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Solar driven cooling systems: An updated review

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ABSTRACT

This paper presents a review of the available technologies to provide cooling from solar energy for both thermal and photovoltaic ways. Several multi-criteria performance indicators figuring in the literature are presented followed by a pros and cons analysis of the different solar thermal cooling processes. A market study is also carried out to evidence the potential of these solar cooling technologies. Finally, an overview of various solar cooling installations in Europe, Egypt and China is presented.

Contents

Abbreviations: FPC, flat plate collector; ETC, evacuated tube collector; SAT, single-axis tracking solar collector (e.g. parabolic trough collectors or Fresnel type collectors); SAHC, solar air heating collector

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1. Introduction

The climate model projections presented in the last Intergovernmental Panel on Climate Change (IPCC) report indicate that the global surface temperature is likely to increase by 1.1 to 6.4° C over the next century. Continued gas emissions at or higher than current rates would cause more warming and lead to several changes within the global climate system throughout the twenty first century [1]. Furthermore, according to the International Energy Agency report [2], the World CO_2 emissions were evaluated at 30,326 MT in 2010 and will certainly increase in the future. This environmental status will cause significant changes in the structure and function of ecosystems, the ecological interactions of various species and their ranges.

In parallel, the demand for energy and associated services, to satisfy social and economic development and ameliorate human comfort and health, is continuously increasing. Since approximately 1850, the global use of fossil fuels (coal, oil and gas) has dramatically raised to dominate energy supply. In fact, the Key World Energy Statistics [2] reported that the global world electricity consumption amounted to19738 TWh in 2010, in which 68% came from fossil origin. The situation becomes serious with the depletion of these resources. Shafiee and Topal [3] among others estimate the time scale of fossil depletion as follows: around 107 years for coal, 37 for gas and solely 35 for oil.

To face the current situation, several conventions were set up, one may cite: the Vienna Convention for the Protection of the Ozone Layer (1985), the five amendments of the Montreal Protocol (1987) or the Kyoto Protocol on Global Warming (1998). All these initiatives aim at reducing the share of fossil fuels in the world energy mix and diminishing the employment of substances responsible on the ozone depletion.

Cooling applications like air- conditioning and refrigeration become as basics of everyday life. However, the conventional systems use some refrigerants with high ozone depletion potential. Consequently, the EC (European Commission) Regulation 2037/2000 has programmed the prohibition of HCFCs (hydrochlorofluorocarbons) by 2015 [4]. Taking into account all these circumstances, new thinking on the development of renewable energies as a solution to meet human needs while saving the environment has become a world top priority. Exploring solar energy seems a fascinating idea since cooling needs coincide most of the time with the solar radiation availability. In this sense, different studies and researches were conducted to develop new cooling technologies employing solar energy. Most of the proposed cycles are able to eliminate or reduce considerably the harmful effects of traditional refrigerating machines while allowing interesting energy savings.

The aim of this paper is to give an overview of the state-of-the-art of solar cooling systems for both thermal and electric paths. Hybrid systems as well as the recent developments of solar refrigeration technologies are also discussed. A comparison of the main techniques is investigated and performance indicators relative to the relevant technology choices are presented.

Table 1
Available solar thermal collectors in the market [5]

Motion	Collector type	Concentration ratio	Temperature range (°C)
Stationary	Flat plate collector (FPC)	1	30–200
	Evacuated tube collector (ETC)	1	50–200
	Compound parabolic collector (CPC)	1–5	60–300
Single-axis tracking	Linear Fresnel reflector (LFR)	10–40	60–250
	Parabolic trough collector (PTC)	15–45	50–400
	Cylindrical trough collector (CTC)	10–50	60–300
Two-axes tracking	Parabolic dish reflector (PDR)	600–2000	100–1500
	Heliostat field collector (HFC)	300–1500	150–2000