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Mapping of Turkey's district heating/cooling requirements

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Mapping of Turkey's District Heating/Cooling Requirements

Highlights

- *The regional residence heating/cooling loads were determined in order to develop technology for regional heating/cooling systems in Turkey.*
- *Heating/cooling loads of the residences were made separately for each province according to the heating regions determined in accordance with TS 825.*
- *Fuel and electricity consumption, population, number of residences and meteorological data were used as the basis for determining the heating/cooling loads.*

Graphical Abstract

Regional residence heating/cooling loads were specified to develop a technology for regional heating/cooling systems in Turkey.

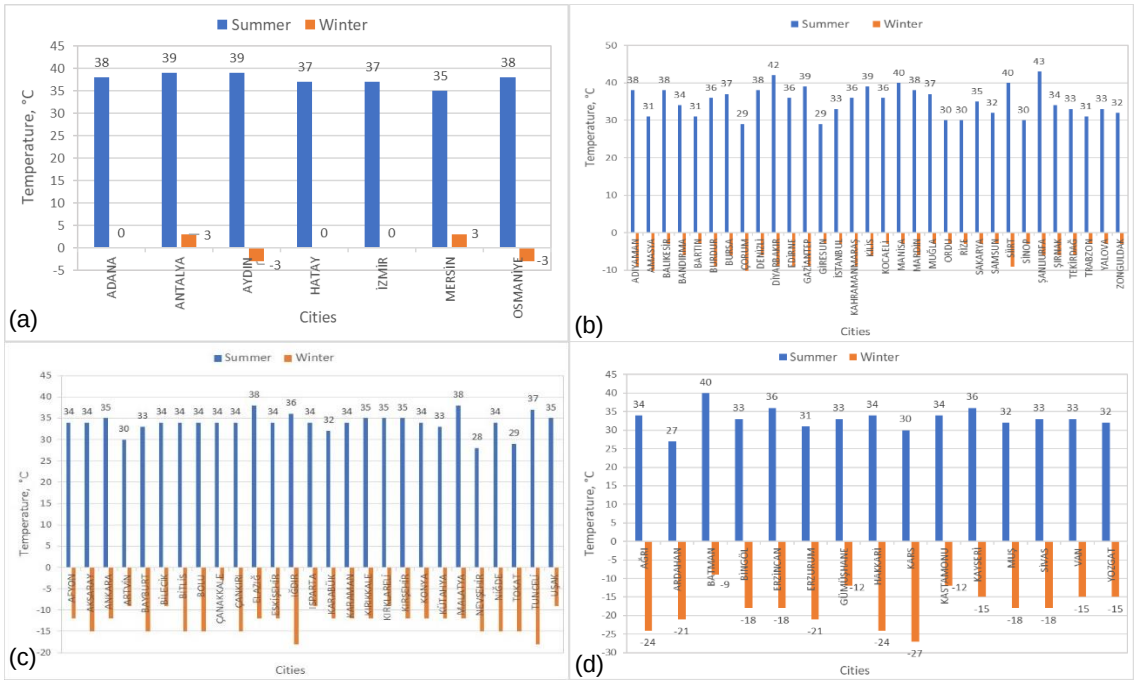

Figure. Average outdoor temperatures of cities used for heat loss and heat gain calculations in (a) Zone 1, (b) Zone 2, (c) Zone 3 and (d) Zone 4

Aim

The aim of this study is to develop a technology for regional heating/cooling systems in Turkey.

Design & Methodology

Fuel and electricity consumption, population, number of residences and meteorological data were used as the basis for determining the heating/cooling loads.

Originality

Using the data obtained, an important source data was obtained to investigate the possibility of using alternative energy sources for each region or even every province.

Findings

The population and the number of houses have a direct effect on the heating need, while the population and the number of houses do not have a direct effect on the cooling need.

Conclusion

The second heating zone had 55% of the total heating need and the first zone had 68% of the total cooling need. The number of population and residences had effects on the heat loads, while and the average daily temperatures and CDD had effects on the cooling loads.

Declaration of Ethical Standards

The authors of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

Mapping of Turkey's District Heating/Cooling Requirements

Araştırma Makalesi / Research Article

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ABSTRACT

One of the most important parameters of energy efficiency is to determine the heating and cooling requirements of the buildings and to develop the appropriate heating/cooling technology. In this study, the regional residence heating/cooling loads were determined in order to develop technology for regional heating/cooling systems in Turkey. Heating/cooling loads of the residences were made separately for each province according to the heating regions determined in accordance with TS 825. Fuel and electricity consumption, population, number of residences and meteorological data were used as the basis for determining the heating/cooling loads. Using the data obtained, an important source data was obtained to investigate the possibility of using alternative energy sources for each region or even every province.

Keywords: Heating, cooling, energy.

1. INTRODUCTION

Population growth in the world, rapid development and growth in industrialization increase the need for energy. However, the increase in energy demand does not parallel the energy supply. World energy council have declared that primary energy consumption can increase of 50% between 1990-2050; also stated that it could increase 275% at the highest growth rates [1]. In order to meet the energy increase, countries have been conducting studies on rehabilitation and more efficient use of existing resources, in addition to researching new resources. New sources research is to create new fossil and renewable energy sources in addition to existing sources. Regarding the correct and more efficient use of existing resources and systems, it is to determine resource, capacity and system suitability and increase their efficiency.

The most effective method of energy efficiency and saving is possible with the conservation of energy [2]. In about 35% of the total energy consumed in residences in Turkey and 65% of the energy consumed is used for heating the residence [3]. When comparing these rates to the EU countries, it is clear that energy rate used in residences in Turkey is high; in case of withdrawal of the EU levels of energy consumption in residential rates in Turkey, nearly 30 - 40% savings will be achieved [4]. In evaluations made to reduce energy consumption in residences, the following titles come to the fore [5]:

- Reduction of heating and cooling loads.
- Efficient use of systems.
- Using electricity-efficient and efficient devices.
- Renewable energy use.

Energy requirements and fuel consumption values required for heating the residences can be determined considering the architectural design, material properties, meteorological data and population [6].

The most important parameters for determining the ideal heating systems to be used in residences are residential heating-cooling loads, primary energy sources in the region where the residence is located and the first source factors of these fuels. It is not possible to determine the heating-cooling loads of the residences by measuring directly. Fuel and electricity consumption in the residences are the climate zones, climate conditions and some statistical data.

There are many studies on determination of energy need, reduction of energy consumption, etc. in the literature. Liu et al. used the machine learning method, which is a promising technique for many practical applications and is rarely used in this field in estimating building energy consumption. They determined the energy consumption estimates via machine learning method by using hourly, daily and annual inputs for residential, commercial, government and educational buildings [7].

Aydin and Bıyıkoğlu, determined the optimum thickness according to the heating load in Turkey. In that study, building heat load was determined according to TS 825 standard [8]. Yua et al. developed a building energy demand prediction model based on decision tree method in their studies. To demonstrate the applicability of the developed method, they used building energy usage intensity levels to estimate residential building energy performance indexes. In practice, energy demands were determined using different types of fuel. It was determined that the developed method made an estimate of 93% for education data and 92% for test data [9]. Lombard et al. examined the studies on energy consumption in buildings in detail and analysed the current information on energy consumption in buildings and especially HVAC systems in their review studies. In that study, the necessary general information, especially

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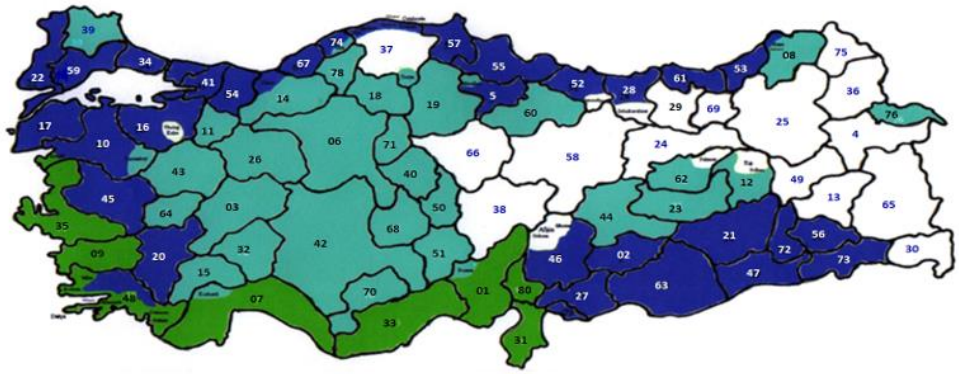
the commercial and office buildings, main building types and comparisons between different countries were made [10]. Erturk et al. examined the global warming effects of residential heating energy and emission changes in Düzce province. In that study, using the meteorological data of the last 30 years, different indoor temperatures (18-28 ° C) were taken as reference, and the changes in energy demand for the Heating Degree Numbers and the temperatures above and below the reference temperatures were determined proportionally [11].

