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DETERMINATION OF FUEL CONSUMPTION OF RESIDENTIAL BUILDINGS BY DEGREE-DAY METHOD IN BALIKESİR AND ÇANAKKALE

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ABSTRACT

In this study, heating and cooling degree days were investigated by using the degree-day method for the Balıkesir and Çanakkale provinces of Turkey. Meteorological data obtained from the General Directorate of Meteorology between 2007 and 2020 were used. Heating and cooling costs per unit area in residential buildings were calculated according to the use of natural gas, coal, LPG or fuel oil for heating and electrical energy for cooling. According to the equilibrium temperature, the annual sum of Heating Degree-Day (HDD) values varied between 1167 and 2750 in Balıkesir and between 897 and 2445 in Çanakkale, while the annual sum of Cooling Degree-Day (CDD) values was 758-103 in Balıkesir and 859-173 in Çanakkale. The lowest fuel cost was acquired when natural gas was used, whilst the highest fuel cost was recorded when LPG was used. It is expected that this study will contribute to the literature and guide investments to be made in this area in the region.

Keywords: Degree day, heating, cooling, energy, fuel consumption.

BALIKESİR VE ÇANAKKALE'DE DERECE GÜN YÖNTEMİ İLE KONUTLARDA YAKIT TÜKETİMİNİN BELİRLENMESİ

ÖZET

Bu çalışmada Balıkesir ve Çanakkale İlleri için Derece gün yöntemi kullanılarak Isıtma ve Soğutma derece gün sayıları araştırılmıştır. Meteoroloji Genel Müdürlüğü'nden temin edilen 2007-2020 yılları arası meteorolojik veriler kullanılmıştır. Isıtmada doğalgaz,

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kömür, LPG, fuel oil ve soğutmada elektrik enerjisi kullanılması durumuna göre konut binalarında birim alan için ısıtma ve soğutma maliyetleri hesaplanmıştır. Denge sıcaklığına göre Isıtma Derece Gün (HDD) değerleri yıllık toplamı Balıkesir'de 1167-2750 ve Çanakkale'de 897-2445 arasında değişirken, Soğutma Derece Gün (CDD) değerleri yıllık toplamı Balıkesir'de 758-103 ve Çanakkale'de 859-173 arasında değişmektedir. En az yakıt maliyeti doğalgaz kullanıldığında elde edilirken, en fazla yakıt maliyeti LPG kullanıldığında elde edilmiştir. Çalışmanın literatüre katkı sağlaması ve bölgede bu alanda yapılacak yatırımlara yol gösterici olması beklenmektedir.

Anahtar Kelimeler: Derece Gün, ısıtma, soğutma, enerji, yakıt tüketimi.

1. INTRODUCTION

One of the most basic indicators of the economic and social development of countries is energy. Procuring energy from sustainable, reliable, clean and economical sources, using it efficiently and paying attention to saving energy have become a necessity due to economic crises and the depletion of resources over time.

Nearly 40% of the energy in Turkey is consumed in buildings. In buildings, more than three quarters of the energy is used for heating and cooling purposes. Although there are many new methods for energy analysis in buildings, the degree-day method is the simplest and most widely used method. In the degree-day method, the energy requirement of a building is directly proportional to the difference between the equilibrium temperature and the exterior temperature related to the indoor temperature of the building. If the indoor temperature and internal heat gains of the building are constant, the heating and cooling energy requirement of the building can be determined precisely by using the degree-day method [1-3].

Many studies on the degree-day method have been found in the literature. Dombaycı and Bayrakçı selected 16 cities with the coldest climatic conditions from Turkey's fourth climate zone (Ağrı, Ardahan, Artvin, Bayburt, Bitlis, Erzincan, Erzurum, Gümüşhane, Hakkari, Kars, Kastamonu, Kayseri, Muş, Sivas, Van and Yozgat), and for five different base temperatures (T_b= 14, 16, 18, 20 and 22 °C) in the warming period, monthly warming degree-days were calculated. In the selected months and base temperatures, Ardahan provided the highest degree-days while Artvin provided the lowest degree-days. For the 18 °C control

