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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

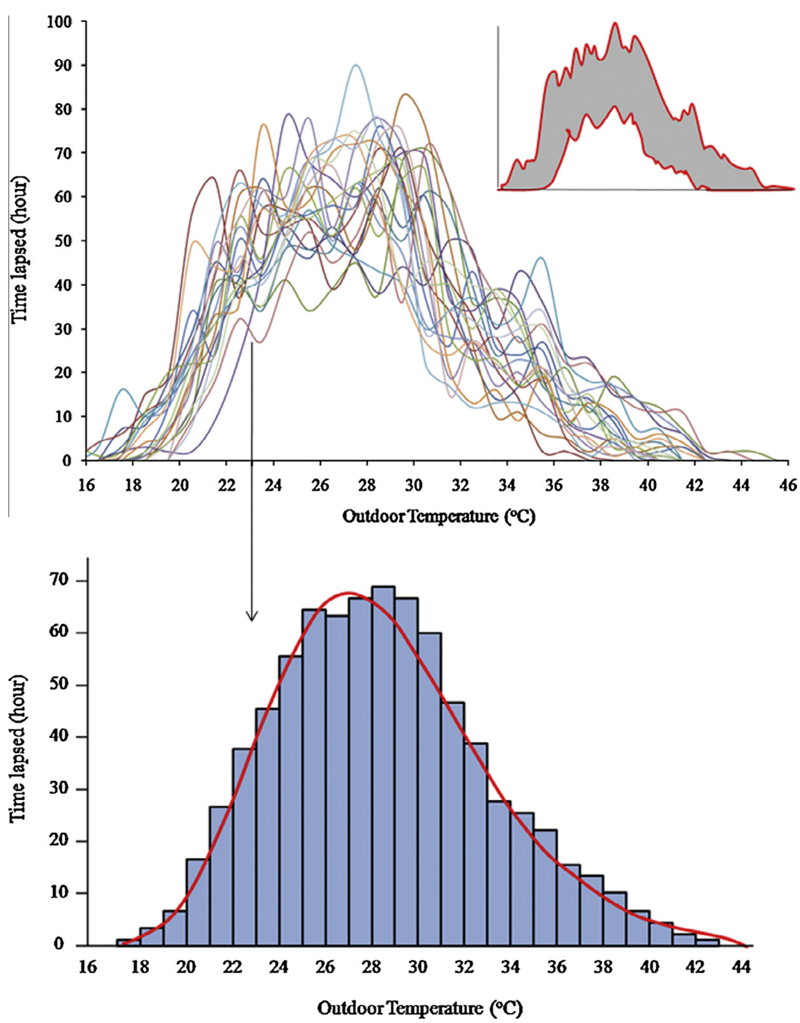


**Fig. 1.** Sample demonstration of outdoor temperature distribution determination for a month.

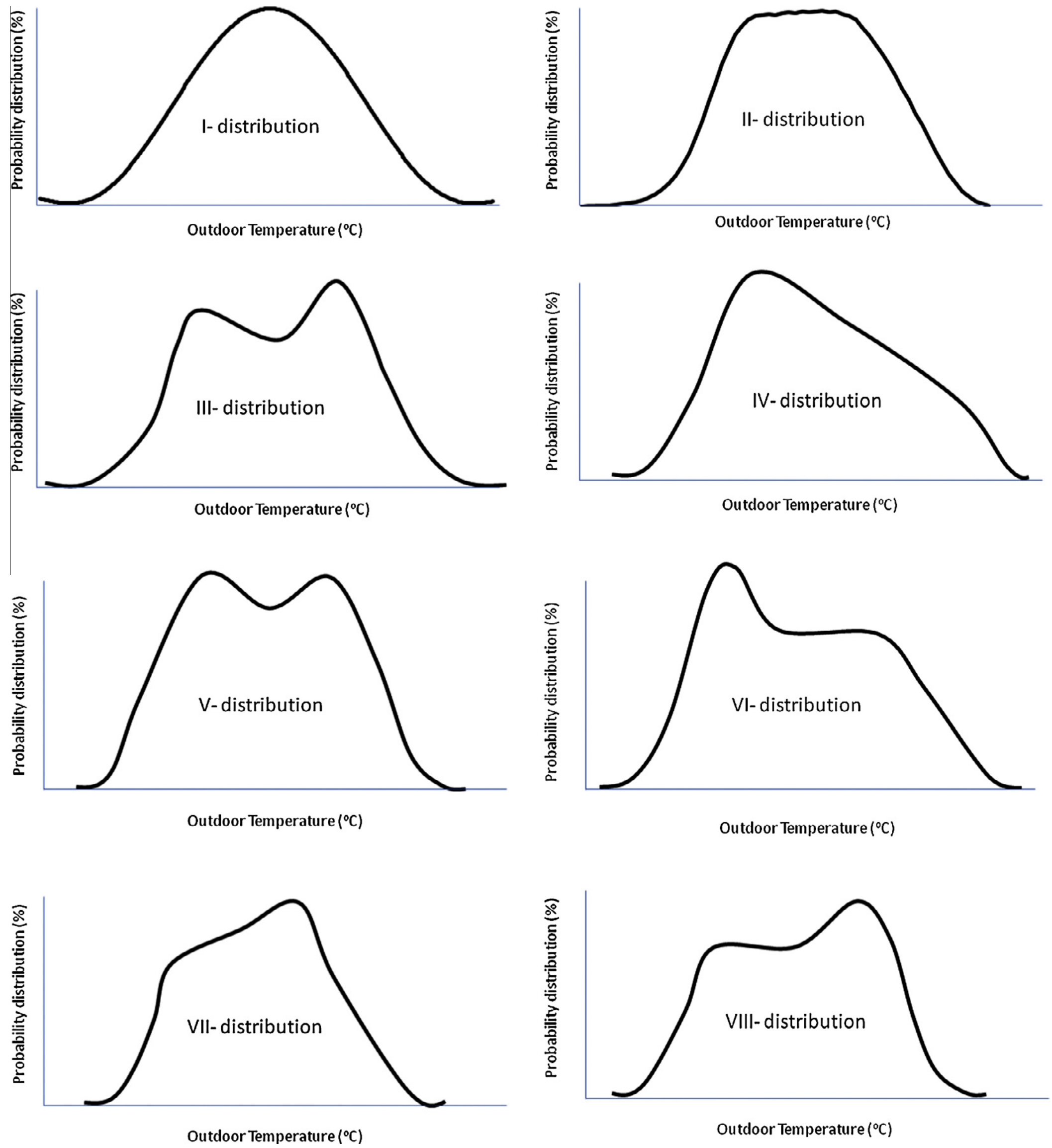


**Fig. 2.** Eight annual ambient temperature distribution trends.

**Table 1**
Annual ambient temperature distribution groups.

| Distribution groups | Cities |
|---|---|
| I | Afyon, Aksaray, Burdur, Çanakkale, Düzce, Erzurum, Isparta, Karaman, Kütahya, Nevşehir |
| II | Balıkesir, Bursa, Bartın, Erzincan, İstanbul, Konya, Sakarya, Samsun, Kırklareli, Kırşehir, Yalova, Yozgat |
| III | Ankara, Antakya, Antalya, Ardahan, Artvin, Amasya, Bayburt, Kars |
| IV | Aydın, Batman, Denizli, Diyarbakır, Uşak |
| V | Ağrı, Çankırı, Çorum, Giresun, Hakkâri, Iğdır, İzmir, K.Maraş, Malatya, Tekirdağ, Kastamonu, Kilis, Mardin, Ordu, Rize, Sinop, Trabzon |
| VI | Adıyaman, Bingöl, Bitlis, Elazığ, Gaziantep, Manisa, Ş.Urfa, Muğla, Muş, Siirt, Tunceli, Van |
| VII | Bilecik, Eskişehir, Gümüşhane, Karabük, Kocaeli, Sivas, Tokat, Zonguldak |