2.1. Meteorological Data

As a vast country, with area of 783.562 km², there are several climates as warm, temperate and terrestrial are available in Turkey. There are 4 heating zones in Turkey by TS 825 [12]. The heating zones by TS 825 are given in Figure 1.

The harshness of a climate is characterized by precision in degrees-days. Different climatic conditions in different regions significantly affect the need for heating or cooling energy. All over the world, degree-day zones (zones) are determined by using degree-day numbers especially for heating, cooling and thermal insulation applications.



01- ADANA	10- BALIKESİR	19- ÇORUM	28- GİRESUN	37- KASTAMONU	46- K.MARAŞ	55- SAMSUN	64- UŞAK	73- ŞIRNAK
02- ADIYAMAN	11- BİLECİK	20- DENİZLİ	29- GÜMÜŞHANE	38- KAYSERİ	47- MARDİN	56- SİİRT	65- VAN	74- BARTIN
03- AFYON	12- BİNGÖL	21- DİYARBAKIR	30- HAKKARİ	39- KIRKLARELİ	48- MUĞLA	57- SİNOP	66- YOZGAT	75- ARDAHAN
04- AĞRI	13- BİTLİS	22- EDİRNE	31- HATAY	40- KIRŞEHİR	49- MUŞ	58- SİVAS	67- ZONGULDAK	76- IĞDIR
05- AMASYA	14- BOLU	23- ELAZIĞ	32- ISPARTA	41- KOCAELİ	50- NEVSEHİR	59- TEKİRDAĞ	68- AKSARAY	77- YALOVA
06- ANKARA	15- BURDUR	24- ERZİNCAN	33- İÇEL	42- KONYA	51- NİĞDE	60- TOKAT	69- BAYBURT	78- KARABÜK
07- ANTALYA	16- BURSA	25- ERZURUM	34- İSTANBUL	43- KÜTAHYA	52- ORDU	61- TRABZON	70- KARAMAN	79- KİLİS
08- ARTVİN	17- ÇANAKKALE	26- ESKİŞEHİR	35- İZMİR	44- MALATYA	53- RİZE	62- TUNCELİ	71- KIRIKKALE	80- OSMANİYE
09- AYDIN	18- ÇANKIRI	27- GAZİANTEP	36- KARS	45- MANİSA	54- SAKARYA	63- ŞANLIURFA	72- BATMAN	81- DÜZCE

Figure 1. Provinces by heating zones [12]

Many countries use different definitions for the calculation of the day degree. In order to create a comparable and common use, the following method is used for calculating the Heating Degree-Day numbers (HDD) and the Cooling Degree-Day numbers (CDD) [13] (The Statistical Office of the European Community (Eurostat) proposes the same method for calculating the HDD and CDD):

HDD = (18 °C - Tm) x d (If Tm ≤ 15 °C) (heating threshold = 15 °C) (1)

HDD = 0 (If Tm > 15 °C)

CDD = (22 °C - Tm) x d (If Tm > 22 °C) (cooling threshold = 22 °C) (2)

CDD = 0 (If Tm ≤ 22 °C)

Tm: daily average temperature (°C)

d: numbers of days

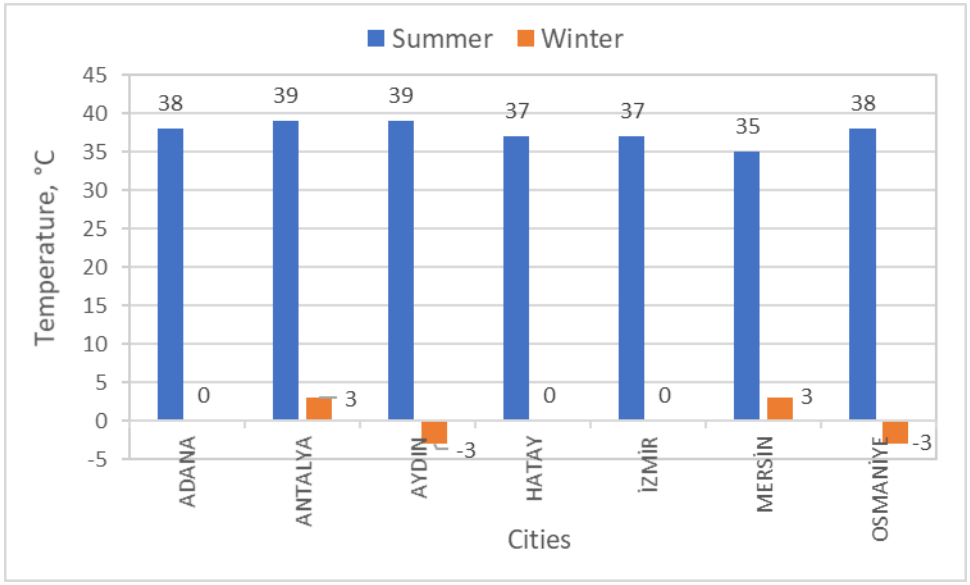
For the cities in heating zones, the average outdoor air temperatures taken into account in determining the HDD and CDD (Figure 2) are given below [13].

In this study, regional heating and cooling systems as a basis for analysing expected residential heating and cooling loads in Turkey were determined. Heating-cooling loads of the houses were specified for each province according to the heating zones determined in accordance with TS 825. Fuel and electricity consumption, population, number of residences and meteorological data, which were the basis for determining the residential heating-cooling loads, were provided for each province.