temperature and January, the heating energy consumption of Ardahan was estimated to be 47% higher than that of Artvin [4]. Özel and Tunç determined the optimum insulation thickness of building exterior walls in Kars, one of the coldest cities in Turkey. For this purpose, using the meteorological data of the province of Kars, heating loads were calculated in degree-days with and without taking into account solar radiation values. As a result, the degree-day values were determined as 3897 and 4867 for the 18 °C equilibrium temperature, respectively, with and without considering the solar radiation values. For Kars, the optimum insulation thickness was obtained as 8 and 9 cm for these degree-day values, respectively [5]. Pusat et al. prepared degree-time (degree-hour and degree-day) data to be used in energy estimation and heat load calculations for Karabük. The collected measurement data were examined in detail, and missing and problematic parts were removed. Degree-time calculations and detailed analysis were carried out for the equilibrium temperatures of 5, 10 and 15 °C. The results were presented as a plot and compared [6]. An et al. also analyzed the change in heating and cooling degree-days based on climate changes in Turkey. The temperature values that were obtained using the RegCM model and the calculated heating and cooling degree-day values were compared. In the comparison, the reference period of 1981-2000 was taken as the basis for the periods of 2016-2035 and 2046-2065. Accordingly, it was stated that there would be a decrease in the number of heating days and an increase in the number of cooling days throughout the country [7]. Baytorun et al. analyzed correlations between heating degree-day data and heat energy requirements for provinces in Turkey where greenhouses are commonly used. The results they acquired showed that HDD values facilitate the determination of thermal energy requirements [8]. D'Amico et al. determined correlations between heating degree-day and heating energy performance to achieve a preliminary assessment of energy demands. The results indicated that the proposed methodology can be extended and used to increase the reliability of any decision support system based on climate indices [9].

In this study, heating and cooling degree-day values for the Balıkesir and Çanakkale provinces in Turkey were studied by using the degree-day method. In the study, the meteorological data for the period between the years 2007 and 2020 were obtained from the General Directorate of Meteorology and analyzed. Calculations were made for the equilibrium temperatures within the limit value ranges of 15-22 °C in heating and 18-24 °C in cooling. Heating and cooling costs per unit area in residential buildings were calculated

according to the consumption of natural gas, coal, LPG, fuel oil in heating and electrical energy in cooling. The aim of this study was to determine the HDD and CDD values for 8 different equilibrium temperatures in heating and 7 different equilibrium temperatures in cooling in both provinces, as well as revealing the cost difference arising from fuel types in heating and cooling for each equilibrium temperature.

2. MATERIALS AND METHODS

2.1. Data Analysis

This study analyzed the outdoor temperature data measured hourly between 2007-2020 obtained from the meteorological station active in Balıkesir and Çanakkale. All data were obtained from the Ankara General Directorate of Meteorology.

2.2. Calculating the Heating and Cooling Degree-Days

Generally, DD is considered one of the simplest methods for energy calculation during heating and cooling buildings. Degree-days are characterized with the sum of temperature differences between the average outdoor air temperature over a given period of time and a known reference temperature. In this study, the number of heating degree days (HDH) and cooling degree days (CDH) were determined using equations (1) and (2) [10-12].

$T_{out} < T_{base}$ ise,

$$HDD = \sum_{1}^{n} (T_{base} - T_{out}) \qquad (1)$$

$T_{base} < T_{out}$ ise,

$$CDD = \sum_{1}^{n} (T_{out} - T_{base}) \qquad (2)$$

where n is the days total number during the period. T_{base} and T_{out} are base temperature and the mean temperature of outside air, respectively.

2.3. Calculating the Heat Load

The heat loss from unit surface:

$$q = U\Delta T \qquad (3)$$

where U is the overall heat transfer coefficient and it was accepted as 1 W/m^2K in this study. The annual heat losses from unit area can be approximately calculated depending on the degree-days number as the following:

$$q_A = 86400\,U\,DD \qquad (4)$$

where DD is the degree days. The annual energy requirement for heating (E_A) can be obtained approximately by dividing the annual heat loss to the efficiency of the heating system (η_s):

$$E_A = \frac{86400\,U\,DD}{\eta_s} \qquad (5)$$

The annual heating cost $C_{A,H}$ ($/m^2-year) per unit area can be calculated by the equation (6):

$$C_{A,H} = \frac{86400\ U\ HDD\ C_f}{H_u\ \eta_s} \qquad (6)$$

where C_f is fuel cost ($/kg) and H_u is the lower heating value of the fuel (J/kg; J/m^3). The annual cooling cost per unit area can be calculated using equation (7). COP is the performance coefficient of the cooling system and it was taken as 2.5 in this study [13]:

$$C_{A,C} = \frac{86400\ U\ CDD\ C_f}{COP} \qquad (7)$$

The data used to calculate the heating and cooling costs are given in Table 1.

Table 1. Properties of fuels and system efficiency [14, 15].

