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# Heating and cooling degree-time calculations for Duzce

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**Abstract**
In our study, heating and cooling degree time data have been prepared for use in the energy estimation and heat load calculations of the buildings for Düzce province. The hourly temperature data to be used in the calculations (between 2007-2017) were obtained from the MGM station. The obtained data was transferred to excel and the data was checked for incorrectly and missing. After correcting the problem data by taking into consideration the average temperature values, 15 ° C for heating and 22 ° C for cooling, equilibrium temperature time calculations were made in addition, 11 years and yearly 8760 hours of annual temperature data from tables and graphics were extracted and examined in detail.

*Keywords:* Degree-time; degree-hour; degree-day; Duzce; climate date.

## 1. Introduction

Comfort is the highest level of satisfaction of the human being by spending the least amount of energy in the physical conditions [1]. However, comfort is a relative concept and people under the same comfort conditions show different satisfaction characteristics. But; As it is not possible to create conditions that will please everyone, the desired conditions can be determined as the comfort conditions accepted by the majority. For example; International Standard ISO 7730 provides at least 80% user satisfaction regarding thermal comfort [2]. Another issue to be considered when considering comfort conditions is energy efficiency.

Houses have a significant share in energy consumption. About 40% of the energy in the world is consumed in buildings. The energy consumed in homes turkey is equal to approximately 25-30% of total power consumption. In addition, in homes 85% of the energy is used for heating [3]. The efficient use of energy in buildings is as important as the production of energy. The emission of carbon dioxide ($CO_2$) from the energy source used causes global warming, which is another reason for the conscious use of energy [4].

Energy-efficient heating and cooling systems, insulating the building and minimizing the lost heat are constantly being done and progress is shown. The most important factor used in these studies is undoubtedly the outside air temperature.

The performance of heating, cooling and air conditioning systems depends on the weather conditions. While the design and performance simulations of these systems are made, the use of climate information that summarizes the values of long periods instead of randomly determined one or several years makes the results more realistic and valuable. Therefore, the required energy analysis provides accurate results only considering the climate data [5-6].

Degree time (degree-clock ve degree-day) method is one of the oldest methods used in energy performance analysis in buildings. Although detailed and complex energy analysis methods have been developed, the degree-day method is still widely used. It is common for countries to assign degree-day zones to be used in different heating, cooling and insulation applications [7-8]. Available some studies related to variable based degree time and degree day calculations for Turkey [9-10].

If the indoor temperature and internal heat gains of the building are constant and the heating and cooling systems are operating continuously throughout the season, the annual heating and cooling loads can be estimated with good precision with the values obtained from the degree-day method.

The heating energy requirement calculated with the

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degree day values depends on the selected "equilibrium point temperature" $T_{den}$. This equilibrium temperature may vary from one building to another. This change can be determined according to the desired indoor temperature, the thermal properties of the building and the way of use. The equilibrium point temperature is the outdoor ambient temperature when heating or cooling is not needed in a building. Heating will only be necessary when the outdoor temperature drops below the equilibrium point temperature[11].

In this study, 11-year external air temperature data were obtained for Düzce province and heating and cooling degree day values were calculated. According to the data provided, tables and graphs were created for different reference temperatures for heating and cooling purposes. The obtained heating and cooling degree day values and the values in the tables and graphs were analyzed and evaluated

## 2. Material and method

Düzce Province is under the influence of humid and non-hard climate in the coastal areas of the Black Sea Region. In addition to the Black Sea climate, similar to the Mediterranean climate and the terrestrial climate. The average annual temperature is 13,0 C° and the total annual precipitation is 823,7 kg/m² and the average relative humidity is 75% [12].
According to the data obtained from the MGM, the average monthly temperature data of the province of Düzce was prepared for many years. According to the data in Table 1, the highest monthly average temperature was 22.6 °C in July and the lowest monthly average temperature was 3.8 °C in January. The average temperature throughout the year was 13.3 °C.

