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Research Article

The effects of different typical meteorological year data on the heating and cooling demand of buildings: Case study of Turkiye

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ABSTRACT

The most important parameter which affects the results of building energy analysis is the weather data and it can be obtained by different methods for the same location. Although lots of studies have been conducted for Türkiye, it was seen that the impact of different weather data for the same location has never been investigated. The aims of this study were to compare the heating and cooling demands of the buildings with respect to different weather files. Building loads were calculated using five different meteorological source data. Calculations are made for eight cities which represent heating and cooling dominated climates of Türkiye. Calculation procedure of internal heat gain was explained in detail. All simulations were performed using Energyplus v9.2. The findings of the comparison showed that although some results are similar to each other for some weather files, they could have great variances in the energy analysis also. A common missing meteorological data-filling algorithm may be developed in order to reduce the deviations in energy analysis results.

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INTRODUCTION

Meteorological data that are widely used in engineering calculations such as heating, cooling, ventilation and air conditioning is very crucial parameters. It is necessary to obtain climate data related to the location of the analyzed building for performing energy analysis. In the absence of meteorological data representing the climatic conditions, it is not possible to conduct an appropriate energy analysis that consider heating, cooling, and lighting loads. Because this data is very important and gives necessary information while creating the thermal balance of the building according to the changing climatic conditions and determining

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the boundary conditions which affect the working order of the equipment used in the building such as heating, cooling or ventilation. Ideally, the usage of real climate data for the exact location of each building is the best in order to reflect the effects of all local conditions. However, it is not possible to access this data separately for each building. For this reason, the meteorological data is created by using the long-term data at the meteorological stations that are located closest to the building under inspection. In this procedure, a year is formed which represents the conditions that the building will be exposed during its life cycle. This representative year can be generated by several methods and named such as typical meteorological year, test reference year. Each technique possesses different importance on meteorological parameters, thus typical annual data may differ from each other.

When the reports on world energy consumption are analyzed, three main factors stand out like industry, transportation and building sector and each of them has approximately the same amount of energy consumption [1]. Therefore, the role of buildings throughout the world is significant [2]. A large division of the energy consumed for heating and cooling systems and the determination of their capacities is also based on climatic conditions.

In this study, typical meteorological year data files created with different weight coefficients and methods for different cities of Türkiye were investigated and energy analyzes of a building have been conducted using related data. Influences of various meteorological data on thermal energy need of the building were evaluated. Before the energy analysis of building is done, all the necessary information and other parameters were explained in detail. In addition, the building was modeled with BepTr building energy performance software according to the Turkish national calculation method and the results were compared [3].

LITERATURE REVIEW

The meteorological data required for building energy analysis can be created by different methods using the long-term meteorological data of the location as mentioned before and the technique, also known as the SandiaMethod developed by Hall et al. is one of the most common procedures. In this method, meteorological data fileswhich are called Typical Meteorological Year (TMY) are prepared with statistical methods, and they consist of atotal of 8760 hours of data. While creating a TMY, the typical months can be selected from the months of differentyears and calculations are based on daily average of meteorological data which are also obtained from hourly average data When determining the Typical Meteorological Year (TMY), the coefficients called FS coefficients are calculated for each meteorological parameter according to a statistical method called Finkelstein-Schafer [4]. Different weights are assigned to each meteorological parameter according to its importance. The weighted sum of all parameters for the considered month is calculated and all months are ranked in ascending order. can be determined by three ways. The first technique is common and known as the Sandia Method which uses the persistent data for selection. Persistency criteria is mainly based on mean dry bulb temperature and daily global horizontal radiation data in terms of frequency and run length [5]. In the second technique, candidate months are scored according to a statistical method known as root mean square deviation (RMSD) with long-term data, and the month with the highest score can be suitable for TMY [6-8]. In the last technique, some researchers designate the month simply by the lowest weighted sum of TMY without any further calculations [9-11]. From the point of view of the energy analysis of buildings by some researchers, it is stated that after the candidate month is ranked according to the weighted sum value, there is no evidence that the typical month selection process is more useful by moving on to a second stage [12, 13].

When the current literature is regarded, there are differences in the weight coefficients (WC) which are used for calculating the weighted sum of meteorological parameters. In a study conducted by the American National Renewable Energy Laboratory (NREL), WCs in Sandia Method were changed, and direct normal radiation was added to weighting indexes. These new findings were published as TMY2 with updated meteorological data [14]. TMY3 which contained more up-to-date data and used more meteorology stations was published after TMY2. The same weightings were mentioned in TMY3 as in TMY2 [15]. TMY2 and TMY3 are generally known as TMY and are widely utilized by researchers. International Weather for Energy Calculations (IWEC) is one of the other technique. It is the result of ASHRAE Research Project 1015. Determining typical years is the same as TMY, but the weight coefficients are varied [16].

Considering weather data used by researchers, it has been realized that the data files generated by the German company –Meteonorm- are widely exploited. Meteonorm provides data from more than 8000 meteorology stations globally and creates weather files through the data of solar radiation via Meteosat Second Generation (MSG) satellite and other data from ground stations. Data sets between 1981-1990 and 1991-2010 are used for solar radiation and data sets between 1961-1990 and 2000-2009 are used for other meteorological parameters. The radiation and temperature data have been constantly updated since 2010 and weather files which are formed by TMY method are available for almost all of the provinces of Türkiye in the database of the firm [17]. Energyplus is a free building energy analysis software widely used worldwide and supported by the American Energy Division. IWEC method was used for forming typical year data. This software supplies weather data files for many locations around the world, however they are limited for Türkiye [18]. Crawley and

Lawrie have constituted meteorological data files by TMY method using the data provided by the National Centers for Environmental Information (NCEI) which is affiliated with the American National Oceanic and Atmospheric Administration (NOAA) for all provinces of Türkiye [19]. There have been over 35,000 weather stations in the database of the American NCEI since 1901 and currently, the number of active stations is over 14,000 [20]. A continuous improvement process has been carried out in the database of meteorological data by the missing data filling algorithms and the first and second versions were published in 2001 and 2003 respectively. After 2003, perpetual updates have been available [21].

Studies focused on TMY in Türkiye are insufficient and hence, there is gap in the literature. In fact, Ecevit et al. have generated TMY files only for Ankara province using the climate data between 1979-1999 [22] and the results have presented limited information due to basing on only one town. Üner and İleri prepared TMY data for 23 provinces of Türkiye with the aid of climate information from 1990 to 1996 [23] and findings indicated that the data in a short time interval (7 years) affected negatively the reliability of TMY data which can fundamentally represent the long term outcomes. The most comprehensive study which included 81 cities of Türkiye was performed by Pusat and Ekmekçi within this context [24]. Generated TMY files predicated on the data that started from 1989 to different end dates (averagely 19 years) and obtained from the General Directorate of Meteorology for every province. While selecting typical meteorological month, weighted sums were calculated, and a second selection procedure was not applied. It was observed that, the WCs by Pusat and Ekmekçi were the same as the WCs by BepTr Turkish national calculation method. However, similar results did not appear by the methods of TMY and IWEC due to using relative humidity instead of dew point temperature. However, unlike TMY and IWEC methods, relative humidity is used as WC instead of dew point temperature by Pusat and Ekmekçi. WCs can be seen in Table 1 [3]. Various researchers have also used the relative humidity in TMY studies [7, 8, 25, 26], however, Sepulveda et al. stated that more accurate results could be obtained when dew point temperature was selected [27]. Different weather files valid for Türkiye were investigated and files provided by Energyplus and Meteonorm were chosen by Ganiç [28]. Atmaca and Yılmaz have used Energyplus meteorological data and revised the temperature, humidity and wind parameters in files of BepTr [29]. Similarly, in the paper of Kalaycıoğlu, modified BepTr files have been used [30]. Weather files of Energyplus also have been used by Solmaz et al. [31] and Dino and Akgül [32].