	Cost	Lower heating value	System efficiency
Natural gas	0.2868 $/$m^3$	34.542x106J/m^3	93
Coal	0.1921 $/kg	25.122x106 J/kg	65
LPG	1.75 $/kg	46.442x106 J/kg	88
Fuel-Oil	0.73 $/kg	41.317x106 J/kg	80
Electricity	0.1252 $/kWh	(COP) 2.5	

3. RESULTS AND DISCUSSION

In this study, heating and cooling degree-day values for the Balıkesir and Çanakkale provinces in Turkey were studied by using the degree-day method. In figures 1 and 2 are given annual average outdoor temperatures between 2007-2020 in Balıkesir and Çanakkale. It is seen from both graphs that the outside air temperature has been increasing over the years as a result of global warming from past to present.

Figure 3 shows the monthly variations in outdoor temperatures in Balıkesir, and Table 2 shows the frequency of temperature values from month to month. The highest mean temperature was seen in August as 25.62 °C, while the lowest mean temperature was recorded in January as 4.26 °C. While the highest rate in the heating season was observed in February as 7 °C, the highest rate in the cooling season was observed in July as 25 °C. Figure 4 shows the monthly variations in outdoor temperatures in Çanakkale, and Table 3 shows the frequency of temperature values from month to month. The highest mean temperature was seen in August as 26.67 °C, while the lowest mean temperature was recorded in January as 6.88 °C. While the highest rate in the heating season was observed in February as 7 °C, the highest rate in the cooling season was observed in July as 26 °C.