| VIII | Adana, Bolu, Edirne, Kayseri, Mersin, Kırıkkale, Osmaniye |

and ambient temperature limit. The new demonstration method is given by the following relations in this study:

$$ {}^{MP}_{TP}P^{HTL}_{LTL} \quad (2)$$

$$ {}^{MP}_{TP}H^{HTL}_{LTL} \quad (3)$$

$$ {}^{MP}_{TP}CDH^{HTL}_{LTL} \quad (4)$$

$$ {}^{MP}_{TP}HDH^{HTL}_{LTL} \quad (5)$$

The main part of the demonstration shows the percentage (*P*), the time lapsed (*H*), the cooling (*CDH*) and the heating degree-hours (*HDH*). A sample demonstration is given in Fig. 3 for the lapsed time between 15 and 22 °C ambient temperatures over a time period of 12:00 and 13:00 during the month of January. The abbreviations used are as follows: January (Jan), February (Feb),

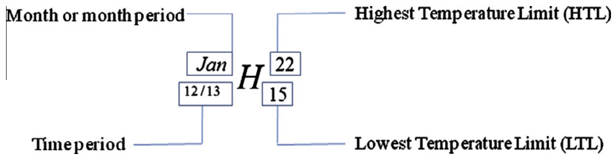


**Fig. 3.** Sample demonstration of the new concept.

March (Mar), April (Apr), May (May), June (Jun), July (Jul), August (Aug), September (Sept), October (Oct), November (Nov), December (Dec). Sample demonstrations and explanations are given in Table 2 for Eqs. (1)–(5).

