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Türkiye'nin Marmara ve Trakya Bölgelerinde Farklı Tipik Meteorolojik Yıl Oluşturma Yöntemlerinin Bina Enerji Analizi Üzerindeki Etkileri

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Öne Çıkanlar:

- 2020–2024 dönemi saatlik verileri, Marmara ve Trakya'daki güncel termal koşulların uzun dönemli iklim referanslarından keskin bir şekilde saptığını kanıtlamaktadır.
- HDD %51'e varan oranlarda azalırken, CDH uzun dönem ortalamalarına göre %90,7 arttı göstermiştir.
- TMY yöntemlerinin karşılaştırması; Finkelstein–Schaefer ve ASHRAE yaklaşımları arasında HDH ve CDH değerlerinde %15'i aşan yöntemsel sapmalar olduğunu göstermektedir.
- Tespit edilen iklimsel kaymalar ve yöntemsel farklılıklar, Sıfır Enerjili Binalarda soğutma yükü tahminlerini ve yıllık enerji dengesinin güvenilirliğini doğrudan etkilemektedir.

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Amaç:
Son yıllarda artan iklim değişkenliği, meteorolojik veri setlerinin bina enerji gereksinimlerini temsil gücünü tartışmalı hale getirmiştir. Bu çalışmanın amacı; Marmara ve Trakya bölgelerindeki beş şehir için 2020–2024 dönemine ait güncel saatlik verileri kullanarak, farklı Tipik Meteorolojik Yıl (TMY) oluşturma yöntemlerinin bina enerji göstergeleri üzerindeki etkilerini nicel olarak ortaya koymaktır. Çalışma, veri setini klasik TMY'den ziyade, güncel koşulları yansıtan bir "yeni normal" yaklaşımıyla değerlendirmektedir.

Metot:
Edirne, Kırklareli, Tekirdağ, Kocaeli ve Sakarya illerinin 2020–2024 dönemi saatlik verileri kullanılmıştır. TMY veri setleri; klasik Finkelstein–Schaefer (FS) yöntemi ile Jiang ve ASHRAE ağırlıklandırma yaklaşımlarıyla oluşturulmuştur. Elde edilen setler; Isıtma ve Soğutma Derece-Gün (HDD/CDD), Derece-Saat (HDH/CDH) ve BinData frekans analizleri kullanılarak değerlendirilmiş; iklim göstergelerinin etkileri yıllık ve saatlik ölçekte incelenmiştir.

Sonuç:
Analizler, 2020–2024 döneminin uzun dönem referanslardan belirgin şekilde ayrıştığını göstermektedir. Bölge genelinde HDD değerlerinde %41–51 azalma, CDH değerlerinde ise yönteme bağlı %90,7'ye varan artışlar saptanmıştır. Jiang ve ASHRAE yöntemleri arasında HDD/CDD bazında %10–12, HDH/CDH bazında ise %15'in üzerinde farklar belirlenmiştir. Bu bulgular, saatlik göstergelerin iklim değişkenliğine daha duyarlı olduğunu kanıtlamaktadır. Sonuç olarak, kısa dönem referans yıllarının kullanımı, özellikle soğutma yükleri ve PV sistem boyutlandırması gibi ZEB odaklı kararlarda daha güvenilir sonuçlar sağlayacaktır.

Anahtar Kelimeler: Tipik meteorolojik yıl, kısa dönem referans yılı, bina enerji performansı, derece-gün, derece-saat, Zero Energy Building (ZEB)

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Research Article

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Effects of Different Typical Meteorological Year Generation Methods on Building Energy Analysis in the Marmara and Thrace Regions of Türkiye

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Highlights:

- Recent hourly climate data (2020–2024) reveals that current thermal conditions in Marmara and Thrace significantly deviate from long-term historical references.
- Heating Degree-Days (HDD) decreased by up to 51%, while Cooling Degree-Hours (CDH) surged by as much as 90.7% compared to long-term averages.
- Comparative analysis of TMY methods shows methodological deviations exceeding 15% in heating and cooling degree-hours between Finkelstein–Schaefer and ASHRAE approaches.
- The identified climatic shifts and methodological discrepancies directly impact the reliability of cooling load estimations and annual energy balances in Zero Energy Buildings.

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Abstract: Typical Meteorological Year (TMY) datasets are widely used in building energy analysis to represent long-term climatic conditions with reduced computational effort. However, the selection of the TMY generation method may significantly influence building energy performance indicators, particularly in regions with transitional climate characteristics. In this study, hourly meteorological data covering the period 2020–2024 were used to generate TMY datasets for five representative cities located in the Marmara and Thrace regions of Türkiye. The classical Finkelstein–Schaefer method and weighted variants based on ASHRAE and Jiang approaches were applied to construct different TMY datasets. The resulting datasets were evaluated using heating and cooling degree-day (HDD/CDD), degree-hour (HDH/CDH), and BinData frequency analyses. The results reveal that different TMY generation methods lead to measurable variations in heating and cooling indicators at both annual and hourly scales. These variations directly affect the representation of climatic conditions used in building energy performance assessments. The findings highlight the importance of selecting appropriate TMY generation methods, particularly for energy-efficient and Zero Energy Building-oriented design and analysis studies.

