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Predicting the solar energy and space-heating energy performance for solid-wall detached house retrofitted with the composite edge-sealed triple vacuum glazing

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Abstract

Triple-Vacuum-Glazing is regarded as evolutionary step in minimising the space-heating loss. This paper takes a comparative analysis approach to envisage space-heating supply required for achieving thermal-comfort temperatures and attainable solar energy gains to households with retrofit of composite edge-sealed triple-vacuum-glazing. Predictions of varying window-to-wall ratios on space-heating energy and solar energy gains for winter months are analysed. The notable winter and annual space-heating energy savings of 14.58% and 15.31%, respectively, were obtained with solid-wall detached-house retrofitted with triple-vacuum-glazed windows compared to single-glazed-windows. The heat-loss calculations show a prominent reduction from 12.92% to 2.69% when replacing single-glazed windows to triple-vacuum-glazed windows.

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1. Introduction

A global challenge of increasing CO_2 emissions, are by now reached at an alarming rate causing fluctuating impacts on temperature and sea levels, are generally acceptable [1-2]. The UK has agreement in minimising CO_2 emissions from 1990 levels to 80% by 2050 [3]. Also there is a serious challenge particularly in the energy field of balancing the gap (a risk to security-of-supply) between peak-demand and generating capacity. This could fall to as little as 5% with a confidence de-rated margin of 0-4% in Winter 2016/17 and 3-7% in Winter 2017/18. This imposes a risk of not having enough generating capacity to meet the peak-demand as according to the OFGEM report on National Grid's Future Energy Scenarios (FES) [4]. In order to reduce such security-of-supply risk, the UK domestic housing stock is a particular focus by reason of its considerable space-heating energy consumption than in any other sector. It accounted approximately 66% of total natural-gas consumption in around 27 million houses in the UK in 2012 [5]. Over eight millions of UK solid-wall houses are so far anticipated to be hard-to-heat [6-7]. In spite of having a number of housing stock insulation methods [8] and improved heating systems as retrofitting measures which are being taken [9], there is still a scope of minimising space-heating energy that brings a need of interposition of progressive technologies, here in particular a focus is, such as triple vacuum glazing that should be consumer-acceptable. It's one thing having a triple vacuum glazing technology, in which the achievable thermal transmittance of the central glazing area is less than 0.5 $Wm^{-2}K^{-1}$ [10, 11], and another thing to persuade the mass market to buy and install this technology. For a large area triple vacuum glazing, the use of tempered glass is beneficial; this attracts a method of the fabrication of triple vacuum glazing at temperatures below 300°C which was first developed at the University of Ulster [12]. This method uses indium or one of its alloys for airtight sealing of the edges of the glass panes at a temperature of less than 200°C. The scarcity and cost of indium are challenges in advancing indium-sealed vacuum glazing technology to the mass production level. A recent low-temperature composite edge sealed triple vacuum glazing shows promising results which was first developed at Loughborough University and reported in Memon et al (2015) [13]. In this paper, the energy and cost savings achievable by retrofitting different glazing systems to an external solid wall insulated detached house are analysed. The predicted performance of triple vacuum glazed windows is compared to a range of different window types; single, double glazed air filled, double glazed argon gas filled and triple glazed air filled windows. The influences of changing window-to-wall area ratio, from 5% to 59%, on the heat supplied and solar energy gain were analysed. The space-heating energy requirement, internal heat gains and solar gains are compared to the calculations of the steady state heat losses of the envelope having solid walls with external wall insulation are analysed by drawing heat flow diagrams.

2. Building simulation methodology

Existing retrofitting of solid wall dwellings has shown significant advantages of using external wall insulations. In this paper, a detached solid-wall dwelling with the brick thick bond having external insulation was designed and modelled [14] which have a structure of early 20th century, located in the Heathrow area of London. The occupancy of this dwelling was modelled to be a family of three adults and one child. The Dimensions of the allocated internal spaces with windows and doors and design parameters are reported elsewhere [15]. To predict the comparative performance of triple vacuum glazing with conventional glazing types in a solid-wall dwelling, the dwelling's fabric was retrofitted to a minimum 1995 building standard; insulations to external solid wall, internal ceiling and floor, loft and ground. The structural U-values used as per 1995 building regulations in the modelled detached solid-wall dwelling are detailed in Table 1. The acceptable thermal comfort temperatures for occupants, allowing natural ventilation during summer months, are between 17°C and 19°C for the winter and summer months, respectively, as per CIBSE Guide-A standard [16]. In these simulations the set-point temperatures were assigned to be 19°C. A version 4 of ASHRAE weather database was implemented to dynamically perform outdoor weather conditions throughout a year [17]. The sectional U values of each element was simulated as per standard of CIBSE Guide-A [16], it complies with the BS EN ISO 6946 [18] standard. A conventional frame material PVC was used whilst calculated their effects on overall U-value of windows following EN-ISO standard method. The k-glass used has a visible light transmittance of 0.74, G-value of 0.76 and surface emissivity of 0.9. The model structural details and U values of conventional glazed windows and triple vacuum glazed window are specified in Table 2. In the dynamic thermal simulations the calculated window U values were incorporated to envisage the winter and annual months' space-heating energy

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