### 2.3. Hourly and monthly temperature distribution

Space limitations prohibit showing the monthly distributions for all 79 cities in the analysis. A sample demonstration is given for the city of İzmir, which has the third highest population in Turkey. The lapsed time between any time intervals can be determined using the outdoor temperature distribution for a year. The annually-based time lapse for each outdoor temperature between 00:00 and 12:00 was determined and the data on the city of İzmir are given in Fig. 4. As can be seen from the figure, each time interval has a different distribution trend. Monthly-based lapsed time for each outdoor temperature can be calculated through the same method. A sample demonstration is given in Fig. 4 for the monthly-based lapsed time over a time interval of 12:00–13:00. Fig. 5 contains the January–June period for İzmir. The monthly and annual outdoor distribution is given in Fig. 6. As can be seen from the figure, the monthly outdoor temperature trends are very different than annual trends. Due to their wide variety, the monthly distribution trends were not classified.

To use the new demonstration concept and calculation method, the hourly, monthly and annually outdoor temperature distributions should be known. After determining the outdoor temperature distribution, the heating and cooling load can be easily calculated for any time interval in a year.

## 3. Determination of population-based outdoor temperature distribution

The annual outdoor temperature distribution for each city in Turkey was determined and thereby used to calculate the average annual outdoor temperature distribution for Turkey as a whole. The population of each city was taken into account. The calculation procedure of the population-based outdoor temperature distribution is given by the following equations:

$$
{}^{A}_{0/24}P_{country}{}^{LTLC+1}_{LTLC} = \sum_{1}^{n}\left[\left({}^{A}_{0/24}P_{city}(n)^{LTLC+1}_{LTLC}\right)\cdot\left(\frac{PPL_{city}(n)}{PPL_{country}}\right)\right]
$$

$$
{}^{A}_{0/24}P_{country}{}^{HTLC}_{HTLC-1} = \sum_{1}^{n}\left[\left({}^{A}_{0/24}P_{city}(n)^{HTLC}_{HTLC-1}\right)\cdot\left(\frac{PPL_{city}(n)}{PPL_{country}}\right)\right] \quad (6)
$$

where *LTLC* and *HTLC* represent the lowest and highest temperature limits for the investigated country; $PPL_{city}$ and $PPL_{country}$ are the populations of the city and country considered in the study, respectively. The lowest and highest temperature limits of the country can be found from the outdoor temperature distribution of each city. In order to illustrate how to use Eq. (6), the average annual outdoor temperature distribution is calculated for a sample country with three cities. The populations of each city ($PPL_{city}$) are 1,400,000, 1,200,000 and 600,000 while the population of the country ($PPL_{country}$) is 3,200,000. The annual outdoor temperature distributions of the three cities are given in Table 3. As can be seen from the table, the *LTLC* and *HTLC* values are −9 and 47 °C.

Sample calculation is conducted for a −6/−7 outdoor temperature range as follows:

$$
{}^{A}_{0/24}P_{country}{}^{-6}_{-7} = \sum_{1}^{3}\left[\left({}^{A}_{0/24}P_{city}(1)^{-6}_{-7}\right)\cdot\left(\frac{PPL_{city}(1)}{PPL_{country}}\right)+\left({}^{A}_{0/24}P_{city}(2)^{-6}_{-7}\right)\cdot\left(\frac{PPL_{city}(2)}{PPL_{country}}\right)+\left({}^{A}_{0/24}P_{city}(3)^{-6}_{-7}\right)\cdot\left(\frac{PPL_{city}(3)}{PPL_{country}}\right)\right]
$$

$$
{}^{A}_{0/24}P_{country}{}^{-6}_{-7} = \sum_{1}^{3}\left[(0.017895133)\cdot\left(\frac{1,400,000}{3,200,000}\right)+(0.002236426)\cdot\left(\frac{1,200,000}{3,200,000}\right)+(0.007202399)\cdot\left(\frac{600,000}{3,200,000}\right)\right]
$$

$$
{}^{A}_{0/24}P_{country}{}^{-6}_{-7} = \sum_{1}^{3}[(0.017895133)\cdot(0.4375)+(0.002236426)\cdot(0.3750)+(0.007202399)\cdot(0.1875)]
$$