Keywords: Typical meteorological year, building energy performance, zero energy building, degree-day analysis, degree-hour analysis, BinData

Nomenclature

AMY Actual Meteorological Year
ASHRAE American Society of Heating, Refrigerating and Air-Conditioning Engineers
BinData Frequency-based bin method for climatic data analysis
CDD Cooling Degree-Day (°C·day)
CDH Cooling Degree-Hour (°C·h)
CDF Cumulative Distribution Function
FS Finkelstein–Schaefer statistic
HDD Heating Degree-Day (°C·day)
HDH Heating Degree-Hour (°C·h)
IWEC International Weather for Energy Calculations
Ktot Overall heat transfer coefficient of the building (W/K)
Nbin,I Number of hours in temperature bin i (h)
Np Number of climatic parameters
Nd Number of days in the corresponding month (day)
PV Photovoltaic
Tb Base temperature for degree calculations (°C)
Ti Hourly outdoor air temperature (°C)
$\bar{T}$i Daily mean outdoor air temperature (°C)
TMY Typical Meteorological Year
To,i Representative outdoor temperature of bin i (°C)
WF Weighting factor assigned to climatic parameter
WS Weighted Finkelstein–Schaefer score
η System efficiency
ZEB Zero Energy Building

1. Introduction

Typical Meteorological Year (TMY) datasets are commonly employed in building energy simulations to represent long-term climatic conditions while reducing data size and computational requirements. A TMY dataset is generally constructed by selecting representative months from multi-year meteorological records using statistical selection techniques, allowing building energy models to approximate average climatic behavior over extended periods [1], [2]. Due to their practicality, TMY datasets have become a standard input for building energy performance assessment, system sizing, and energy efficiency studies.

Despite their widespread use, the accuracy of building energy simulations strongly depends on the method used to generate TMY datasets. Different selection techniques may represent temperature, solar radiation, and other energy-related climatic parameters in different ways, leading to noticeable variations in predicted heating and cooling energy demands [3], [5]. These variations become particularly critical in regions characterized by transitional climate conditions, where small changes in temperature distribution or solar availability can significantly influence building energy performance indicators.

Building energy performance assessment plays a central role in the design and evaluation of energy-efficient buildings and Zero Energy Building concepts. In such buildings, the balance between annual energy demand and on-site renewable energy production is highly sensitive to the climatic input data used in simulations. Therefore, the reliability of TMY datasets directly affects annual energy balance calculations, system sizing decisions, and the evaluation of energy-saving strategies.

Various statistical methods have been proposed in the literature for TMY generation, among which the Finkelstein–Schaefer (FS) method is one of the most widely adopted approaches [1]. To improve the representation of energy-relevant climatic variables, weighted versions of the FS method have been introduced, assigning different importance levels to parameters such as air temperature, solar radiation, humidity, and wind speed. Notably, weighting schemes proposed by ASHRAE and Jiang have been applied in several studies to enhance the suitability of TMY datasets for building energy analysis [4], [5].

In addition to TMY generation techniques, several indicators are commonly used to consider building energy performance. Degree-day (HDD/CDD) and degree-hour (HDH/CDH) methods provide practical and comparable measures of heating and cooling energy demand based on temperature deviations from reference base values [4]. Furthermore, frequency-based approaches such as the BinData method allow for a more detailed evaluation of hourly temperature distributions, supporting the analysis of peak loads and operational energy behavior [9].

In Türkiye, studies focusing on TMY generation and building energy analysis have generally relied on long-term historical datasets. However, limited research has addressed the combined effects of different TMY generation methods using recent high-resolution (hourly) meteorological data, particularly for the Marmara and Thrace regions. These regions exhibit pronounced transitional climate characteristics, making them suitable case studies for investigating the sensitivity of building energy performance indicators to TMY selection methods.

The objective of this study is to comparatively evaluate different TMY generation methods using recent hourly meteorological data for selected cities in the Marmara and Thrace regions of Türkiye and to assess their effects on building energy analysis indicators. By combining classical and weighted FS approaches with degree-day, degree-hour, and BinData analyses, this study aims to provide a comprehensive framework for climate data selection in building energy performance and Zero Energy Building-oriented studies.

2. Material and Method

2.1. Study Area and Meteorological Data

This study focuses on five representative cities located in the Marmara and Thrace regions of Türkiye: Edirne, Kırklareli, Tekirdağ, Kocaeli, and Sakarya. These cities were selected due to their distinct geographical characteristics and transitional climate features, which include both coastal and inland influences. Such climatic diversity provides an appropriate basis for evaluating the sensitivity of building energy analysis results to different Typical Meteorological Year (TMY) generation methods.

Hourly meteorological data covering the period from 2020 to 2024 were obtained from the Turkish State Meteorological Service [8]. The dataset includes key climatic parameters commonly used in building energy performance analysis, such as dry-bulb air temperature, relative humidity, wind speed, wind direction, global solar radiation, and sunshine duration. Prior to analysis, the raw data were subjected to basic quality control procedures, including missing data checks and consistency verification, to ensure suitability for TMY generation.

2.2. Typical Meteorological Year Generation Methods

Typical Meteorological Year datasets were generated to represent long-term climatic conditions using statistically selected representative months. In this study, the classical Finkelstein–Schaefer (FS) method was employed as the baseline approach for TMY construction [1]. The FS method evaluates the cumulative distribution functions (CDFs) of selected meteorological parameters for candidate years against long-term reference distributions, allowing the identification of months that best represent average climatic behavior.

To improve the representation of energy-relevant climatic variables, weighted versions of the FS method were also applied. Weighting schemes proposed by ASHRAE and Jiang were used to assign different importance levels to parameters such as air temperature, solar radiation, relative humidity, and wind speed [4], [5]. For each month, weighted FS scores were calculated, and the candidate year with the lowest overall score was selected as the representative month. As a result, multiple TMY datasets were generated, enabling a comparative assessment of different weighting strategies.

2.3. Degree-Day and Degree-Hour Analysis

The generated TMY datasets were evaluated using heating and cooling degree-day (HDD/CDD) and degree-hour (HDH/CDH) indicators, which are widely used for estimating building heating and cooling energy demand [4]. Degree-day values were calculated based on daily mean air temperatures, while degree-hour values were derived from hourly temperature data to capture short-term temperature variations.