MATERIAL AND METHOD

Meteorological Data

In the present study, five different weather files were accepted as source data files for energy analysis. The first one was created by Crawley and Lawrie (TmyCL) [19] and the other (TmyTur) was formed by Pusat et al. [33]. In addition, files from Meteonorm and Energyplus (E+, only available for 3 provinces) were also utilized. Besides, the building under inspection has been analyzed by BepTr Turkish building energy performance software with its own weather data. WCs for different meteorological data files were given in Table 1.

Degree day regions and station numbers were given in Table 2 according to TS 825 [34] standard and the World Meteorological Organization station numbers, respectively. Heating degree days (HDD) and cooling degree

Table 1. Different WCs in Literature

Parameter		*WCs*			
		TMY [14]	*IWEC [16]*	*TmyTur [33]*	*BepTr [3]*
Dry Bulb Temperature	*Maximum*	*5/100*	*5/100*	*5/100*	*5/100*
	Mean	*5/100*	*30/100*	*30/100*	*30/100*
	Minimum	*10/100*	*5/100*	*5/100*	*5/100*
Dew Point Temperature	*Maximum*	*5/100*	*2.5/100*	-	-
	Mean	*5/100*	*5/100*	-	-
	Minimum	*10/100*	*2.5/100*	-	-
Wind Speed	*Mean*	*5/100*	*5/100*	*5/100*	*5/100*
	Maximum	*5/100*	*5/100*	*5/100*	*5/100*
Solar Radiation	*Global Radiation*	*25/100*	*40/100*	*40/100*	*40/100*
	Direct Radiation	*25/100*	-	-	-
Relative Humidity		-	-	*10/100*	*10/100*

Table 2. Cities and meteorology stations

Climate Region	*Province*	*HDD*	*CDD*	*E+*	*Meteonorm*	*TmyCL*	*TmyTur*	*BepTr*
		(Tb=18oC)						
1	*Izmir*	*1080*	*1410*	*172180*	*172180*	*172180*	*172200*	*172200*
2	*Istanbul*	*1492*	*944*	*170600*	*170600*	*170600*	*170620*	*170620*
	Canakkale	*1646*	*915*	*-*	*171120*	*171120*	*171120*	*171120*
	Mugla	*1870*	*1058*	*-*	*172920*	*172920*	*172920*	*172920*
	Trabzon	*1438*	*818*	*-*	*170380*	*170380*	*170380*	*170380*
3	*Ankara*	*2958*	*578*	*171280*	*171280*	*171280*	*171300*	*171300*
	Konya	*2662*	*727*	*-*	*172440*	*172440*	*172440*	*172440*
4	*Hakkari*	*2790*	*1047*	*-*	*172850*	*172850*	*172850*	*172850*

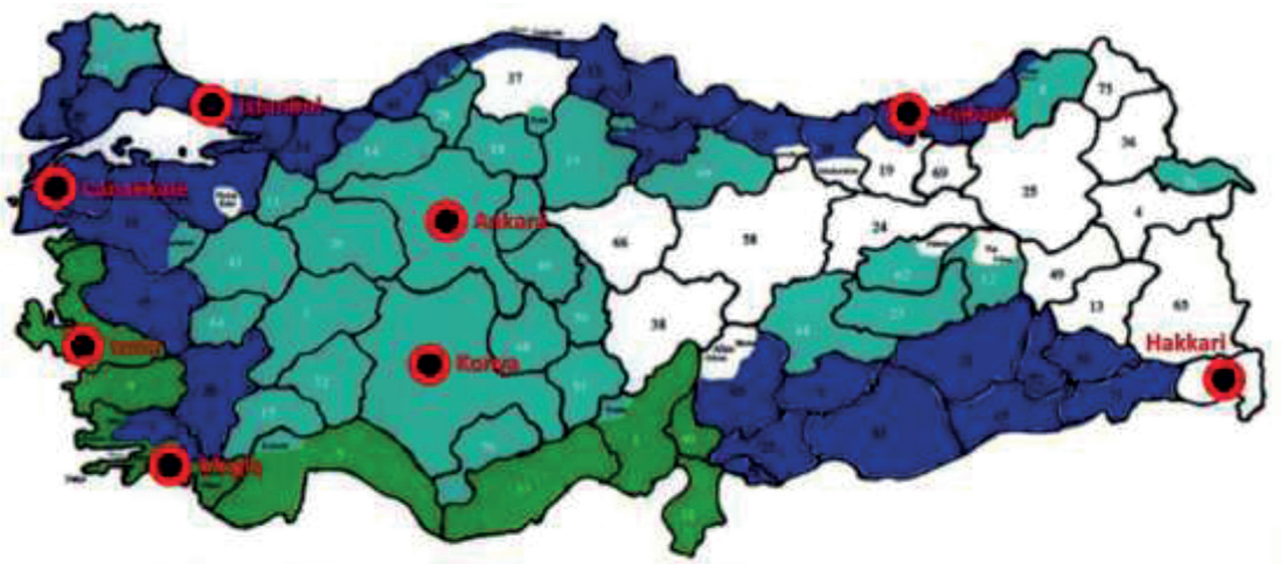

Figure 1. Location of provinces [34].

days (CDD) of the stations have also been given in Table 2 [35]. Although the station numbers were explicitly given by Energyplus, Meteonorm, Crawley and Lawrie, Pusat and Ekmekçi, the station numbers used in the BepTr software were tried to be determined through the station coordinates which were given in the file content.

Even though the provinces subjected to the study were shown in Table 2 according to Degree Day regions of TS 825 standard, they were also classified according to one of the most common climate classifications in the world, the Köppen-Geiger. In Köppen-Geiger classification [36]. In Köppen-Geiger classification, there are 5 basic climate types (A, B, C, D, E) with respect to monthly temperature and precipitation. Climate types are represented by a 3-letter code. The first, second and third letter represents the basic climate type, the precipitation feature and the temperature feature respectively. Selected provinces represents diverse climatic characteristics of Türkiye. According to Köppen-Geiger classification, İstanbul, Canakkale, Izmir and Mugla are classified as Csa, Ankara and Konya are classified as Bsk, Trabzon is classified as Cfa and Hakkari is classified as Dsb [37]. Location of the investigated provinces are shown in Figure 1.