**Table 2**
Sample demonstrations and explanations of the new demonstration concept.

| Demonstration | Explanation | Time period | Month period | Highest temperature limit | Lowest temperature limit |
|---|---|---|---|---|---|
| ${}^{Jun/Aug}_{10/16}P^{HTL}_{22}$ | Percentage (%) | Between 10:00 and 16:00 | Between June and August | HTL | 22 °C |
| ${}^{A}_{10/17}P^{22}_{LTL}$ | Percentage (%) | Between 10:00 and 17:00 | Annual | 22 °C | LTL |
| ${}^{A}_{0/24}P^{30}_{20}$ | Percentage (%) | During the day | Annual | 30 °C | 20 °C |
| ${}^{Jan/Apr}_{07/17}H^{18}_{LTL}$ | Time lapsed (h) | Between 07:00 and 17:00 | Between January and April | 18 °C | LTL |
| ${}^{Apr}_{10/20}H^{25}_{LTL}$ | Time lapsed (h) | Between 10:00 and 20:00 | April | 25 °C | LTL |
| ${}^{Apr}_{10/18}H^{HTL}_{24}$ | Time lapsed (h) | Between 10:00 and 18:00 | April | HTL | 25 °C |
| ${}^{Jun/Aug}_{10/16}CDH^{HTL}_{22}$ | Cooling degree-hours | Between 10:00 and 16:00 | Between June and August | HTL | 22 °C Base temperature |
| ${}^{A}_{10/16}CDH^{HTL}_{22}$ | Cooling degree-hours | Between 10:00 and 16:00 | Annual | HTL | 22 °C Base temperature |
| ${}^{A}_{0/24}CDH^{HTL}_{22}$ | Cooling degree-hours | During the day | Annual | HTL | 22 °C Base temperature |
| ${}^{A}_{0/24}HDH^{19}_{LTL}$ | Heating degree-hours | During the day | Annual | 19 °C Base temperature | LTL |
| ${}^{Jan}_{6/18}HDH^{19}_{LTL}$ | Heating degree-hours | Between 06:00 and 18:00 | January | 19 °C Base temperature | LTL |
| ${}^{Jan/Apr}_{6/18}HDH^{19}_{LTL}$ | Heating degree-hours | Between 06:00 and 18:00 | Between January and April | 19 °C Base temperature | LTL |