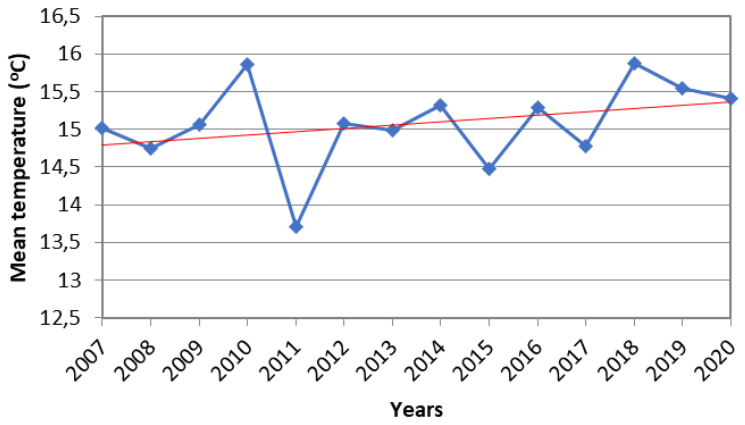

Figure 1. Mean temperatures of 2007-2020 years for Balıkesir

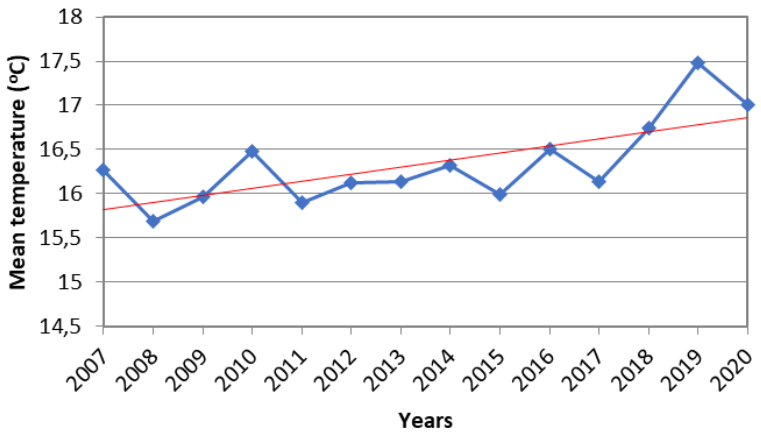

Figure 2. Mean temperatures of 2007-2020 years for Çanakkale

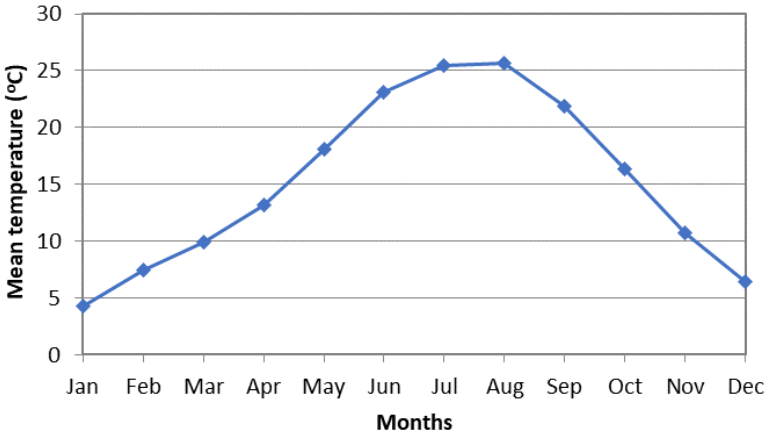

Figure 3. Monthly temperature distribution for Balıkesir

Table 2. Frequency of temperature values for Balıkesir

Temp. (°C)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	3.2	0	0	0	0	0	0	0	0	0	0	0
1	6.5	0	0	0	0	0	0	0	0	0	0	0
2	6.5	0	0	0	0	0	0	0	0	0	0	0
3	22.6	0	0	0	0	0	0	0	0	0	0	3.2
4	29.0	3.6	0	0	0	0	0	0	0	0	0	9.7
5	25.8	7.1	0	0	0	0	0	0	0	0	0	25.8
6	3.2	14.3	3.2	0	0	0	0	0	0	0	0	32.3
7	3.2	46.4	6.5	0	0	0	0	0	0	0	6.7	3.2
8	0	14.3	16.1	0	0	0	0	0	0	0	16.7	22.6
9	0	10.7	16.1	0	0	0	0	0	0	0	26.7	3.2
10	0	3.6	45.2	10.0	0	0	0	0	0	0	13.3	0
11	0	0.0	12.9	13.3	0	0	0	0	0	3.2	6.7	0
12	0	0	0	23.3	0	0	0	0	0	3.2	10.0	0
13	0	0	0	23.3	0	0	0	0	0	9.7	13.3	0
14	0	0	0	16.7	0	0	0	0	0	6.5	6.7	0
15	0	0	0	3.3	9.7	0	0	0	0	12.9	0	0
16	0	0	0	10.0	22.6	0	0	0	0	29.0	0	0
17	0	0	0	0	16.1	0	0	0	0	12.9	0	0
18	0	0	0	0	12.9	0	0	0	1.2	22.6	0	0
19	0	0	0	0	25.8	0	0	0	1.2	0	0	0
20	0	0	0	0	9.7	6.7	0	0	0.6	0	0	0
21	0	0	0	0	3.2	13.3	0	0	0.3	0	0	0
22	0	0	0	0	0	26.7	0	0	2.7	0	0	0
23	0	0	0	0	0	16.7	0	0	1.8	0	0	0
24	0	0	0	0	0	26.7	32.3	19.4	1.2	0	0	0
25	0	0	0	0	0	10.0	51.6	45.2	0	0	0	0
26	0	0	0	0	0	0	16.1	35.5	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0

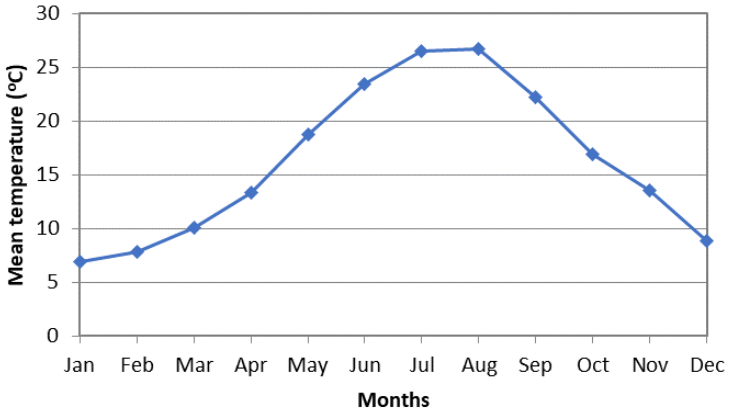

Figure 4. Monthly temperature distribution for Çanakkale

Table 3. Frequency of temperature values for Çanakkale

Temp. (°C)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	3.2	0	0	0	0	0	0	0	0	0	0	3.2
5	16.1	3.6	0	0	0	0	0	0	0	0	0	3.2
6	29.0	14.3	0	0	0	0	0	0	0	0	0	0
7	29.0	42.9	0	0	0	0	0	0	0	0	0	22.6
8	19.4	32.1	9.7	0	0	0	0	0	0	0	0	29.0
9	3.2	7.1	35.5	0	0	0	0	0	0	0	0	19.4
10	0	0	35.5	3.3	0	0	0	0	0	0	0	12.9
11	0	0	19.4	6.7	0	0	0	0	0	0	10.0	3.2
12	0	0	0	30.0	0	0	0	0	0	0	30.0	6.5
13	0	0	0	30.0	0	0	0	0	0	3.2	26.7	0
14	0	0	0	20.0	0	0	0	0	0	16.1	13.3	0
15	0	0	0	6.7	0	0	0	0	0	3.2	20.0	0
16	0	0	0	3.3	12.9	0	0	0	0	22.6	0	0
17	0	0	0	0	19.4	0	0	0	0	25.8	0	0
18	0	0	0	0	12.9	0	0	0	0	16.1	0	0
19	0	0	0	0	38.7	0	0	0	1.5	12.9	0	0
20	0	0	0	0	16.1	16.7	0	0	1.5	0	0	0
21	0	0	0	0	0	6.7	0	0	0.3	0	0	0
22	0	0	0	0	0	6.7	0	0	1.5	0	0	0
23	0	0	0	0	0	20.0	0	0	2.7	0	0	0
24	0	0	0	0	0	40.0	0	0	1.2	0	0	0
25	0	0	0	0	0	10.0	19.4	16.1	0.3	0	0	0
26	0	0	0	0	0	0	61.3	45.2	0	0	0	0
27	0	0	0	0	0	0	19.4	38.7	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0