Table 3 indicates the typical meteorological months of particular years (which are created by Crawley and Lawrie, Energyplus, and Pusat and Ekmekçi.) versus both provinces and data sources. When the Meteonorm and BepTr data files were examined, information about selected years could not be found. The data provided by Pusat and Ekmekçi. started mostly from 1989, but the end years were variable

Table 3. Provinces and Typical Meteorological Months

Province	*Data Source*	*Typical Meteorological Months*											
		Jan.	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sep.*	*Oct.*	*Nov.*	*Dec.*
Istanbul	*TmyCL*	*1991*	*1979*	*1977*	*2004*	*2002*	*2006*	*1963*	*1989*	*1998*	*2000*	*2016*	*1978*
	E+	*1991*	*1983*	*1992*	*1985*	*1997*	*1993*	*1990*	*1993*	*1986*	*1982*	*1992*	*1995*
	TmyTur	*2004*	*2005*	*2006*	*2005*	*1997*	*1996*	*1995*	*2002*	*2006*	*1999*	*2001*	*2003*
Ankara	*TmyCL*	*2007*	*2011*	*1983*	*2010*	*2002*	*1981*	*1975*	*1996*	*1995*	*2016*	*2017*	*1983*
	E+	*1991*	*1990*	*1982*	*1990*	*1988*	*1990*	*1989*	*1993*	*1982*	*1987*	*1994*	*1983*
	TmyTur	*1991*	*1990*	*1995*	*1992*	*1994*	*2004*	*1999*	*1993*	*2005*	*1997*	*1997*	*1995*
Izmir	*TmyCL*	*1982*	*1974*	*2011*	*1977*	*1955*	*1987*	*1955*	*1988*	*1974*	*2016*	*1979*	*1982*
	E+	*1984*	*1988*	*1986*	*1982*	*1984*	*1982*	*1984*	*1982*	*1984*	*1986*	*1982*	*1982*
	TmyTur	*2004*	*2006*	*1993*	*1990*	*1990*	*1997*	*1997*	*1989*	*2006*	*2006*	*2001*	*2003*
C.kale	*TmyCL*	*1982*	*1988*	*1977*	*1979*	*1978*	*2000*	*2014*	*1985*	*1974*	*1973*	*1968*	*1973*
	TmyTur	*2002*	*1991*	*1992*	*2002*	*1990*	*1997*	*1990*	*1991*	*1998*	*2002*	*1998*	*1989*
Hakkari	*TmyCL*	*2015*	*2016*	*2017*	*2014*	*2014*	*2017*	*2018*	*2016*	*2014*	*2015*	*2015*	*2019*
	TmyTur	*1990*	*1995*	*1998*	*2000*	*2005*	*1994*	*2002*	*2000*	*2005*	*1997*	*2005*	*2002*
Konya	*TmyCL*	*1980*	*2005*	*1977*	*2017*	*2004*	*2005*	*1975*	*1996*	*1998*	*2002*	*1980*	*1979*
	TmyTur	*1996*	*1997*	*1999*	*1991*	*2004*	*1991*	*1994*	*1993*	*1991*	*1991*	*2004*	*2007*
Mugla	*TmyCL*	*1991*	*1988*	*1983*	*1991*	*1982*	*2013*	*1994*	*2005*	*1995*	*1998*	*1993*	*1982*
	TmyTur	*1991*	*1999*	*1999*	*2001*	*1994*	*1998*	*1996*	*1996*	*1993*	*2000*	*1991*	*1997*
Trabzon	*TmyCL*	*1967*	*1995*	*1990*	*1990*	*1955*	*1977*	*1998*	*1979*	*2005*	*1997*	*1964*	*1978*
	TmyTur	*1991*	*2004*	*2004*	*1990*	*1999*	*2004*	*1996*	*2004*	*2000*	*1997*	*2005*	*2003*

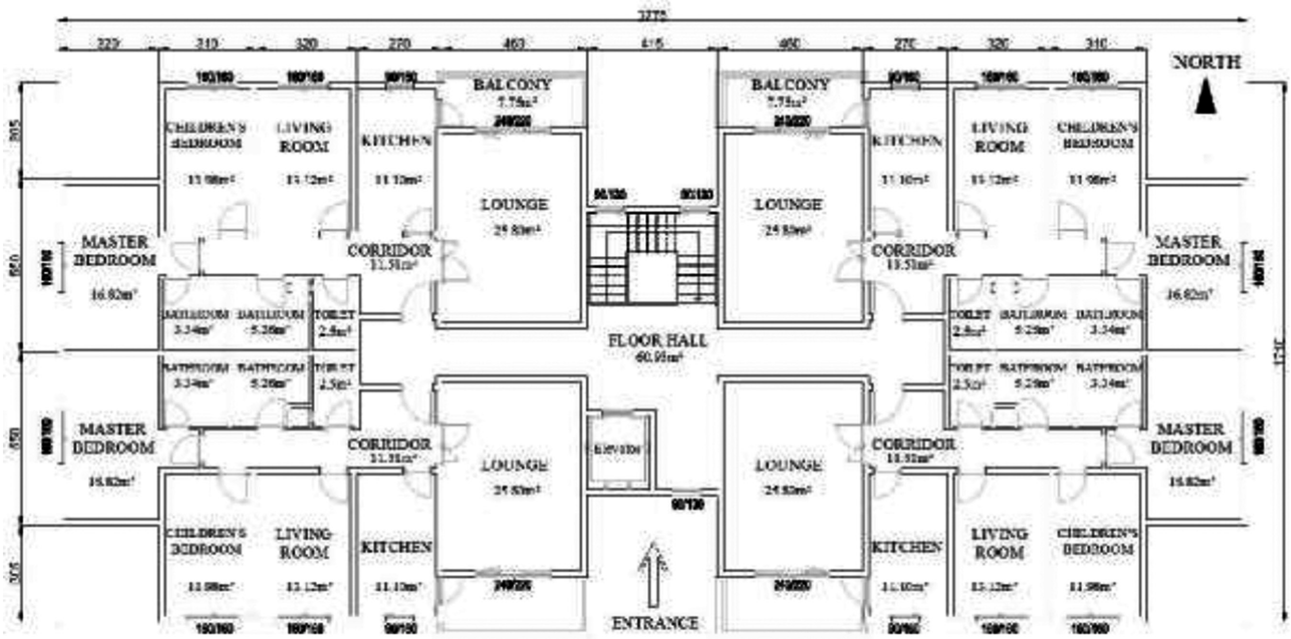

Figure 2. Floor plan.

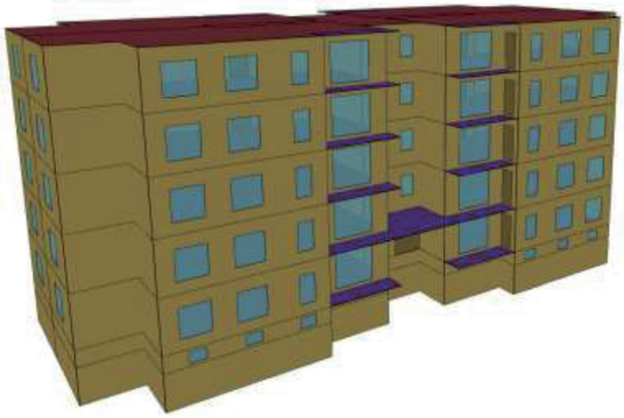

Figure 3. 3D geometry of the building.

according to the provinces [24]. In Energyplus (E+) data, typical months were selected between 1982-1995, and according to TmyCL and TmyTur data, typical months were chosen by using a narrower time range.

