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Shallow gravel aquifers and the urban 'heat island' effect: a source of low enthalpy geothermal energy

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Abstract

Northern European countries with no high temperature geothermal resources can utilise the urban 'heat island' effect to generate low enthalpy geothermal energy for space heating/cooling systems in buildings, provided a suitable aquifer underlies the urban area. Buried valleys, formed at the height of the Pleistocene glaciation 15,000 years ago, when sea level was 130 m lower than present, and infilled with gravels as sea level rose again at the end of the Pleistocene, underlie many European cities. These high yielding aquifers exist at only a few metres depth, and can provide a supply of groundwater at temperatures elevated 3–4 K above the average rural groundwater temperatures. This can produce a marked improvement both in the output and in the efficiency of a geothermal system making use of this source. When passed through a heat pump operating at a Coefficient of Performance (COP) of 4.5:1, a well yielding 20 l/s of groundwater at 13 °C can generate 865 kW heat, sufficient to supply space heating for buildings with a footprint in excess of 12,000 m^2 with a peak heating intensity of 70 W/m^2. The economics of this low enthalpy geothermal energy source are outlined. Although development costs are minimal, at current low natural gas fuel prices in Ireland, heating-only applications will be less attractive, and a real cost saving will only accrue if dual heating/cooling functions can be developed.
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Keywords: 'Heat island' effect; Low enthalpy; Buried valleys; Gravel aquifers; Heat pumps; Ireland

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1. Introduction

Northern Europe, with the exception of Iceland, is impoverished in geothermal energy resources, mainly because it lies outside the sphere of recent Alpine tectonic activity and is distant from plate boundaries. In addition, old crystalline rocks with generally poor porosity underlie much of this part of Europe and relatively young sedimentary sequences are usually superficial, so deep permeable basins that might store groundwater at elevated temperatures are in general absent. Thus significant high temperature geothermal energy resources are unlikely to exist in northern Europe, bar rare exceptional circumstances.

Ireland falls into the above category, occupying a within-plate setting, far removed from recent tectonic activity, and possessing no high temperature geothermal resources. Although Tertiary volcanic activity in Northern Ireland gives rise to higher heat flow values and, thus, greater potential, the only recognised geothermal resources within the Irish Republic are 29 warm springs in the eastern and southern parts of the country, ranging in temperature from 13 to 22 °C (Aldwell, 1984), one of which has been utilised to heat a municipal swimming pool. The main geothermal energy development in Ireland is space heating based on ground sourced heat pump technology, mainly at a domestic level but also encompassing smaller public buildings (O'Connell and Cassidy, in press). One other source of geothermal energy currently being developed is a hydrogeothermal source utilising shallow groundwater in gravels beneath urban areas where the urban 'heat island' effect gives rise to slightly enhanced groundwater temperatures. This source, which also employs heat pump technology for space heating, has been successfully employed in a small number of projects in Dublin, and is currently being developed in Cork, where it probably has greater potential for exploitation.

2. The 'heat island' phenomenon

The 'heat island' phenomenon (Howard, 1833) is a function of urbanisation, which leads to microclimatic changes, principally increased air temperatures (Kratzer, 1956; Bornstein, 1968; Oke, 1973; Chandler, 1981), which, under favourable weather conditions, can be as much as 10 °C higher than those in the surrounding countryside. This heating effect is maximised in summer, when temperatures are already high, and more so at night than during the day (Jauregui et al., 1997) but the phenomenon is also significant in winter. The effect is a function of city size (Oke, 1973), magnifying as city size and population increase (Xie and Cao, 1996). Temperatures are unevenly distributed within large cities, being higher in the more built-up business districts than in suburban areas with parks and gardens. Not all cities experience the 'heat island' phenomenon. Its occurrence depends on a number of factors, including regional weather patterns, local topography, density of streets, buildings and other man-made structures, and the proportion of natural surfaces such as parks and gardens.

The 'heat island' effect is attributed to a combination of causes, including urban pollution 'domes', trapping of long wavelength radiation beneath the urban canopy, the high thermal absorption of concrete and tarmac surfaces, reduction in evaporation

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