Standard base temperature values commonly adopted in the literature were used to ensure consistency and comparability. HDD and CDD indicators provide an annual-scale overview of heating and cooling demand, whereas HDH and CDH indicators offer a more detailed representation of hourly energy demand fluctuations. This combined approach allows both long-term and short-term energy performance characteristics to be evaluated using the same climatic input datasets.

2.4. BinData Frequency Analysis

To further investigate the hourly characteristics of the generated TMY datasets, the BinData method was applied as a frequency-based analysis technique [9]. In this approach, hourly air temperature values were grouped into predefined temperature intervals (bins), and the total number of hours falling within each interval was calculated over the entire year.

The BinData method enables an assessment of temperature distribution patterns beyond mean values, providing insights into the frequency of specific temperature ranges and the occurrence of extreme conditions. This information is particularly useful for analyzing peak loads and operational energy behavior in building energy performance studies. In this study, BinData analysis was used as a complementary tool to degree-day and degree-hour indicators to evaluate differences among TMY generation methods at an hourly resolution.

2.5. Methodological Framework

The overall methodological framework of this study consists of the following steps: (i) acquisition and preprocessing of recent hourly meteorological data, (ii) generation of multiple TMY datasets using the classical FS method and weighted FS approaches, (iii) evaluation of the generated TMY datasets using degree-day and degree-hour indicators, and (iv) detailed examination of hourly temperature distributions through BinData analysis. This structured approach ensures methodological consistency and supports the reproducibility of the results obtained in this study.

$$S_n(X) = \begin{cases} 0 & \text{for } X < X_1 \\ (k-0.5)/n & \text{for } X_k < X < X_{k+1} \\ 1 & \text{for } X > X_n \end{cases} \quad (1)$$

The selection of representative months for the Typical Meteorological Year (TMY) was carried out using the Finkelstein–Schaefer (FS) statistical method. For a given climatic variable Xi, the FS statistic for month m of year y is calculated as:

$$FS_{Xi}(y,m) = \frac{1}{N_d}\sum_{j=1}^{N_d}\left| CDF_m(X_{ij}) - CDF_{y,m}(X_{i,j}) \right| \quad (2)$$

Nd the number of days in the corresponding month, CDFm represents the long-term cumulative distribution function of the variable for month m, and CDFy,m represents the cumulative distribution function of the same variable for month mmm in year y.

To account for the relative importance of different climatic variables in building energy analysis, a weighted FS score was calculated. The weighted score for a given year y and month m is expressed as:

$$WS(y,m) = \frac{1}{N_P}\sum_{i=1}^{N_p} WF_{X_i} . FS_{x_i}(y,m) \quad (3)$$

Np is the number of climatic parameters considered and W FXi is the weighting factor assigned to parameter Xi. The weighting factors satisfy the normalization condition:

$$\sum_{i=1}^{N_p} WF_{x_i} = 1 \quad (4)$$

The TMY datasets selected using these methods were subsequently employed to calculate heating and cooling indicators based on Degree-Day (HDD/CDD) and Degree-Hour (HDH/CDH) approaches. In this study, a base temperature of 18 °C was adopted for heating analyses, while 23.3 °C was used for cooling analyses. For comparison, the Turkish State Meteorological Service applies reference base temperatures of 15 °C for heating and 22 °C for cooling.

Heating and cooling degree-hour values were calculated using hourly temperature data as follows:

$$HDH = \Sigma_{i=1}^{N} (Tb – Ti)_{+} \quad (5)$$

$$CDH = \Sigma_{i=1}^{N} (Ti – Tb)_{+} \quad (6)$$

Tb denotes the base temperature, Ti is the hourly outdoor air temperature, N is the total number of hours considered, and the superscript "+" indicates that only positive values are included in the summation.

Similarly, heating and cooling degree-day values were calculated based on daily mean temperatures:

$$HDD = \Sigma_{i=1}^{N} (Tb - \bar{T}_I)_{+} \quad (7)$$

$$CDD = \Sigma_{i=1}^{N} (\bar{T}_I – Tb)_{+} \quad (8)$$

Ti represents the daily mean outdoor air temperature.

Finally, hourly temperature, humidity, and solar radiation data were classified into predefined intervals (bins), and frequency distributions were generated using the BinData method. This approach enables the assessment of microclimatic variability and its impact on building energy loads by analyzing the duration of specific climatic conditions at an hourly resolution.

The thermal load associated with each temperature bin was estimated using:

$$Qbin,I = Nbin,i\frac{Ktot}{\eta}(Tb – TO,i) +- \quad (9)$$

Nbin,i is the number of hours within bin i, Ktot is the overall heat transfer coefficient of the building, η represents system efficiency, and To,i is the representative outdoor temperature of bin i. The sign of the temperature difference accounts for heating or cooling conditions.

3. Results

3.1. Comparison of TMY Generation Methods

The application of different Typical Meteorological Year (TMY) generation methods resulted in noticeable variations in the representation of climatic conditions for the selected cities in the Marmara and Thrace regions. TMY datasets generated using the classical Finkelstein–Schaefer (FS) method and the weighted FS approaches based on ASHRAE and Jiang weighting schemes exhibited differences in the selection of representative months and corresponding climatic parameters.

The weighted FS approaches produced TMY datasets with altered distributions of air temperature and solar radiation compared to the classical FS method. In particular, weighting energy-relevant parameters led to differences in monthly temperature profiles, which were reflected in the derived heating and cooling indicators. These differences demonstrate that the selection of weighting strategies influences the resulting TMY datasets and their suitability for building energy analysis.

3.2. Degree-Day Analysis Results

Heating Degree-Day (HDD) and Cooling Degree-Day (CDD) values derived from the 2020–2024 dataset and different TMY generation methods reveal pronounced quantitative differences when compared with long-term climatic observations. Table 6 presents a direct comparison between long-term reference data (1989–2012) and recent-period (2020–2024) results for all five cities.

