to a reduction in system efficiency and can also instigate adverse environmental consequences. Larger GSHP systems with imbalanced ground heat loads have already led to a situation where warming of aestifers has been observed in several locations [3, 4]. Indeed Sowers et al [4] found that the thermal imbalance of the closed loop BHE system installed to provide heating and cooling of an academic building at Richard Stockton College in New Jersey in the United States led to a progressive thermal build up, which in turn led to changes of the microbial community in the aquifers surrounding the system. A cooling tower was subsequently added to the system in order to improve its thermal balance. These previous experiences have resulted in a situation where heat is increasingly being considered as a form of pollution by Environmental Agencies. It should be

considered good practice to design GSHP systems with due regard to ground energy balance, so that both system efficiencies and Environmental Authorities can be satisfied.

### 3. BHE post-installation quality control

Quality control of closed loop BHE systems should be completed by carrying out flow and pressure testing as a minimum. This is vital in order to ensure the integrity and longevity of installed piping and associated fittings (manifolds, elbows, u-bends etc.). Flow testing is also important to ensure that the installed system does not suffer from excessive hydraulic resistance at a pre-defined flow rate, thereby showing that flow has not been restricted in the pipe by for example partial collapse of the installed BHE. Results from the flow test can be compared against theoretical allowable maximum hydraulic resistance for the given piping diameter and type.

Pressure testing is normally carried out by pressurising the BHE to some multiple of the operating pressure. Pressure testing should be carried out at the following stages:

- a) Immediately after installation – this may be carried out and documented by the driller / installer to prove that the BHE system has been correctly installed;
- b) At suitable time intervals until connection of the system (if there is a long time period between drilling and commissioning);
- c) Immediately prior to commissioning – it is important to subject the entire system to a pressure test to ensure that all fittings and connecting pipe have been installed correctly.

### 4. Groundwater protection & BHE permitting

Development of documents regulating the installation of BHE systems must strike an appropriate balance between satisfying groundwater protection imperatives, while not excessively prohibiting installation of BHE systems in cases where developers propose appropriate groundwater protection mitigation measures.

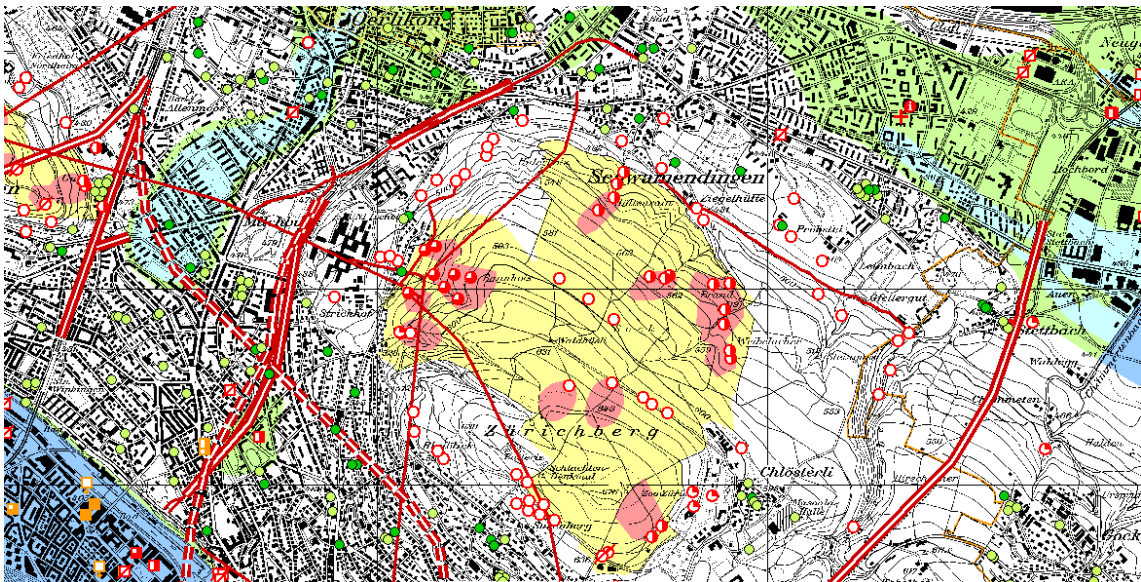


Figure 1 – Online Heat Use Atlas – BHE Map (Zurich Construction Authority - Office for Spatial Development. Website: <http://www.gis.zh.ch>)

Switzerland's Public Construction Authority Office for Spatial Development provide a good example of an interactive online tool (shown in figure 1) which categorizes land areas in Switzerland into one of six zones. Table 1 provides a high-level description of each zone designation in terms of general permission for geothermal borehole heat exchangers. The online tool further categorizes each designated zone to provide in-depth information on, and place specific conditions on i) thermo-active elements, ii) liquid operated systems, iii) air operated systems & iv) groundwater heat-recovery.

