Recent large scale ground-source heat pump installations in Ireland

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Abstract

This paper examines the effectiveness and suitability of Ground Source Heat Pump technology for the Irish climate. The success of the installations to date is evaluated in the areas of operation of overall system, environmental benefits and financial benefits accrued. Geothermal resources in Ireland are mainly low temperature. As a result of this, geothermal energy is used for heating and cooling of buildings as there is insufficient resources for electricity generation. Ground Source Heat Pumps are mainly used for heating, as there is little need for summer cooling. While there are over 500 domestic installations in the country it is only recently that large-scale projects have been introduced. Buildings in both urban and rural settings are looked at. Building types range from swimming pools to office buildings. The performance of ground source heat pumps in large-scale applications has been excellent. There are significant reductions in CO_2 emissions. Payback periods are 4-6 years despite installation costs being high. More installers and a reduction in heat pump costs could reduce installation costs.

Keywords: *Ground-source heat pumps, Ireland, case studies.*

1 Introduction

Thermal energy consumption in Ireland is 1.032 Mtoe (155.67 TWh) for domestic heating. For the tertiary sector it is 0.421 Mtoe (63.50 TWh) (Dubuisson 2002). Less than 1% of Irish households are heated using a heat pump. This contrasts sharply with Switzerland, one of the world leaders in heat pump technology, in which 67% of homes are equipped with a heat pump (Rybach and Sanner 2000). The reasons for such a low number of installations in Ireland is due to a) low public awareness of heat pump technology and its advantages over conventional heating systems, b) air conditioning, which drove the heat pump market, especially in the US, is not required in Ireland, c) a lack of hot springs, a feature which usually promotes the use of ground source heat pumps (GSHP) and d) few installers to promote and install heat pump systems.

There are between 500 to 600 domestic ground source heat pump installations in Ireland, typically in the range between 10 and 14 kW. Presently, there are approximately 17 large-scale commercial systems installed (Sikora 2002). The installed thermal capacity in Ireland is 6-7 MWt. This paper deals with these large-scale commercial installations that have an output larger than 12kW. This figure was chosen so direct comparisons with other countries could be made using the data compiled by Lund and Freeston (2000) in their assessment of global geothermal energy.

While the number of GSHP systems currently installed in Ireland is low, there appears to be a large potential for growth in the area due to the prevailing climatic and soil conditions. Ireland has a mild climate due to the proximity of Gulf Stream currents in the Atlantic Ocean. The average annual air temperature is 9°C. The lowest mean daily minimum temperature in winter is 2.5°C. The country has both a high

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rainfall rate, 800 to 2,800 mm per annum, and high relative humidity values are between 71% and 91% (Met Eireann 2002). These factors combine to ensure a large moisture content in the soil thereby increasing its thermal conductivity. Saturated soil has a thermal conductivity value up to four times greater than dry soil. The overall geological composition in Ireland, 40% of parent soil composition at depths of 1m and greater consists of either Sandstone or Limestone (Gardiner and Radford 1980). Sandstone has a thermal conductivity of between 1.28 W/mK and 5.10 W/mK. Limestone has thermal conductivity between 1.96 W/mK and 3.93 W/mK. Average ground temperatures at depths of 1m and greater are between 9^{o}C to 13^{o}C (Connor 1998). Horizontal collector ground loops may thus be used in Ireland, as the collector will not encounter external frost since diurnal damping depths are 0.2 m for sandstone, and 0.1 m for damp soil consisting of organic matter. This, together with the easy availability of land and the cheaper installation cost over conventional vertical borehole collectors, means that horizontal collectors are the most common form of collector type used.

