



# Copt Hewick Ground Source Heat Pump Project Case Study 2007

The study and results of the installation of eight ground source heat pumps in social housing for older people at Copt Hewick near Ripon, North Yorkshire

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Working for you

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## Introduction

This report describes and explains the installation of eight ground source heat pumps by Harrogate Borough Council into its older persons' bungalows within the village of Copt Hewick near Ripon in North Yorkshire.

This is believed to be the first Local Authority owned homes in the United Kingdom to have ground source heat pumps installed, and as such the project was undertaken as a pilot scheme to test the technology and financial arrangements.

The Authority entered into a partnership with Ice Energy to supply the heat pump equipment and ancillaries, and Help Link as installers. The partnership arrangement enabled the financial model to be developed whilst technical learning points could also be discussed and solutions found.

The Authority's motivation for the pilot was threefold:

To trial the installation of ground source heat pumps as an alternative to electric storage and solid fuel space heating;

To test a financial model which enables whole life costings to be used;

To evaluate the affordable warmth potential of retrospective installations.



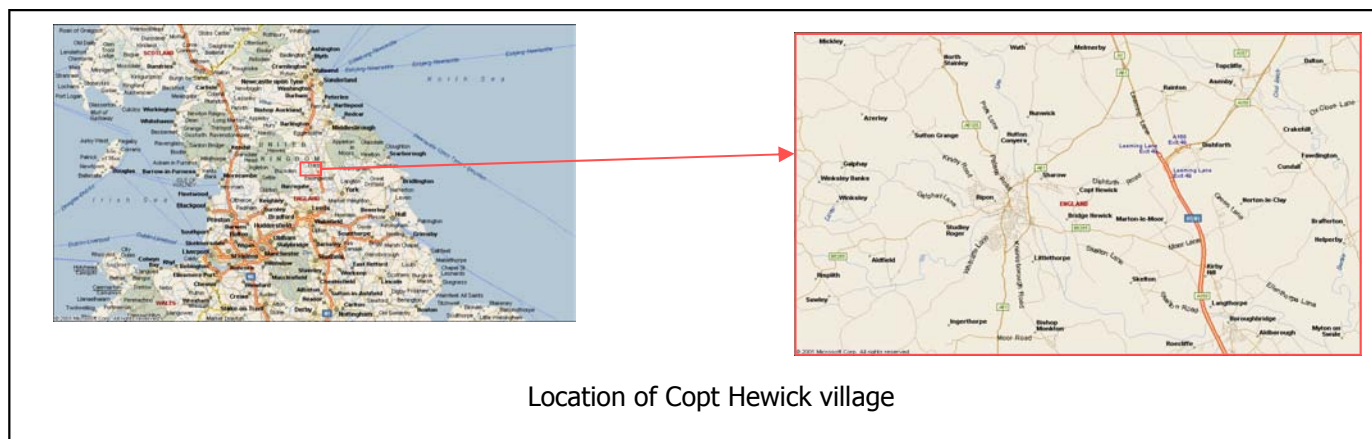
## Description of Dwellings

Copt Hewick is a small village lying at the heart of North Yorkshire in the North of England, 24 miles from Leeds, 21 miles from York, and 29 miles from Middlesbrough. Within the Local Authority Ward (Fountains) 12% of all pensioners live in Local Authority accommodation, compared to the national average of nearly 17%; this reflects the low levels of affordable housing across the District.

The dwellings are one and two bedroom bungalows built by the Local Authority during the 1970s. They are of cavity wall construction with pitched, tiled roofs and uPVC double glazed windows. The bungalows are built on a short cul-de-sac with shared outside spaces laid to garden.

Prior to the installation of heat pumps the dwellings received works to ensure that insulation levels were optimised. Cavity wall insulation had been installed as part of previous planned improvements, as had loft insulation, however additional loft insulation was laid to bring it in to match the prevailing grant availability.