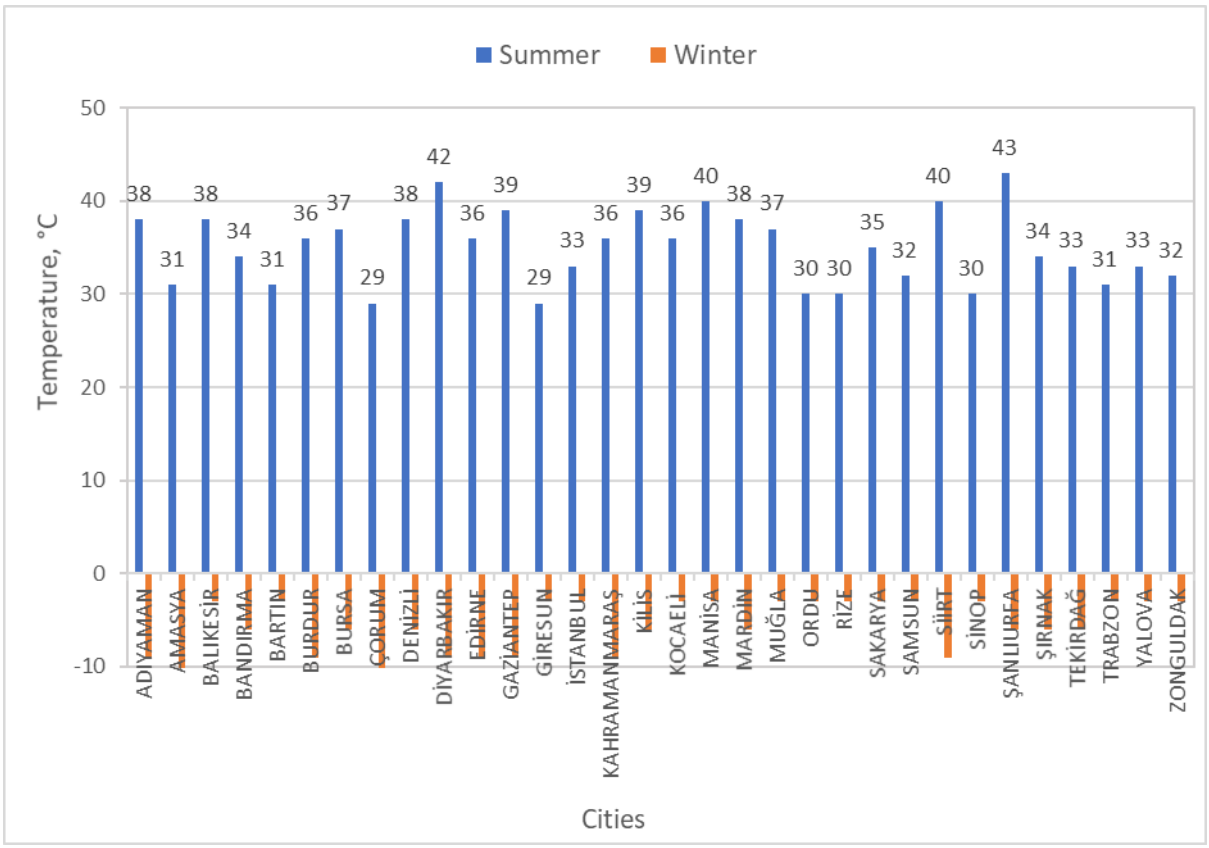
2. PARAMETERS USED IN DETERMINATION OF HEATING-COOLING LOADS

It is not possible to determine the heating-cooling loads of the residences with a direct measurement. Therefore, some statistical data were used to determine the heating-cooling loads. Statistical information required for determining Turkey's annual ambient heating and cooling necessities have been constituted with appropriate assumptions providing by relevant institutions, standards, projects, etc. Some statistics used are as follows:

- Meteorological data
- Demography information
- The number of house
- Energy consumption statistics for different fuel types

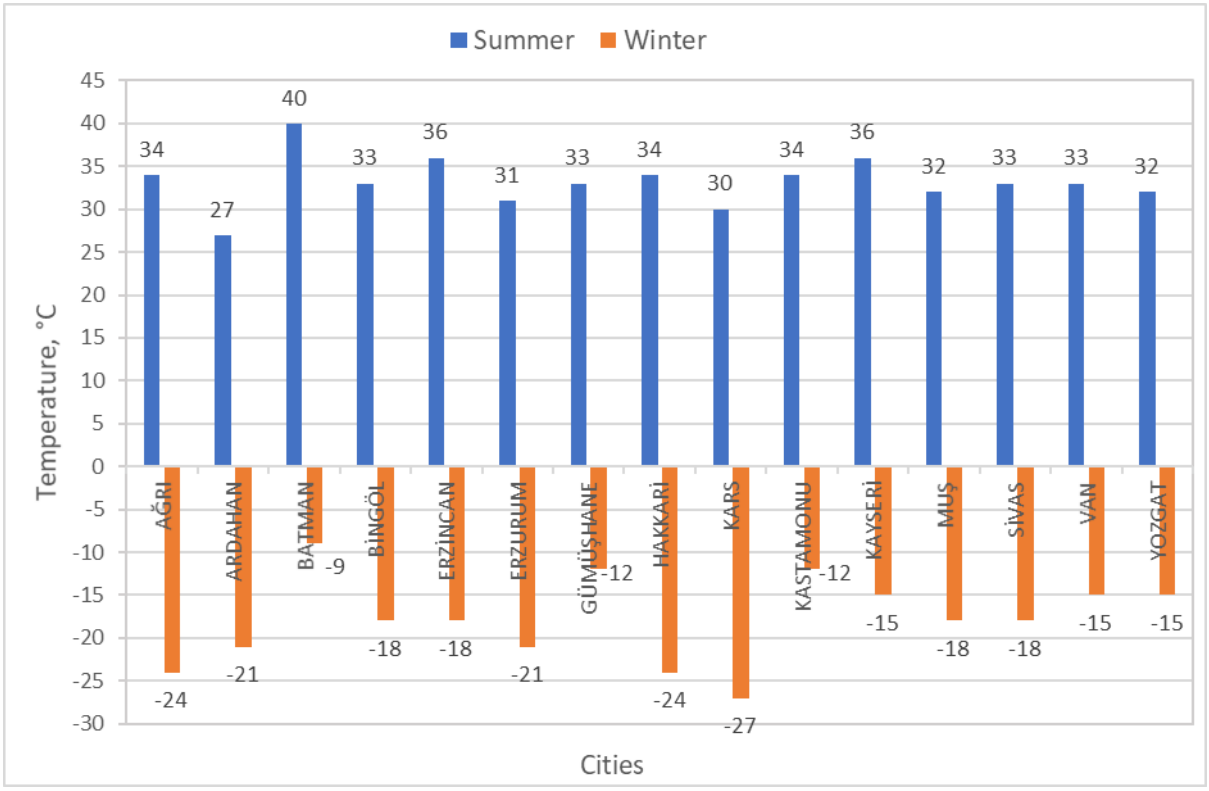

Summer
Winter
Temperature, °C
45
40
35
30
25
20
15
10
5
0
-5
38
39
39
37
37
35
38
0
3
-3
0
0
3
-3
ADANA
ANTALYA
AYDIN
HATAY
İZMİR
MERSİN
OSMANİYE
Cities

(Zone 1)


Summer
Winter
Temperature, °C
50
40
30
20
10
0
-10
38 31 38 34 31 36 37 29 38 42 36 39 29 33 36 39 36 40 38 37 30 30 35 32 40 30 43 34 33 31 33 32
ADIYAMAN
AMASYA
BALIKESİR
BANDIRMA
BARTIN
BURDUR
BURSA
ÇORUM
DENİZLİ
DİYARBAKIR
EDİRNE
GAZİANTEP
GİRESUN
İSTANBUL
KAHRAMANMARAŞ
KİLİS
KOCAELİ
MANİSA
MARDİN
MUĞLA
ORDU
RİZE
SAKARYA
SAMSUN
SİİRT
SİNOP
ŞANLIURFA
ŞIRNAK
TEKİRDAĞ
TRABZON
YALOVA
ZONGULDAK
Cities

(Zone 2)

(Zone 3)

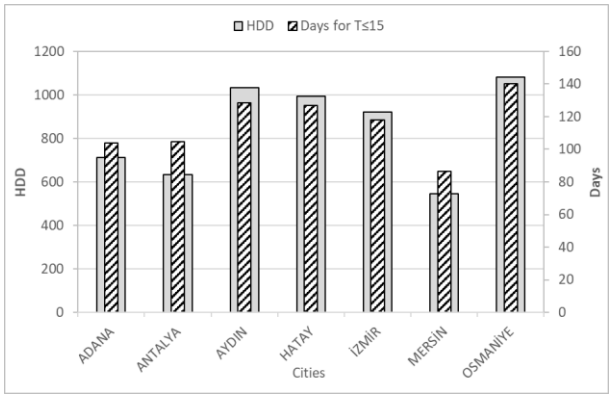


(Zone 4)

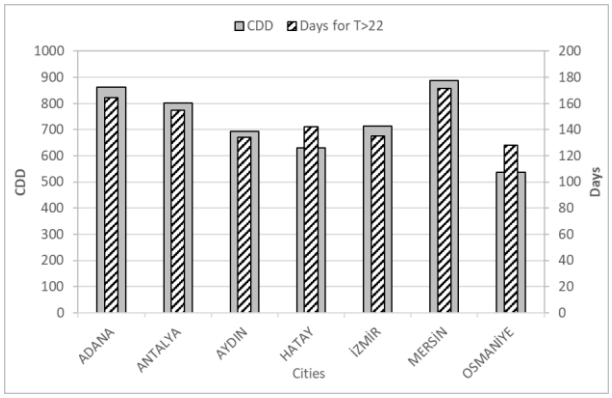
Figure 2. Average outdoor temperatures of cities used for heat loss and heat gain calculations in Zones

It is seen in Figure 2 that the warmest average daily temperatures occur in the second heating shade and the coldest average daily temperatures occur in the fourth heating zone. While the average hottest days are similar in all regions, the coldest days are seen in the second, third and fourth regions. Temperatures below zero in the first region are only seen in two provinces.