General Information about Building

The building in this study was selected among the residential projects by Housing Development Administration of Türkiye (TOKI) which has an important target of building 1 million 200 thousand houses in 81 provinces of country until 2023 in Türkiye [38]. The building consists of 6 floors which are basement, ground and 4 normal floors. The building has 5 floors (except basement) and each floor has 4 flats. Basement floor and floor halls are considered as non-air-conditioned space in the energy model. The examined

Table 4. The characteristics of building envelope

Construction	*Material*	*Thickness (m)*	*Thermal conductivity (W/m. K)*	*Specific Heat (j/kg. K)*	*Density (kg/m³)*	*U-Factor (W/m². K)*
	External Plaster	*0.03*	*1.6*	*840*	*2000*	
External Wall	*Aerated Concrete*	*0.19*	*0.13*	*1000*	*400*	*0.60*
	Internal Plaster	*0.02*	*1.0*	*840*	*1800*	
	Gravel	*0.05*	*0.7*	*840*	*1800*	
	Levelling concrete	*0.10*	*1.65*	*1000*	*2200*	
Roof	*Insulation Material*	*0.06*	*0.03*	*1500*	*25*	*0.42*
	Reinforced Concrete	*0.16*	*2.5*	*1000*	*2400*	
	Internal Plaster	*0.02*	*1.0*	*840*	*1800*	
	Gravel	*0.10*	*0.7*	*840*	*1800*	
	Lean Concrete	*0.10*	*1.65*	*1000*	*2200*	
Ground Floor	*Reinforced Concrete*	*0.60*	*2.5*	*1000*	*2400*	*1.47*
	Levelling concrete	*0.10*	*1.65*	*1000*	*2200*	
	Marble Flooring	*0.02*	*3.5*	*802*	*2800*	
	Timber Flooring	*0.016*	*0.20*	*1255*	*800*	
	Levelling concrete	*0.10*	*1.65*	*1000*	*2200*	
Basement Floor Ceiling	*Reinforced Concrete*	*0.16*	*2.5*	*1000*	*2400*	*0.45*
	Insulation Material	*0.05*	*0.03*	*1500*	*25*	
	Internal Plaster	*0.02*	*1.0*	*840*	*1800*	
	Internal Plaster	*0.02*	*1.0*	*840*	*1800*	
Internal Wall	*Aerated Concrete*	*0.135*	*0.13*	*1000*	*400*	*0.80*
	Internal Plaster	*0.02*	*1.0*	*840*	*1800*	
	Timber Flooring	*0.016*	*0.20*	*1255*	*800*	
Intermediate Floors	*Levelling concrete*	*0.10*	*1.65*	*1000*	*2200*	*2.53*
	Reinforced Concrete	*0.16*	*2.5*	*1000*	*2400*	
	Internal Plaster	*0.02*	*1.0*	*840*	*1800*	
Windows Frame	***Glazing Property***		***Solar Heat Gain Coefficient***	***Visible Transmittance***	***U-Factor (W/m².K)***	
PVC	*4mm/12mm/4mm Air Filled*		*0.78*	*0.82*	*2.9*	

Table 5. Internal heat gains from people and equipment

Hours	*Kitchen + Lounge (W/m²)*			*Other Conditioned Areas (W/m²)*		
	People	*Equipment*	*Total*	*People*	*Equipment*	*Total*
07:00-17:00	*2.8*	*5.2*	*8*	*1*	*0*	*1*
17:00-23:00	*2.8*	*17.2*	*20*	*1*	*0*	*1*
23:00-07:00	*2*	*0*	*2*	*1*	*5*	*6*

building has a footprint of 548 m^2 and total constructional area of 3457 m^2 and each flat is 121 m^2 gross, except balcony. Each flat consists of kitchen, lounge, living room, two bedrooms, bathroom, toilet and corridor. The floor plan and 3D geometry of the building are given in Figure 2 and Figure 3.

The Properties of Building Envelope

Aerated concrete blocks were used as external wall material and the windows were selected as double-glazed and PVC-framed windows. Thermal insulation was not applied onto the ground of the building, but it was available in flats which were located on the ground floor. The roof was modeled as a flat terrace form. The constructions used in the building envelope and the materials that make up these constructions are given in Table 4 together with their features. TS 825 standard was used to determine the material properties [34].

Internal Heat Gains

Heating and cooling loads in buildings are significantly affected by meteorological conditions as well as internal heat gains [39]. Internal heat gains are caused mainly by people, equipment, lighting fixtures and depend on the type of building. In this study, the internal heat gains described in the BepTr were applied to the building [3]. Internal heat gains from people were given directly in W/m^2 in the BepTr. The kitchen and lounge areas must be known and the internal heat gains resulting from these spaces are calculated together for residential buildings. Internal heat gains from the equipment are calculated separately for the kitchen and living room, as well as for the other rooms, and the gains are given in W/m^2. The values vary at different time intervals of the day, but they are all the same for seven days of week in the BepTr (Table 5).

Lighting fixtures that provide the minimum level of illumination required to calculate the internal heat gains need to be known. Due to the luminaires in the places, the illuminance level calculated in the location should be maximum 10% below or above the required illuminance level according to the BepTr. In addition, it is assumed that the lighting system is not operated in residential buildings between 01:00 and 06:00 (am). In this study, compact fluorescent lamps were used for lighting. Following assumptions are considered; the lighting switches are opened and closed manually, the environment is clean, the luminaire is bare, the floor height is 3 m, the reflection coefficients are 0.7, 0.5 and 0.3 for the ceiling, the wall and the floor respectively. According to these parameters, the efficiency of each lighting fixture was calculated as 0.57 using the tables in the BepTr. Accordingly, for instance, the ideal luminous flux of 3 compact fluorescent lamps with 25 W used in the kitchen area is 5250 lumens, however the flux of these luminaires has been calculated as $5250 \times 0.57 = 2997.7$ lumens considering the efficiency of lighting fixture. Artificial illuminance levels are determined for all locations and given in Table 6. The average power of lighting is determined by dividing the installed power of the lighting fixtures into the net thermal zone area. The lighting powers were specified as 2.8 W/m^2 (282 Watt/100.9 m^2) and 2.5 W/m^2 (150 Watt/61 m^2) for the apartments and the floor hall, respectively. On the other hand, if 60% or more of the required illuminance level in the spaces cannot be met by daylight, it must be illuminated with lighting fixtures. For this reason, lighting fixtures were connected to daylight sensors so that they were not operated when illuminance level is not sufficient enough. The average illuminance level representing the thermal zone is determined by dividing the calculated luminous flux sum into the net thermal zone area. 102 lux (10309.1 lm/100.9 m^2) and 98 lux (5995.3 lm/61 m^2) were the average illuminance levels for the apartments and floor halls, respectively.