Table 1. Long years Monthly Temperature Average for Düzce Province [13].

| Months | Avarage Temperature (C) |
|---|---|
| **January** | 3.8 |
| **February** | 5.3 |
| **March** | 7.8 |
| **April** | 12.3 |
| **May** | 16.7 |
| **June** | 20.6 |
| **July** | 22.6 |
| **August** | 22.4 |
| **September** | 18.8 |
| **October** | 14.3 |
| **November** | 9.6 |
| **December** | 5.8 |
| **Yearly** | 13.3 |

Degree-day values are one of the simplest units of measurement used to estimate the annual energy need of a building in any place. The annual energy requirement of the building can be easily calculated using the average day value and the average U value of the building outer shell elements.
Determination of the number of heating degree days (HDD) and cooling degree days (CDD) numbers separately at any location; heating and cooling systems are important for determining their capacity and costs. In the calculation of these parameters; The equations proposed by the European Union Statistical Office (Eurostat) to create a comparable and common use are given below.

$$HDD\ (T_h) = \sum_1^N (T_h - T_0) \quad (1)$$

(only days with $T_h > T_0$ are calculated)

$$CDD\ (T_c) = \sum_1^M (T_0 - T_c) \quad (2)$$

(only days with $T_0 > T_h$ are calculated)

In the equations; $T_0$ the daily average outside temperature, Th and Tc, is the equilibrium or threshold temperature determined for the heating and cooling period, respectively. Although N and M values are the total number of days in heating and cooling period respectively; days that do not require heating or cooling are not included in these numbers [14].

In our work we have taken reference to the temperatures where the outside air temperature for heating is less than and equal to 15 °C, and the temperature for cooling degree is greater than and equal to 22 °C. In calculations heating degree time

months are January – February – March –April – October – November - December and cooling degree time months are May – June – July - August and September. Isıtma derece zaman hesabı yaptığımız aylar In our calculations, we used the months of January – February – March – April – October – November - December for heating-time calculation, and the months of May – June – July - August and September for cooling-time calculation.

## 3. Data analysis calculation

### 3.1 Data analysis and evaluation for heating degree time calculations

According to the 11-year temperature data of Düzce province, the number of days with a mean temperature below 15 ° C was calculated and a graph was created (Figure1). Number of days remaining below 15 ° C (days in need of heating); least in 2011 164 days and most in 2011 with 213 days. The average number of days in need of heating is 192 days.