The HDD and CDD numbers for Balıkesir are given in Figures 5 and 6, and those for Çanakkale are given in Figures 7 and 8. While the HDD values varied between 1167 and 2750, and the CDD values varied between 758 and 103 for Balıkesir, the HDD values varied between 897 and 2445, and the CDD values varied between 859 and 173 for Çanakkale. The HDD values of Balıkesir were higher than those of Çanakkale, whereas the CDD values of Balıkesir were recorded as lower than those of Çanakkale.

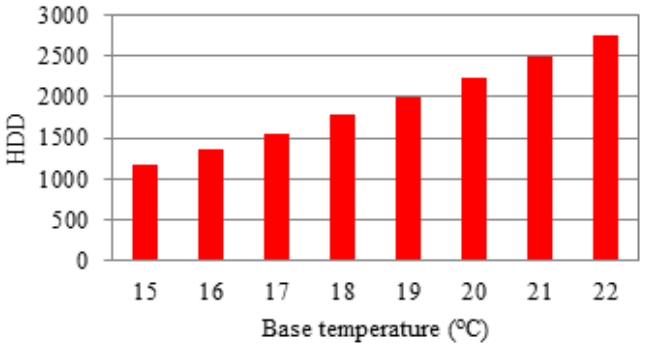

Figure 5. HDD values for Balıkesir

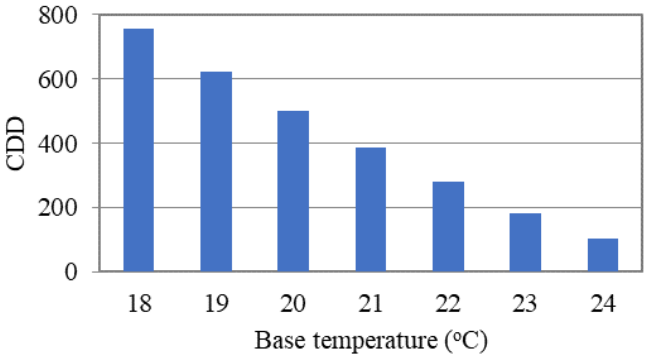

Figure 6. CDD values for Balıkesir

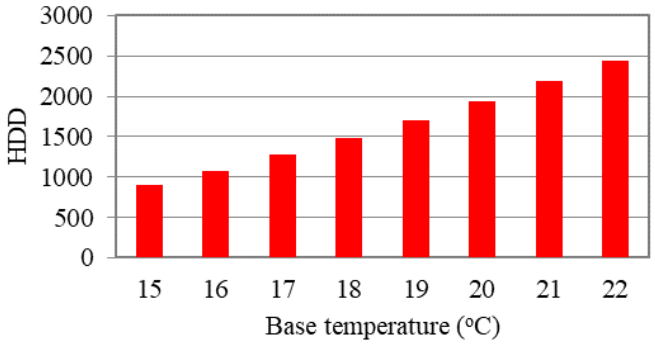

Figure 7. HDD values for Çanakkale

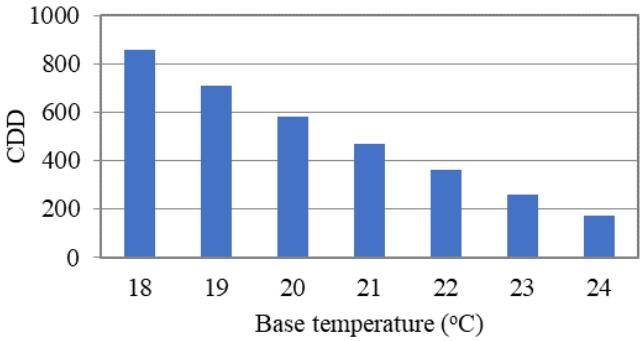

Figure 8. CDD values for Çanakkale

In Table 4, HDD and CDD values are given as monthly and annual totals. In both cities, HDD values were obtained in January, February, March, April, May, October, November, December, and only for the base temperature of 20-22 °C for June, July, August and September in heating. Other values were obtained as zero. Likewise, CDD values were obtained in both cities in June, July, August and September and for the 18-20 °C base temperature of May in cooling, while the other values were obtained as zero.