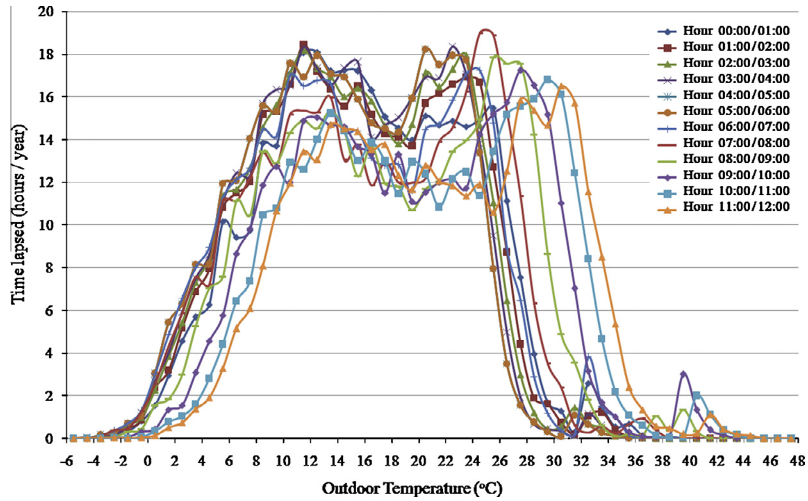


**Fig. 4.** Distribution of annually-based time lapsed between 00:00 and 12:00 for İzmir.

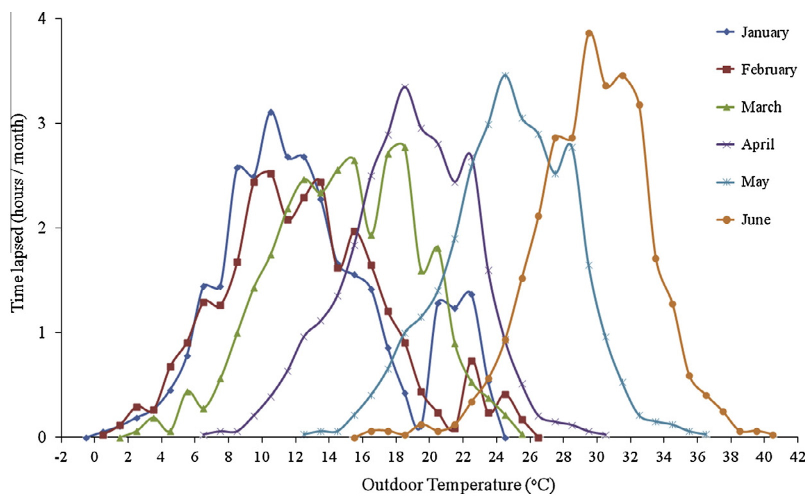


**Fig. 5.** Monthly based lapsed time for 12:00–13:00 time interval in İzmir.

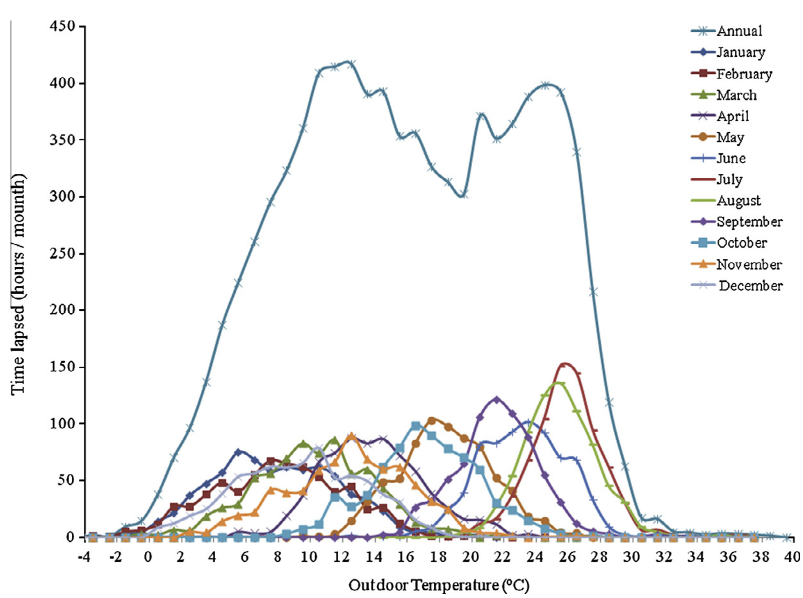


**Fig. 6.** Monthly and annual lapsed time distribution for İzmir.

**Table 3**
Annual outdoor temperature distributions of three cities.

| Temp. range | Annual outdoor temperature distribution (%) | | | Population rate (–) | | | ${}_{0/24}^{A}P_{country}{}_{-9}^{47}$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | City-1 | City-2 | City-3 | | | | | | | |
| −9/−8 | 0.003840954 | – | – | 0.4375 | 0.375 | 0.1875 | 0.001680 | – | – | 0.001680 |
| −8/−7 | 0.008664888 | – | 0.004998770 | 0.4375 | 0.375 | 0.1875 | 0.003791 | – | 0.000937 | 0.004728 |
| −7/−6 | 0.017895133 | 0.002236426 | 0.007202399 | 0.4375 | 0.375 | 0.1875 | 0.007829 | 0.000839 | 0.001350 | 0.010018 |
| −6/−5 | 0.042585971 | 0.009543531 | 0.020887771 | 0.4375 | 0.375 | 0.1875 | 0.018631 | 0.003579 | 0.003916 | 0.026127 |
| −5/−4 | 0.067838894 | 0.026871189 | 0.051112574 | 0.4375 | 0.375 | 0.1875 | 0.029680 | 0.010077 | 0.009584 | 0.049340 |
| −4/−3 | 0.136957448 | 0.051131148 | 0.105808710 | 0.4375 | 0.375 | 0.1875 | 0.059919 | 0.019174 | 0.019839 | 0.098932 |
| −3/−2 | 0.222788666 | 0.125788139 | 0.167021232 | 0.4375 | 0.375 | 0.1875 | 0.097470 | 0.047171 | 0.031316 | 0.175957 |
| −2/−1 | 0.506043540 | 0.234299317 | 0.295015586 | 0.4375 | 0.375 | 0.1875 | 0.221394 | 0.087862 | 0.055315 | 0.364572 |
| −1/0 | 0.863757122 | 0.381553328 | 0.460270271 | 0.4375 | 0.375 | 0.1875 | 0.377894 | 0.143082 | 0.086301 | 0.607277 |
| 0/1 | 1.578280515 | 0.780291620 | 0.811078770 | 0.4375 | 0.375 | 0.1875 | 0.690498 | 0.292609 | 0.152077 | 1.135184 |
| 1/2 | 2.011935357 | 1.213366903 | 1.234515249 | 0.4375 | 0.375 | 0.1875 | 0.880222 | 0.455013 | 0.231472 | 1.566706 |
| 2/3 | 2.326599826 | 1.762383855 | 1.518499471 | 0.4375 | 0.375 | 0.1875 | 1.017887 | 0.660894 | 0.284719 | 1.963500 |
| 3/4 | 2.820349774 | 2.440913534 | 2.020237357 | 0.4375 | 0.375 | 0.1875 | 1.233903 | 0.915343 | 0.378795 | 2.528040 |
| 4/5 | 3.240402551 | 2.947926248 | 2.500511079 | 0.4375 | 0.375 | 0.1875 | 1.417676 | 1.105472 | 0.468846 | 2.991994 |
| 5/6 | 3.555959539 | 3.682422238 | 3.210411862 | 0.4375 | 0.375 | 0.1875 | 1.555732 | 1.380908 | 0.601952 | 3.538593 |