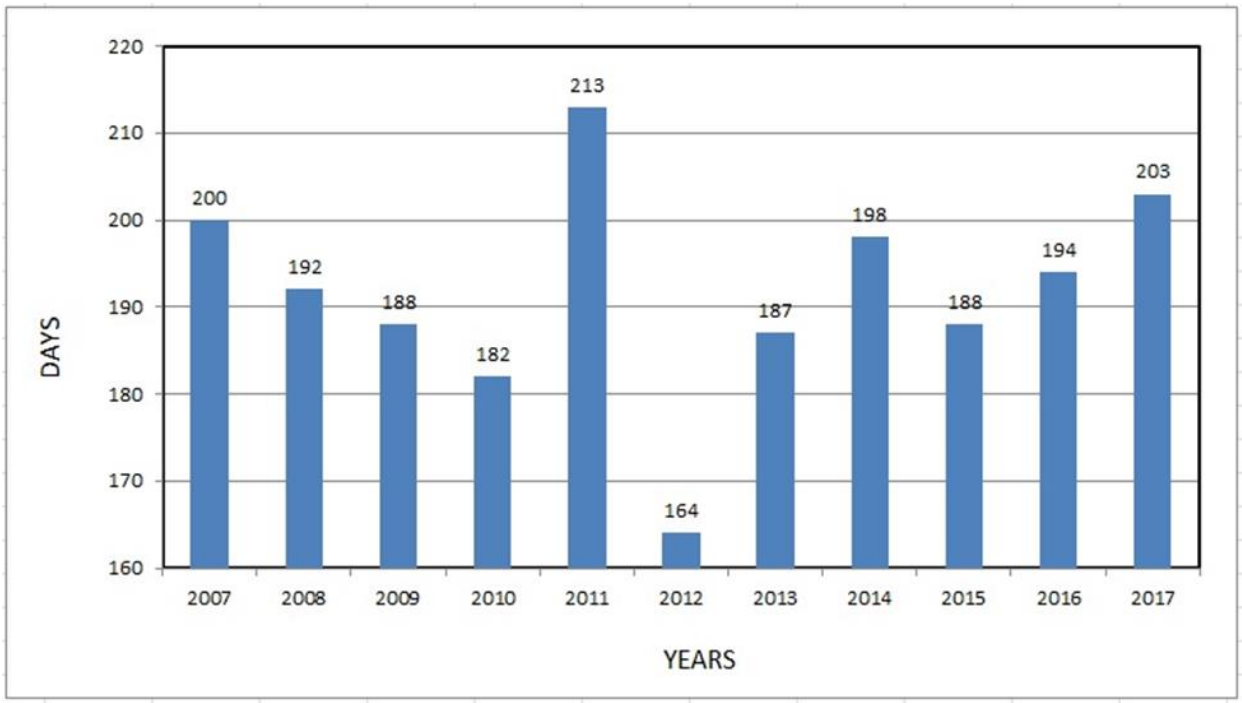


Figure 1. Chart showing days remaining below the average temperature of 15 ° C according the years.

Heating degree day values were calculated for the equilibrium temperature of 15 ° C. (Figure 2). According to Figure 2, the maximum heating degree day value was 2318 in 2011, while the minimum heating degree day value was 1620 in 2010. Also the average yearly 1938 heating degree day value was obtained.

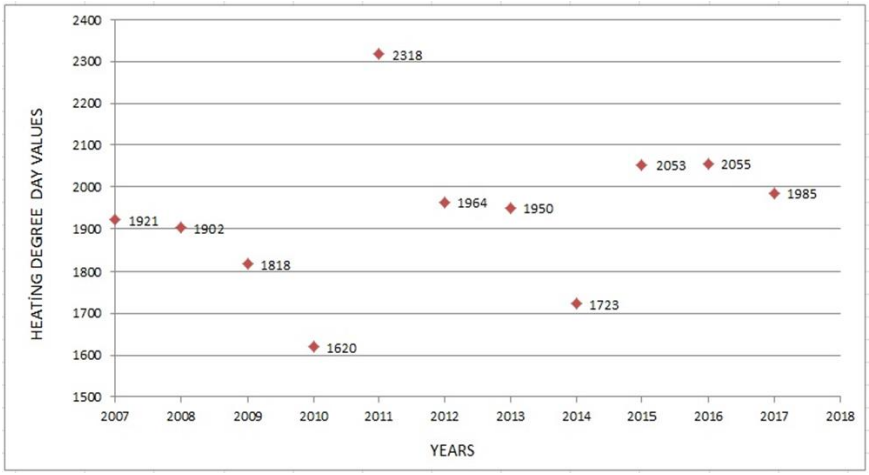


Figure 2. Heating degree day values for 15 ° C.

After the calculation of the degree day, a degree hour was calculated to compare. Table 2; Shows the monthly and annual number of 3 different equilibrium temperature measurements.Looking at the 11-year data:

- The monthly measured number of temperatures below 5 ° C varies between 448-13. The average monthly rate is 122.
- The monthly measured number of temperatures below 10 ° C varies between 639-121. The average monthly rate is 249.
- The monthly measured number of temperatures below 15 ° C varies between 714-407. The average monthly rate is 348.
- The monthly measured number of temperatures above 15 ° C varies between 337-30. The average monthly rate is 77.

Figure 3 shows the annual total number of hourly measurements of different equilibrium temperatures. According this;

- The sum of the annual measured values of temperatures below 5 ° C is maximum 1849. The average is 1454.
- The sum of the annual measured values of temperatures below 10 ° C is maximum 3688. The average is 2989.
- The sum of the annual measured values of temperatures below 15 ° C is maximum 4614. The average is 4176.
- The sum of the annual measured values of temperatures above 15 ° C is maximum 1142. The average is 920.