Tables 5-8 show the energy costs needed for the unit area according to the equilibrium temperatures and the annual total value. While calculations were made for natural gas, coal, LPG and fuel oil in heating, they were made for electrical energy in cooling. In the comparison of the fuels, the most inexpensive one was identified to be natural gas, while LPG was the most expensive one. High energy costs in heating indicate the importance of facility planning.

Table 4. HDD and CDD according to base temperature

B.Temp. (°C)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
HDD for Balıkesir													
15	332	210	159	58	0	0	0	0	0	10	129	266	1167
16	363	238	190	84	1	0	0	0	0	18	159	297	1353
17	394	266	221	113	9	0	0	0	0	34	189	328	1558
18	425	294	252	143	20	0	0	0	0	55	219	359	1771
19	456	322	283	173	37	0	0	0	1	82	249	390	1999
20	487	350	314	203	59	0	0	0	7	113	279	421	2239
21	518	378	345	233	89	0	0	0	17	144	309	452	2492
22	549	406	376	263	120	5	0	0	27	175	339	483	2750
CDD for Balıkesir													
18	0	0	0	0	23	153	230	236	115	0	0	0	758
19	0	0	0	0	10	123	199	205	87	0	0	0	624
20	0	0	0	0	3	93	168	174	63	0	0	0	501
21	0	0	0	0	0	64	137	143	42	0	0	0	387
22	0	0	0	0	0	38	106	112	23	0	0	0	280
23	0	0	0	0	0	20	75	81	7	0	0	0	184
24	0	0	0	0	0	7	44	50	1	0	0	0	103
HDD for Çanakkale													
15	251	201	152	52	0	0	0	0	0	3	46	190	897
16	282	229	183	80	0	0	0	0	0	10	74	221	1081
17	313	257	214	110	1	0	0	0	0	20	104	252	1274
18	344	285	245	140	9	0	0	0	0	39	134	283	1482
19	375	313	276	170	21	0	0	0	0	64	164	314	1699
20	406	341	307	200	41	0	0	0	1	94	194	345	1932
21	437	369	338	230	71	1	0	0	11	125	224	376	2185
22	468	397	369	260	102	7	0	0	21	156	254	407	2445
CDD for Çanakkale													
18	0	0	0	0	31	162	262	268	127	6	0	0	859
19	0	0	0	0	11	132	231	237	97	0	0	0	711
20	0	0	0	0	1	102	200	206	68	0	0	0	579
21	0	0	0	0	0	73	169	175	48	0	0	0	467
22	0	0	0	0	0	49	138	144	29	0	0	0	362
23	0	0	0	0	0	27	107	113	11	0	0	0	261
24	0	0	0	0	0	10	76	82	3	0	0	0	173

In the comparison between Balıkesir and Çanakkale, the heating energy requirements were found higher in Balıkesir in proportion to the HDD and CDD values, while the cooling energy requirements were higher in Çanakkale.

For Balıkesir, when the equilibrium temperature was increased from 15°C to 22°C for natural gas, which was found as the most economical fuel in heating, the required consumption of fuel increased approximately 2.35 times, while it increased 2.72 times for Çanakkale. When the equilibrium temperature was reduced from 24 °C to 18 °C in cooling, the consumption of electricity increased 7.4 times for Balıkesir and 5 times for Çanakkale.

Table 5. Heating costs per unit area for Balıkesir ($/m^2)