| 6/7 | 3.725959910 | 4.175801942 | 3.551329107 | 0.4375 | 0.375 | 0.1875 | 1.630107 | 1.565926 | 0.665874 | 3.861907 |
| 7/8 | 4.045649259 | 4.544494992 | 3.761175483 | 0.4375 | 0.375 | 0.1875 | 1.769972 | 1.704186 | 0.705220 | 4.179378 |
| 8/9 | 3.962736105 | 4.630967975 | 3.885982656 | 0.4375 | 0.375 | 0.1875 | 1.733697 | 1.736613 | 0.728622 | 4.198932 |
| 9/10 | 3.640948414 | 4.264235256 | 3.490673519 | 0.4375 | 0.375 | 0.1875 | 1.592915 | 1.599088 | 0.654501 | 3.846504 |
| 10/11 | 3.867960905 | 4.411175486 | 3.602421291 | 0.4375 | 0.375 | 0.1875 | 1.692233 | 1.654191 | 0.675454 | 4.021878 |
| 11/12 | 3.816318941 | 4.222448880 | 3.166499206 | 0.4375 | 0.375 | 0.1875 | 1.669640 | 1.583418 | 0.593719 | 3.846776 |
| 12/13 | 4.017049666 | 4.172771512 | 3.052221156 | 0.4375 | 0.375 | 0.1875 | 1.757459 | 1.564789 | 0.572291 | 3.894540 |
| 13/14 | 3.937945918 | 4.224887576 | 2.882704919 | 0.4375 | 0.375 | 0.1875 | 1.722851 | 1.584333 | 0.540507 | 3.847691 |
| 14/15 | 4.036157103 | 4.261504875 | 2.749802887 | 0.4375 | 0.375 | 0.1875 | 1.765819 | 1.598064 | 0.515588 | 3.879471 |
| 15/16 | 4.148264231 | 4.317474489 | 2.635700313 | 0.4375 | 0.375 | 0.1875 | 1.814866 | 1.619053 | 0.494194 | 3.928112 |
| 16/17 | 4.266482157 | 4.159250425 | 2.590153444 | 0.4375 | 0.375 | 0.1875 | 1.866586 | 1.559719 | 0.485654 | 3.911959 |
| 17/18 | 4.218597672 | 4.263961330 | 2.450609281 | 0.4375 | 0.375 | 0.1875 | 1.845636 | 1.598985 | 0.459489 | 3.904111 |
| 18/19 | 4.314600542 | 4.599393166 | 2.516892205 | 0.4375 | 0.375 | 0.1875 | 1.887638 | 1.724772 | 0.471917 | 4.084327 |
| 19/20 | 3.965767154 | 4.397463591 | 2.390585672 | 0.4375 | 0.375 | 0.1875 | 1.735023 | 1.649049 | 0.448235 | 3.832307 |
| 20/21 | 4.164672555 | 4.563893564 | 2.783158549 | 0.4375 | 0.375 | 0.1875 | 1.822044 | 1.711460 | 0.521842 | 4.055347 |
| 21/22 | 3.717182125 | 4.219362591 | 2.691537879 | 0.4375 | 0.375 | 0.1875 | 1.626267 | 1.582261 | 0.504663 | 3.713192 |
| 22/23 | 3.353646990 | 3.943199975 | 2.782908920 | 0.4375 | 0.375 | 0.1875 | 1.467221 | 1.478700 | 0.521795 | 3.467716 |
| 23/24 | 2.917685106 | 3.633635827 | 2.713058636 | 0.4375 | 0.375 | 0.1875 | 1.276487 | 1.362613 | 0.508698 | 3.147799 |
| 24/25 | 2.576704880 | 3.063328428 | 2.841353513 | 0.4375 | 0.375 | 0.1875 | 1.127308 | 1.148748 | 0.532754 | 2.808810 |
| 25/26 | 2.232721965 | 2.659497774 | 2.946535245 | 0.4375 | 0.375 | 0.1875 | 0.976816 | 0.997312 | 0.552475 | 2.526603 |