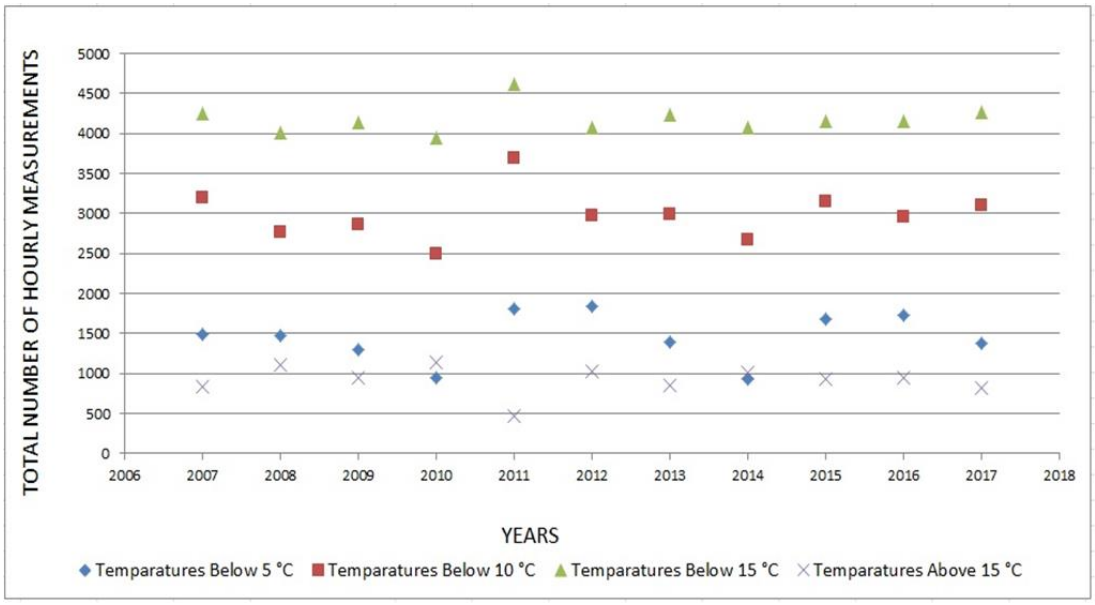


Figure 3. Annual total number of hourly measurements of different equilibrium temperatures.

Table 2. Monthly and annual number of 3 different equilibrium temperature measurements.