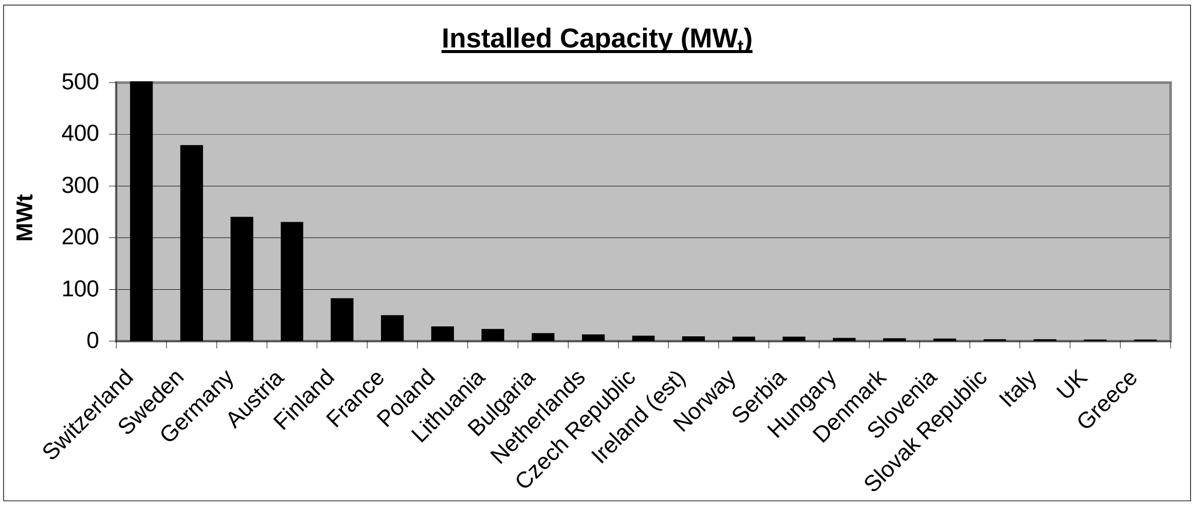

Figure 1: Installed Ground-source Heat Pump capacity in Europe. (Lund and Freeston 2000).

Installed ground-source heat pump capacity for Europe is shown in Figure 1. Total European installed capacity is 1,577 MW of which the estimated installed capacity for Ireland is 3.7 MW. The European annual growth rate is 15% (Rivoalen 2001). Geothermal heat pump installations in the US have total capacity of 1,356 MW, comparable to the whole of Europe and are expected to increase at a rate of 10% annually (Lund and Freeston 2000). The estimated Irish annual growth rate is 30%. The high Irish growth rate is due to the lack of maturity in the heat pump market.

2 Recent large scale GSHP installations in Ireland

The following is an analysis of installations that have been recently installed in Ireland. Most have been extremely successful and indicate that ground-source heat pumps are well suited to the Irish climate. The majority of these large scale installations have been in showcase buildings which feature a range of renewable energy technologies such as solar panels for hot water heating, sustainable building design and layout and natural ventilation. Table 1 gives a summary of these installations.

Table 1: Commercial GSHP installations in Ireland.

Building Location	Building Type	Installed	Collector Type	Collector Length (m)	Heat Pump (k W)	COP	Payback period (years)	Estimated % CO2 Emissions Reduction
Trinity College, Dublin (out of commission)	4 University buildings		Aquifer Boreholes (solar add-on)	4 x 12	6 Heat Pumps 450 kW	~ 4	1.5 - 4	60
Motor Tax Office, Tralee, Co. Kerry	Office	1999	Horizontal Closed Loop	5100	130 kW	3.7	4	52 (B. & E. M. 2001)
Share Hostel, Cork.	Residential	2002	Shallow Aquifer Borehole	20	100 kW	3.5		30
Mallow Swimming Pool, Co. Cork	Swimming Pool	1987	Geothermal Aquifer Borehole	75	100 kW	4	11.5	
Carbery GAA, Co. Kildare	Sports Hall	2003	Direct Expansion Horizontal	440	46 kW	6 (max)		
Dolmen Centre, Co. Donegal	Sports Complex	2000	Horizontal Closed Loop	1800	45 kW	~ 3		45
Marlton House, Wicklow Town	Residential with Swimming Pool		Horizontal Closed Loop	2800	40 kW	3.5	6 - 8	45
Sports Centre Churchfield, Cork	Sports Complex	1997	Horizontal & Vertical	600 Horiz 120 Vert	34 kW	2.37		
Camp Hill Community, Callan, Co. Kilkenny	Residential Care Facility	1996	Artesian Well & Tubing on Roof		30 kW	3.5	6 - 8	45
Spiddal, Co. Galway	Private dwelling &swimming pool	2001	Horizontal Closed Loop	1500	30 kW	3.5	6 - 8	45
An Seanscoill, Co. Galway	Old School House		Horizontal Closed Loop	1500	30 kW	3.5	6 - 8	45
Caheroye House, Athenry, Co. Galway	Country Hotel	2002	Horizontal Closed Loop	1500	30 kW	3.5	6 - 8	45
Navan, Co. Meath	Private dwelling & Offices	2000	Pipe in stream Closed Loop	1500	30 kW	3.5	6 - 8	45
Briar Hill	Large Private Dwelling			1500	30kW	3.5	6 - 8	
Landfill Site Office, Kinsale Road, Cork.	Office	2000	Horizontal Closed Loop	2400	28 kW	3.5	4.5 - 6	30
Pairc Gno an Daingan, Co.Kerry.	Technology Park Offices	2002	Horizontal Closed Loop	960	26 kW			
Green Building, Temple Bar, Dublin	Apartments / Office / Retail	1994	Vertical Borehole	150	23 kW	4.87	2.5	86 (Cooper 1995)
Heritage House Ballyhooley, Co.Cork	Residential Listed building	1995	Air & Horizontal in compost	1050	19 kW	3.3 – 3.6	6	45