The average HDD and CDD values were taken from the Turkish State Meteorological Service (MGM) [11] (MGM uses the same method for calculating HDD and CDD). The following figures give the heating and cooling degree days by the cities of zones in Turkey [13].

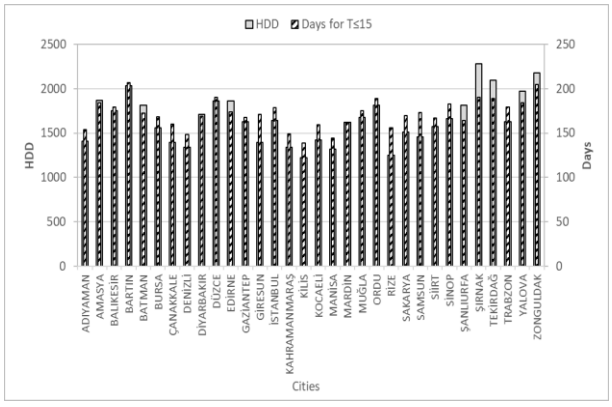


(a)

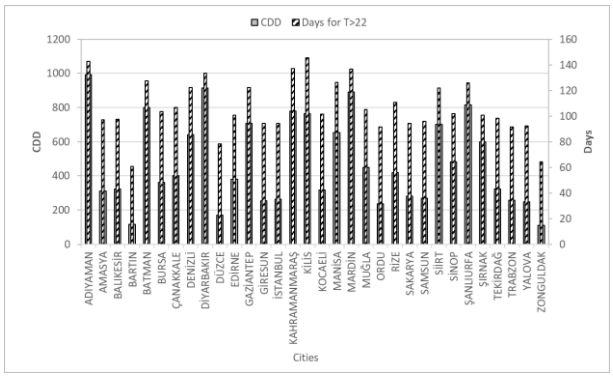


(b)

Figure 3. Heating Degree-Day numbers (a) and Cooling Degree-Day numbers (b) of cities in Zone 1

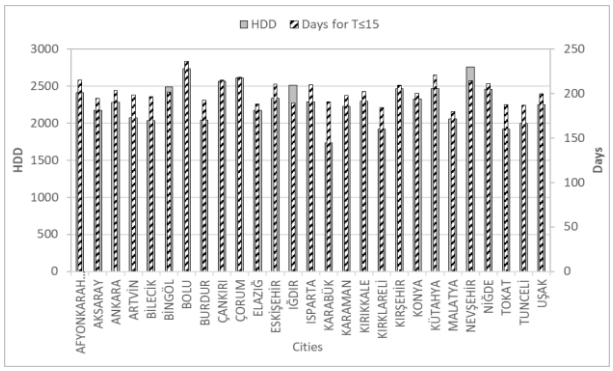


(a)

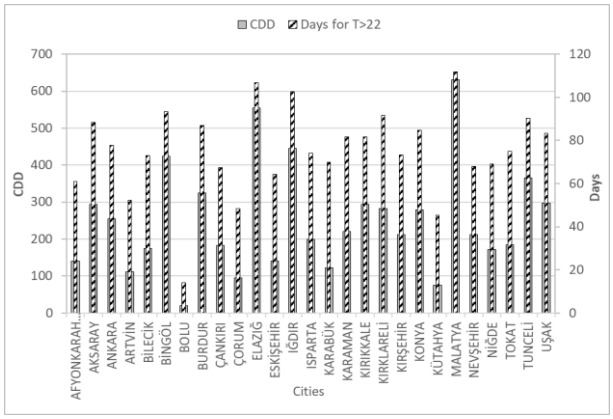


(b)

Figure 4. Heating Degree-Day numbers (a) and Cooling Degree-Day numbers (b) of cities in Zone 2

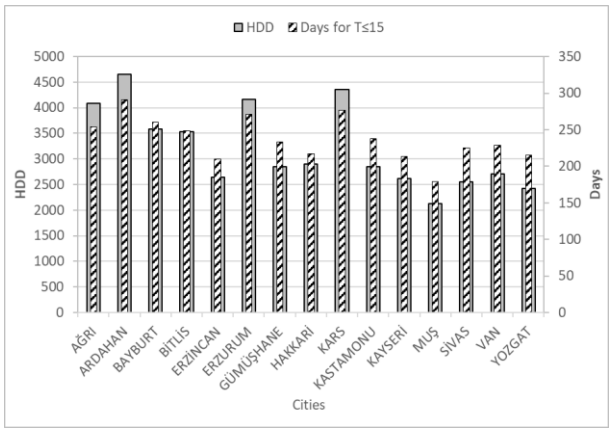


(a)

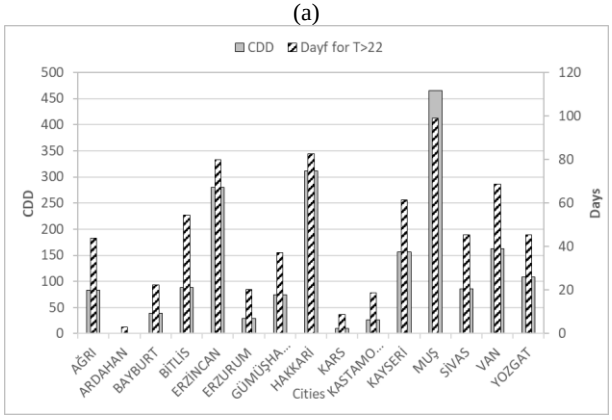


(b)

Figure 5. Heating Degree-Day numbers (a) and Cooling Degree-Day numbers (b) of cities in Zone 3



(a)



(b)

Figure 6. Heating Degree-Day numbers (a) and Cooling Degree-Day numbers (b) of cities in Zone 4

2.2. Demography

One of the parameters in determining residential heating cooling loads is population. Population of Turkey is about 83 million in 2019 [14]. Turkey's population density maps according to the climate zones was given in Figure 7.

Since the heating-cooling loads in the residences were made according to the heating zones determined in accordance with TS 825 (TS 825 Thermal insulation requirements for buildings (Turkish Standard)) standard, the population amounts for the provinces in the heating zones were given in Figure 8 to Figure 11.

