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Integrated solar thermal façade system for building retrofit

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Abstract

In the perspective of the Net Zero Energy Buildings as specified in the EPBD 2010/31/EU, we propose the concept and design of a modular unglazed solar thermal (UST) façade component for facilitating the installation of active solar façades. The renovation of existing buildings offers an opportunity to improve the energy efficiency when using such a system and a novel design methodology tackled via a parametric approach is here proposed. We analysed a variety of building typologies as potential application targets of the UST collector, properly sizing the collector field for each typology to match the heat loads profile. We investigated the thermal behaviour of the novel thermal façade component and the energy potentiality in covering the heat demand using the TRNSYS software's model of the UST collector field as a part of a combisystem. We concluded with the definition of rules of thumb for early design stage. The work here presented demonstrates that the low-cost, the versatile modularity and the easy installation make this active solar façade an innovative and promising technology for the building stock transformation, despite of the low quality of the produced energy due to the low outcome temperature of the unglazed collector.

Keywords: Unglazed solar thermal collector; Metal cladding; Façade; Building energy retrofit; Trnsys; *EnergyPlus*

1. Introduction

Given their mature and technical reliability, Solar Thermal (ST) technologies are used more and more to cover building heat loads, mainly Domestic Hot Water (DHW) preparation and Space Heating (SH) (D'Antoni and Saro, 2012). Nowadays, there is still a lack of optimised ST technologies, conceived specifically for the existing building stock, due to high complexity and number of building/urban contexts (EA ECBCS Annex50, 2011). However, the envelope system has a significant impact on the building energy performances and on the overall value when retrofitted or replaced. More specifically, the renovation of the façade allows the buildings not only to change according to modern aesthetic perception, but also to improve their energy behaviour.

The Building Performance Institute Europe (Nolte and Strong, 2011) reports that the non-residential building

Abbreviations: α, absorbance; A_C, collector area; ε, emittance; AL, active layer; BIST, building integrated solar thermal; DHW, domestic hot water; DOE, department of energy; $\dot{m}$, collector mass flow rate; $\dot{m}_1$, flow rate of the primary solar loop; Q_{LOADS}, heat loads for DHW and SH; Q_{SUN}, useful energy gain of collector field; SH, space heating; SF, solar fraction; ST, solar thermal; UST, unglazed solar thermal; V_C, storage tank volume.

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stock accounts for 25% in floor space of the European total stock, and it represents the most complex and heterogeneous sector compared to the residential one. According to Balaras et al. (2005), about 70% of the European residential stock was built before 1970, when energy efficiency was not an issue neither for opaque (walls, roofs) nor transparent (windows) envelope parts, and so the buildings built between 1945 and 1970 should be the priority for energy retrofit actions. Therefore, the development of novel solar thermal components represent a promising choice for the renovation market when they are conceived as integrated in the building envelope and no longer as mere additional technical elements (see Bergmann, 2002; Hestnes, 2000; Munari Probst and Roecker, 2007).

In these last decades the European policies actively push to improve the production of energy for building needs by using solar technologies and Buildings Integrated Solar Thermal (BIST) are becoming more interesting and attractive (Bergmann, 2002; Hestnes, 2000). Specifically, the façade represents a fairly easy option for the installation of collectors as it provides a further potential envelope surface for solar thermal integration to supply hot water for domestic use, space heating and cooling. Although the amount of incident solar radiation on the vertical surface is about 30% lower than the amount hitting an optimal tilted surface, the implementation of these technologies into the façade avoids heat overproduction and collectors' overheating in summer-time, and allows to properly size the building energy system according to the actual heat demand (Munari Probst and Roecker, 2007). Moreover, when ST collectors are mounted in vertical, they are less sensitive to the weather conditions and dust, rain and snow will not damage them.

Nevertheless, buildings integrated solar thermal into façade are still rare since the design of an active façade represents a tricky phase for architects and engineers dealing with both aesthetic and functional issues (higher visibility of the collectors) and with energy and technical aspects (support structure typology and presence of hydraulic connections) as investigated by Munari Probst and Roecker (2007). Generally, the integration of such solar technologies in the building envelope is much easier to achieve for the new constructions. The façade retrofitting with ST collector integration opens up a new challenge for designers and manufacturers, requiring greater design efforts from the architectural and engineering point of view and needing appropriate components.

1.1. ST integration into façade for energy retrofit

The solar thermal integration entails that the building envelope, specifically the façade, acquires the feature of multifunctionality, since (1) the ST collector must guarantee the same envelope functions of the replaced element(s), and (2) the envelope takes up the new function of collecting solar irradiation, producing and distributing hot water.

The solar thermal façade solutions available on the market still focus on the maximisation of energy production and generally do not match neither the multifunctionality nor the possibility of being integrated in the façade systems (module size, colour, texture, jointing typology, collector field dimension). As found in IEA SHC Task 41 – SubtaskA (2012), there are still few commercial applications of solar thermal collector in the refurbishment market and the few available products are mainly conceived for the implementation in new buildings.

1.2. Metal unglazed solar thermal collectors

Among the available ST technologies, the metal unglazed solar thermal (UST) collectors have a lower efficiency and a lower outlet temperature compared to the performances of the flat plate glazed collectors. Nevertheless, the metal UST collectors are simpler, cheaper and aesthetically appealing. The European project Solabs (Solabs, 2006) exploited the idea of developing an unglazed coloured metal solar absorber for building façades and for the integration into heating systems. Later the European project Bionicol (Bionicol, 2011) developed an aluminium roll-bond solar absorber prototype and a novel approach for the optimisation of the absorber channels layout.

1.3. Research objectives

We present here a novel concept of a solar façade system, which integrates an unglazed solar collector, to be used in building retrofit actions. Merging two different technologies – roll-bond technology and metal cladding system – into one component may solve both the engineering and architectural issues, only when they are correctly tackled.

We developed a methodological approach to address the design of an unglazed-solar–thermal/façade-cladding system investigating its application in selected reference buildings and analysing the thermal and energy potentialities of this low temperature solar thermal technology by simulations. The outcome is a UST collector conceived as a unique, active, functional module both for the thermal energy production (as an absorber) and for the existing façade re-cladding. The potential development as an industrial product is based on three factors: (1) high modularity by easily installable elements to be sized for the specific needs of the buildings, (2) low-price technology, given by the industrial process already developed for the fridge evaporators, and (3) versatile modules to be used both for new buildings and for energy retrofitting of existing buildings. Fig. 1 shows the methodological approach developed in the present work.

2. Integrating the technologies: a novel solar façade

The present work aims to facilitate the process of integration of solar technologies in the envelope, as previously