Horizontal collectors are the preferred option as vertical boreholes are 4-5 times more expensive to install in Ireland than horizontal systems (O'Brien 2002). The horizontal collectors have all been installed at a depth of 1 m with the exception of the Churchfield installation, which was installed at 0.5 m depth. Ireland is not a densely populated country with only 52 persons per square kilometre thus accounting for the availability of land to install horizontal collectors. Typically ¾ inch diameter pipe is laid in parallel and manifolded together.

The borehole collector at Mallow Swimming pool uses the Mallow geothermal aquifer as its source. The water from this aquifer has an average recorded temperature of 19^{o}C. The borehole at Churchfield was installed to compare its performance with that of the horizontal collector. The horizontal loop proved to be more efficient. A vertical borehole was chosen for the Green Building in Temple Bar due to space restrictions. Some seepage from the bedrock also increases the heat pump COP. The decomposing waste at the Kinsale Road Landfill site is used as the heat source for the Administration building. The Share Hostel in Cork uses the Lee Valley aquifer, which, due to the heat island effect, has a water temperature of 12-13^{o}C. The collector installed in Navan was placed on a streambed and consists of stainless steel piping. Where possible, favourable geophysical features have been used for the collector, for example, the artesian well in Callan, Co. Kilkenny. In theory this should improve the system performance, however, the systems have not been monitored so the reduction in energy consumption has not been quantified.

The 5 heat pumps installed in Trinity College, Dublin range in size from 50 kW to 150 kW. The 30 kW systems are a standard size and the associated horizontal collectors are 1500 m in length. Tralee Motor Tax office is the largest installation serving a single building.Mallow Swimming pool payback period is significantly higher because the project was the first of its kind in the country and encountered much higher exploration costs to determine the heating potential of the aquifer. For the Green Building in Temple Bar, the payback period for the entire building is estimated to be 18 years. As ground source heat pumps are a much more commercially attractive solution than other forms of renewable energy, they have a significantly shorter payback period than the building as a whole. For the Tralee Motor Tax office, the payback period was good due to its use for both heating and cooling. This can be accounted for by the very low running costs for the GSHP system. For example, in February 2001, heating costs amounted to approximately 15 euros per week.

For the Tralee Motor Tax office, CO_2 emissions were reduced by 52% as compared with a BRESCU type-3 office building. For the entire Green Building in Temple Bar, the reduction was 86%. This reduction was enhanced by the inclusion of foliant species as well as other renewable energies. The heat pumps in Trinity reduced CO_2 emissions by 920,000 kgCO_2/kWh annually. In Churchfield, a natural gas fired boiler is running continuously so there is a neglible reduction in emissions. CO_2 emissions for the other buildings have been estimated based on heat pump annual energy consumption and using BRECSU CO_2 emissions indicators (BRECSU 2000). The 45% reduction is based on a comparison with an oil-fired boiler while the 30% reduction is based on comparison with Natural Gas where it is available.