The existing heating of the dwellings was a mix of electric storage heating and solid fuel central heating; these systems were due for replacement under standard cyclical improvement plans.



## Heating Refurbishment Options

The development of the ground source heat pump pilot was anchored in the Council's belief that its residents should not suffer from fuel poverty and should receive the highest quality of services. To this end the Authority reviewed its heating replacement options and identified ground source heat pumps as a viable proposal.

The dwellings are not serviced by the mains gas network and the option to bring this to the village carried excessive costs which could not be borne by the Authority. Consequently replacement of systems with mains gas fired boilers was not a practical option.

The use of LPG fuelled systems was rejected on the grounds of affordability for the residents, and on the requirement for fuel to be bought in bulk quantities rather than 'on-demand'.

The option for oil fired heating received consideration, however the Authority believed that the escalating costs of heating oil and the bulk nature of purchase were not conducive with the aim to provide affordable warmth. This was the existing alternative to storage and solid fuel heating.

In considering heat pumps, the Authority did not believe that adequate warmth could be provided through the use of air source units. Although the dwellings were insulated to current standards, it was the belief of the Council that the type of construction was not suitable for this technology. In addition the Authority wanted to make a provision for the installed system to provide heat and hot water, and this was not available at the time of specification.

Ground source heat pumps were considered and found to be an appropriate heating system for the dwellings whilst retaining the existing energy supplies to the development. There were also adequate grounds for the heat collection loops. There were concerns over the capital costs of this technology, however the Authority was willing to accept a funding model which took into consideration the life time costs of installation and maintenance in comparison to the alternatives.

## Description of the Selected Technology

Ground source heat pump heating systems are comprised of three key elements: the heat pump unit, the heat collection source element and the heat distribution element.

The heat pump itself works by exploiting the physical properties of an evaporating and condensing fluid. This fluid, in its gaseous state, is pressurised and circulated through the system by a compressor. On the discharge side of the compressor, the now hot and highly pressurised gas is cooled in a heat exchanger called a condenser until it condenses into a high pressure, moderate temperature liquid. The condensed fluid then passes through a pressure-lowering device called an expansion valve. This passes the low pressure fluid to another heat exchanger called the evaporator where the fluid evaporates into a gas. As the fluid evaporates into gas heat is liberated which is absorbed by a second heat exchanger. The low pressure gas then returns to the compressor and the cycle is repeated.

The heat collection source part of the system brings a constant supply of warmth to the heat pump. In a ground source heat pump this is comprised of a system of pipe work which is installed under ground. The pipe work can be a long, coiled pipe buried in a horizontal trench; a single loop of pipe within a vertical bore hole; or, as in the Copt Hewick installation, a series of pipe work panels within a horizontal trench. The ground temperature below approximately 2 metres depth is retained at a relatively constant level by solar energy heating the ground. This is the source of heat collected by the underground collector.

Once the heat has been transferred from the ground loop, by the heat pump, into a smaller volume of hotter fluid, it needs to be distributed around the building. This can be achieved through a 'traditional' wet radiator system or under floor heating pipes. Because the temperature of the water in the radiators is usually lower than in a



The layout of a ground source heat pump system

combustion heated system, the radiation surfaces (radiators or under floor matrix) must be larger. Heat pumps are an efficient form of heating because they use compression to generate heat; increasing the amount of heat produced requires an increase in pressure, and consequently more energy is needed to compress the fluid. Because of this the energy efficiency decreases with increasing temperature difference and so a ground-source heat pump, which has a very small temperature rise to achieve, is relatively efficient. This is why insulation is so important to the deployment of this technology.



Ground panels laid out prior to ground work commencing

The efficiency of a heat pump is measured as its 'Coefficient of Performance' (CoP) which is an expression of the amount of heat energy produced as a coefficient of the amount of electrical energy consumed to do so. So a CoP of 4 means that for every 1 kilo watt hour (kWh) of electrical energy consumed by the heating system, 4 kWh of heat energy is produced.

