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Hybrid roof panels for night cooling and solar energy utilization in buildings

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Abstract

The aim of this contribution is to evaluate the usability of solar hybrid panels, which were originally optimized for heat load removal from buildings by radiation against the night sky, for water preheating. First we created a surrogate model based on CFD simulations defining performance of the panel dependent on changing boundary conditions. This model was then implemented to the water heating model created in TRNSYS software. Estimated hot water usage would suffice for operation of 2 restaurant facilities in a building of our interest. Subsequent simulations were carried out using reference year climate data for Brno (Central Europe). Results demonstrated that in the given conditions, the average annual efficiency of solar energy usage is 55 %. The results also showed that the system is able to cover approximately 7 % of the heat demand for water heating.

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Keywords: Night sky cooling; Solar hot water heating; Surrogate model; Numerical simulation; CFD simulation; TRNSYS;

1. Introduction

Night sky cooling represents a method of passive cooling of buildings. It is based on the principle of heat radiation from hot surface of a solar panel against the cold night sky. Temperature of the night sky on the atmospheric boundary layer reaches 4 K [1]. This method of cooling is preferably applicable in dry climatic conditions because high air humidity absorbs heat radiated from the ground and therefore this heat is partially emitted back. According to previous studies [2,3], the efficiency of cooling collectors is affected not only by relative

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humidity, but also by other climatic conditions. Therefore, the evaluation of passive solar cooling efficiency against the night sky is primarily based on local climate data [4].

This paper builds on previous article [5], in which the applicability of the night sky cooling in context of climatic conditions in the Czech Republic was assessed by simulation method. The research was applied on a specific office building with varying occupancy parameters, settings of natural ventilation, different heat sources from lights etc. This model examined the effect of climatic conditions on energy performance of the panel throughout the year. The assessed model of the whole system employed heat activation of concrete floor system (TACC) used for storage of cold in reinforced concrete slabs. Results showed that the night sky cooling has favourable impact on interior temperature leading to decrease of the temperature to optimal value. These results were supported by calculated PMV and PPD parameters.

The aim of this paper is to evaluate usability of these hybrid roof panels during daytime. These panels might serve during daytime as solar collectors for pre-heating of hot water. Daily heat demand for restaurants is set as 0.389 MWh. Article [6] deals with optimization of water heaters. Article [7] presents design of a suitable water heating system of water heating using solar and heat pumps in six different ways. Literature [8] provides a life cycle assessment of solar systems used for heating of hot water. Article [9] presents a comparative study between solar and conventional heating of water and [11] presents analyses of combined solar systems. Study [12] deals with comparison of the design methods of hot water storage tanks. Article [13] provides an overview of technology and installation and summarizes behavior of the photovoltaics used for hot water heating. Economic analysis of solar hot water heating system is described in [14]. Different types of water heating systems are analyzed in terms of economic characteristics and impacts on global warming in article [15]. Study [16] investigates the efficiency of different types of home heating system in terms of energy use. Articles [17] and [18] deal with Legionella pneumophila in hot water systems and its negative impact on human health.

Nomenclature

c	specific heat capacity [J/(kg·K)]
I	specific solar irradiation [W/m^2]
m	mass flow [kg/s]
Q_{2D}	performance of hybrid panel in 2D model [W/m]
Q	performance of hybrid panel [W]
q	densitiy of heat flux [W/m^2]
t	temperature [°C]
w	wind velocity [m/s]
TACC	thermal activation of concrete ceiling

Subscripts

e	external
m	heat transfer medium in panel
in	enters
out	leaving
$2D$	two dimensional

2. Methods

Thermal performance of panels is dependent on both climatic and operating conditions. The most important parameters influencing the panel heat gains are solar radiation intensity I, outside air temperature t_e, wind velocity w as climatic parameters and mean temperature of the medium in the panel t_m as an operating parameter.