As shown in Table 6, HDD values calculated from the 2020–2024 period is substantially lower than long-term averages for all cities. The reduction in HDD ranges between 41.6% and 51.4%, with the largest decrease observed in Kırklareli (–51.4%) and Edirne (–47.6%). This indicates a significant reduction in heating demand under recent climatic conditions. Conversely, CDD values exhibit a marked decrease of approximately 75%–82% relative to long-term averages, reflecting a shift in temperature distributions during the analyzed period.

City-based HDD and CDD comparisons using different TMY datasets are detailed in Tables 7–11. For Edirne (Table 7), the ASHRAE-weighted TMY yields an HDD value of 1677.39, which is within 0.3% of the 2020–2024 mean (1682.6), while the classical FS-based TMY slightly overestimates heating demand by approximately 3.2%. Similar method-dependent deviations are observed for other cities. For example, in Kocaeli (Table 9), the Jiang-weighted TMY produces a CDD value (364.23) that is 9.3% higher than the recent-period mean (333.2), indicating higher sensitivity of cooling demand estimation to parameter weighting.

These results demonstrate that HDD and CDD values derived from recent climate data are not only significantly different from long-term references but also sensitive to the selected TMY generation method. The numerical deviations reported in Tables 6–11 confirm that recent climatic conditions lead to systematically lower heating demand and altered cooling demand characteristics, consistent with warming trends observed in the region.

3.3. Degree-Hour Analysis Results

Heating Degree-Hour (HDH) and Cooling Degree-Hour (CDH) results provide a more detailed representation of short-term temperature variability and reveal stronger method-dependent sensitivities than degree-day indicators. Quantitative comparisons presented in Table 6 show that HDH values for the 2020–2024 period differ from long-term values by –10.1% to +45.4%, depending on the city.

For instance, in Kırklareli, HDH values increased by 45.4% compared to long-term observations, while CDH values increased by 90.7%, indicating a substantial rise in hourly cooling-related thermal stress (Table 6). In contrast, Edirne exhibits a 19.2% decrease in HDH but a 23.7% increase in CDH, highlighting asymmetric changes between heating and cooling behavior at the hourly scale.

The higher sensitivity of degree-hour indicators is particularly evident during summer periods. For coastal cities such as Kocaeli and Sakarya, CDH values increased by 25.3% and 39.6%, respectively, relative to long-term data (Table 6). These increases are not directly captured by daily average-based CDD values and demonstrate that hourly-based metrics are more responsive to recent extreme temperature events.

Overall, the degree-hour analysis confirms that the 2020–2024 dataset reflects intensified short-term thermal variability. The numerical differences reported in Table 6 indicate that degree-hour metrics provide critical additional information for evaluating cooling-dominated energy demand under recent climatic conditions.

3.4. City-Based Climatic Characteristics

City-specific comparisons further highlight the spatial variability of recent climatic impacts on building energy indicators. Tables 7–11 present HDD and CDD values for individual cities derived from long-term observations and different TMY datasets.

In inland cities such as Edirne and Kırklareli, heating demand remains dominant; however, HDD values based on recent data are reduced by approximately 45%–51% compared to long-term averages (Tables 6–8). For example, Edirne's long-term HDD value of 3202.10 decreases to 1677.39 in the 2020–2024 period (Table 6). This reduction directly reflects warmer winter conditions in recent years.

In contrast, coastal and near-coastal cities such as Kocaeli, Sakarya, and Tekirdağ exhibit relatively higher cooling sensitivity. In Sakarya, CDH values increased by 39.6%, while in Kocaeli the increase reached 25.3% (Table 6). These results indicate that recent climatic conditions disproportionately affect cooling-related energy demand in coastal regions.

The city-based quantitative comparisons demonstrate that the impact of recent climate variability is not uniform across regions. Instead, the magnitude of change depends on geographic location and proximity to coastal influences, emphasizing the importance of location-specific climate data selection in building energy analysis.

3.5. BinData Frequency Analysis Results

BinData frequency analysis was conducted to quantify changes in hourly temperature distributions and to identify shifts in the occurrence of extreme temperature ranges. Tables 13–22 provide a detailed comparison between recent-period (2020–2024) and long-term (1989–2012) temperature frequency distributions.

For Edirne, the ASHRAE-weighted TMY dataset (Table 13) shows a clear concentration of hourly temperatures within the 12–24 °C range, with a total of approximately 3,200 hours, whereas long-term data (Table 14) exhibit a higher frequency of sub-zero temperature bins. The reduction in hours below 0 °C exceeds 40%, indicating a significant decline in cold extremes.

Similar patterns are observed for Kırklareli and Sakarya (Tables 15–16 and 19–20). In Kırklareli, hours exceeding 30 °C increased noticeably in the recent dataset, while long-term records show minimal occurrence in these bins. For Kocaeli (Tables 17–18), the number of hours within the 24–30 °C range increased by approximately 20%, indicating enhanced cooling load potential.

These frequency-based results quantitatively demonstrate that recent climatic conditions are characterized by fewer cold extremes and more frequent high-temperature events. The BinData analysis confirms that recent-period datasets capture short-term variability and extreme events more effectively than aggregated indicators, supporting their use in detailed building energy performance and peak load assessments.

3.6. Summary of Results

Overall, the results indicate that different TMY generation methods produce varying representations of climatic conditions at both annual and hourly scales. While general regional climatic patterns remain consistent across methods, the magnitude and distribution of heating and cooling indicators differ depending on the applied TMY generation technique. Degree-day, degree-hour, and BinData analyses consistently reveal method-dependent variations in building energy-related climatic indicators for the studied cities.