B.Temp.(°C)	Jan	Feb	Mar	Apr	May	Oct	Nov	Dec	Annual
Natural gas									
15	0.2568	0.1624	0.1229	0.0448	0	0.0078	0.0999	0.2056	0.9003
16	0.2807	0.184	0.1468	0.0652	0.0009	0.014	0.1231	0.2295	1.0443
17	0.3046	0.2056	0.1707	0.0878	0.0071	0.0262	0.1462	0.2535	1.2018
18	0.3286	0.2272	0.1946	0.111	0.016	0.0426	0.1693	0.2774	1.3667
19	0.3525	0.2488	0.2186	0.1341	0.0292	0.064	0.1925	0.3013	1.5422
20	0.3764	0.2704	0.2425	0.1573	0.0462	0.0879	0.2156	0.3252	1.7274
21	0.4003	0.292	0.2664	0.1804	0.0694	0.1118	0.2388	0.3491	1.9222
22	0.4242	0.3136	0.2903	0.2035	0.0932	0.1357	0.2619	0.373	2.1212
Coal									
15	0.3384	0.214	0.1619	0.059	0	0.0103	0.1317	0.271	1.1862
16	0.3699	0.2425	0.1935	0.0859	0.0011	0.0185	0.1622	0.3025	1.376
17	0.4014	0.2709	0.225	0.1157	0.0093	0.0346	0.1927	0.334	1.5836
18	0.4329	0.2994	0.2565	0.1462	0.021	0.0562	0.2231	0.3655	1.8009
19	0.4644	0.3278	0.288	0.1767	0.0385	0.0843	0.2536	0.397	2.0321
20	0.496	0.3563	0.3195	0.2072	0.0609	0.1158	0.2841	0.4285	2.2762
21	0.5275	0.3848	0.351	0.2377	0.0915	0.1473	0.3146	0.46	2.5329
22	0.559	0.4132	0.3825	0.2682	0.1228	0.1788	0.3451	0.4915	2.7951
LPG									
15	1.2323	0.7793	0.5897	0.2148	0	0.0374	0.4795	0.9867	4.3196
16	1.347	0.8829	0.7045	0.3127	0.0042	0.0674	0.5905	1.1014	5.0106
17	1.4618	0.9866	0.8192	0.4215	0.0339	0.126	0.7015	1.2161	5.7665
18	1.5765	1.0902	0.9339	0.5325	0.0766	0.2046	0.8126	1.3309	6.5577
19	1.6912	1.1938	1.0487	0.6435	0.1401	0.3069	0.9236	1.4456	7.3997
20	1.806	1.2975	1.1634	0.7546	0.2216	0.4216	1.0346	1.5604	8.2887
21	1.9207	1.4011	1.2781	0.8656	0.333	0.5364	1.1457	1.6751	9.2234
22	2.0355	1.5047	1.3929	0.9766	0.4473	0.6511	1.2567	1.7898	10.178
Fuel oil									
15	0.7819	0.4945	0.3742	0.1363	0	0.0237	0.3042	0.6261	2.7409
16	0.8547	0.5602	0.447	0.1984	0.0027	0.0428	0.3747	0.6989	3.1794
17	0.9275	0.626	0.5198	0.2674	0.0215	0.0799	0.4451	0.7717	3.659
18	1.0003	0.6918	0.5926	0.3379	0.0486	0.1298	0.5156	0.8445	4.1611
19	1.0731	0.7575	0.6654	0.4083	0.0889	0.1947	0.586	0.9173	4.6953
20	1.1459	0.8233	0.7382	0.4788	0.1406	0.2675	0.6565	0.9901	5.2594
21	1.2187	0.889	0.811	0.5492	0.2113	0.3403	0.727	1.0629	5.8525
22	1.2915	0.9548	0.8838	0.6197	0.2838	0.4132	0.7974	1.1357	6.4583

Table 6. Cooling costs per unit area for Balıkesir ($/m^2)

B.Temp. (°C)	May	Jun	Jul	Aug	Sep	Annual
Electricity						
18	0.0724	0.4655	0.6984	0.7168	0.3505	2.3036
19	0.0304	0.3745	0.6043	0.6227	0.2645	1.8963
20	0.0093	0.2834	0.5102	0.5286	0.1922	1.5236
21	0	0.1949	0.4161	0.4345	0.1302	1.1756
22	0	0.1179	0.3219	0.3403	0.0709	0.851
23	0	0.0627	0.2278	0.2462	0.0227	0.5595
24	0	0.0225	0.1337	0.1521	0.0052	0.3136

Table 7. Heating costs per unit area for Çanakkale ($/m^2)