**Table 1 – Zone Designation**

<b>Designated Zone</b>	<b>Information / Condition</b>
A - Protected zones and protected areas	No geothermal BHE's permitted
B – Gravel aquifers suitable for drinking water	No geothermal BHE's permitted
C – Gravel aquifers unsuitable for drinking water	Geothermal BHE's normally permitted, subject to certain specific conditions
D – Gravel aquifers unsuitable for drinking water	Geothermal BHE's normally permitted, subject to certain specific conditions (note: different specific conditions to zone C)
E – Source water areas suitable for drinking water	Geothermal BHE's normally permitted, subject to specific conditions for aquifer protection
F – Area outside of useable groundwater resources	Geothermal BHE's normally permitted

## **5. Building heat load estimation**

Knowledge of the heating / cooling load of a building is necessary for the sizing and design of a ground source energy system. Many techniques for estimating loads have been developed and are routinely used by M&E and Building Services engineers. Informed estimates may be used in the early stages of pre-feasibility, however accurate and verifiable calculations should be carried out by an appropriately qualified professional at full feasibility and design stages. Load calculations can be influenced by many factors (e.g. insulation level of building envelope, air infiltration, system design temperatures, heating / cooling infrastructure, solar gains, ambient temperatures and many more) and as such, under no circumstances should a GSHP designer calculate the building loads to be used in the final design unless they are appropriately qualified to do so.

There are many different software packages available for the design of heat pump and ground loop systems and in many cases the format in which building energy loads must be entered into this software may vary (e.g. one may ask for monthly energy base loads, peak loads and peak hours in a certain format, which may differ from another software package). The GSHP system designer should therefore specify the format in which the building energy loads should be supplied by the appropriately trained M&E professional in order to ensure minimisation of any errors / misinterpretation of the data.

## **6. Open loop considerations in brief**

Open loop systems are the highest risk of all GSHP system types from a groundwater protection perspective [5]. Although this paper focuses primarily on factors relating to closed loop systems, many of the arguments presented can also be considered in the context of open loop systems. This point is well illustrated by a statement made by Ferguson & Woodbury [6], who state that developments of groundwater resources for thermal applications may be unsustainable (and even fail) for three basic reasons: firstly due to insufficient water supply, secondly due to significant increases / decreases in temperature at a production well due to injection of warm / cold water at a recharge well in an individual system and thirdly due to increases in temperature at the production well due to injection at neighbouring wells. This 'high-level statement' echoes the arguments made in other sections of this paper for the need to find a consensus on ownership of ground heat resources, whether or not developers should be required to balance net heat energy extraction / injection from season to season and the appropriate minimum distance between neighbouring systems.

Open loop systems must be both appropriately sized and spaced to take account of both thermal and hydraulic effects of the aquifer from which they are abstracting. Theoretical and physical analyses carried out by Ferguson and Woodbury [6] on a carbonate rock aquifer with several open loop systems installations have shown that a minimum spacing of approximately 500 m is required in order to isolate the hydraulic and thermal effects of one system from the other. Monitoring of the effects of several open loop systems in a number of countries [3, 7] has led the UK Environmental Agency to restrict use of groundwater by requesting the return of pumped water to the aquifer. In addition to restricting groundwater abstraction, the Environmental Agency in the UK recognises aquifer thermal interference as a potential pollutant and requires new open loop geothermal applicants to demonstrate that the thermal plume from any proposed system will not adversely affect other water abstraction licensees [3].

Analysis performed in Ireland by Hemmingway & Long [8] illustrates the importance of carrying out chemical analysis of groundwater for any proposed open loop system. They have shown that a large area of Cork City (the Republic of Ireland's second largest city) may not be suitable for open loop geothermal energy exploitation due to the high potential for scaling and corrosion of heat pumps associated with the chemical characteristics of the groundwater contained in the aquifer below parts of the City. Due regard should be given to carrying out the chemical analysis tests outlined by Hemmingway & Long [8] in addition to those now described in Annex A of the British Standard 'Heating systems in buildings – design of heat pump heating systems' [9] so that unexpected heat pump maintenance / replacement costs brought about by installation of the wrong technology in the wrong location, can be avoided.

## **7. Education / Certification**

Education of personnel involved in the design, drilling, installation & maintenance of geothermal systems, progressing eventually to a situation where only certified professionals are permitted to carry out these activities, is an important early step in the development of a geothermal energy industry. Appropriate education and training will help ensure that systems installed have been designed & installed by personnel with appropriate technical expertise. This will help minimise the number of instances where poorly designed systems are installed and therefore help improve the quality of design, drilling, installation & maintenance work in the industry and the associated perception of the industry.