4. Discussion

The results obtained in this study demonstrate that building energy indicators derived from the most recent five-year climatic period (2020–2024) are strongly influenced by both recent climate variability and the selected methodological approach. As quantitatively shown in Tables 6–22, the observed differences in heating and cooling indicators are not limited to marginal deviations but reach substantial magnitudes at both annual and hourly scales. These findings indicate that the analyzed dataset should not be interpreted as a classical long-term Typical Meteorological Year (TMY), but rather as a short-term reference representation reflecting recent climatic conditions often described as the "new normal."

The comparison between the classical Finkelstein–Schaefer (FS) method and weighted FS approaches reveals that methodological sensitivity increases under recent climate conditions characterized by higher variability and extreme events. Weighting schemes based on ASHRAE and Jiang methodologies emphasize energy-relevant parameters such as air temperature and solar radiation, which directly affect building heating and cooling demand. As demonstrated in Tables 6–11, the use of weighted methods results in deviations of up to to approximately 10–12% in HDD and CDD values and more than 15% in HDH and CDH values relative to the classical FS approach. These numerical differences confirm that the representation of climatic input data becomes increasingly method-dependent when recent climate variability is taken into account, consistent with previous findings on weighted statistical selection techniques [5], [6].

The degree-day and degree-hour analyses further highlight the importance of temporal resolution in capturing the energy impacts of recent climatic conditions. While degree-day indicators provide a simplified annual-scale representation, degree-hour metrics respond more strongly to short-term temperature fluctuations and extreme events. As shown in Table 6, CDH values increase by up to 90.7% for certain cities when recent-period data are compared with long-term observations, whereas corresponding CDD values exhibit considerably smaller changes. This discrepancy demonstrates that daily mean-based indicators may underestimate cooling-related thermal stress under recent climate conditions, a limitation also emphasized in earlier building energy studies [4], [7].

City-based comparisons confirm that the impact of recent climate variability is spatially heterogeneous. Inland cities such as Edirne and Kırklareli remain heating-dominated; however, HDD values derived from the 2020–2024 period are reduced by more than 45% relative to long-term averages (Tables 6–8), indicating significantly milder winter conditions. In contrast, coastal and near-coastal cities including Kocaeli, Sakarya, and Tekirdağ exhibit pronounced increases in cooling-related indicators. For example, CDH values increase by approximately 25–40% in these cities (Table 6), highlighting the growing importance of cooling demand under recent climatic conditions. Similar region-dependent sensitivities have been reported in previous studies conducted for Türkiye and other transitional climate regions [11], [12].

The BinData frequency analysis provides further insight into the physical drivers of these indicator changes by explicitly examining hourly temperature distributions. As shown in Tables 13–22, recent-period datasets are characterized by a substantial reduction in the frequency of sub-zero temperature hours (exceeding 40% in some cities) and a noticeable increase in the occurrence of high-temperature bins above 30 °C. These shifts explain the observed reductions in heating-related indicators and the simultaneous increase in cooling-related stress at the hourly scale. The ability of BinData analysis to capture such distributional changes supports its use as a complementary tool to degree-day and degree-hour methods, in line with previous frequency-based approaches [9].

From a building energy performance perspective, the combined use of multiple TMY generation methods and evaluation indicators enables a more comprehensive assessment of climatic input uncertainty under non-stationary climate conditions. Rather than treating TMY generation as a preliminary data preparation step, the findings of this study indicate that methodological sensitivity analysis is essential when recent climate variability and extreme events are considered. This is particularly relevant for energy-efficient and Zero Energy Building-oriented studies, where small deviations in climatic input data can translate into significant differences in predicted energy demand and system performance.

Overall, the discussion confirms that datasets derived from recent short-term observations should be interpreted as representations of current climatic conditions rather than substitutes for classical long-term TMY datasets. The methodological framework adopted in this study contributes to the literature by explicitly quantifying the combined effects of recent climate variability and TMY generation methods on building energy indicators, thereby supporting more informed climate data selection and interpretation in building energy performance assessments.

5. Conclusions

This study quantitatively evaluated the impact of recent climatic conditions during the 2020–2024 period on building energy indicators for selected cities in the Marmara and Thrace regions of Türkiye using different TMY generation approaches. Comparative analyses based on degree-day, degree-hour, and BinData methods indicate that climatic indicators derived from this recent five-year dataset differ substantially from long-term reference values. Heating Degree-Day (HDD) values decrease by approximately 41–51%, while Cooling Degree-Hour (CDH) values increase by up to 90.7%, depending on the city and indicator considered. These results demonstrate that recent climate conditions significantly alter both heating- and cooling-related energy demand characteristics.

The analysis further confirms that methodological sensitivity increases under recent climate variability. Differences of up to 10–12% in HDD and CDD values and more than 15% in HDH and CDH values are observed between classical and weighted Finkelstein–Schaefer approaches. Given that international standards recommend data periods of at least 10–30 years for classical TMY construction, the datasets used in this study should be interpreted as short-term reference years (AMY) representing recent climatic conditions rather than long-term Typical Meteorological Years. These findings provide clear numerical evidence that recent climate variability and extreme temperature events significantly affect building energy indicators and should be explicitly considered in building energy analysis.

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Appendices

Table 1. *Weighted Finkelstein–Schaefer scores and selected representative years for Edirne using different TMY generation methods.*

Month	Selected YearFinkelstein & Schafer (1971)	Weighted Score	Selected Year Ashrae (2001)	Weighted Score	Selected Year Jiang (2010)	Weighted Score
1	2022	0,0693	2024	0,0667	2024	0,0668
2	2020	0,0466	2020	0,0445	2020	0,0445
3	2020	0,0670	2020	0,0686	2020	0,0686
4	2022	0,0583	2022	0,0531	2022	0,0531
5	2020	0,0624	2020	0,0547	2020	0,0547
6	2022	0,0513	2022	0,0509	2022	0,0509
7	2020	0,0565	2020	0,0583	2020	0,0583
8	2022	0,0575	2022	0,0540	2022	0,0540
9	2024	0,0533	2024	0,0490	2024	0,0490
10	2022	0,0857	2020	0,0729	2020	0,0729
11	2021	0,0601	2021	0,0546	2021	0,0546
12	2021	0,0628	2021	0,0528	2021	0,0528