| MONTHS | REFERENCE TEMPERATURES | YEARS | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
| JANUARY | Temperatures Belowe 5 °C | 413 | 598 | 417 | 346 | 393 | 537 | 363 | 293 | 524 | 530 | 506 |
| | Temperatures Belowe 10 °C | 609 | 714 | 600 | 594 | 700 | 683 | 571 | 584 | 648 | 640 | 685 |
| | Temperatures Belowe 15 °C | 703 | 740 | 692 | 682 | 740 | 739 | 707 | 715 | 708 | 695 | 737 |
| | Temperatures Above 15 °C | 41 | 4 | 52 | 62 | 4 | 5 | 37 | 29 | 36 | 49 | 7 |
| FEBRUARY | Temperatures Belowe 5 °C | 257 | 448 | 286 | 154 | 329 | 532 | 171 | 216 | 308 | 169 | 325 |
| | Temperatures Belowe 10 °C | 529 | 618 | 494 | 382 | 591 | 663 | 464 | 485 | 507 | 407 | 535 |
| | Temperatures Belowe 15 °C | 628 | 665 | 640 | 573 | 649 | 692 | 590 | 603 | 594 | 608 | 620 |
| | Temperatures Above 15 °C | 44 | 31 | 32 | 99 | 23 | 4 | 82 | 69 | 78 | 88 | 52 |
| MARCH | Temperatures Belowe 5 °C | 128 | 45 | 248 | 144 | 292 | 411 | 156 | 116 | 155 | 117 | 128 |
| | Temperatures Belowe 10 °C | 504 | 364 | 547 | 510 | 503 | 608 | 369 | 448 | 535 | 442 | 484 |
| | Temperatures Belowe 15 °C | 647 | 566 | 651 | 677 | 649 | 677 | 559 | 611 | 681 | 587 | 626 |
| | Temperatures Above 15 °C | 97 | 178 | 93 | 67 | 95 | 67 | 185 | 133 | 63 | 157 | 118 |
| APRIL | Temperatures Belowe 5 °C | 91 | 1 | 28 | 21 | 30 | 22 | 1 | 25 | 155 | 19 | 62 |
| | Temperatures Belowe 10 °C | 372 | 118 | 301 | 215 | 420 | 155 | 242 | 180 | 384 | 152 | 340 |
| | Temperatures Belowe 15 °C | 592 | 382 | 555 | 516 | 631 | 388 | 487 | 463 | 555 | 424 | 521 |
| | Temperatures Above 15 °C | 128 | 338 | 165 | 204 | 89 | 332 | 233 | 257 | 165 | 296 | 199 |
| OCTOBER | Temperatures Belowe 5 °C | 0 | 0 | 0 | 10 | 48 | 0 | 43 | 15 | 7 | 13 | 3 |
| | Temperatures Belowe 10 °C | 125 | 59 | 28 | 121 | 250 | 29 | 298 | 62 | 67 | 116 | 177 |
| | Temperatures Belowe 15 °C | 339 | 402 | 290 | 449 | 537 | 284 | 547 | 348 | 308 | 478 | 499 |
| | Temperatures Above 15 °C | 405 | 342 | 454 | 295 | 207 | 460 | 197 | 396 | 436 | 266 | 245 |
| NOVEMBER | Temperatures Belowe 5 °C | 148 | 52 | 123 | 34 | 350 | 45 | 72 | 72 | 62 | 217 | 94 |
| | Temperatures Belowe 10 °C | 423 | 308 | 387 | 178 | 643 | 256 | 319 | 411 | 294 | 463 | 397 |
| | Temperatures Belowe 15 °C | 634 | 577 | 636 | 436 | 718 | 603 | 596 | 640 | 570 | 623 | 625 |
| | Temperatures Above 15 °C | 86 | 143 | 84 | 284 | 2 | 117 | 124 | 80 | 150 | 97 | 95 |
| DECEMBER | Temperatures Belowe 5 °C | 448 | 338 | 195 | 234 | 370 | 302 | 592 | 200 | 467 | 662 | 268 |
| | Temperatures Belowe 10 °C | 642 | 586 | 504 | 490 | 581 | 588 | 731 | 503 | 711 | 737 | 491 |
| | Temperatures Belowe 15 °C | 707 | 680 | 672 | 613 | 690 | 694 | 744 | 699 | 744 | 744 | 636 |
| | Temperatures Above 15 °C | 37 | 64 | 72 | 131 | 54 | 50 | 0 | 45 | 0 | 0 | 108 |

### 3.2 Data analysis and evaluation for cooling degree time calculations

According to the 11-year temperature data of Düzce province, the number of days with a mean temperature above 22 ° C was calculated and a graph was created (Figure4). Number of days remaining above 22 °C (days in need of cooling); least in 2011 46 days and most in 2010 with 84 days. The average number of days in need of cooling is 71 days

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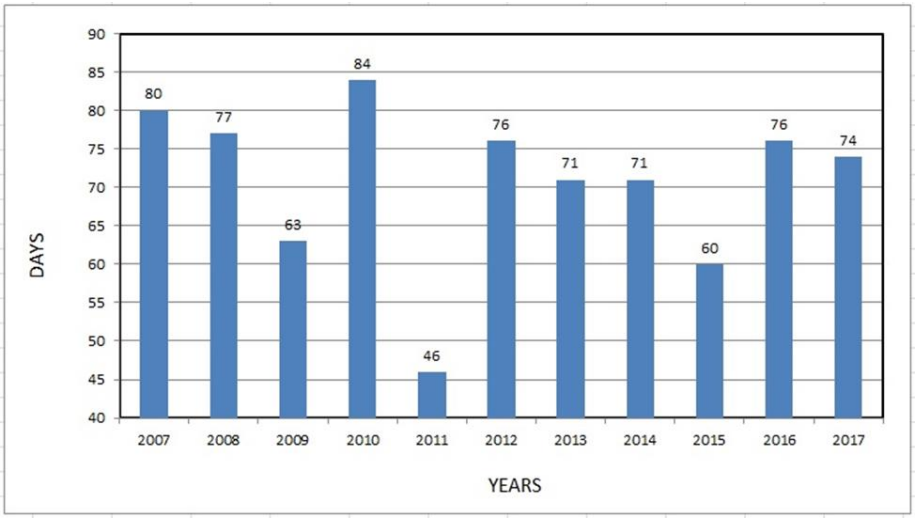


Figure 4. Chart showing days remaining above the average temperature of 22 ° C according the years.