B.Temp. (°C)	Jan	Feb	Mar	Apr	May	Oct	Nov	Dec	Annual
Natural gas									
15	0.194	0.1551	0.1173	0.0402	0	0.0031	0.0356	0.1467	0.692
16	0.218	0.1767	0.1412	0.0621	0	0.0081	0.0576	0.1706	0.8342
17	0.2419	0.1983	0.1651	0.085	0.0014	0.0162	0.0807	0.1945	0.9832
18	0.2658	0.2199	0.1891	0.1082	0.0077	0.0305	0.1039	0.2184	1.1434
19	0.2897	0.2415	0.213	0.1313	0.0164	0.0496	0.127	0.2423	1.3108
20	0.3136	0.2631	0.2369	0.1545	0.0321	0.0732	0.1502	0.2662	1.4908
21	0.3375	0.2847	0.2608	0.1776	0.055	0.0971	0.1733	0.2901	1.6855
22	0.3614	0.3063	0.2847	0.2007	0.0789	0.121	0.1964	0.314	1.886
Coal									
15	0.2557	0.2044	0.1546	0.053	0	0.004	0.0469	0.1933	0.9119
16	0.2872	0.2329	0.1861	0.0818	0	0.0107	0.0759	0.2248	1.0993
17	0.3187	0.2613	0.2176	0.1121	0.0018	0.0213	0.1064	0.2563	1.2955
18	0.3502	0.2898	0.2491	0.1425	0.0101	0.0402	0.1369	0.2878	1.5066
19	0.3817	0.3182	0.2806	0.173	0.0216	0.0654	0.1674	0.3193	1.7273
20	0.4132	0.3467	0.3121	0.2035	0.0423	0.0964	0.1979	0.3508	1.9644
21	0.4447	0.3752	0.3436	0.234	0.0725	0.128	0.2283	0.3823	2.221
22	0.4762	0.4036	0.3752	0.2645	0.104	0.1595	0.2588	0.4138	2.4852
LPG									
15	0.931	0.7443	0.5629	0.193	0	0.0147	0.1709	0.7037	3.3206
16	1.0458	0.848	0.6777	0.2979	0	0.0389	0.2763	0.8185	4.0029
17	1.1605	0.9516	0.7924	0.408	0.0067	0.0776	0.3874	0.9332	4.7174
18	1.2753	1.0552	0.9071	0.5191	0.0368	0.1465	0.4984	1.0479	5.4863
19	1.39	1.1589	1.0219	0.6301	0.0786	0.2382	0.6094	1.1627	6.2898
20	1.5047	1.2625	1.1366	0.7411	0.1542	0.3512	0.7205	1.2774	7.1531
21	1.6195	1.3661	1.2513	0.8522	0.264	0.4659	0.8315	1.3921	8.0876
22	1.7342	1.4698	1.3661	0.9632	0.3787	0.5807	0.9426	1.5069	9.0497
Fuel oil									
15	0.5908	0.4723	0.3572	0.1225	0	0.0093	0.1084	0.4465	2.107
16	0.6636	0.538	0.43	0.189	0	0.0247	0.1753	0.5193	2.54
17	0.7364	0.6038	0.5028	0.2589	0.0042	0.0493	0.2458	0.5921	2.9933
18	0.8092	0.6696	0.5756	0.3294	0.0234	0.093	0.3163	0.6649	3.4812
19	0.882	0.7353	0.6484	0.3998	0.0499	0.1511	0.3867	0.7377	3.991
20	0.9548	0.8011	0.7212	0.4703	0.0978	0.2229	0.4572	0.8105	4.5388
21	1.0276	0.8668	0.794	0.5407	0.1675	0.2957	0.5276	0.8833	5.1318
22	1.1004	0.9326	0.8668	0.6112	0.2403	0.3685	0.5981	0.9562	5.7423

Table 8. Cooling costs per unit area for Çanakkale ($/m^2)

B.Temp. (°C)	May	Jun	Jul	Aug	Sep	Annual
Electricity						
18	0.096	0.4926	0.7982	0.8156	0.3865	2.6093
19	0.0362	0.4015	0.7041	0.7215	0.2955	2.1602
20	0.0046	0.3104	0.61	0.6274	0.2083	1.7607
21	0	0.2226	0.5158	0.5333	0.1469	1.4186
22	0	0.1501	0.4217	0.4392	0.0887	1.0997
23	0	0.0839	0.3276	0.345	0.036	0.7926
24	0	0.0306	0.2335	0.2509	0.0107	0.5258

Calculating HDD and CDD values provides important information. With this information, it will be possible to choose the appropriate system and material to meet the energy needs for designing a building.

It was seen that the HDD values were higher than the CDD values throughout the region. It is an important advantage if the energy costs for cooling are quite low. In order to make heating energy consumption more economical, the evaluation of renewable energy resources may be considered.

Furthermore, thermal insulation is very important in reducing energy costs. If the exterior walls and roofs of buildings are insulated with appropriate insulation materials, the energy needs of the building will be reduced, and savings will be increased. Insulation will contribute to environmental factors as well as savings.

4. CONCLUSION

In this study, heating and cooling degree-day values for the Balıkesir and Çanakkale provinces in Turkey were studied by using the degree-day method. In the study, the meteorological data for the period between the years 2007 and 2020 were obtained from the General Directorate of Meteorology and analyzed. Heating and cooling costs per unit area in residential buildings were calculated according to the consumption of natural gas, coal, LPG, fuel oil in heating and electrical energy in cooling. The results of this study showed that heating costs were higher. Additionally, the equilibrium temperature was an important factor. The appropriate selection of the equilibrium temperature significantly affects fuel consumption. It is concluded that insulation will be an important factor in reducing energy costs for existing buildings and new buildings planned to be built in the region. In addition to this, insulation is also extremely important in terms of reducing emissions.

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