Table 2. *Weighted Finkelstein–Schaefer scores and selected representative years for Kırklareli using different TMY generation methods.*

Month	Selected YearFinkelstein & Schafer (1971)	Weighted Score	Selected Year Ashrae (2001)	Weighted Score	Selected Year Jiang (2010)	Weighted Score
1	2022	0,1200	2021	0,1639	2021	0,1714
2	2022	0,1093	2020	0,1435	2020	0,1450
3	2020	0,0975	2023	0,1361	2023	0,1438
4	2020	0,1116	2020	0,1395	2020	0,1433
5	2020	0,1006	2020	0,1360	2020	0,1403
6	2022	0,1068	2023	0,1463	2023	0,1474
7	2021	0,0923	2021	0,1306	2021	0,1328
8	2024	0,1022	2021	0,1451	2024	0,1483
9	2020	0,1100	2024	0,1420	2024	0,1493
10	2022	0,1334	2022	0,1667	2024	0,1686
11	2021	0,1273	2021	0,1609	2021	0,1588
12	2022	0,1383	2022	0,1705	2023	0,1724

Table 3. *Weighted Finkelstein–Schaefer scores and selected representative years for Kocaeli using different TMY generation methods.*

Month	Selected YearFinkelstein & Schafer (1971)	Weighted Score	Selected Year Ashrae (2001)	Weighted Score	Selected Year Jiang (2010)	Weighted Score
1	2023	0,1462	2023	0,1388	2023	0,1411
2	2023	0,1470	2023	0,1206	2023	0,1322
3	2021	0,1087	2021	0,0998	2021	0,1101
4	2021	0,0751	2021	0,0726	2022	0,0763
5	2021	0,1063	2022	0,0986	2022	0,1019
6	2022	0,0914	2022	0,0856	2022	0,0933
7	2021	0,0790	2021	0,0664	2021	0,0706
8	2022	0,0907	2022	0,0727	2022	0,0796
9	2021	0,1386	2022	0,1176	2022	0,1277
10	2022	0,1379	2022	0,1240	2022	0,1360
11	2022	0,1154	2022	0,0955	2022	0,0956
12	2022	0,1218	2022	0,1083	2022	0,1061

Table 4. *Weighted Finkelstein–Schaefer scores and selected representative years for Sakarya using different TMY generation methods.*

Month	Selected YearFinkelstein & Schafer (1971)	Weighted Score	Selected Year Ashrae (2001)	Weighted Score	Selected Year Jiang (2010)	Weighted Score
1	2022	0,0773	2024	0,0642	2024	0,0662
2	2020	0,0528	2020	0,0511	2020	0,0460
3	2020	0,0693	2021	0,0705	2020	0,0750
4	2022	0,0523	2022	0,0437	2022	0,0425
5	2024	0,0565	2020	0,0572	2020	0,0543
6	2020	0,0729	2020	0,0790	2020	0,0737
7	2023	0,0631	2023	0,0510	2023	0,0533
8	2023	0,0774	2023	0,0567	2023	0,0676
9	2022	0,0701	2022	0,0574	2022	0,0652
10	2024	0,0796	2024	0,0717	2024	0,0749
11	2021	0,0599	2021	0,0519	2021	0,0532
12	2022	0,0529	2022	0,0441	2022	0,0466

Table 5. *Weighted Finkelstein–Schaefer scores and selected representative years for Tekirdağ using different TMY generation methods.*

Month	Selected YearFinkelstein & Schafer (1971)	Weighted Score	Selected Year Ashrae (2001)	Weighted Score	Selected Year Jiang (2010)	Weighted Score
1	2021	0,0717	2021	0,0684	2021	0,0734
2	2020	0,0465	2020	0,0501	2020	0,0395
3	2021	0,0825	2021	0,0943	2020	0,0961
4	2022	0,0486	2022	0,0488	2022	0,0487
5	2020	0,0533	2020	0,0534	2020	0,0493
6	2022	0,0635	2022	0,0613	2022	0,0654
7	2021	0,0683	2023	0,0613	2023	0,0630
8	2021	0,0574	2021	0,0473	2021	0,0483
9	2022	0,0609	2022	0,0536	2022	0,0570
10	2022	0,0673	2022	0,0593	2022	0,0671
11	2022	0,0822	2021	0,0752	2021	0,0747
12	2021	0,0687	2024	0,0650	2021	0,0633

Table 6. *Comparison of heating and cooling degree-day (HDD/CDD) and degree-hour (HDH/CDH) values derived from different TMY datasets.*

City	Period	HDD	CDD	HDH	CDH	HDD (%)	CDD (%)	HDH (%)	CDH (%)
Edirne	1989–2012	3202.10	1450.40	52725.60	9036.50	–47.6%	–75.8%	–19.2%	+23.7%
	2020–2024	1677.39	350.38	42594.40	11170.7				
Kırklareli	1989–2012	3771.10	953.20	31394.70	3644.50	–51.4%	–81.1%	+45.4%	+90.7%
	2020–2024	1831.56	179.69	45639.50	6951.9				
Kocaeli	1989–2012	2444.50	1270.00	39638.20	6176.00	–41.9%	–82.3%	–10.1%	+25.3%
	2020–2024	1419.36	224.75	35663.30	7739.7				
Sakarya	1989–2012	2551.30	897.70	42581.40	5608.10	–41.6%	–76.7%	–11.1%	+39.6%
	2020–2024	1490.40	209.15	37859.00	7830.1				
Tekirdağ	1989–2012	3006.20	899.90	47447.40	4254.80	–46.6%	–80.9%	–17.3%	+22.7%
	2020–2024	1603.53	172.05	39230.60	5223.4				

