Available online at www.sciencedirect.com

ScienceDirect

Renewable and Sustainable Energy Reviews
12 (2008) 2194–2210

RENEWABLE & SUSTAINABLE ENERGY REVIEWS

www.elsevier.com/locate/rser

Economic considerations and cost comparisons between the heat pumps and solar collectors for the application of plume control from wet cooling towers of commercial buildings

S.K. Tyagi[a,*], Shengwei Wang[a], S.R. Park[b], Atul Sharma[c]

[a]Department of Building Services Engineering, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong

[b]Unutilized Energy Research Center, Korea Institute of Energy Research, P.O. Box 103, Yusong, Taejeon 305-343, South Korea

[c]Department of Mechanical Engineering, Kun Shan University, Yung-Kung City, Tainan 710, Taiwan

Received 21 February 2007; accepted 22 March 2007

Abstract

This communication presents a case study based on the economic considerations and comparisons between the heat pump and solar collector heating systems for the application and utility to control the visible plume from wet cooling towers of a huge commercial building in Hong Kong. A detail economic study for both cases, i.e. for heat pumps as well as for solar collectors is done and compared using different (capital and operational) costs, taking other constraints into account. The capital cost is the actual cost of the device, for example, for a heat pump it is the cost of the heat pump machine. For a solar collector it is the cost of all the components like the collector, pipes, pump, heat exchanger, etc. On the other hand, the operational cost is the cost that keeps the system working in good condition. For a heat pump, the cost of the input power to the compressor is the running cost, while the necessary maintenance and replacement of parts comes under other cost. Similarly, for a solar collector, the cost of the power consumed by the pump/compressor to circulate the working fluid is the running cost which is very less as compared to the former. It is found that all the costs are much lesser for a solar collector system while it is reverse in the case of an air-cooled

*Corresponding author. Tel.: +852 2766 5847; fax: +852 2774 6146.
E-mail address: sudhirtyagi@yahoo.com (S.K. Tyagi).

doi:10.1016/j.rser.2007.03.012

geothermal heat pump system. Other comparisons between the electric and geothermal heat pump systems are also given among different possible options.

Keywords: Wet cooling tower; Solar collector; Heat pump; Water-cooled chiller; Visible plume; Commercial building; Ambient air temperature; Relative humidity

Contents

1. Introduction

Cooling towers are the enclosed boxes for the evaporating cooling of water by direct contact with the air, which is achieved partly by an exchange of latent heat from the water evaporation and partly by a transfer of sensible heat. They are used for heat rejection purposes and are among the important component of any power plant, HVAC, and industrial applications, especially, where the availability of cooling water is not sufficient. Physically they are often the single largest item of plant at the site and their visual impact is greatly increased if they emit a visible plume of superheated air into the atmosphere. The development of the cooling tower analysis began in the 19th century with the first work carried out by Lewis [1] and was used by Robinson [2] for the first time to establish the general principles, applicable to cooling tower design and derived equations for the designers. He further stated a series of fundamental concepts about the mechanism involved in the transfer of heat between liquid, gasses, and on the vaporization of liquid. Merkel [3] used the enthalpy potential as the driving force for air–water exchange and assumed a similarity between heat and mass convective transfer by means of Lewis number equals to unity which has been used to date.

For several decades, many authors have studied the convection phenomena occurring in cooling towers. Baker and Shrylock [4] developed a detailed explanation of the concept of cooling tower's performance clarifying the assumptions and approximations used by Merkel. Sutherland [5] showed that Merkel's theory leads to an underestimation of tower size by 5–15%. Braun [6] developed a confined method to model the performance of both cooling tower and dehumidifying coils. Based on Merkel's theory, the effectiveness-NTU relationships method has been developed by Braun et al. [7], taking into account the saturated air specific heat used for sensible heat exchanger. In the model, two parameters,