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Modelling and simulation of Building-Integrated solar thermal systems: Behaviour of the system

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ABSTRACT

Building-Integrated Solar Thermal (BIST) systems are a new tendency in the building sector and provide multiple advantages in comparison with the Building-Added (BA) installations. The present paper is a critical review about solar system modelling with emphasis on BIST configurations. The review includes also BI solar systems which produce electricity (Photovoltaic: PV) or both electrical/thermal energy (Photovoltaic/Thermal: PVT) in order to provide a more complete view of the current literature. For some cases where the system and/or the model are of great interest, BA configurations are also cited. The references are presented separated into groups, based on the model type (thermal, energetic simulation, etc.) and system characteristics (solar thermal collector, skin façade, etc.). The present review is the 2nd part of an investigation about BIST modelling and it focuses on modelling studies about the solar system itself. The results reveal that most of the investigations about BI configurations refer to PVT, PV or skin façades while there are few studies about BIST systems. Thus, there is a need for more investigations about BIST installations, especially for active configurations which could provide thermal (or electrical/thermal) energy for building energy requirements. On the other hand, more optical simulations as well as more life-cycle analysis studies about BIST are also necessary. Taking into account the findings of the 1st part of the present investigation, majority of the BIST modelling studies focus on the system itself; thereby, more investigations which examine the system in conjunction with the building are needed. Moreover, concepts such as BI concentrating solar systems could also be examined provided that the system is viable from technical/economic point of view.

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1. Introduction

Solar energy technologies provide promising solutions for the reduction in the energy consumption of buildings. Building-Integrated Solar Thermal (BIST) systems are a new tendency in the building sector[1]. BIST configurations offer multiple advantages compared to Building-Added (BA) installations due to higher aesthetic value, replacement of the traditional building elements and utilization of solar energy in buildings [1].

The present study investigates theoretical and experimental-based studies on BIST systems. Since BISTs are a new tendency, only few investigations have been reported in this area. These studies are experimental-based [2,3] and/or modelling-based [4–7]. In terms of integration, some systems are in building façade [2,3] or in building gutters [5–7]. Concerning modelling investigations, some studies give emphasis on the system itself [5–7] and some examine the system in conjunction with the building in a holistic approach [4,8,9].

The present study provides an extensive literature review grouped into model types such as thermal, energetic simulation and specific characteristics of the system such as solar thermal collector, Photovoltaic/Thermal (PVT), Concentrating PVT (CPVT), skin façade, etc. Although emphasis is given on the BIST systems, other types of systems (BIPV, BA solar thermal, etc.) are also presented to provide a complete picture of the current literature. The present investigation is the 2nd part of a review study on BIST modelling. The 1st part of that review [10] focuses on studies which examine building/system in a holistic approach while the 2nd part (present paper) focuses on studies which examine the system itself (not in conjunction with the building). In this way, the gaps in the literature in the field of BIST modelling are identified while BI configurations for future studies are also proposed. In the literature, there is a review about opaque solar façades and transparent/translucent solar façades [11,12]; however, that investigation ([11,12]) included experimental as well as theoretical studies and did not focus on modelling. In the frame of the present paper (as well as in the 1st part of the present investigation), emphasis is given on the BIST modelling studies providing details about the adopted modelling methodologies and identifying gaps in the literature in terms of model types and system types. Thus, the present investigation provides useful information for the development of future BIST systems.

[1] It should be noted that some types of BIST exist several years ago; the word "tendency" means that over the last years there is an increasing interest for BIST (certainly, the interest begins from the research).

2. Modelling of Building-Integrated Solar Thermal (BIST) Systems

The studies are grouped into the following categories: energetic, thermal, energetic/thermal and optical simulations. "Energetic" modelling refers to empirical models which use for instance a collector efficiency curve. "Thermal" modelling refers to detailed physical models which use thermal nodes and resistances. Within each of these categories the investigations are presented based on the type of the system: solar thermal collector, skin façade, PVT, etc.

2.1. Studies of energetic simulation

2.1.1. BI, solar thermal

Windholz et al. [13] built a demonstrator with different BIST (and BIPV) façade elements and monitored the temperatures of the layers and the heat transfer medium as well as the heat flux to the building interior. CFD (computational fluid dynamics) simulations were used to analyze the physical processes in the façade elements. An empirical model was fitted to the monitoring data. For times with fluid flow, a good agreement between simulation and measurement results was achieved.

Dowson et al. [14] presented measurement results of a polymer air collector with aerogel. Based on the measurements, the collector was modelled and the annual gain was calculated as well as a payback time. A steady-state model was developed to characterize the aerogel solar collector. This type of collectors offers the opportunity to improve the efficiency of flat-plate solar