Building Energy Model

Energy calculations in buildings consist of multi-parameter equations that must be solved together and simultaneously[40]. For this reason, it is not possible to make these calculations without using computers. The reliability and accuracy of the results of software related to building energy analysis can be determined according to a method developed by the International Energy Agency, called (BESTest) Building Energy Simulation Test [41]. In this method, steady-state or time-dependent analytical or numerical solutions for different heat transfer problems occurring such as in the building envelope and/or elements like ground contact wall or ground floor are compared with

Table 6. Lighting calculations

Room	*Required illuminance (Lx)*	*Area (m²)*	*Required Luminous flux (Lm)*	*Compact Fluorescent Lamp*					*Calculated Luminous flux (Lm)*	*Calculated illuminance (Lx)*
				Power (W)	*Luminous flux (Lm)*	*Number of Lamp*	*Ideal luminous flux (Lm)*	*Total Power (W)*		
Kitchen	*300*	*11.1*	*3330*	*25*	*1750*	*3*	*5250*	*75*	*2997.7*	*270.1*
Lounge	*100*	*25.8*	*2580*	*23*	*1440*	*3*	*4320*	*69*	*2466.7*	*95.6*
Liv. room	*100*	*13.1*	*1310*	*20*	*1200*	*2*	*2400*	*40*	*1370.4*	*104.6*
Bedroom	*50*	*28.5*	*1425*	*20*	*1200*	*2*	*2400*	*40*	*1370.4*	*48.1*
Bathroom	*100*	*8.6*	*860*	*23*	*1440*	*1*	*1440*	*23*	*822.2*	*95.6*
Toilet	*100*	*2.3*	*230*	*8*	*395*	*1*	*395*	*8*	*225.5*	*98.1*
Corridor	*100*	*11.5*	*1150*	*27*	*1850*	*1*	*1850*	*27*	*1056.3*	*91.9*
Floor Hall	*100*	*61*	*6100*	*25*	*1750*	*6*	*10500*	*150*	*5995.3*	*98.3*

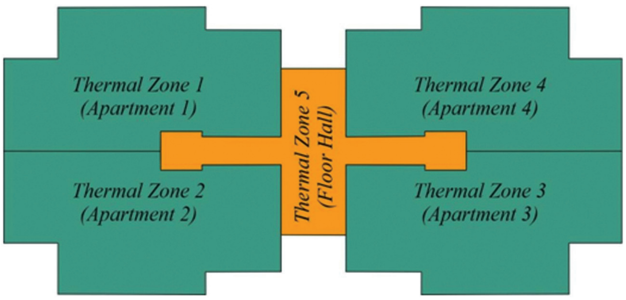

Figure 4. The schematic representation of the thermal zones.

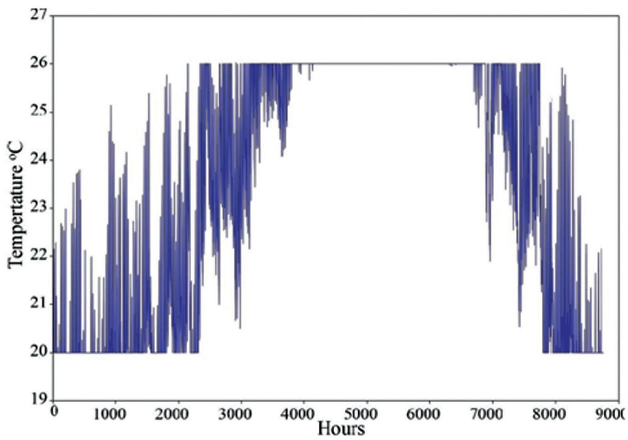

Figure 5. The temperature profile of conditioned thermal zone.

the results of simulation software. In this study, Energyplus V9.2 building energy simulation software, which has the widespread usage in worldwide and BESTest qualification, is used for energy analysis. The Energyplus file is created by using the OpenStudio 2.9 software because of having a more user-friendly interface than the Energyplus.

Moreover, the building subject to the study is modeled with BepTr software and the results are examined. BepTr energy performance software is a national energy performance calculation platform used by certificated technical personnel. The national conditions are also determined for Türkiye which basically refers to standards such as EN 13970, TS 825 and TS 2164. Firstly, BepTr solves time-dependent energy equations based on the resistance-capacity model of the building according to data entered by certified experts. In the second step, program defines a virtual reference building with same geometric properties, and annual energy analysis is repeated for that building by making certain changes in its components and mechanical systems. After that, the results of actual building are compared with the reference building. The energy performance and carbon emission classes of the actual building are determined after the comparison. In BepTr calculation method, the energy requirement of the building is converted to primary energy by using conversion factors. According to the current legislation, it is mandatory that new buildings must meet the requirements of class C in energy performance and carbon emission at least. BepTr software allows the entry of buildings with very different geometrical features and can perform energy calculations without need for another program. Within the scope of this study, the results of virtual reference building created by BepTr were not used, but only the findings of the actual building were evaluated.

For the residential buildings, small non-conditioned spaces (toilets, cellars, etc.) in the thermal zone are not defined as separate within the apartment because of frequent opening of the doors and the general circulation areas; however flats and floor halls are accepted as separate zones. The schematic representation of the thermal zoning is given in Figure 4.

Thermal zone temperatures of the residential buildings were determined as 20°C and 26°C for heating and cooling, respectively [42]. Besides, the air change rate is taken as 0.5 ACH which is recommended for the close buildings in the city center and the buildings where the air tightness is in the middle level. The equations for energy analysis are solved for 8760 hours at 15-minute intervals. The solution also takes into account the shadings caused by the balconies. It is assumed that the solar radiation is completely distributed on the inner and outer surfaces. (Full Exterior and Interior Model). Simple Sky Diffuse Model, TARP model, DOE-2 model and Conduction Transition Function (CTF) were used for the calculations of shading, internal heat transfer coefficient, external heat transfer coefficient, and heat flux on external walls respectively. Heating and cooling requirements of the thermal zones were calculated according to the set points. The temperature of the thermal zone changes throughout the year for several reasons such as outside temperature, solar radiation, different internal gains from people or equipment, etc. Ideal load air system was utilized in calculating the thermal demand of the building. In this system, each thermal zone is connected to an infinite capacity air handling unit which operates at 100% efficiency and has capable of both heating and cooling. When the temperature of the thermal zone falls below 20°C, heating mode becomes active in order to increase the zone temperature above 20°C, or vice versa. Hence, thermal demand of the building could be determined throughout the year to ensure the thermal zone is kept within the desired temperature range.

RESULTS AND DISCUSSIONS

The calculated temperature of thermal zone in Izmir with respect to the ideal load method can be seen in Figure 5. When the graph is examined, it was seen that the temperature of the thermal zone does not fall below 20°C throughout the year and does not exceed 26°C, so the temperature of the thermal zone remains between these two setting temperatures. In Figure 6, the floor hall temperature which indicates an unconditioned thermal zone is given. Although the floor hall is not exposed to heating or cooling, change in temperature is more stable when compared to the outside air temperature despite the parallel fluctuations. When the zone temperature is below or above the set values, the amount of heating or cooling energy required

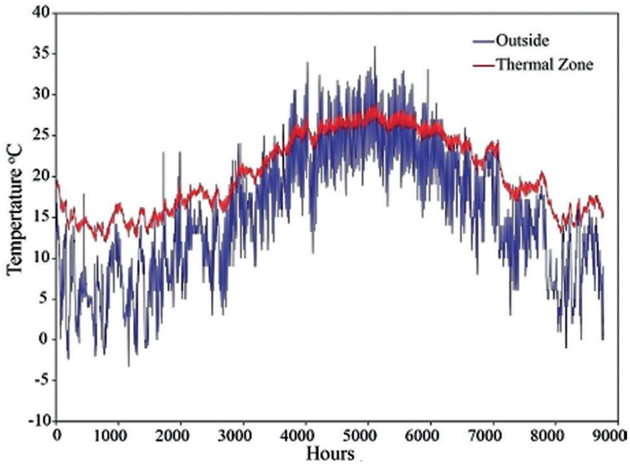

Figure 6. The Temperature Profile of Unconditioned Thermal Zone.

to keep the zone within the specified temperature range was identified. This determination was done for all thermal zones of the building. So that the total heating and cooling energy requirement of the building was determined. Considering the calculated temperatures of the thermal zones the performed energy analysis kept the internal temperatures within a certain range, therefore the observed values of heating and cooling energy were the same as predicted ones.

