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A new approach to determine the outdoor temperature distributions for building energy calculations

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ABSTRACT

This study formulated annual, monthly and hourly ambient temperature distributions for simplifying the calculation of cooling and heating degree-hours. In this regard, Turkey was selected as an application country, of which 79 cities were considered for modeling purposes. The temperature data over a period of 42 years were also utilized in the analysis. Similar outdoor distributions were categorized in the same group. The analysis results showed eight main annual distribution trends for the cities in Turkey. Such a detailed analysis and categorization for the outdoor temperature has been done for the first time in the literature. The outdoor temperature distributions are very useful tools for determination of heating and cooling loads while they enable the calculation of the annual-, monthly- and hourly-based degree-hours values. In this regard, a population-based outdoor temperature distribution concept was also introduced to the literature and tested for Turkey. One temperature distribution was achieved for Turkey with reference to population.

1. Introduction

Outdoor temperature conditions have a crucial impact on the energy consumption for heating and cooling. In order to predict the amount of energy consumption and to use energy efficiently, it is quite important to know the outdoor temperature distributions. Many heating/cooling firms spend a huge amount of money for determining the hourly outdoor distribution. It becomes easy to evaluate degree-hour values over any time period in a year by knowing the hourly outdoor temperature distribution. Firms mainly utilize the hourly outdoor distribution for economical evaluation of their heating/cooling machines and bidding strategies. Because of trade secrets, it is nearly impossible to achieve open access outdoor temperature distribution data for an academic research.

The degree-hour calculation method is one of the techniques using the outdoor temperature distribution to estimate and analyze the amount of energy for heating and cooling of residences. It is known that degree-hour values are calculated simply by summing up the differences between the hourly dry-bulb temperatures and a standard reference temperature (base temperature). The reference temperatures for heating/cooling in building applications vary from country to country. The determination of the degree-hour values correctly with smallest amount of error is substantially important for designers and manufacturers working in the heating and cooling sector. Meanwhile, the use of the degree-hour values in the calculation of insulation thickness affects the direct costs and thus draws interest from investors. Many researchers [1–4] have determined the optimum insulation thickness for different applications using the degree-day or degree-hour method.

Several studies on analyzing the outdoor temperatures have been undertaken using degree-hour/day values to predict the energy and exergy requirements for the heating and cooling of buildings [5–10]. Coskun et al. [11–13] proposed the outdoor temperature distribution concept. They applied this approach to many cities in Turkey. They investigated monthly outdoor temperatures for five cities in Turkey. In this study, we have extended the mentioned studies (Ref. [11–13]) to 79 cities in Turkey. Also, the main difference of this investigation is to add hourly distribution concept to outdoor temperature calculation process. In this contribution, a new approach and demonstration method was proposed for heating and cooling degree-hours. We applied the proposed approach to determination of the annual, monthly and hourly temperature distribution trends in Turkey.

2. Analyzes

2.1. Determination of outdoor temperature distribution and degree-hour values

A temperature data set of 367,920 for each city was taken from the State Meteorology General Directorate in txt. file format. Those

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temperature data were transferred to a Microsoft office excel program for classification. A new programming was written in Matlab program for analyzing the classified temperature data. The Matlab program can read the data from the excel and calculate the annual, monthly and hourly distribution in percentage range at an interval of 1 °C. After determining the required temperature distribution in this range, it is transferred to hour based lapsed time (Fig. 1). Heating (*HDH*) or cooling (*CDH*) degree-hours values can be calculated using the hour based outdoor temperature distribution as follows:

$$HDH = \sum_{hours} (T_i - T_0)^+ \quad (1)$$

$$CDH = \sum_{hours} (T_0 - T_i)^+$$

where T_i and T_o indicate the indoor and outdoor temperatures, respectively. The '+' sign over the parenthesis in the equations indicates that only positive values are to be included in the calculation.