Cooling degree day values were calculated for the equilibrium temperature of 22 ° C. (Figure 5). According to Figure 5, the maximum cooling degree day value was 253 in 2010, while the minimum cooling degree day value was 83 in 2011. Also the average yearly 154 cooling degree day value was obtained.

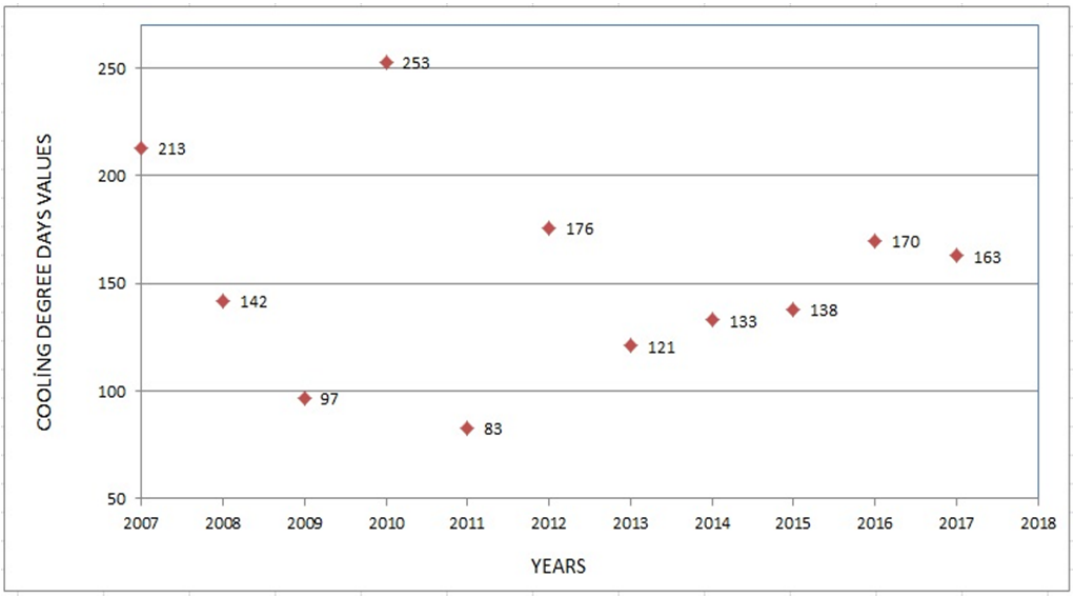


Figure 5. Cooling degree day values for 22 ° C.

After the calculation of the degree day, a degree hour was calculated to compare. Table 3; Shows the monthly and annual number of 3 different equilibrium temperature measurements.Looking at the 11-year data:

- The monthly measured number of temperatures above 22 ° C varies between 451-146. The average monthly rate is 311.
- The monthly measured number of temperatures above 27 ° C varies between 191-39. The average monthly rate is 118.
- The monthly measured number of temperatures above 32 ° C varies between 29-3. The average monthly rate is 17.

Table 3. Monthly and annual number of 3 different equilibrium temperature measurements.