Energy analysis of described model has been conducted using Energyplus with different weather files such as E+, Meteonorm, TmyCL and TmyTur. The same building was also modeled and analyzed with the BepTr. All results are given in Figure 7. E+ weather files were only available for Istanbul, Ankara and Izmir provinces. When these cities were analyzed in terms of cooling demands, it was seen that cooling demands calculated by Meteonorm and TmyCL were higher than E+ which was also greater than BepTr. E+ weather data was compared with the data of TmyTur at the same time and the results of E+ in Ankara and Izmir were lower than TmyTur but higher in Istanbul. On the other hand, Cooling demands calculated by BepTr were lower than E+ for all three cities.

On the contrary, heating demands offered by Meteonorm and TmyCL weather data had higher values than E+. Results of TmyTur in Istanbul and Izmir were higher than E+ but lower in Ankara. Heating demands by BepTr were lower for Istanbul and Ankara, but BepTr results for Izmir were greater than the outcomes of E+.

Figure 8 shows the deviations with respect to reference weather data (Meteonorm). Deviation rates allowed results to be compared with each other in detail. Separate calculations were performed for heating and cooling demands and relative decreases or increases were taken as absolute

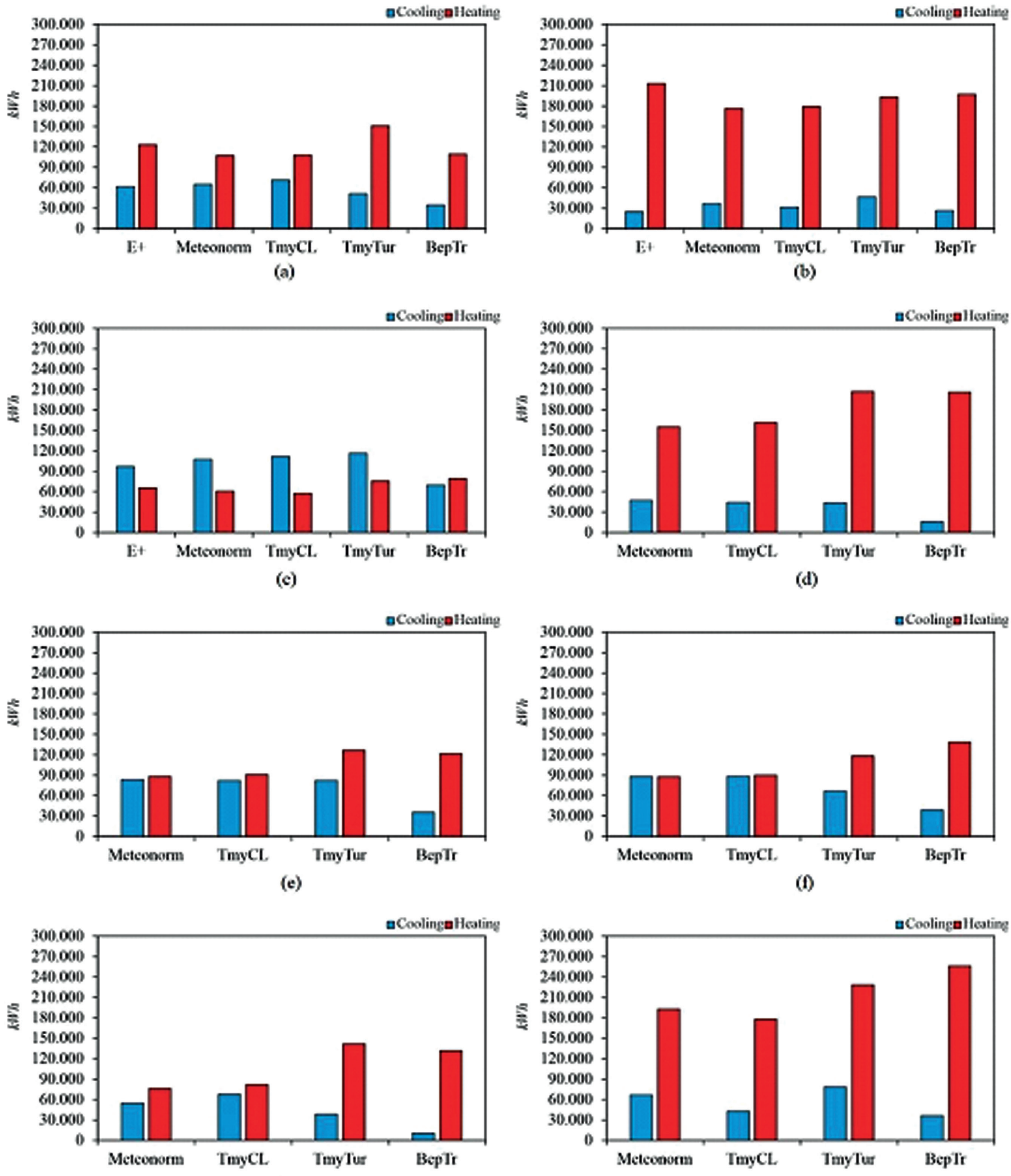

Figure 7. Heating and cooling demands, (a) Istanbul, (b) Ankara, (c) Izmir, (d) Konya, (e) Canakkale, (f) Mugla, (g) Trabzon, (h) Hakkari.

