



Investigations on the integration and acceptability of GSHP in the UK dwellings



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ABSTRACT

Heating and cooling in residential buildings is becoming significantly important and constitutes large proportion of total energy consumption. In order to create green and sustainable buildings it becomes imperative to use low carbon, efficient and renewable energy technologies to reduce and deliver the heating and cooling demand. Ground source heat pump (GSHP) uses the ground or ground water as heat source-sink. However, integrating the technology at end user and its acceptability significantly affects its performance. Present study examines the integration and acceptability of GSHP in the UK dwellings. Many factors at end user side e.g. awareness, cost, economics, comfort, supplier's quality, etc. are considered in the present research. These factors deemed to be responsible of GSHP penetration into the UK renewable energy sector for dwellings. GSHP from single suppliers are installed in 62 houses spread across Coventry, situated in the West Midlands, UK. During the course of installation and operation data are collected in the form of questionnaire survey to establish factors around integration, user awareness and ability to adopt and training for end user and how it affected the performance of GSHP. Also in the whole process of operation end users perception regarding energy bills, comfort and ease of operation is also taken into account. According to the data analysis occupancy, end users' awareness and understanding of GSHP, additional heating and technical support have been found very significant factors affecting energy saving and performance of installed GSHP.

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1. Introduction

In current scenario if national and local governments are serious to address greenhouse gas mitigation, buildings must be given high importance. In the UK buildings create 40% of UK total carbon emissions and residential buildings share is roughly half [1,2]. UK government aims to reduce the greenhouse gas emission by at least 80% (from the 1990 baseline) by 2050 [3]. This reduction target is only achievable by shifting to more energy efficient and low carbon economy. This will not only help the UK in becoming less reliant on fossil fuel import but will also control exposure to increasing energy prices in future. In order to make sure that the UK government policies contribute effectively to greenhouse gas mitigation a detailed plan is set up by the government which encompasses strategies, for investing in low carbon technologies [4]. Green Deal [4] is one of the milestones taken by government to promote use of low carbon technologies e.g. ground source heat pump (GSHP) by

providing subsidies and feed in tariff for renewable energy generated. These GSHP have been recognised to provide viable, environment-friendly alternatives to conventional unitary systems and can make significant contributions in reducing the electrical energy usage and CO₂ emissions. There are four basic types of ground loop systems used in GSHP, which are horizontal loop, vertical loop, pond/lake loop and open loop respectively [5]. For the horizontal-loop systems, the piping is buried horizontally in trenches. This can reduce the installation cost of the ground heat exchanger, since trenching cost is generally lower than drilling cost. However they require more landing and more piping [6]. For pond/lake loop and open loop water reservoir is required to exploit the stored energy. For dwellings where limited space is available vertical borehole is most suitable option [6] as it requires less total pipe length and less ground area than other closed loop systems; seasonal soil temperature swings are not a concern; need the least pumping energy and have high efficiency.

Several studies have been reported in recent years on technical performance [7–15]; cost assessment [16]; installation [17,18]; applications [13,15,19]; experimental study [20,21] and barriers for the GSHP market [22–25]. However research articles on real life

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installation and user interaction with the installed technology is still under highlighted. Performance of GSHP can vary significantly depending on user interaction and operation behaviour. Karytsas and Theodoropoulou, 2014 [25] presented detail study on how public awareness and willingness to adopt with GSHP technology. Study claimed that use of GSHP technology is positively related to the user's interest with environment, technology and awareness towards renewable energy services. However there are many factors which might affect the uptake of heat pump technology in domestic sector. Recent study [26] investigated despite the excellent performance of heat pumps; technology is still not primary choice of the general UK dwellings end user. It is because of several influencing factors e.g. technological issues, installation constraints, effect of climate, laws, policies and grants, infrastructure and lack of UK specific data played a vital role in penetration of renewable energy in the UK domestic sector. It can be concluded from the study that consumers' confidence can only be built if the GSHP market have enough local data available to full proof the concept of technology and can be helped by existing infrastructure [26]. The current UK market for ground source heating and cooling is still small, but growing rapidly. The GSHP technology has the potential to increase energy efficiency whilst simultaneously reducing CO₂ emissions, decreasing demand on the utility's services networks and assisting to meet the UK government targets [27]. However any real life trials study on post installation of GSHP emphasising on energy saving potential and user interaction with technology is not reported yet. Present research article investigated the real life data on GSHP performance, economics, user's acceptance and comfort. The system performance and economics of operation might impact significantly as per GSHP is operated by different householders with different knowledge, understanding and awareness of technology. Present study will also explore that the claimed performance of GSHP from manufacturer is quite different for various users and up to a lot extent depends on the end users capability to deal with technology. Detailed survey is being conducted to collect important data required for the study.

