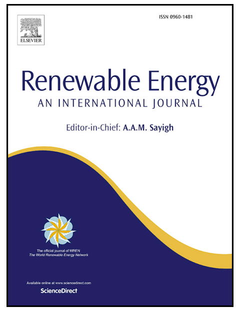
Accepted Manuscript



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PII: S0960-1481(17)30278-1

DOI: 10.1016/j.renene.2017.03.087

Reference: RENE 8680

To appear in: *Renewable Energy*

Received Date: 20 July 2016

Revised Date: 18 January 2017

Accepted Date: 28 March 2017

Photovoltaic evaporative chimney as a new alternative to enhance solar cooling

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Abstract

Cooling sector plays a crucial role in the World's transition towards an efficient and decarbonised energy system. Solar cooling is an attractive idea because of the chronological coincidence between available solar radiation and cooling needs. This paper studies the possibility of increasing the efficiency of solar photovoltaic modules by evaporative cooling. This, combined with the use of a water condensed chiller, will enable an efficient cooling system design as a whole. To achieve this goal this paper experimentally evaluates the thermal and electrical performance of a Photovoltaic Evaporative Chimney. A prototype with two photovoltaic modules was built; one of them is used as a reference and the other is modified in its rear side including the evaporative solar chimney. The system is able to dissipate a thermal power of about 1500 W with a thermal efficiency exceeding 30% in summer conditions. The module temperature differences reach 8 K, depending on the wind conditions and ambient air psychrometric properties. Regarding the electrical efficiency, the results showed an average improvement of 4.9% to a maximum of 7.6% around midday in a typical summer day for a Mediterranean climate.

Keywords: Solar cooling, Solar chimney, Evaporative cooling, PV/T, Cooling Tower, HVAC

1. Introduction

Heating and cooling constitute around half of the European Union's final energy consumption and is the biggest energy end-use sector, ahead of transport and electricity. Around 85% of heating and cooling is produced from natural gas, coal, oil products and non-RES electricity. Only 15% is generated from renewable energy, (European-Commission, 2015). This shows that the heating and cooling sector has a crucial role to play in the World's transition towards an efficient and decarbonised energy system and in achieving long term energy security. The purpose is to moderate the heating and cooling demand, to increase energy efficiency in supply, to maximise the use of renewable energy and to reduce the cost of heating and cooling to affordable levels.

Although electrically driven chillers have reached a relatively high standard concerning energy consumption, the installed capacity of air conditioning systems has caused an increase of the electricity peak demand in the summer period in many countries. Blackouts and brownouts in summer have frequently been attributed to the large number of conventional cooling systems running on electrical energy. An obvious possibility to counter this trend is to use the same energy for cooling generation that contributes to creating the cooling demand. Solar cooling is an attractive idea because of the chronological coincidence between available solar radiation and cooling needs. The grand challenge is to design solar air conditioning systems in a cost-efficient way. So far, different technical solutions that combine solar energy and air conditioning have been studied.

Solar energy can be converted into cooling using two main principles. Ghafoor and Munir (2015) presented an overview of different available and actually installed solar driven technologies used for cooling or air-conditioning purposes. In Solar Thermal driven Cooling (ST-C), heat generated with solar thermal collectors can be converted into cooling using thermally driven refrigeration or air-conditioning technologies. Most of these systems use the physical phenomena of sorption in either an open or closed thermodynamic cycle. There are several studies where these technologies are exposed and they are developed with flat plate solar collectors or solar vacuum tubes as solar caption surface. Other technologies, such as steam jet cycles or other cycles using a conversion of heat to mechanical energy and of mechanical energy to cooling are less significant. Best and Rivera (2015) presented a review of the performance and development of thermal-powered cooling systems. In Photovoltaic driven Cooling (PV-C), electricity generated with photovoltaic modules can be converted into cooling using well-known refrigeration technologies that are mainly based on vapor compression cycles. In Aguilar et al. (2014) an experimental study with PV-C is described. Also, in Ji et al. (2008) a performance analysis of a PV heat pump is shown.

It is difficult for solar thermal cooling to emerge as a

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