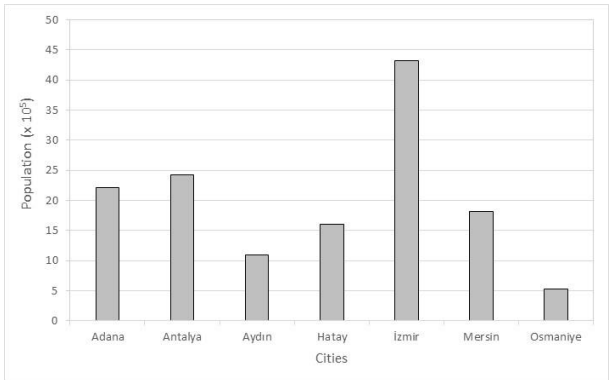


Figure 8. The population of cities in Zone 1 [14]

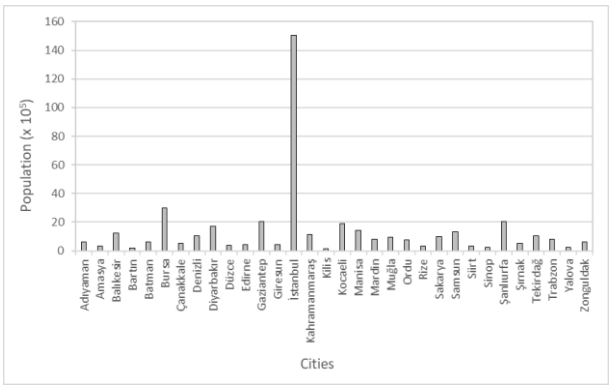


Figure 9. The population of cities in Zone 2 [14]

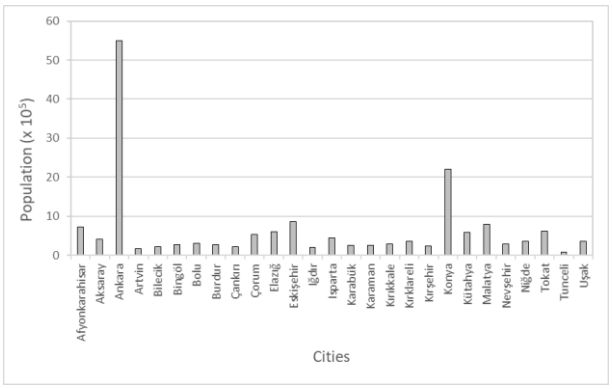


Figure 10. The population of cities in Zone 3 [14]

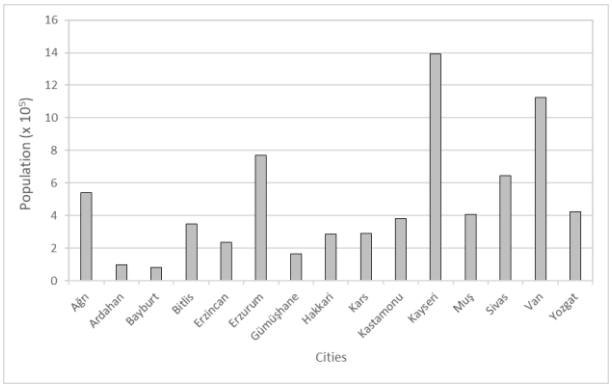


Figure 11. The population of cities in Zone 4 [14]

2.3. The number of house

In calculation of heating zones and total heating-cooling loads, the number of residences should be known. In this study, the residences were not separated according to their types, but were evaluated according to the number of households. The number of residences for provinces in the heating zones [16] were given in Figure 12 to Figure 15.

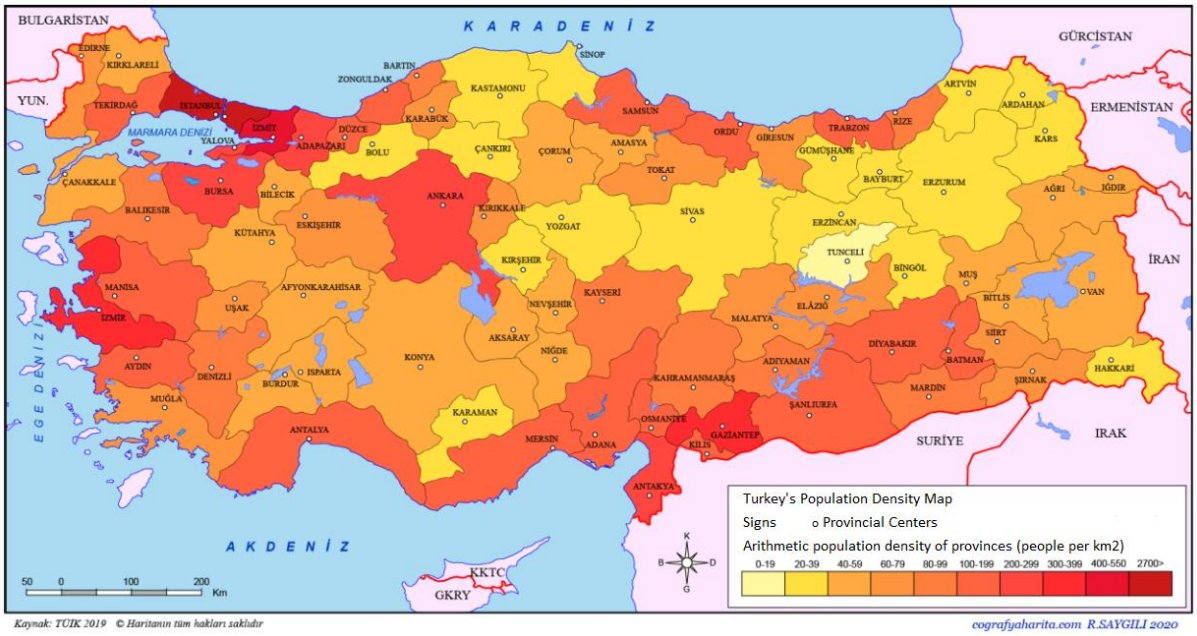


Figure 7. Population density by cities in Turkey [15]

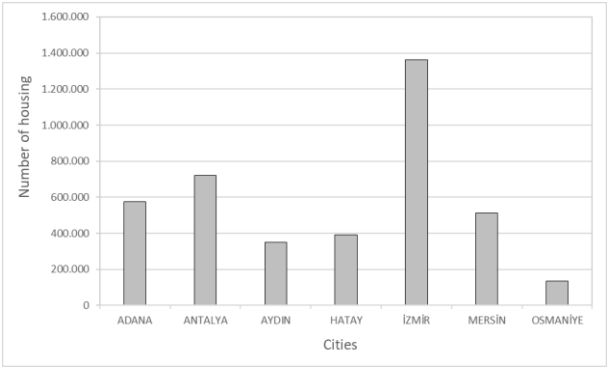


Figure 12. Number of housing in cities in Zone 1

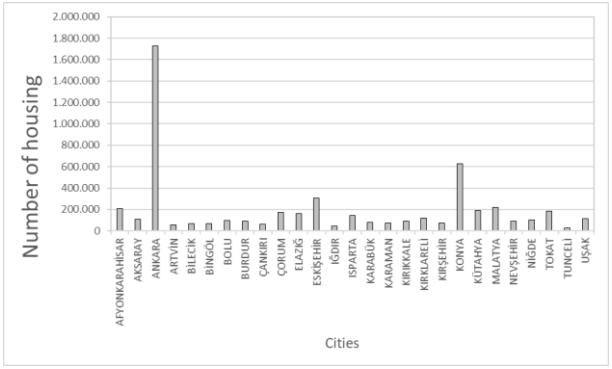


Figure 14. Number of housing in cities in Zone 3

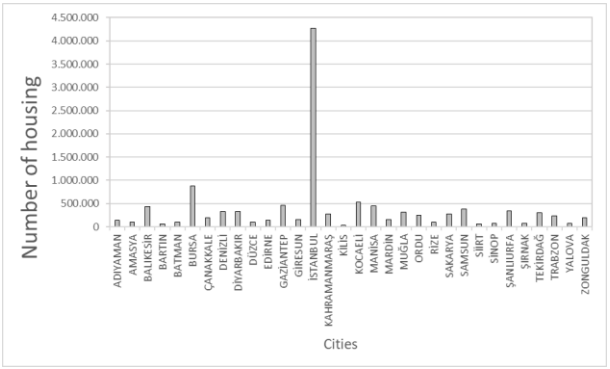


Figure 13. Number of housing in cities in Zone 2

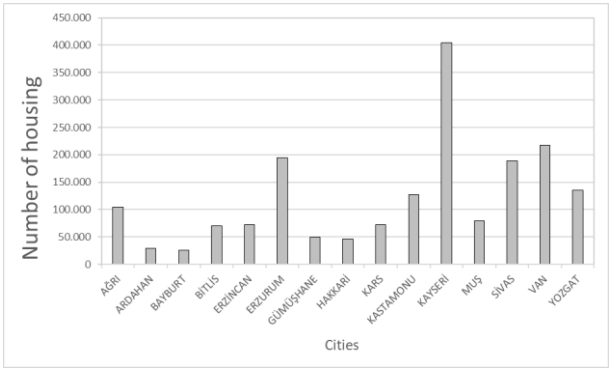


Figure 15. Number of housing in cities in Zone 4

3. HEATING AND COOLING DEMANDS

In determining heating and cooling necessities, energy consumption statistics by different fuel types, meteorological data population and so on were used.