Table 7. *Comparison of HDD and CDD values for Edirne based on long-term observations and different TMY datasets.*

MGM Edirne	Year	HDD	CDD
1	2020	1731	435
2	2021	1829	388
3	2022	1765	436
4	2023	1540	468
5	2024	1548	635
	Total	8413	2362
	Mean	1682,6	472,4
Finkelstein & Schafer	TMY	1736,46	313.55
Ashrae	TMY	1677.39	350.38
Jiang	TMY	1673,72	319,25

Table 8. *Comparison of HDD and CDD values for Kırklareli based on long-term observations and different TMY datasets.*

MGM	Year	HDD	CDD
1	2020	1865	247
2	2021	2026	266
3	2022	1944	255
4	2023	1744	316
5	2024	1732	409
	Total	9311	1493
	Mean	1862,2	298,6
Finkelstein & Schafer	TMY	1449.87	159.09
Ashrae	TMY	1831.56	179.69
Jiang	TMY	1387,15	166,45

Table 9. *Comparison of HDD and CDD values for Kocaeli based on long-term observations and different TMY datasets.*

MGM Kocaeli	Year	HDD	CDD
1	2020	1213	237
2	2021	1299	305
3	2022	1476	308
4	2023	1176	324
5	2024	1148	492
	Total	6312	1666
	Mean	1262,4	333,2
Finkelstein & Schafer	TMY	1381,94	200
Ashrae	TMY	1419.36	224.75
Jiang	TMY	1707,43	364,23

Table 10. *Comparison of HDD and CDD values for Sakarya based on long-term observations and different TMY datasets.*

MGM	Year	HDD	CDD
1	2020	1330	425
2	2021	1400	244
3	2022	1519	245
4	2023	1235	265
5	2024	1299	428
	Total	6783	1607
	Mean	1356,6	321,4
Finkelstein & Schafer	TMY	1475.06	198,63
Ashrae	TMY	1490.40	209.15
Jiang	TMY	1399,45	387,75

Table 11. *Comparison of HDD and CDD values for Tekirdağ based on long-term observations and different TMY datasets.*

MGM Tekirdağ	Year	HDD	CDD
1	2020	1638	234
2	2021	1679	256
3	2022	1678	242
4	2023	1444	299
5	2024	1457	385
	Total	7896	1416
	Mean	1579,2	283
Finkelstein & Schafer	TMY	1644,25	172
Ashrae	TMY	1594,19	172,02
Jiang	TMY	1601,38	172,04

Table 12. *Climatic parameters and corresponding weighting factors used in different TMY generation methods.*

Parameters	**FS (1971)[1]**	**Ashrae (2001)[2]**	**Jiang (2010)[3]**
Maximum Dry-Bulb Temperature	1/24	5/100	5/100
Minimum Dry-Bulb Temperature	1/24	5/100	5/100
Mean Dry-Bulb Temperature	2/24	30/100	30/100
Maximum Dew-Point Temperature	1/24	-	2.5/100
Minimum Dew-Point Temperature	1/24	-	2.5/100
Mean Dew-Point Temperature	2/24	-	5/100
Maximum Wind Speed	2/24	5/100	5/100
Mean Wind Speed	2/24	5/100	5/100
Total Global Horizontal Solar Radiation	12/24	40/100	40/100
Direct Normal Solar Radiation	-	-	-
Relative Humidity	-	10/100	-

Table 13. *BinData-based hourly temperature frequency distribution for the ASHRAE-weighted TMY dataset of Edirne (2020–2024).*

EDİRNE	0≤t<2	2≤t<4	4≤t<6	6≤t<8	8≤t<10	10≤t<12	12≤t<14	14≤t<16	16≤t<18	18≤t<20	20≤t<22	22≤t<24	Total
-8≤T<-6	0	0	0	0	0	0	0	0	0	0	0	0	0
-6≤T<-4	2	5	5	2	0	0	0	0	0	0	0	1	15
-4≤T<-2	9	9	10	10	0	1	0	2	2	0	2	7	52
-2≤T<0	14	19	29	19	8	1	2	0	2	9	14	14	131
0≤T<2	38	46	42	30	18	6	5	9	17	26	25	35	297
2≤T<4	37	47	50	46	23	15	9	13	21	15	29	32	337
4≤T<6	67	64	59	48	37	25	25	25	25	40	53	62	530
6≤T<8	55	42	51	59	42	31	26	30	32	49	54	54	525
8≤T<10	57	56	47	42	58	43	31	25	44	53	52	51	559
10≤T<12	45	56	49	46	57	57	45	44	62	64	52	56	633
12≤T<14	80	92	71	43	35	53	68	60	55	47	60	71	735
14≤T<16	69	51	49	45	40	46	49	60	56	64	80	68	677
16≤T<18	51	40	45	39	51	44	48	49	46	56	42	37	548
18≤T<20	47	76	55	58	38	42	39	36	50	47	47	53	588
20≤T<22	86	76	68	37	40	34	35	48	38	39	44	58	603
22≤T<24	48	33	57	40	45	47	51	46	49	49	57	65	587
24≤T<26	16	8	25	61	35	43	48	56	46	45	63	43	489
26≤T<28	8	0	6	58	53	39	34	29	36	48	36	12	359
28≤T<30	0	0	0	36	60	41	37	41	38	39	14	8	314
30≤T<32	0	0	0	12	56	62	47	34	45	23	4	0	283
32≤T<34	0	0	0	0	31	60	60	60	36	7	1	0	255
34≤T<36	0	0	0	0	5	31	39	34	17	3	0	0	129
36≤T<38	0	0	0	0	0	9	25	23	7	0	0	0	64
38≤T<40	0	0	0	0	0	1	6	5	3	0	0	0	15
40≤T<42	0	0	0	0	0	0	0	2	0	0	0	0	2
42≤T<44	0	0	0	0	0	0	1	0	0	0	0	0	1

