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Comprehensive review of cooling and heating degree days characteristics over Kingdom of Saudi Arabia

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ABSTRACT

This paper presents the annual and seasonal cooling (CDD) and heating (HDD) degree day values over Saudi Arabia by utilizing the long-term daily average temperatures from 38 meteorological stations. The values of CDDs and HDDs have been calculated for a base temperature of 18.3 °C. The maximum annual mean CDDs of 7549 were observed at Makkah while the minimum of 3132 at Abha. On the other hand the maximum HDDs of 985 were found in Guriat and minimum of 0 at Gizan, Jeddah, Rabigh, Makkah, Sabya, Sharourah, Wejh and Yanbu. The annual and seasonal values of CDD and HDD provided in this paper could be used to estimate the fuel or energy requirement for cooling or heating of buildings in respective areas both on annual and seasonal bases.

Contents

1. Introduction

Globally increasing demands of energy have become the matter of concern to people from all walks of life due to its adverse effect on the climatic conditions of the earth. The Saudi Arabian population is also increasing at around 2% but the energy demand is going up every year by 4–5%. The erection of fossil fuel based power plants is both time and money intensive. Moreover each MW of electricity produced using mixed fossil fuel adds up around 1.5–1.7 t of green house gases (GHGs) equivalent to CO_2 into the atmosphere. Hence means should be explored to protect environment and at the same time meet the energy demands needs of the people. According to energy conservation experts, implementation of incentive oriented policies and awards [1–4], careful design of the building fabric [5] including the size and orientation of windows, thermal insulation [6], solar shading [7], application of ventilated double-skin facade to buildings in hot-summer and cold-winter zone [8,9] and utilization of new and clean sources of energy [10–14] may assist in reducing solar heat gain.

According to Liu et al. [15], human beings have no choice but to reduce energy consumption to combat adverse environmental changes. This can be achieved by increasing the efficiency of energy conservation and exploitation of new and clean sources of energy. Ma and Wang [16] provided an overall review of the building energy research and efforts in Hong Kong over the last decade. Day et al. [17] described how energy/degree-day correlations can be properly identified while taking into consideration

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the energy balance of the building. This methodology further helps in identifying the building base temperature from reduced data sets. Yuan et al. [18] presented a systematical review and prospective analysis on policy evolution and progress of energy conservation and emission reduction in China during the 11th financial year plan. Accordingly China has achieved 3.9% annual energy saving from 1980 to 2005. Caia and Jiang [19] studied the differences in energy consumption between rural and urban households to assess energy conservation implications in five cities. Energies used in urban households are more convenient, cleaner, and more efficient than those used in rural areas, where biomass and coal are common fuels. Furthermore, the energy consumptions in the rural and domestic sectors directly affect the sustainable and balanced economic development [20] and household energy consumption in rural areas also composes an important part of China's national energy consumption [21].

Ambient temperature variations directly affect transportation, water resources, power generation, agriculture, construction, and in particular the energy consumption for cooling and heating of buildings [22,23]. Several case studies have indicated considerable impacts of temperature changes on energy consumption in buildings [24–28]. Degree-day, which is truncation of daily temperature series at a base temperature, is usually accepted as an index of energy consumption for heating and cooling of the buildings [26,27]. As early as 1983, Walsh and Miller [29] presented a simple graphical means for predicting degree day totals for a given period as a function of the mean and standard deviation of the daily average outdoor temperature.

According to Buyukalaca et al. [30], the degree-day method is the simplest method used in Heating, Ventilating and Air-Conditioning industries to estimate heating and cooling energy requirements. The authors estimated HDD and CDD for different base temperatures and presented in the form of tables and the contour maps using temperature data from 78 weather stations in Turkey. Kodah and El-Shaawari [31] recommended a heating base temperature of 15.5 °C for Jordan while Badescu and Zamfir [32] 18 °C for heating degree-day calculations for Romania. Papakostas and Kyriakis [33] reported the heating and cooling degree-hours for two cities of Greece, viz. Athens and Thessaloniki. Recently, Christenson et al. [34] analyzed time series data for the present-day and future climates and estimated heating and cooling degree-days. Their analysis showed that heating degree-days decrease whereas cooling degree-days continue to increase in future climates.

The impact of climate warming on Swiss building energy demand was investigated by means of the degree-day method by Mourshed [35]. During 1901–2003, the HDDs were found to have decreased by 11–18%, depending on the threshold temperature (8, 10 or 12 °C) and location. Jiang et al. [36] reported that heating degree-days varied between 2700 and 7973 °C for a base temperature of 18 °C and heating degree days between 0.4 and 792 °C at a base temperature of 24 °C. Gelegenis [37] reported a simplified second-degree expression for the estimation of annual HDD at various base temperatures. The quadratic relation proved to be quite accurate when applied to data from many cities from Greece and other countries. Papakostas [38] presented annual values of heating and cooling degree-days for typical base temperatures of 15 °C for heating and 24 °C for cooling for Athens and Thessaloniki, Greece. The results showed a reduction of the heating energy demand by 11.5% and 5% and an increase of the cooling energy demand by 26% and 10%, for Athens and Thessaloniki respectively.

Energy conservation is one of the important avenues which could be very effective in meeting the energy demands and at the same time safeguarding our environment and the earth, our home. The present study aims at studying the variation of degree-days and providing the maps of cooling and heating degree-days for the Kingdom so that these could be used effectively in designing and managing the cooling and heating

Fig. 1. Location map of meteorological stations used in the present study.