3.1. Heating Demands

While specifying heating requirement,

- national statistics and general assumptions based on current necessities and fuel/energy consumptions for heating purposes,
- population density of the provinces,
- degree day numbers of the provinces,
- climatic zones of the provinces

were taken into account.
The coverage ratio of the Turkey's total heat requirement was provided by the heating demand of the fuel in Figure 16. Natural gas, solid fuel (wood and coal) and electricity, which are used mostly, were taken into consideration, while other types of fuel and energy consumed at low rates were ignored. In Figure 16, the number of houses taken into account in determination of heat requirement in Turkey and the number of electrically-heating houses is given. In Figure 17, the number of residences heated by electricity were given.

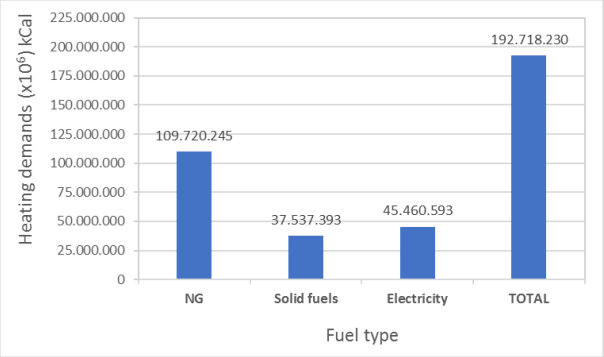


Figure 16. The types of fuels used to meet heating demands and the average annual total heating demands in Turkey

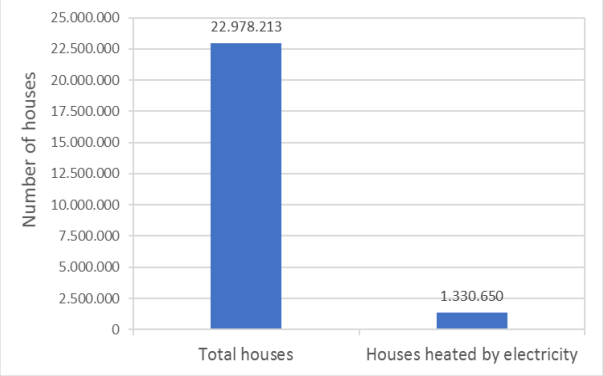
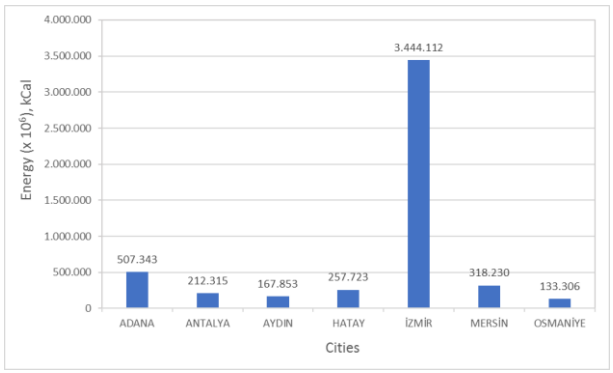
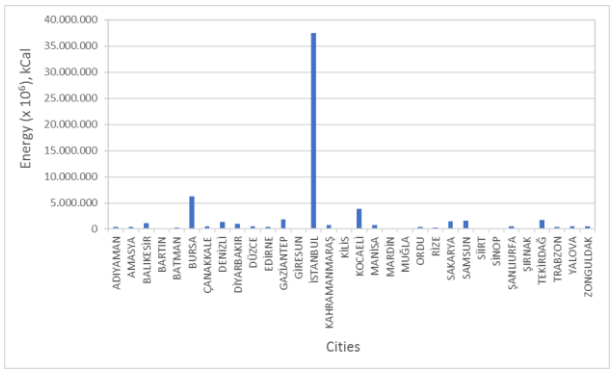


Figure 17. The total number of houses and number of houses heated by electricity

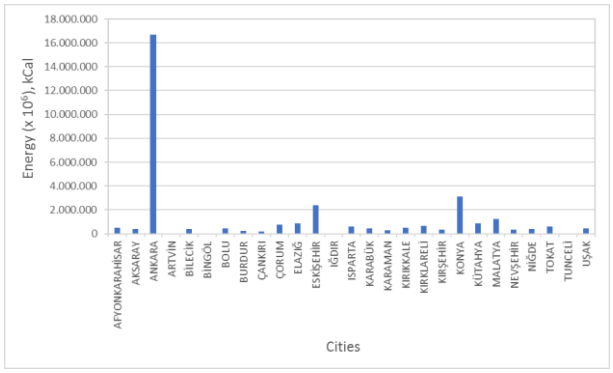
Consumptions according to these energy sources are obtained from the reports of the relevant ministries and statistical information (natural gas [17-19], solid fuels [20-22], electricity [23-25]). For the provinces in heating zones, the compensation ratio of the heating requirement to the fuel in the current situation (Figure 18 - Figure 20) were given below.



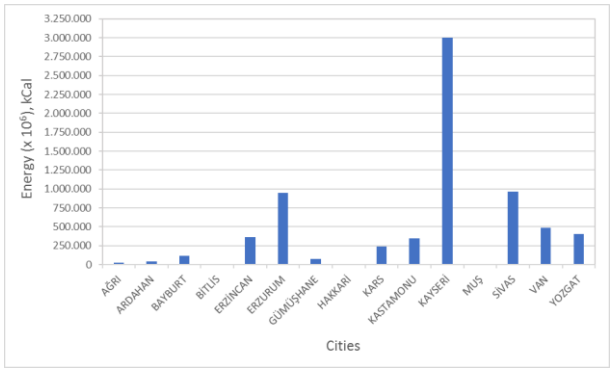
(Zone 1)



(Zone 2)

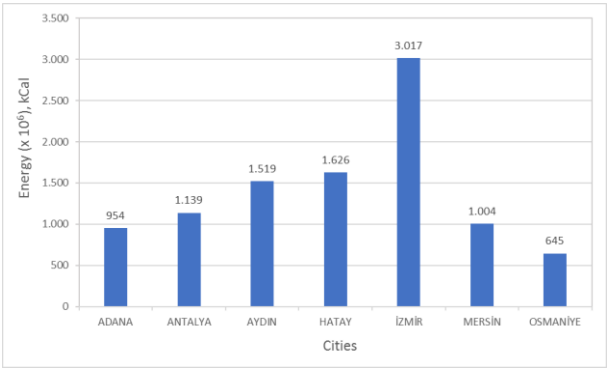


(Zone 3)

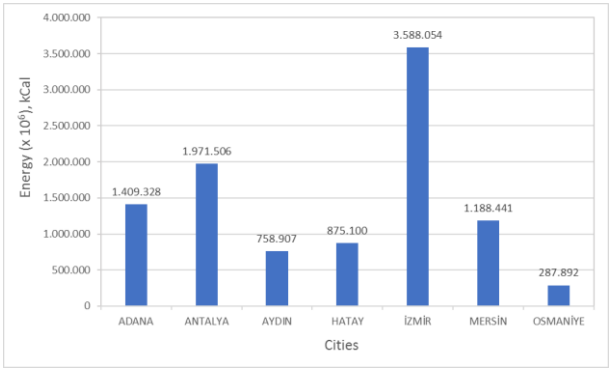


(Zone 4)