## Heat Pump Specification and Ground Loop Design

The ground source heat pump systems specified by Harrogate Borough Council for its pilot project were sourced from ICE Energy Ltd of Eynsham in Oxfordshire. The main component is a Bosch IVT Greenline heat pump manufactured in Sweden. Rated at 4kW consumption, these units utilise an in line immersion heater to ensure that stored hot water is pasteurised on a weekly basis, and to provide back up heating. This direct electrical element operates on on-peak electricity.

The ground loop installation consists of nine ICE Energy panels buried variously in vertical or horizontal orientation. The panels can be laid in either orientation as long as a minimum burial depth of 1m is maintained. In this installation the variation allowed the ground works to avoid disturbing tree roots which may have interfered in future years.

Heating radiators were installed in all of the dwellings, oversized by 30% compared to a combustion fired system.



Vertical ground panels installed

## Control Set-Up



In order to enable comparable monitoring to be carried out, and to optimise efficiency performance the systems were set up to operate constantly throughout 24 hours per day. The heat pumps 'fire'

<b>Energy Ratings for Pilot Dwelling Heating Types</b>				
<b>Heating Type</b>	<b>Existing SAP Rating</b>	<b>Predicted SAP Rating</b>	<b>Existing CO<sub>2</sub> Emissions</b>	<b>Predicted CO<sub>2</sub> Emissions</b>
<b>Coal Fired C/H</b>	48	68	5.8	1.7
<b>Electric Heating</b>	57	68	3.2	1.5

on demand from the room thermostats in conjunction with external temperature sensors; in this way the requirements for large heat demands being made on the pumps are minimised, and consequently more efficient operation is achieved. Tenants have been able to vary the room temperature settings through a standard thermostat; this has led to variety in the performance data. This variety is acceptable to the Authority as the installations are on occupied homes with varying demands, and not laboratory tests. Variations in room temperature settings have varied across the dwellings between 19°C and 23.5°C.



Connected ground panel in-situ

Should the external temperature rise to 18°C the control system switches to run the hot water system only, eliminating the heating circuit.

## Energy Rating Calculations

During the selection and design phase of the pilot the energy performance of the dwellings was assessed using the Government's Standard Assessment Procedure (SAP). This assessment includes estimates of the dwellings energy use and Carbon Dioxide (CO<sub>2</sub>) emissions. The dwellings were also modelled to predict their performance after installation. Examples of the results are given below.

From these examples it can be seen that predictions for 50% CO<sub>2</sub> reductions could be made for the eight dwellings as a whole.



Nine panels laid horizontally and ready for back filling

## Issues Identified and Their Resolutions

What went wrong and how they were put right



including connection breakage on panel

Residents were initially concerned that the hot water temperature of 55°C would be insufficient to fulfil their needs. Experience has proven to them that the systems operating temperature is adequate and that a degree of behavioural change is necessary when using hot water. To assist with residents' concerns regarding wasted water, pipe runs have been modified and shortened to reduce the hot water run off period.

The primary defect experienced following installation was leakage from the ground loop systems caused by ground settlement. Four of the eight ground loop systems suffered from failure of the connections between panels caused by differential settlement of the panels. The joint is a rigid element and several were cracked as one panel moved in relation to its neighbours. This defect

<b>Pilot Dwelling Sample Running Costs and Second Period Savings</b>			
<b>Annual cost predicted from 21 months consumption</b>	<b>Annual cost predicted from first 10 months consumption</b>	<b>Annual cost predicted from second 11 months consumption</b>	<b>% Reduced in second period</b>
£335	£461	£208	55%
£232	£283	£182	36%
£307	£370	£244	35%

was rectified by the replacement of the rigid construction with a loop of flexible pipe. With this configuration a degree of mobility is allowed to each panel and further joint fractures have been avoided.