Future projects include geothermal heating systems for Nursing home and health care projects with floor areas between 1200-1800m^2 in planning or progress. The Ballymun regeneration project in Dublin plans to install ground-source heat pumps in five houses to evaluate their practicality in high-density urban dwellings (Sikora 2002). Macroom Environmental Industrial Estate is a project initiated by Cork County Council. The pilot building will use an open loop water source heat pump to provide heating for the building. A 200kW system is under construction for University College Cork utilising boreholes in a gravel aquifer. Inniscarra Environmental offices will have a buried horizontal loop installation with a proposed total heat output of 42kW, due to start on site in Sept 2003.

3 Discussion

Running costs for GSHP systems in Ireland are significantly lower than other forms of heating. For example, a domestic oil boiler has running costs 66% greater than a ground-source heat pump. However, the high initial investment may be a deterrent to prospective users. Installation costs are 40% greater than oil or gas fired boilers, the most common forms of residential space heating, and 50% greater than electric storage heaters (O'Brien 2000). This is largely due to the lack of competition installing ground-source heat pump systems and the high cost of heat pump units. As the environmental and cost saving benefits of ground-source heat pumps becomes more widely known, this should encourage growth in the market and so reduce the initial installation costs. Organisations such as The Geothermal Association of Ireland, Sustainable Energy Ireland, and government funded Energy Offices at both national and local level are raising the profile of ground-source heat pumps in Ireland.

The increasing urbanisation of Ireland will require GSHP installations to become more compact. An alternative to borehole heat exchangers is to install the collector under or in building foundations. This technology has never been applied in Ireland although it has been developed extensively in Austria mainly using foundation piles containing HDPE piping with brine as the heat transfer fluid. Collector piping has also been installed in raft foundations and diaphragm walls (Brandl 1998). This technology has also been implemented in Canada for a 211 kW heat pump capacity system under an office building (Caneta 1999) and in the US for a 6-ton (21kW) sub-slab heat pump installation (Drown et al. 1992). A project is currently underway at Cork Institute of Technology to install a collector under the footprint of a building (O'Connell in prep.). The aim of this project is to demonstrate the technical and economic feasibility of locating collectors in the foundations of buildings in Ireland. This, it is hoped, will make the use of GSHP in the urban environment more widespread in Ireland.

Ireland exceeded the maximum permissible greenhouse gas emission target set by the Kyoto protocol at 13% over 1990 levels in 1999. To limit energy related CO_2 gas emissions, renewable energy may be used to reduce emissions of CO_2 by over 4.25 million tonnes, which is over 35% of Ireland's target (Kellett 2002). Ground-source heat pumps may contribute greatly to this reduction as they reduce CO_2 emissions by between 30% and 100% as compared with conventional heating systems (Dubuisson 2002).

4 Conclusions and recommendations

The majority of the projects detailed in this paper have received funding incentives from local, national or EU level. It is hoped that these buildings will demonstrate the commercial viability of ground source heat pumps to the wider public and so increase the take up of this technology. The potential for ground source heat pumps in Ireland is extensive. At present the percentage of heating requirements met by heat pumps is insignificant. The potential primary energy savings for residential and tertiary sectors is 2,426 TWh/year equivalent to 80,000 units as estimated by Sustainable Energy Ireland. These would reduce CO_2 emissions by 617000 tonnesCO_2/year and the primary energy requirement for heating would be cut by 5%. The extra investment required would be 602.6 million euros (Dubuisson 2002).

The barriers preventing this potential from being realised include: higher capital cost of GSHP systems; higher perceived risk; price distortions (external cost of fossil fuels, subsidies for infrastructures); unfavourable market characteristics; lack of installation experience; absence of quality standards and, finally, low level of awareness among the general public and decision makers in government and county councils.

To encourage greater use of GSHP systems, the following measures should be undertaken:

- Subsidies for installation of domestic heat pumps as well as the existing subsidies for developers.
- Certified installers.
- Standards for new building codes with regard to technical/economic considerations for heat-pump installation.
- Standards for use of heating and cooling systems in buildings with air conditioning.
- Restrictions on use of fossil fuel and direct electricity heating.
- Carbon fuel tax.
- Continual research and development of heat-pump systems specially designed for conditions in Ireland.

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