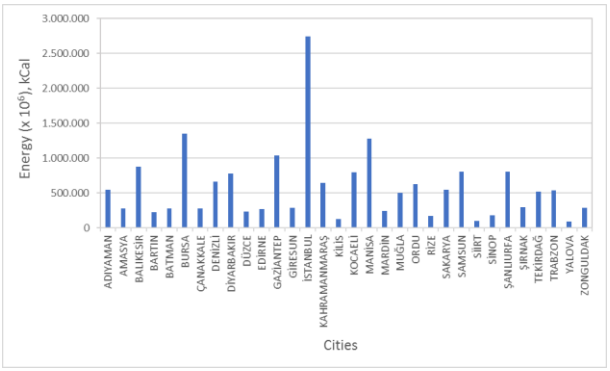
Figure 18. Energy from natural gas in cities in Zones



(Zone 1)



(Zone 1)



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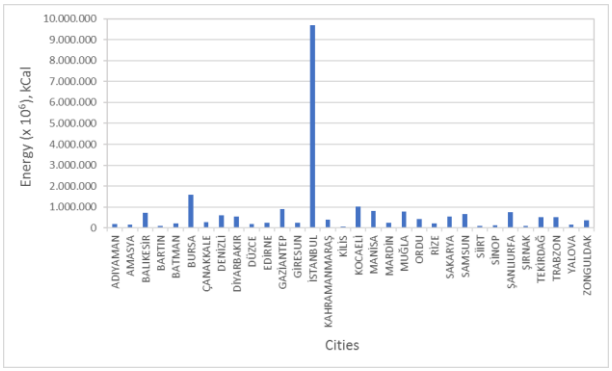
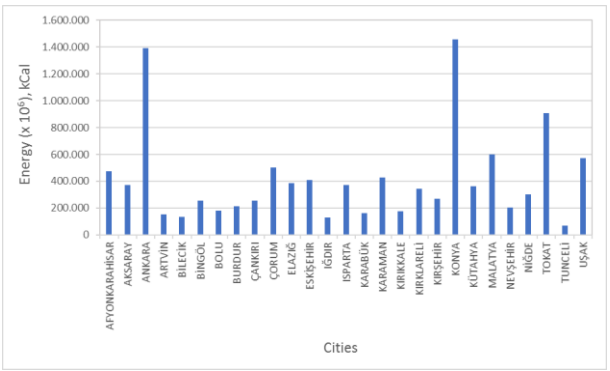
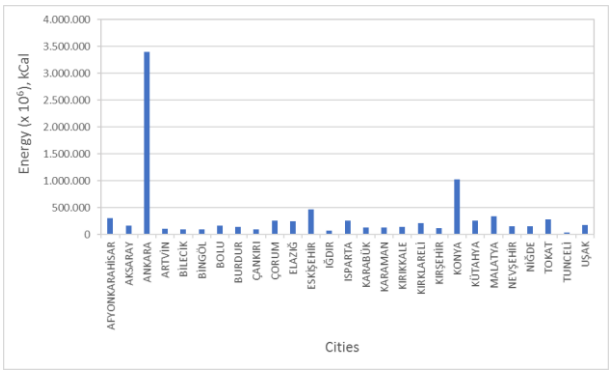


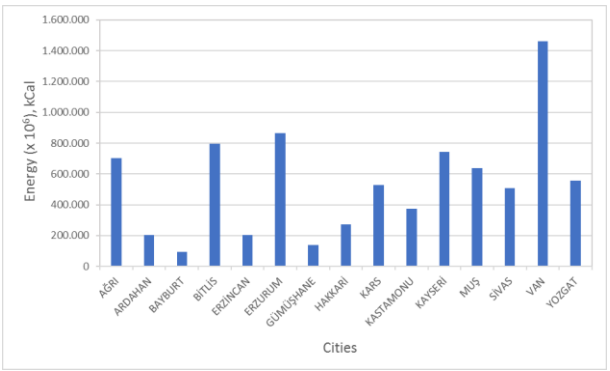
(Zone 2)



(Zone 3)

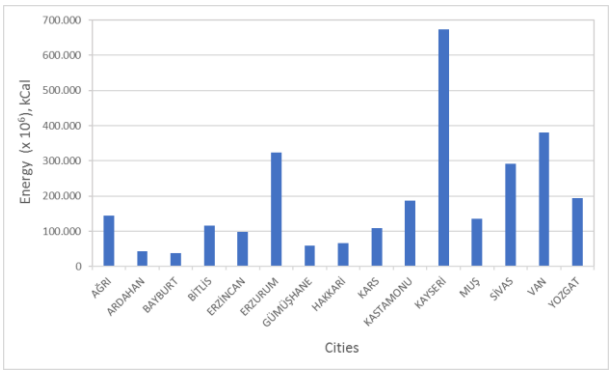


(Zone 3)



(Zone 4)

Figure 19. Energy from solid fuels in cities in Heating Zones

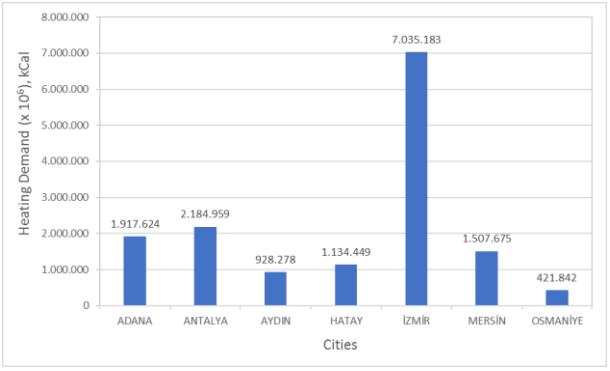


(Zone 4)

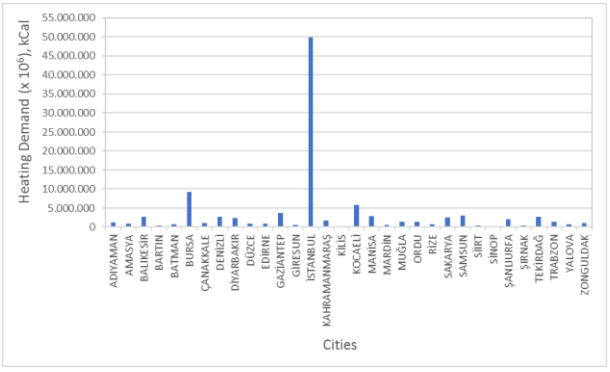
Figure 20. Energy from electricity in cities in Heating Zones

As it can be understood from Figure 18-20, heating needs have substantially been met from natural gas in all heating zones. Solid fuel and electricity follow the natural gas. Electrical energy is most commonly used in the first heating zone, where daily average temperatures are high and the number of HDDs is low. In other warming areas where the opposite situation is dominant, natural gas and solid fuel are used more, respectively.

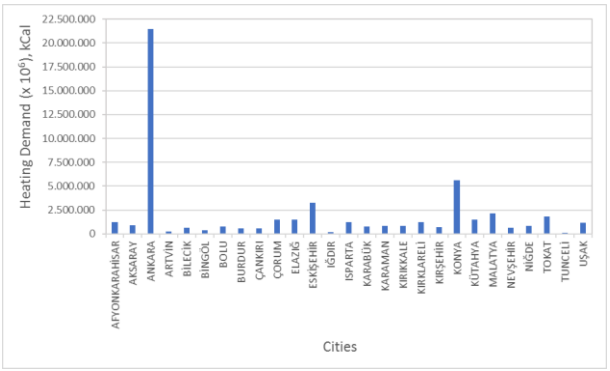
It is not possible to determine the heating demands of the residences. Heating demands of buildings can be determined using different methods. In this study, the heating demands of the residences were determined by considering the parameters above. The heating requirement in heating zones was given below in Figure 21.