In the calculation, the hourly dry-bulb outdoor temperature data, based on the last 42 years and recorded by the Turkish State Meteorological Station, were used. Annual ambient temperature distribution was determined for the 79 cities in Turkey and categorized into eight different distribution groups (Fig. 2). In this analysis, we investigated the 79 cities for modeling purposes in spite of there are 81 cities in Turkey. We did not cover 2 cities in the calculation. Main reason for this is that the long term full data sets for two cities (Şırnak and Niğde) are not available in the Turkish State Meteorological Station. That is why we did not consider these cities (accounting for 1.019% of the total population of the country) for the calculation procedure. We assume that Turkey has 79 cities for modeling purposes'.

The annual ambient temperature distribution group for each city in Turkey is given in Table 1. *X* and *Y*-axes show the distribution and the outdoor temperature, respectively. In this analysis, the eight annual outdoor distribution trends were found in Turkey. Each country has different outdoor temperature characteristics. Different countries could be studied all over the world for determining their annual outdoor temperature distribution trends.

2.2. New demonstration concept

A new demonstration concept is introduced for standardization of degree-hour and outdoor temperature distribution. It contains five components, namely main body, month period (*MP*), time period (*TP*) and two temperature limits. The main body includes four components as follows: percentage (*P*), hour (*H*), cooling degree-hours (*CDH*) and heating degree-hours (*HDH*).

We can change four parameters, the month period (*MP*), the time period (*TP*), the highest (*HTL*) and the lowest temperature limit (*LTL*). Also we can find four values: the percentage, the time lapsed, the cooling and heating degree-hours for any month, time

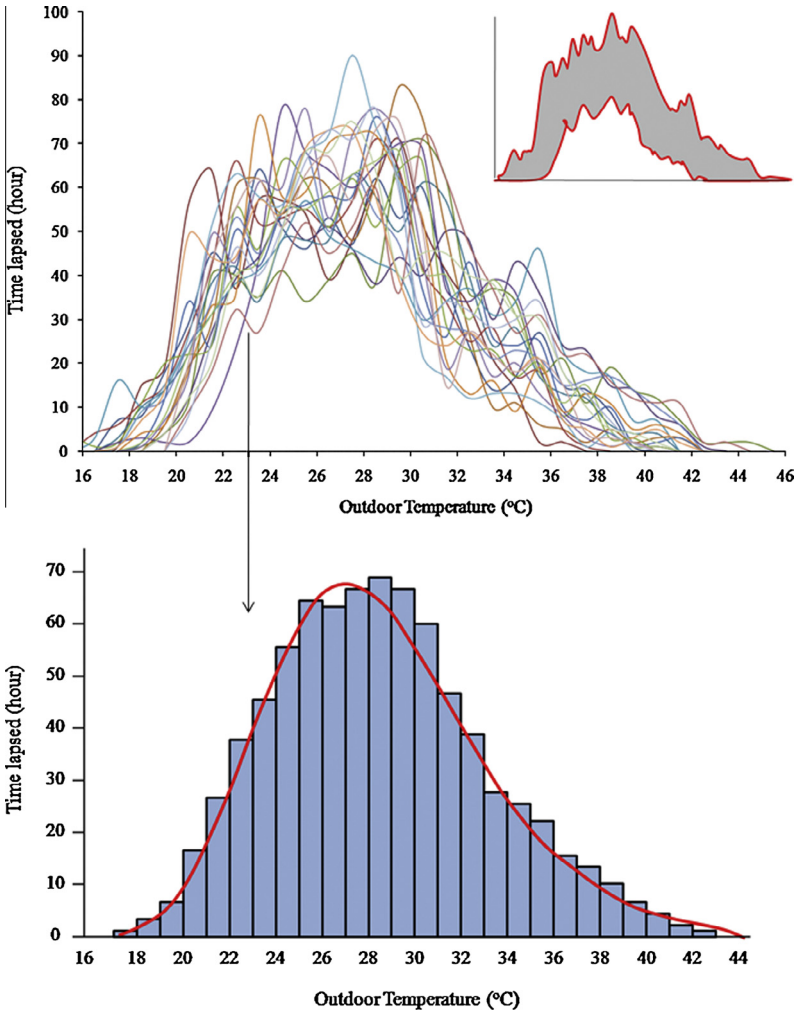

Fig. 1. Sample demonstration of outdoor temperature distribution determination for a month.