Residents have, for the length of their occupation of the dwellings, lived with systems which provide sporadic heating, and the introduction of 24 hour warmth proved uncomfortable for some. The installation of thermostatic valves to bedroom radiators appears to have resolved this issue by giving control to the residents.

## **Performance Over 24 Months**

Of the eight dwellings taking part in the pilot, results from only three are reported in this document. Monitoring has required continual cooperation and this is a factor to be taken into account when data is analysed.

The calculations are based upon meter readings and data captured by the heat pump units themselves to give a consumption and 'model' cost for heating and hot water.

Taking the monitored data over twenty one months, an estimated average annual cost has been estimated and shows that the bungalows in the pilot have experienced running costs of between 64p and 92p per day. The variation in cost is accounted for by the size of the dwellings, with the two bedroom units costing more due to their size and higher number of residents.

These figures are averaged over a period of 21 months, however it can be seen in the raw data that residents have adapted their use of the heating systems over the second half of the monitoring

period and have experienced significantly reduced running costs.

It can be seen from these results that heat and hot water is being provided to meet the residents requirements for a daily cost of between 49p and 67p.

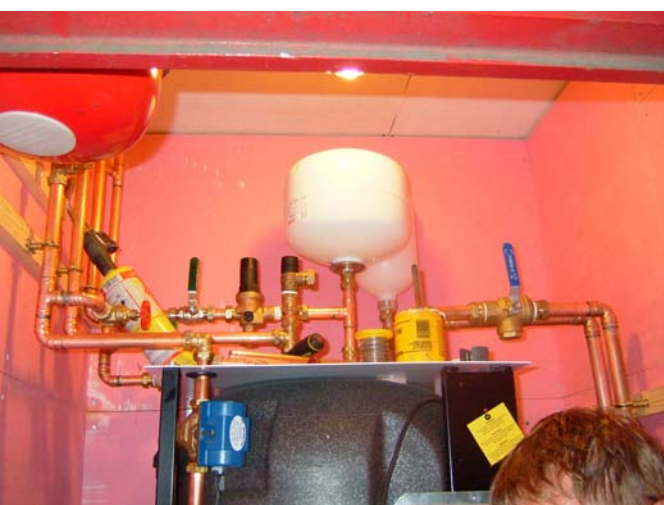
An additional calculation was carried out using available data from six of the eight dwellings to estimate the cost of heating and hot water were the residents to change to split rate such as Economy Seven.

Based on the evidence collected during the pilot period from the dwellings with two rate meters installed prior to the pilot it has been estimated that the electricity use will be split on a ratio of 2:1 between the tariff rates. This leads to estimates for the one bedroom units' heating and hot water costs to range between £133 and £186 per year whilst the two bedroom units are estimated with annual running costs of between £166 and £259.

## Affordable Warmth

An important factor of the pilot was to establish the Affordable Warmth potential of the technology within existing Council owned dwellings, and to this end a series of calculations were undertaken. Having established that two rate metering could reduce overall energy costs, a comparison of estimated costs to the minimum, benefit level income for single and twin occupation was carried out on this basis. Affordable Warmth requires that a household does not need to spend more than 10% of its income on keeping adequately warm. Using an absolute minimum pension income level of £82 per week per occupant suggests that costs need to be maintained below £ 8.20 per week. In the pilot calculations the weekly running costs ranged between £2.56 and £4.99; again there is variation between dwelling size and occupation levels.

Compared to the minimum pension level income for the occupation levels in the pilot, it can be seen that heating and hot water costs do not approach the levels which would breach the Affordable Warmth threshold. This is calculated to be the case even where a larger dwelling is occupied by a single resident with the associated lower minimum income. The income levels do not reflect the



Installed plumbing sits above the heat pump unit

actual incomes of the residents and most will receive a higher weekly income, further reducing the relative burden of comfortably heating their homes. However, using the minimum income levels it is estimated that the residents of dwellings similar to those in the pilot would be required to spend between 1.95% and 4.18% of their minimum level of income on heat and hot water. In understanding the meaning of these calculations it is important to recognise that different residents have maintained their dwellings at different temperatures, and live a variety of lifestyles with some being particularly active whilst others are much less mobile.