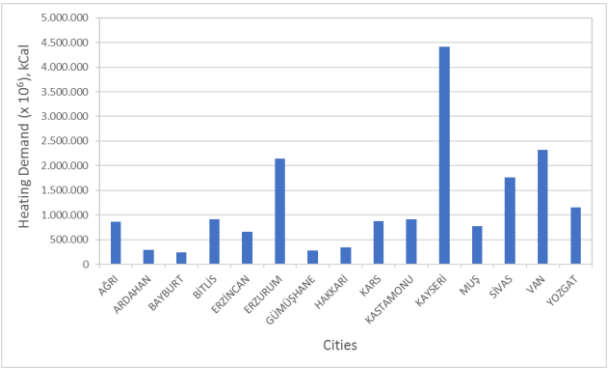
(Zone 1)



(Zone 2)



(Zone 3)



(Zone 4)

Figure 21. The Average annual total heating demands of cities in Heating Zones

It can be seen from Figure 21 that the second region has 55% of the total heating requirement. When Figure 21 is evaluated together with the residence and population, it can be seen that the population and the number of houses have a direct effect on the heating need. The second zone has 53% of the total population and 51% of the heating needs of residences, which corresponds to 50% of Turkey's overall poses. A similar case is valid in other heating zones. The third zone has 27%, the fourth zone has 9% and the first zone has 8% of total heating requirement. Population rates are also similar. The third region has 21%, the first region has 17% and the fourth region has 9% of the overall population; and the third region has 23%, the first region has 18% and the fourth region has 8% of total number of residences.

3.2. Cooling Demands

While determining the cooling requirement,

- National statistical data and general assumptions regarding the number of air-conditioners in-use,
- COPs of air-conditioners,
- Mean electricity consumption of air-conditioners,
- The number of houses of the provinces,
- degree day numbers of the provinces,
- climatic zones of the provinces

were taken into consideration. There are approximately 6.2 million air conditioners in Turkey. Based on statistical information, the number of air-conditioning units in the climate zones was determined based on the following rates:

- Zone 1: 68%
- Zone 2: 19%
- Zone 3: 9%
- Zone 4: 4%

The cooling load calculation is determined by the following equation:

$$Q_c = N_C \,.\, Z \,.\, COP \qquad (3)$$

where N_C stands for the number of air conditioners in the city, Z refers to average electricity consumption of an air conditioner, COP denotes the average COP of an air

conditioner. In calculations, the average annual electricity consumption of an air conditioner was taken as 325 kWh and its COP as 3.85.

$$N_C = (P \,.\, P_{THZ}).\, N_{HZ} \qquad (4)$$

In Eq. 4, P is the population of the province, P_{THZ} is the total population of the heating zone and N_{HZ} is the number of air conditioners in the heating zone.

In Figure 22, Turkey's cooling requirements both total and in climate zones is given. The cooling requirement in heating zones are given below in Figure 23.

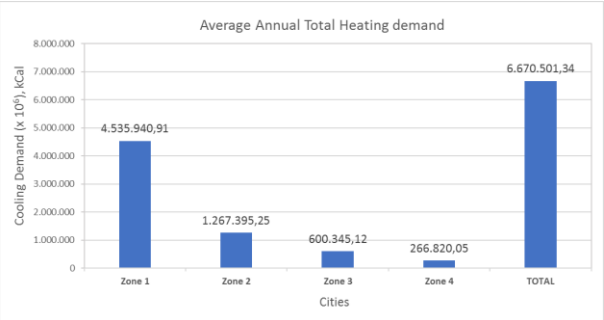
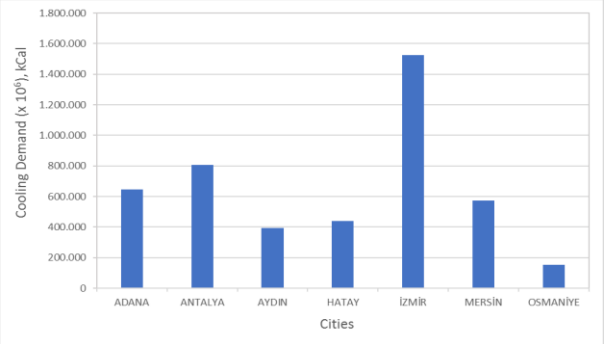
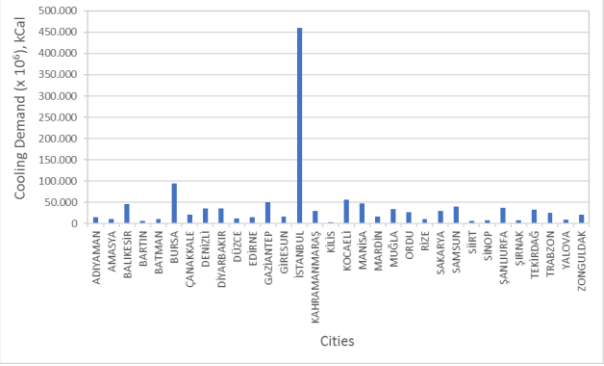


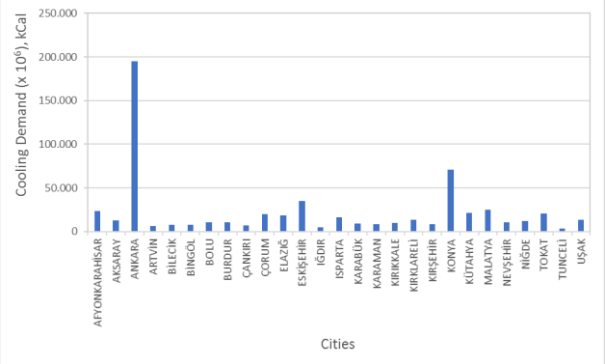
Figure 22. The average annual total cooling demands in Turkey



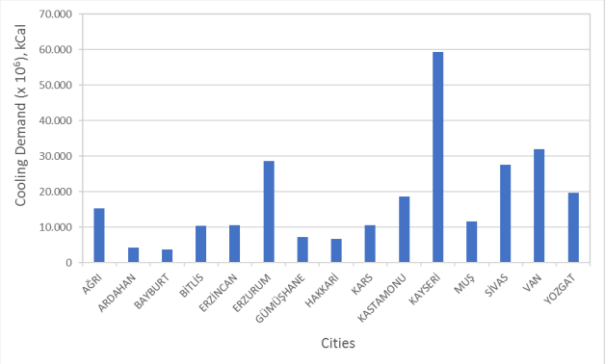
(Zone 1)



(Zone 2)



(Zone 3)



(Zone 4)

Figure 23. The Average annual total cooling demands of cities in Zones

It can be seen from Figure 22 and Figure 23 that the first region has 68% of the total cooling requirement. When Figure 22 and Figure 23 are evaluated together with the residence and population, it is seen that the population and the number of houses do not have a direct effect on the cooling need, while the daily average temperatures and CDD have a direct effect on the cooling need. The CDD / HDD ratio in the first region constitutes 87% of the total HDD and CDD total of the first region. The same is true in other heating zones. The second zone has 19%, the third zone has 9%, and the fourth zone has 4% of the total cooling requirement. There is a similarity in CDD / HDD ratios. It is seen that CDD / HDD ratios are 29% in the second region, 11% in the third region, and 4% in the fourth region.

4. CONCLUSION

In this study, regional heating and cooling systems as a basis for analysing expected residential heating and cooling loads in Turkey were determined. Heating/cooling loads of the residences were specified for each province according to the heating zones determined in accordance with TS 825. In the study, it was determined that the second heating zone had 55% of the total heating need and the first zone had 68% of the total cooling need. It was observed that the number of population and residences had effects on the heat loads,

while and the average daily temperatures and CDD had effects on the cooling loads.

ACKNOWLEDGMENT

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