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Summer discomfort reduction by direct evaporative cooling in Southern Mediterranean areas

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Abstract

The present study analyses the effect of direct evaporative cooling (DEC) in reducing the number of discomfort hours in the area of Southern Europe and the Mediterranean. A total of 20 urban locations were selected in order to cover different climate conditions in the chosen area. Cooling degree hours and virtual climatic discomfort hours were calculated for the entire set of locations. Furthermore, the analysis is based on a sample building simulated in EnergyPlus for every location considering both a baseline (free running) and a direct evaporative cooling case. Night ventilation was also simulated in order to compare this technique with DEC. The chosen DEC model is the direct CelDekPad, a single stage evaporative cooler compatible with EnergyPlus. A psychrometric analysis was carried out and comfort boundaries identified for helping designers in considering DEC and night ventilation suitability from the early design phases (e.g. building programming).

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Keywords:

1. Introduction

The primary energy consumption of the building sector in Europe, as in most industrialised countries, is about 40% of the total [1] or even more according to recent research studies [2, 3]. The main contribution is related to energy demand for cooling and heating, hot water production, cooking, lighting and other appliances, with half of it occurring in residential buildings. Indoor temperature and humidity control for heating and cooling represents the highest cause of energy consumption in buildings, with energy demand for cooling constantly increasing in both industrialized and growing countries as demonstrated by trends in the air conditioning market showing a growth of

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70% between 2010 and 2015 [4]. This trend has a strong impact on the electrical energy consumption in many countries, increasing peak demand, energy costs, and GHG emissions due to the high emission factor of electricity [5]. The application of passive cooling systems, and, particularly DEC, could represent an alternative solution, hence contributing to the reduction of global warming as set by the agreement reached among 195 countries at the recent COP21 Conference in Paris.

1.1. Structure

This paper focuses on an evaluation of the potential of direct evaporative cooling technologies (DEC) for reducing the amount of discomfort hours in the southern Europe and the Mediterranean region, considering a sample of 20 urban locations which are representative of the different climatic characteristics of this territory. The research deals with an extended summer period that was fixed for this study from May 1st to October 31st for including different durations of the cooling season in the selected locations. The study firstly analyses the climate-dependent cooling demand by calculating the cooling degree hours (CDH) of each location and the number of "virtual" climatic discomfort hours based on the hourly Typical Meteorological Year – TMY – data provided by the EnergyPlus climate database. Secondly, a sample-building unit was simulated in EnergyPlus in order to calculate the number of discomfort hours in the extended summer period for each location. Dynamic simulations were carried out considering different cases ("free running", "active with DEC", "free running with night ventilation", and "active with DEC and night ventilation") as described in the following paragraphs. A comfort model developed by ASHRAE and based on both temperature and relative humidity is considered. The calculation of the number of discomfort hours is used to analyse the applicability of DEC and night ventilation (NV) in the chosen set of locations for developing new maps of applicability. Furthermore, a psychrometric analysis was carried out (see par. 4) in order to identify comfort boundaries of DEC applicability. A new correlation between expected indoor comfort and outdoor wet bulb temperature (WBT) is presented, defining an outdoor comfort line – when mechanical comfort model is used – of direct evaporative cooling in treating inlet air in buildings.

2. Sample locations and climatic analyses

The Mediterranean area is characterized by the homonym climate, even if southern locations are classified as BWh (cold desert climate) in the Köppen-Geiger classification (see Table 1). The map presented in Fig. 1 shows the climate classification of the chosen set of locations based on the TMY files used.

Fig. 1. Köppen-Geiger classification of the chosen set of locations.