| MONTHS | REFERENCE TEMPERATURES | YEARS | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
| MAY | Temparatures Above 22 °C | 191 | 136 | 138 | 201 | 102 | 126 | 243 | 137 | 149 | 102 | 80 |
| | Temparatures Above 27 °C | 56 | 36 | 34 | 63 | 15 | 19 | 81 | 30 | 44 | 33 | 11 |
| | Temparatures Above 32 °C | 5 | 4 | 3 | 0 | 0 | 0 | 14 | 0 | 0 | 0 | 2 |
| JUNE | Temparatures Above 22 °C | 346 | 319 | 336 | 290 | 229 | 338 | 338 | 238 | 181 | 350 | 294 |
| | Temparatures Above 27 °C | 155 | 129 | 143 | 91 | 46 | 172 | 111 | 76 | 12 | 151 | 108 |
| | Temparatures Above 32 °C | 37 | 10 | 21 | 9 | 6 | 20 | 10 | 5 | 0 | 25 | 12 |
| JULY | Temparatures Above 22 °C | 460 | 397 | 424 | 525 | 460 | 506 | 383 | 420 | 394 | 424 | 446 |
| | Temparatures Above 27 °C | 213 | 195 | 158 | 220 | 228 | 249 | 142 | 166 | 137 | 160 | 162 |
| | Temparatures Above 32 °C | 49 | 22 | 14 | 23 | 30 | 48 | 6 | 14 | 32 | 14 | 37 |
| AUGUST | Temparatures Above 22 °C | 469 | 477 | 355 | 610 | 339 | 391 | 426 | 438 | 493 | 501 | 462 |
| | Temparatures Above 27 °C | 211 | 235 | 108 | 321 | 112 | 184 | 197 | 170 | 203 | 186 | 164 |
| | Temparatures Above 32 °C | 33 | 46 | 5 | 103 | 0 | 40 | 16 | 19 | 14 | 30 | 11 |
| SEPTEMBER | Temparatures Above 22 °C | 252 | 188 | 164 | 224 | 215 | 255 | 172 | 188 | 315 | 204 | 244 |
| | Temparatures Above 27 °C | 76 | 73 | 24 | 58 | 71 | 85 | 36 | 38 | 99 | 56 | 102 |
| | Temparatures Above 32 °C | 10 | 10 | 3 | 0 | 1 | 7 | 3 | 0 | 34 | 7 | 24 |

Figure 6 shows the annual total number of hourly measurements of different equilibrium temperatures.

According this;

- The sum of the annual measured values of temperatures above 22 ° C is maximum 1850. The average is 1554.
- The sum of the annual measured values of temperatures above 27 ° C is maximum 753. The average is 587.
- The sum of the annual measured values of temperatures above 32 ° C is maximum 135. The average is 81.

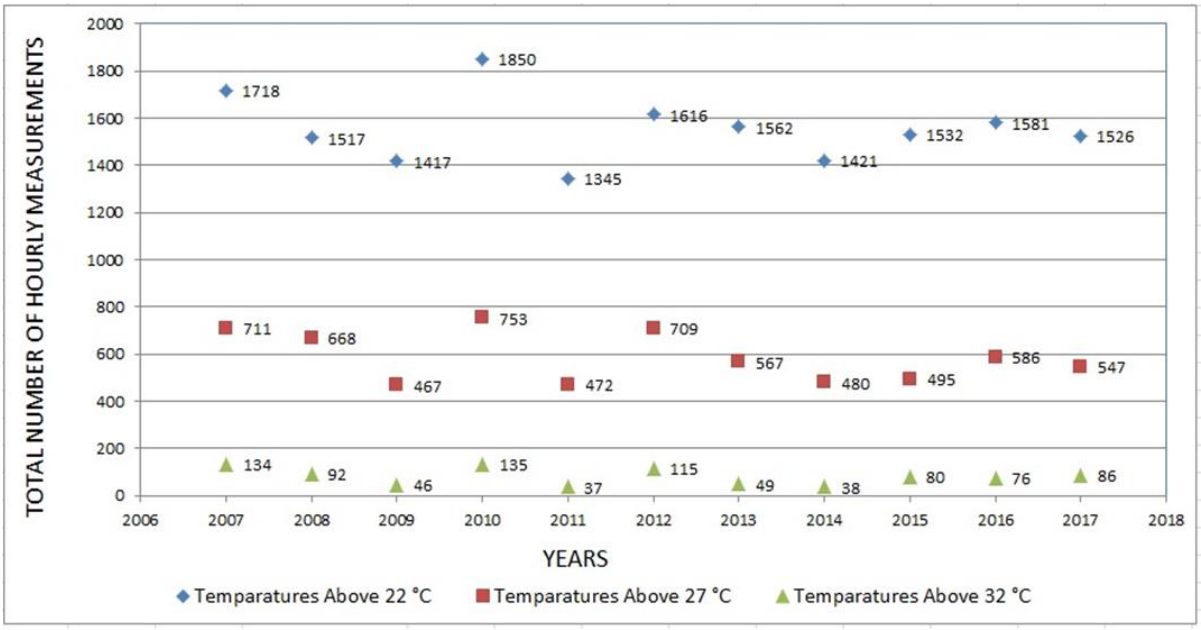


Figure 6. Annual total number of hourly measurements of different equilibrium temperatures.