## **8. Development incentives / grant aid**

Development incentives and grant aid such as subsidies or tax breaks are an extremely effective driving mechanism in the early stage development of any industry. They are required in order to develop domestic research expertise, develop technical competence and raise the profile of the technology in countries with underexploited resources. The Irish Government through the Sustainable Energy Authority of Ireland's Greener Homes Scheme have part-funded the installation of over 5,000 domestic ground source heat pump systems to date [8]. Implementation of a similar scheme aimed at medium to large-scale geothermal systems may prove beneficial in the coming years, however in order to achieve maximal benefits, the authors suggest that this financial assistance should only be provided following discussion and agreement on many of the topics raised in this document and in recent consultation exercises.

### **8.1 Other issues in brief**

Wind turbines and solar panels are considerably more recognisable and visible than GSHP systems and as such the general public in many countries tend to be unfamiliar with GSHP system benefits and constraints. This increases the importance of creating and distributing comprehensive, coherent public awareness & education documentation in the early stages of industry development.

### **8.2 Quality of materials**

The typical design life of a building can be in the range of 25 to 30 years (in reality the operational life of buildings can be much longer). Durability of materials used, particularly those items such as piping & pipe fittings which will remain in direct contact with the 'outside environment', is therefore an extremely important requirement. Consideration should be given to the specification of minimum quality standards for these components.

### **8.3 Heat pump efficiency**

The uptake of renewable energy technologies is driven to a large extent by the increasing costs of conventional energy generation. As heat pumps consume a certain quantity of electricity, it is prudent to introduce minimum efficiency requirements on heat pumps – particularly in the case where developers can avail of any subsidies for installing the technology. (Note: it is important to recognise that there may be differences between the coefficient of performance quoted by the manufacturer, which are generally based on idealised conditions, and the installed operational coefficient of performance of the system. Any potential 'minimum heat pump efficiency requirement' should be evaluated based on data taken from operational systems).

### **8.4 Borehole decommissioning**

Although the industry in the majority of European and indeed worldwide countries has not reached the point where decommissioning of systems has been required on any significant scale, it may be sensible to prepare some general guidelines for such a case so that, for example, in cases where heat transfer fluids other than water are used, they are removed from the BHE system prior to abandonment.

## **Conclusions**

Shallow geothermal energy is considered to be a mature form of renewable energy technology in several European countries. The technology is very much in its infancy Ireland, as is the case in many other European countries, relative to other forms of renewable energy technology. This 'early stage position' offers these countries the chance to develop a coherent set of policies, regulations and guidance documents based on critical

review of and improvement on the precedent set by counties with developed geothermal industries. This paper outlines and discusses some of the issues which should be addressed prior to any potential large-scale advance of the industry in Ireland.

## References

1. Goodman, R., et al., *Geothermal Energy Resource Map of Ireland*. 2004, *Sustainable Energy Ireland*. p. 101.
2. Hemmingway, P. and M. Long. *Energy Foundations - Potential for Ireland*. in *Geo-Frontiers*. 2011. Dallas, Texas, USA.
3. Boennec, O., *Shallow Ground Energy Systems*. *Energy*, 2008. 161(2): p. 57-61.
4. Sowers, L., K. York, and L. Stiles, *Impact of Thermal Buildup on Groundwater Chemistry and Aquifer Microbes*, in *10th International Conference on Thermal Storage - Ecostock 2006: Thermal Energy Storage Here and Now*. 2006: Stockton, USA.
5. Eugster, W.J. and B. Sanner. *Technological Status of Shallow Geothermal Energy in Europe*. in *European Geothermal Congress*. 2007. Unterhaching, Germany.
6. Ferguson, G. and A. Woodbury, *Observed thermal pollution and post-development simulations of low-temperature geothermal systems in Winnipeg, Canada*. *Hydrogeology Journal*, 2006. 14(7): p. 1206-1215.
7. Flores-Márquez, E., et al., *Study of geothermal water intrusion due to groundwater exploitation in the Puebla Valley aquifer system, Mexico*. *Hydrogeology Journal*, 2006. 14(7): p. 1216-1230.
8. Hemmingway, P. and M. Long, *Geothermal Energy: Settlement & Water Chemistry in Cork*. Accepted for Publication in *ICE Journal of Engineering Sustainability*, August 2010, 2011.
9. *British Standards Institution, Heating Systems in Buildings - Design of Heat Pump Heating Systems (BS EN 15450:2007)*. 2007, BSI: London.