<b>Heating Costs Compared to Theoretical Minimum Incomes</b>				
<b>Pilot Dwelling Reference Number</b>	<b>Weekly Heat &amp; Hot Water Cost (£)</b>	<b>Weekly Minimum Income to Achieve Affordable Warmth (£)</b>	<b>Minimum Weekly Pension Income (£)</b>	<b>% of Income Required for Heat and Hot Water Costs</b>
A2	4.99	49.93	164	3.04%
B2	3.92	39.18	164	2.39%
A1	3.59	35.93	82	4.38%
C2	3.20	32.01	164	1.95%
D2	4.04	40.44	164	2.47%
B1	2.56	25.62	82	3.12%
D1	3.43	34.29	82	4.18%

All income figures are based on minimum pension levels and do not pertain to actual residents in the pilot

This will significantly affect the heating demands placed on the pilot systems, however in the worst case scenario of the calculations, a single occupier paying for the highest heat demand will be required to spend only 6.1% of his/her minimum pension income to do so. If a two rate tariff is not applied, then the highest annual heat and hot water cost is estimated to be £461, based on the highest actual consumption during the initial eleven months of the pilot, prior to the residents voluntarily reducing their heating demands. In this case, a single resident would be required to spend 10.81% of his/her income on providing adequate heat (using the actual room thermostat setting of 23°C).

## Summary

During 2005 Harrogate Borough Council's pilot project installed eight ground source heat pumps into existing older persons' bungalows and monitored their energy consumption over a twenty one month period. Residents were encouraged to adopt a 24 hour heating pattern to provide the optimum heat pump operating conditions, and were able to set the room temperature to meet their own



Pressure testing the ground loops

aspirations for comfort. Over the monitoring period residents reduced the room thermostat temperature settings to prevent overheating and requested that thermostatic radiator valves be installed in bedrooms to provide a more comfortable sleeping environment.

During the pilot period a number of installations suffered installation defects arising from ground settlement which were remedied using a modified ground panel coupling which allows for independent movement of panels within the filled trench.

Residents have monitored consumption with assistance from Authority officers, however full records



New radiator installed and working

have not been available. Using available data a model of heating costs was established, and a comparison made to the adoption of two rate metering such as Economy Seven which suggested that using the 24 hour heating regime benefits could be gained. Further calculations to compare the possible running costs with an index for Affordable Warmth showed that the pilot dwellings could be heated to meet the varying demands of residents well within 10% of the minimum pension level income of a single occupier. It was also calculated that without the use of two rate metering a single occupant could expect to meet the highest heating

demand in the pilot dwellings for 7.7% of his/her minimum pension level income.

## Conclusions

The conclusions of this report are as follows, based upon the evidence presented by Harrogate Borough Council and the pilot partners:

The pilot has shown that articulated jointing of rigid structures forming part of the ground loop must be employed to prevent the incidence of settlement fractures and the associated issues of performance loss and rectification.

It has also been shown that the employment of a 24 hour heating regime can provide suitable conditions for older people's accommodation without compromising affordability, and that the technology can be appropriately deployed into existing housing stock.

Residents have also demonstrated that the adoption of heat pump technologies and the associated changes to heating regimes can be accommodated by first generation users. The continued success of the pilot may depend upon the successful adoption by subsequent occupiers of the dwellings who have not participated in the development and installation of the project.

The key conclusion from the pilot is that older residents can live in existing homes fitted with ground source heat pumps and receive appropriate levels of heating to meet their requirements without compromising their financial well being, and within the defined boundaries of Affordable Warmth.



Post installation ground reinstatement completed and returned to lawn

## Contact Details

For further information relating to this project please use the following contact details:

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Installers and residents

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