## 4. Results and discussion

In our study, heating and cooling degree time data have been prepared for use in the energy estimation and heat load calculations of the buildings for Düzce province.

The hourly temperature data to be used in the calculations ( between 2007-2017) were obtained from the State Meteorological Services in Düzce. The obtained data was transferred to excel and the data was checked for incorrectly and missing. After correcting the problem data by taking into consideration the average temperature values, 15 ° C for heating and 22 ° C for cooling, equilibrium temperature time calculations were made in addition, 11 years and yearly 8760 hours of annual temperature data from tables and graphics were extracted and examined in detail. Some results are summarized below:

- It is determined that an average annual heating of 192 days is required for the 15 ° C equilibrium temperature.
- The average annual heating degree-day value is 1938.
- The average annual heating temperature rating for an equilibrium temperature of 15 ° C is 4176.
- It is determined that an average annual cooling of 71 days is required for the 22 ° C equilibrium temperature.
- The average annual cooling degree-day value is 154 derece.
- The average annual cooling time for the equilibrium temperature of 22 ° C is 1554.

## References

[1] Şenkal, Sezer, F. "Progress of Thermal Insulation Systems in Turkey and Exterior Wall Insulation Systems in Dwellings", Uludag University Journal of Faculty of Engineering and Architecture, Volume 10 Issue 2, 79-85, (2005)

[2] Yüksel, N. "A Study Directed at Determining Structural Comfort Conditions for Present

Public Institutions", Uludag University Journal of Faculty of Engineering and Architecture, Volume 10 Issue 2, (2005)

[3] Pusat, Ş. , Tunç, N. , Ekmekçi, İ. , Yetişken, Y. "Degree Time Calculations For Karabük" 3rd International Symposium On İnnnovative Technologies In Engineering and Science Universidad Politecnica de Valencia Spain (3-5 June 2015)

[4] Hens, H. , Verbeeck, G., Verdonck, B., "Impact of Energy Efficiency Measures on The CO2 Emissions in The Residential Sector, a Large Scale Analysis", Energy and Buildings, Vol. 33, p.p. 275-281, (2001)

[5] Bulut, H., Büyükalaca, O., Yılmaz, T., Aktacir, M. A., "DETAILED WEATHER DATA FOR GAP REGION", University of Harran GAP IV. Proceedings of Engineering Congress, 183-191, Şanlıurfa, (2002)

[6] Papakostas, K., Kyriakis, N., "Heating and Cooling Degree-Hours For Athens and Thessaloniki, Greece", Renewable Energy, 30, 1873-1880, (2005)

[7] Lstiburek, JW. "Hygrothermal climate regions, interior climate classes and durability". Proceedings of the Eighth Conference on Building Science and Technology, Toronto, Canada, 319-29, (2001)

[8] Sahal, N. "Proposed Approach for Defining Climate Regions for Turkey Based on Annual Driving Rain İndex and Heating Degree-Days for Building Envelope Design". Building andEnvironment 41, 520-526, (2006)

[9 Dombaycı, OA. "Degree-Days Maps of Turkey for Various Base Temperatures". Energy, Volume 34, Issue 11, (November 2009).

[10] Uner M., İleri A., "Typical Weather Data of Main Turkish Cities for Energy Applications". International Journal of Energy Research, 24: 727-748, (2006)

[11] Büyükalaca O., Bulut H., Yılmaz T., "Turkey's Degree Day Values for Some Provinces" ULIBTK'99-023 12. National Heat Science and Technique Congress Sakarya, (8-10 September 1999)

[12] http://duzcekultur.gov.tr/TR-211369/iklimi-ve-bitki-ortusu.html (Access: 12.12.2018)

[13] https://www.mgm.gov.tr/veridegerlendirme/il-ve-ilceler-istatistik.aspx?m=DUZCE (Access: 12.12.2018)

[14] Şensoy, S., Sağır, R., Eken, M., Ulupınar, Y., "Long Years of Turkey Heating and Cooling Degree Day", Turkish State Meteorological Service, Ankara, (2007).