| 26/27 | 1.894472913 | 1.716789875 | 2.865551729 | 0.4375 | 0.375 | 0.1875 | 0.828832 | 0.643796 | 0.537291 | 2.009919 |
| 27/28 | 1.630357676 | 1.052015662 | 2.817050291 | 0.4375 | 0.375 | 0.1875 | 0.713281 | 0.394506 | 0.528197 | 1.635984 |
| 28/29 | 1.335965502 | 0.479577360 | 2.819733796 | 0.4375 | 0.375 | 0.1875 | 0.584485 | 0.179842 | 0.528700 | 1.293027 |
| 29/30 | 0.951022532 | 0.236603476 | 2.583737026 | 0.4375 | 0.375 | 0.1875 | 0.416072 | 0.088726 | 0.484451 | 0.989249 |
| 30/31 | 0.719821069 | 0.082231930 | 2.523568175 | 0.4375 | 0.375 | 0.1875 | 0.314922 | 0.030837 | 0.473169 | 0.818928 |
| 31/32 | 0.441868280 | 0.021503043 | 2.263641540 | 0.4375 | 0.375 | 0.1875 | 0.193317 | 0.008064 | 0.424433 | 0.625814 |
| 32/33 | 0.294415509 | 0.011725750 | 2.077371285 | 0.4375 | 0.375 | 0.1875 | 0.128807 | 0.004397 | 0.389507 | 0.522711 |
| 33/34 | 0.169970878 | 0.004970318 | 1.880705365 | 0.4375 | 0.375 | 0.1875 | 0.074362 | 0.001864 | 0.352632 | 0.428858 |
| 34/35 | 0.100573103 | 0.002135137 | 1.684471139 | 0.4375 | 0.375 | 0.1875 | 0.044001 | 0.000801 | 0.315838 | 0.360640 |
| 35/36 | 0.057812033 | 0.000723380 | 1.577364285 | 0.4375 | 0.375 | 0.1875 | 0.025293 | 0.000271 | 0.295756 | 0.321320 |
| 36/37 | 0.030370277 | 0.002135137 | 1.418979148 | 0.4375 | 0.375 | 0.1875 | 0.013287 | 0.000801 | 0.266059 | 0.280146 |
| 37/38 | 0.015972689 | 0.001400090 | 1.210004107 | 0.4375 | 0.375 | 0.1875 | 0.006988 | 0.000525 | 0.226876 | 0.234389 |
| 38/39 | 0.011994101 | – | 0.905146263 | 0.4375 | 0.375 | 0.1875 | 0.005247 | – | 0.169715 | 0.174962 |
| 39/40 | 0.006323738 | – | 0.639817615 | 0.4375 | 0.375 | 0.1875 | 0.002767 | – | 0.119966 | 0.122732 |
| 40/41 | 0.003150202 | – | 0.436687948 | 0.4375 | 0.375 | 0.1875 | 0.001378 | – | 0.081879 | 0.083257 |
| 41/42 | 0.001750112 | – | 0.234048312 | 0.4375 | 0.375 | 0.1875 | 0.000766 | – | 0.043884 | 0.044650 |
| 42/43 | 0.001400090 | – | 0.120874403 | 0.4375 | 0.375 | 0.1875 | 0.000613 | – | 0.022664 | 0.023276 |
| 43/44 | 0.000350022 | – | 0.034313863 | 0.4375 | 0.375 | 0.1875 | 0.000153 | – | 0.006434 | 0.006587 |
| 44/45 | – | – | 0.010500672 | 0.4375 | 0.375 | 0.1875 | – | – | 0.001969 | 0.001969 |
| 45/46 | – | – | 0.001050067 | 0.4375 | 0.375 | 0.1875 | – | – | 0.000197 | 0.000197 |
| 46/47 | – | – | 0.000700045 | 0.4375 | 0.375 | 0.1875 | – | – | 0.000131 | 0.000131 |

