Renewable Energy 96 (2016) 843–849

Contents lists available at ScienceDirect

Renewable Energy

journal homepage: www.elsevier.com/locate/renene

# Heat recovery from air in underground transport tunnels

Konstantinos Ninikas [a, *], Nicholas Hytiris [a], Rohinton Emmanuel [a], Bjorn Aaen [a], Paul L. Younger [b]

[a] School of Engineering and Built Environment, Glasgow Caledonian University, Glasgow G4 0BA, UK
[b] School of Engineering, University of Glasgow, Glasgow G12 8QQ, UK

ARTICLE INFO

Article history:
Received 7 September 2015
Received in revised form
4 April 2016
Accepted 4 May 2016

Keywords:
Heat recovery
Thermal comfort
Air source heat pump

ABSTRACT

The performance of a typical air source heat pump could be increased dramatically by a relatively stable air temperature with a high humidity, even during the peak heating months. In this short communication we show such conditions exist in the underground transport tunnels of the Glasgow Subway system, where we had conducted an annual survey of air flow, air temperature and relative humidity at thirty different points within the subway network. We found relatively stable temperatures and sufficient air movement inside the twin tunnels (average temperature during winter = 15 °C, annual variation = 2.6 °C; average air flow = 16.47 $m^3$/h) indicating higher system efficiency compared to a conventional air source heat pump installation. Potential energy and carbon savings are discussed.


## 1. Introduction

The need to find alternative energy sources to replace fossil fuel is now being more important than ever. This is recognised in the UK government legislative obligation of reducing the $CO_2$ emissions by 80% of the 1990's levels by 2050 [1].

The Scottish Government has set a target for the equivalent of 100% of Scotland's electricity demand to be supplied from renewable sources by 2020 [1]. This is complemented by an equally stringent target for an increase in renewable heat generation, as well as an increase in community and local ownership of renewable energy schemes [2]. Air source heat pump (ASHP) systems have shown potential to reduce energy consumption and as a result $CO_2$ reduction of more than 50% compared with conventional heating systems (electricity, oil, gas) can be achieved [3].

This paper reports a year-long study carried out since June 2014 in the Glasgow Subway system to investigate the possibility of using the air that circulates inside the tunnels for space heating through an ASHP. This could be useful to cut down both energy use and carbon emission since the Subway stations are currently heated with electric radiators where the energy cost and the CO2 emissions are high.

## 2. Methodology

The Glasgow Subway tunnel system forms a circle in the centre-west of the city. The entire passenger railway is underground, contained in twin tunnels, allowing clockwise circulation on the "outer" circle and anticlockwise on the "inner". Fifteen stations are distributed along the route length of just over 10 km. The river Clyde dissects the circular route, with eight stations in the North and seven in the South as shown in Fig. 1.

### 2.1. Proposed heating system

The proposed heating system is a conventional air source heat pump (ASHP) but unlike in a standard installation, utilises the air from within the built confines of the subway platform (as opposed to the outside air) as shown in Figs. 2 and 3. In a conventional set-up the external heat exchange coil recovers heat from outside air; however, under colder conditions (such as those prevailing in Glasgow) the efficiency of the ASHP is likely to be low. In the case of our installation, it was hypothesised that a higher efficiency could be achieved, given the relatively warmer conditions inside the subway tunnels and platform. In order for this to work at high efficiency, two conditions need to be present: relatively stable and warm air temperatures and sufficient air movement to ensure continuous operability. Given the enclosed nature of the platform/tunnel area it was surmised air temperatures will be relatively warm and stable. In terms of air movement, although no forced air

* Corresponding author.
E-mail address: kninik200@caledonian.ac.uk (K. Ninikas).