2. Decision making factors for GSHP choice

There are many factors encompassing legislative, socio economic, installation, operation and running cost of the GSHP [25] which are decisive in decision making. In the present research Orbit Housing Group dwellings are improved using government scheme so installation cost and sourcing suppliers at the beginning do not play major role in decision making for the choice of GSHP installation. However how and why the end consumer is operating the GHSP depends on their own choice as they are responsible to pay the utility bills. This also depends on their awareness and training provided for operating the GSHP. Karytsas and Theodoropoulou, 2014 [25] summarised major influential factors which dominates the consumer behaviours and their preferences while selecting renewable energy based heating/cooling systems. It is being claimed that economic aspects, environmental considerations/energy saving potential, energy security, comfort and aesthetics attitude of end user, knowledge and social awareness and availability of reliable suppliers/services are major factors where consumer's choice is influenced. Some major factors for the present study have been identified as given in Table 1.

Aforesaid seven factors (Table 1) play a dominating role in dissemination of renewable energy technology among end user. While cost is one of the major issue but social issues are nonetheless less important. Researchers also claimed that user's experience also plays a very vital role while selecting and running the system. End use is more comfortable to make informed choice based on feedback from friends/relative or a trust worthy supplier.

Technological bliss may be good selling point though ease of use and operation with convenience seems more important for end user and they are not willing to buy the system with high challenge to operate and understand the technique, even sometime because of their personal feelings.

Based on these findings from literature review questionnaire and research structures for the GSHP adaptation and its applicability among dwelling users are designed. It is interesting to see the varying performances of the same GSHP system while used by various users and the intervention taken by them (informed or self-experience).

3. Materials and method

In the selected retrofit project of 62 dwellings Calorex WW6500 ground source heat pump 6.5 Kw using vertical borehole is installed on average property size of 60 m². A typical installation is shown in Fig. 1. The occupants are provided training for operating GSHP e.g. how to set heating times, temperature thresholds, etc. As GSHP technology works differently than conventional heating used in the dwellings and user need to keep it on for all the time if they need to acquire a set temperature. However, various occupants behaved in different ways. Their interaction with installed GSHP technology is studied by questionnaire and logging their feedback for the GSHP installations.

3.1. Questionnaire survey design and data collection

Questionnaire is designed as per GSHP user's satisfaction and their expectations from the GSHP installations. How the system is used has an important effect on the performance of GSHP. Therefore, a questionnaire sheets have been sent to total 62 householders who have installed GSHP systems.

Four main objectives kept in mind while creating questionnaire:

(i) How users' operation impact the energy consumption

The study of EST (Energy Saving Trust 2012) [40] suggests that users' operation will impact the GSHP performance significantly and GSHP may need to be on constantly to provide heat efficiently. So questions, including 'do you start the system with higher temperature than needed?', 'Do you heat the whole property or just heat occupied rooms?', 'Do you run the system constantly/short period during the day/night?' and 'Do you change the heating times depend on season/weather?' were asked.

The study of Paul J [46] suggests that the coefficient of performance (COP) of heat pump is a function of the entering water temperature which is influenced by the setting temperature of the system. So, 'What temperature do you set for your GSHP?' is an essential question.

According to the communication with tenants from Orbit Heart of England, some tenants may use extra heating devices supplementing the GSHP. Using extra device will definitely increase the electricity consumption, since they are not as efficiency as GSHP. Therefore, questions 'Do you use separate heating device in any room in addition to GSHP?' and 'How regularly do you use an immersion heater for your hot water?' were added to the questionnaire.

(ii) Whether users are satisfied with the GSHP performance and customer service

International Ground Source Heat Pump Association [47] gives some 'Frequently Asked Questions' on GSHP, in which, questions such as 'How noisy is the GSHP unit?', 'What about comfort that

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