$$
{}_{0/24}^{A}P_{country}{}_{-7}^{-6} = \sum_{1}^{3}[(0.007829) + (0.000839) + (0.001350)] = 0.10018\%
$$

In this study, the average outdoor temperature distribution for Turkey was calculated and given in Fig. 7 using the new calculation concept. As can be seen from this figure, the highest lapsed time for Turkey occurs between an outdoor temperature range of 10 and 11 °C. The average annual outdoor temperature distribution for Turkey is similar to distribution-I given in Fig. 1.

## 4. Building heating and cooling loads

Building heating and cooling loads mainly depend on outdoor temperature, solar radiation, moisture content, wind speed and direction. Outdoor, solar, moisture and wind speed distribution should be known for accurate building heating or cooling load calculations. Our resource team investigates the mentioned four distribution trends for each city in Turkey. This study is one part of the data set preparation for the national building energy analyzes program. The data set for outdoor temperature distributions for Turkey was completed. Solar, moisture and wind speed distribution were completed with a rate of 35% while it is also planned

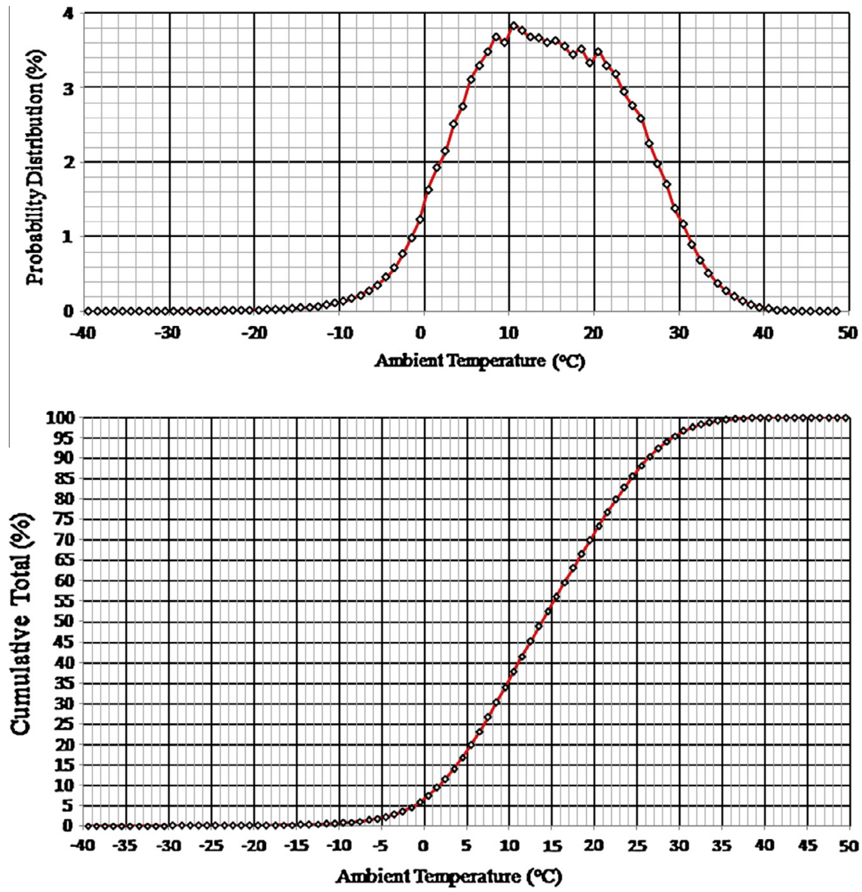


**Fig. 7.** Population-based outdoor temperature distribution in Turkey.

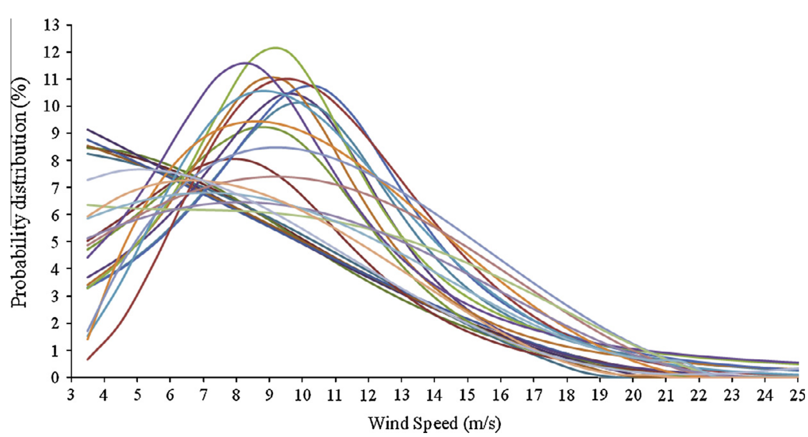


**Fig. 8.** Hourly wind speed distribution for a sample month.

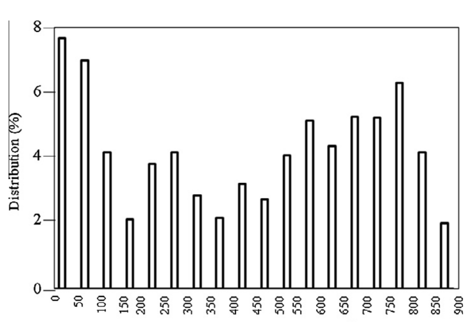


**Fig. 9.** Hourly global solar radiation distribution for a sample month.

to complete all data set within the 3 years. After determination of four distributions, the national building energy analyzes program will be designed. A sample demonstration of hourly solar radiation and wind speed distribution is given in Figs. 8 and 9.

## 5. Conclusions

We have formulated the probable hourly, monthly and annual outdoor temperature distributions to simplify the calculation of cooling and heating degree-hour in this study. We have also developed a new approach and demonstration method, which simplifies the gathering of information for any user, who wants to undertake detailed energy calculations. This method can be directly used by designers, engineers and energy managers for practical applications.

Some concluding remarks of the study may be listed as follows:

(a) Outdoor temperature distributions did not have a similar distribution pattern for each city. However, since the distribution had a stable trend, the similar trends were grouped together. Cities having similar distributions were categorized into eight different groups and were given in figures.
(b) An hourly and monthly outdoor temperature distribution concept was proposed.
(c) A population-based country outdoor temperature distribution concept was proposed.
(d) A new demonstration concept was introduced for standardization of the degree-hour and outdoor temperature distribution.
(e) This is the first practical method available in the literature for determination of the probable cooling degree-hours values for both each month and part-time operating buildings.

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