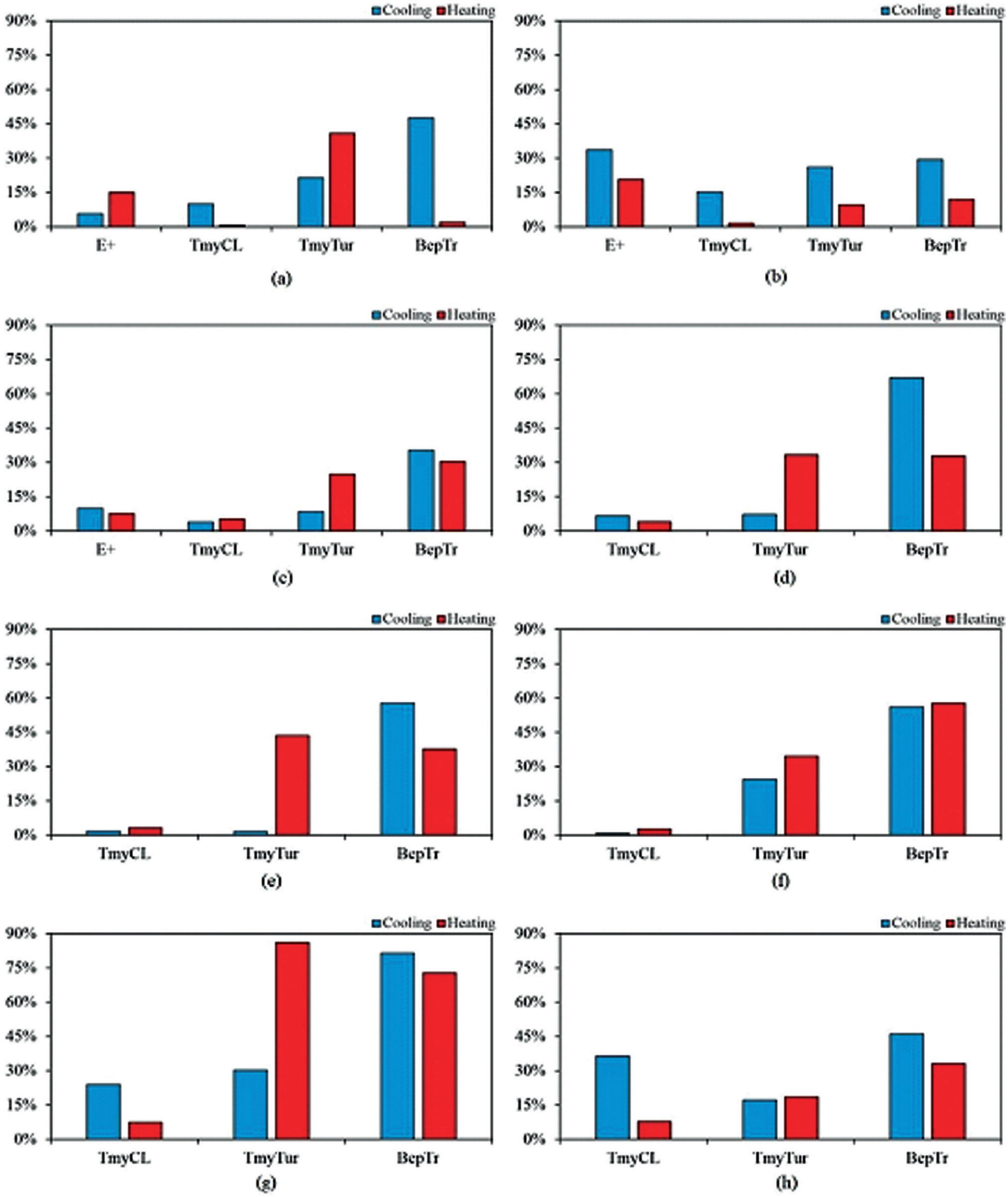

Figure 8. Comparison of heating and cooling demands (a) Istanbul, (b) Ankara, (c) Izmir, (d) Konya, (e)Canakkale, (f) Mugla, (g) Trabzon, (h) Hakkari.

values. Deviations around 10% couldbe acceptable. A low deviation was specified for Istanbul and Izmir, however this rate increased considerably for Ankara. The TmyCL results were generally in an agreement with the outcomes of Meteonorm. The findings of TmyTur were consistent with Meteonorm in heating and cooling loads for Ankara and Izmir, Canakkale, Konya respectively, but there were obvious differences in other provinces. BepTr gave high deviations in other provinces except for the heating load of Istanbul.

Energy usage intensity (EUI) is a parameter calculated by dividing the total energy consumption by gross floor area of the building. EUI is calculated for different purposes such as having an idea about the general energy consumption of the building and setting the targets of energy performance. In this study, instead of the total energy consumption of the buildings, the energy demand intensity was determined by dividing the energy demand of the building by its area. Energy demand intensities are depicted in Figure 9.

Although, the energy demand intensities were close to each other in some provinces, the dominance of heating or cooling differed from building to building. In Table 7, the ratio of heating and cooling demands to total demand is given. Results showed that, TmyCL and Meteonorm were generally close to each other; however, TmyTur almost gave lower cooling demands than TmyCL and Meteonorm. From BepTr point of view, the values of loads were usually below TmyCL, Meteonorm and TmyTur.

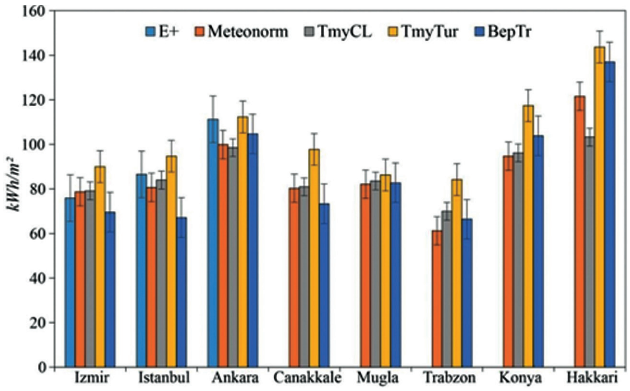

Figure 9. The intensities of energy demand.

CONCLUSIONS

In this paper, available TMY data files for Türkiye were investigated. Cooling and heating need of building calculated. Calculations were made for provinces of Istanbul, Ankara, Izmir, Konya, Canakkale, Mugla, Trabzon and Hakkari. Simulations conducted by Energyplus v9.2. Moreover, the building subject to the study is modeled with BepTr software and the results are examined.

The findings of the comparison showed that although some results are similar to each other for some weather files, they could have great variances in the energy analysis also. This situation increases questions about the reliability of the used data sets. The findings indicated that the results

Table 7. The ratios of heating and cooling loads

Province	*Demand*	*TmyCL*	*Meteonorm*	*TmyTur*	*BepTr*	*E+*
Izmir	*Cooling*	*66%*	*64%*	*61%*	*47%*	*60%*
	Heating	*34%*	*36%*	*39%*	*53%*	*40%*
Istanbul	*Cooling*	*40%*	*38%*	*25%*	*24%*	*33%*
	Heating	*60%*	*62%*	*75%*	*76%*	*67%*
Ankara	*Cooling*	*15%*	*17%*	*19%*	*12%*	*10%*
	Heating	*85%*	*83%*	*81%*	*88%*	*90%*
Canakkale	*Cooling*	*47%*	*49%*	*39%*	*23%*	
	Heating	*53%*	*51%*	*61%*	*77%*	
Mugla	*Cooling*	*50%*	*50%*	*36%*	*22%*	
	Heating	*50%*	*50%*	*64%*	*78%*	
Trabzon	*Cooling*	*45%*	*42%*	*21%*	*7%*	
	Heating	*55%*	*58%*	*79%*	*93%*	-
Konya	*Cooling*	*21%*	*23%*	*17%*	*7%*	
	Heating	*79%*	*77%*	*83%*	*93%*	
Hakkari	*Cooling*	*19%*	*26%*	*26%*	*12%*	
	Heating	*81%*	*74%*	*74%*	*88%*	

of energy analysis conducted by Meteonorm and TmyCL weather files were very close to each other. However, heating demands were generally higher for TmyTur files. Also, because the results suggested by BepTr software differ, the calculation methods of energy analysis should be examined in more detail.

For future work, sensitivity analysis of meteorological parameters should be done in order to determine the most important parameters. The reliability and quality of meteorological data that will constitute the basis of the TMY files are very important. In order to complete the missing weather data, a common algorithm may be developed so that it would be possible to collect the data to be used in studies on a common denominator. Hence, variation in results may be reduced.

AUTHORSHIP CONTRIBUTIONS

Authors equally contributed to this work.

DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

ETHICS

There are no ethical issues with the publication of this manuscript.