http://dx.doi.org/10.1016/j.renene.2016.05.015
0960-1481/

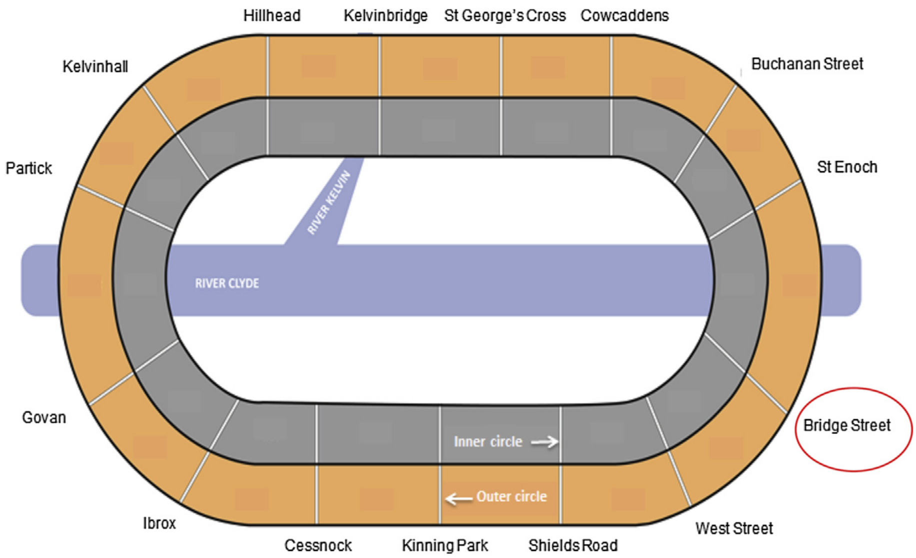


**Fig. 1.** A typical Glasgow Subway map. Note: Case study station highlighted with a red circle.

**Fig. 2.** A typical Glasgow Subway's platform.

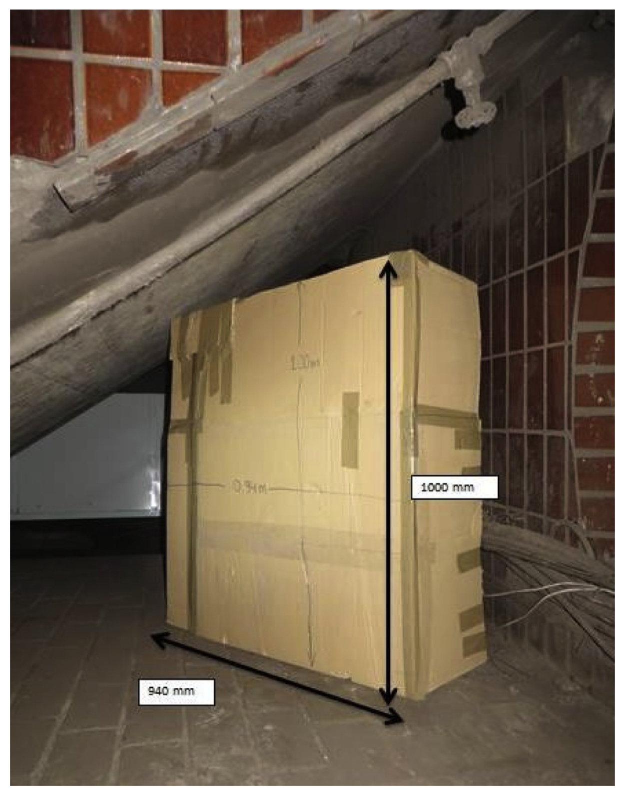


**Fig. 3.** A mock-up of the proposed heat pump condenser below the platform's stairs.

ventilation system exists in any station, the air is constantly in motion and at relatively high speeds due to the movement of trains as well as from the natural air movement between the platform and the surrounding atmosphere in the concourse level.

In order to test this hypothesis we undertook two sets of measurements: air temperature and humidity on the platforms and tunnels and, air flow within the platform/tunnel areas. A twelve-month series of measurements of air temperature and relative humidity in the platforms as well as the tunnels, were undertaken since 1st June 2014 to explore the seasonal variations of the air temperature (Tiny Tag, TGP4020, range = −40° to +125 °C, accuracy = ±0.35 °C in the 0–60 °C range) and humidity (ELMA, DT 171, range: 0–100 RH, accuracy: ± 3% RH). Background weather conditions (temperature, humidity, atmospheric pressure and rainfall) were simultaneously monitored at a city centre location (Glasgow Caledonian University's meteorological station). In total, the underground temperature and humidity has been monitored in 30 different places inside the Subway system (fifteen locations on the platforms and fifteen spots inside the tunnels between two consecutive stations) as shown in Fig. 4.

Between the two tunnels and at approximately every 25 m there are cross-passages which allow the air movement from one tunnel to the other. For this reason half of the tunnel measurements have been conducted on the "inner circle" and the other half on the "outer circle". The readings were taken approximately in the middle of each tunnel section.

In addition to the above, an air velocity meter was also used during October 2014 to measure the volume of air that circulates inside the tunnels and the Station platforms. This portable air