REFERENCES

[1] Belussi L, Barozzi B, Bellazzi A, Danza L, Devitofrancesco A, Fanciulli C, et al. A review of performance of zero energy buildings and energy efficiency solutions. J Build Eng 2019;25:100–772. [CrossRef]

[2] Sharif HZ, Leman AM, Krizou AN, Al-Tarawne MTA, Subbiah M, Muna AF. Analysis of nearly zero energy residential building in muscat. J Therm Eng 2020;6:346–358. [CrossRef]

[3] Notice on National Energy Performance Calculation Method in Buildings, 2017

[4] Finkelstein JM, Schafer RE. Improved goodness-of-fit tests. Biometrika 1971;58:641–645. [CrossRef]

[5] Hall IJ, Anderson H, Boes E. Generation of typical meteorological years for 26 SOLMET stations. Albuquerque, NM,USA: Sandia National Laboratories, 1979

[6] Pissimanis D, Karras G, Notaridou V, Gavra K. The generation of a "typical meteorological year" for the city of Athens. Sol Energy 1988;40:405–411. [CrossRef]

[7] Skeiker K, Ghani BA. Advanced software tool for the creation of a typical meteorological year. Energy Convers Manag 2008;49:2581–2587. [CrossRef]

[8] Janjai S, Deeyai P. Comparison of methods for generating typical meteorological year using meteorological data from a tropical environment. Appl Energy 2009;86:528–537. [CrossRef]

[9] Fagbenle RL. Generation of a test reference year for Ibadan, Nigeria. Energy Convers Manag 1995;36:61–63. [CrossRef]

[10] Lee K, Yoo H, Levermore GJ. Generation of typical weather data using the ISO Test Reference Year (TRY) method for major cities of South Korea. Build Environ 2010;45:956–963. [CrossRef]

[11] Bre, F., Fachinotti, V.D. Generation of typical meteorological years for the Argentine Littoral Region. Energy Build 2016;129:432–444. [CrossRef]

[12] Yang L, Lam JC, Liu J. Analysis of typical meteorological years in different climates of China. Energy Convers Manag 2007;48:654–668. [CrossRef]

[13] Pernigotto G, Prada A, Gasparella A, Hensen JL. Analysis and improvement of the representativeness of EN ISO 15927-4 reference years for building energy simulation. J Build Performance Simul 2014;7:391–410. [CrossRef]

[14] Marion, W., Urban, K., Users manual for TMY2s: Derived from the 1961-1990 National Solar Radiation Data Base. Golden, CO, USA: National Renewable Energy Lab. 1995. [CrossRef]

[15] Wilcox, S., Marion, W., Users manual for TMY3 data sets. Golden, CO, USA: National Renewable Energy Laboratory. 2008. [CrossRef]

[16] Thevenard DJ, Brunger AP. The development of typical weather years for international locations: part I, algorithms. ASHRAE Trans 2002;108:376.

[17] Meteonorm Software. Available at: https://meteonorm.com/en/ Accessed on Oct 11, 2022.

[18] EnergyPlus Weather Data. Available at: https://energyplus.net/weather Accessed on Oct 11, 2022.

[19] Crawley D, Lawrie L. Development of Global Typical Meteorological Years (TMYx). Available at: http://climate.onebuilding.org Accessed on Oct 11, 2022.

[20] Integrated Surface Database (ISD). Available at: https://www.ncdc.noaa.gov/isd Accessed on Oct 11, 2022.

[21] Lott JN. The quality control of the Integrated Surface Hourly Database. 14th Conference on Applied Climatology. Seattle, USA, 2004.

[22] Ecevit A, Akinoglu B, Aksoy B. Generation of a typical meteorological year using sunshine duration data. Energy 2002;27:947–954. [CrossRef]
[23] Üner M, İleri A. Typical weather data of main Turkish cities for energy applications. International J Energy Res 2000;24:727–748. [CrossRef]
[24] Pusat S, Ekmekçi İ. Determination of Typical Meteorological Year For Turkey. 20th National Thermal Science and Technology Congresses. Balıkesir, Türkiye, 2015.
[25] Petrakis M, Kambezidis HD, Lykoudis S, Adamopoulos AD, Kassomenos P, Michaelides IM, et al. Generation of a "typical meteorological year" for Nicosia, Cyprus. Renew Energy 1998;13:381–388. [CrossRef]
[26] Sawaqed, N.M., Zurigat, Y.H., Al-Hinai, H. A step-by-step application of Sandia method in developing typical meteorological years for different locations in Oman. Int J Energy Res 2005;29:723–737. [CrossRef]
[27] Sepúlveda C, Merino G, Pino FJ, Cañumir JA. Comparison of methodologies for TMY generation using 15 years data for Chillan, Chile. IOSR J Eng 2014;04:24–34. [CrossRef]
[28] Sağlam NG, Yılmaz AZ, Becchio C, Corgnati SP. A comprehensive cost-optimal approach for energy retrofit of existing multi-family buildings: Application to apartment blocks in Turkey. Energy Build 2017;150:224–238. [CrossRef]
[29] Atmaca, M., Yılmaz, A.Z. A Study on Energy and Cost Efficiency for Existing Hotel Buildings in Turkey. E3S Web of Conferences. 2019.
[30] Kalaycıoglu, E. New Approach to Evaluate The Nearly Zero Energy Concept of EPBD Recast At istrict Scale. 2017
[31] Solmaz AS, Halicioglu FH, Gunhan S. An approach for making optimal decisions in building energy efficiency retrofit projects. Indoor Built Environ 2018;27:348–368. [CrossRef]
[32] Dino IG, Akgül CM. Impact of climate change on the existing residential building stock in Turkey: An analysis on energy use, greenhouse gas emissions and occupant comfort. Renewable energy 2019;141:828–846. [CrossRef]
[33] Pusat S, Ekmekçi İ, Akkoyunlu MT. Generation of typical meteorological year for different climates of Turkey. Renew Energy 2015;75:144–151. [CrossRef]
[34] TS825 Thermal insulation requirements for buildings (Binalarda Isı Yalıtım Kuralları), 2008
[35] "Heating and Cooling Degree Days" 2020. Available at: https://www.degreedays.net/ Accessed on Oct 11, 2022.
[36] Erlat E. Dünya İklimleri. Ege Üniversitesi Edebiyat Fakültesi Yayınları, 2014
[37] Öztürk MZ, Çetinkaya G, Aydın S. Köppen-Geiger iklim sınıflandırmasına göre Türkiye'nin iklim tipleri. Coğrafya Dergisi 2017;17–27. [Turkish] [CrossRef]
[38] TOKI. Housing Development Administration of Turkey. Available at: https://www.toki.gov.tr/ Accessed on Oct 11, 2022.
[39] Coşkun, T. The importance of internal heat gains for building cooling design. Journal of Thermal Engineering 2017;3:1060–1064. [CrossRef]
[40] Anand Y, Anand S, Gupta A, Tyagi, S. Building envelope performance with different insulating materials–An exergy approach. J Therm Eng 2015;1:433–439. [CrossRef]
[41] International Energy Agency building energy simulation test (BESTEST) and diagnostic method, 1995.
[42] TS EN ISO 13790 Energy performance of buildings - Calculation of energy use for space heating and cooling, 2013.