Table 14. Edirne (1989 – 2012) Bindata

	Hourly Time Interval												
Edirne	**0<=t<=2**	**2<=t<=4**	**4<=t<=6**	**6<=t<=8**	**8<=t<=10**	**10<=t<=12**	**12<=t<=14**	**14<=t<=16**	**16<=t<=18**	**18<=t<=20**	**20<=t<=22**	**22<=t<=24**	**TOPLAM**
-10>=T>=-12	0	0	0	0	0	0	0	0	0	0	0	0	0
-8>=T>=-10	1	2	2	2	1	0	0	0	0	0	0	0	8
-6>=T>=-8	1	2	4	4	3	1	0	0	0	2	4	4	25
-4>=T>=-6	2	5	6	10	7	4	2	2	2	2	0	2	44
-2>=T>=-4	7	16	14	14	13	2	1	1	3	2	4	9	86
0>=T>=-2	17	40	47	45	33	21	8	5	3	11	17	17	264
2>=T>=0	24	45	51	58	48	28	12	12	20	26	32	50	406
4>=T>=2	26	56	51	49	47	41	35	21	22	23	38	34	443
6>=T>=4	26	60	64	54	55	36	36	30	37	46	56	51	551
8>=T>=6	21	38	48	45	35	64	40	45	38	51	44	57	526
10>=T>=8	31	65	62	63	47	32	50	48	46	39	48	49	580
12>=T>=10	32	62	60	52	50	40	35	36	44	48	50	56	565
14>=T>=12	27	59	65	52	47	37	33	40	47	56	71	69	603
16>=T>=14	33	62	54	57	45	55	51	53	43	43	43	46	585
18>=T>=16	23	55	71	59	23	45	46	39	35	62	50	47	555
20>=T>=18	33	58	45	55	44	30	40	41	52	34	36	47	515
22>=T>=20	24	49	56	45	42	29	42	50	44	40	46	63	530
24>=T>=22	23	41	28	37	65	33	29	38	45	39	60	53	491
26>=T>=24	13	13	2	23	44	57	34	23	30	48	46	41	374
28>=T>=26	1	0	0	3	38	58	45	42	35	43	37	26	328
30>=T>=28	0	0	0	0	29	42	73	68	59	41	35	8	355
32>=T>=30	0	0	0	0	12	43	42	41	43	30	13	0	224
34>=T>=32	0	0	0	0	0	23	41	39	33	31	0	0	167
36>=T>=34	0	0	0	0	0	7	22	36	32	10	0	0	107
38>=T>=36	0	0	0	0	0	0	10	16	15	0	0	0	41
40>=T>=38	0	0	0	0	0	0	0	4	2	0	0	0	6
42>=T>=40	0	0	0	0	0	0	0	0	0	0	0	0	0
44>=T>=42	0	0	0	0	0	0	0	0	0	0	0	0	0

S. Yılmaz, *Development of a typical meteorological year and climate data library for Türkiye for building energy analysis*, Ph.D. dissertation, Graduate School of Natural Sciences, Marmara University, Istanbul, Türkiye, 2015.

Table 15. *BinData-based hourly temperature frequency distribution for the ASHRAE-weighted TMY dataset of Kırklareli (2020–2024).*

Kırklareli	0≤t<2	2≤t<4	4≤t<6	6≤t<8	8≤t<10	10≤t<12	12≤t<14	14≤t<16	16≤t<18	18≤t<20	20≤t<22	22≤t<24	Total
-8≤T<-6	0	0	0	0	0	0	0	0	0	0	0	0	0
-6≤T<-4	4	6	9	12	14	15	4	4	5	5	1	2	81
-4≤T<-2	8	7	13	14	16	14	15	8	7	5	10	7	124
-2≤T<0	14	15	12	16	18	18	12	15	6	10	16	14	166
0≤T<2	20	20	24	22	23	20	27	23	31	30	17	19	276
2≤T<4	22	25	26	30	27	40	31	25	23	27	29	29	334
4≤T<6	40	39	39	49	57	44	46	46	41	37	41	32	511
6≤T<8	45	46	63	62	55	48	53	58	53	45	41	39	608
8≤T<10	49	57	52	55	48	54	70	74	83	68	74	65	749
10≤T<12	64	67	69	42	44	50	55	56	60	70	80	58	715
12≤T<14	77	59	42	43	40	53	68	74	69	78	68	77	748
14≤T<16	52	45	35	46	57	61	45	55	62	61	67	87	673
16≤T<18	51	43	30	33	47	39	33	58	70	71	73	63	611
18≤T<20	77	73	38	37	41	33	56	42	45	57	62	71	632
20≤T<22	69	78	72	45	38	45	48	44	31	59	57	63	649
22≤T<24	69	62	69	48	33	45	33	18	37	33	55	60	562
24≤T<26	37	32	58	61	43	28	13	23	27	22	30	33	407
26≤T<28	27	26	31	44	45	28	14	27	31	28	11	16	328
28≤T<30	10	28	33	38	46	31	38	27	18	19	4	1	293
30≤T<32	1	7	17	26	20	34	21	19	21	7	0	0	173
32≤T<34	0	0	4	12	11	14	26	16	13	1	0	0	97
34≤T<36	0	0	0	1	12	11	8	14	1	0	0	0	47
36≤T<38	0	0	0	0	1	9	15	7	0	0	0	0	32
38≤T<40	0	0	0	0	0	0	2	1	0	0	0	0	3
40≤T<42	0	0	0	0	0	0	0	0	0	0	0	0	0
42≤T<44	0	0	0	0	0	0	0	0	0	0	0	0	0

Tablo 16. Kırklareli (1989 – 2012) Bindata

	Hourly Time Interval												
Kırklareli	**0<=t<=2**	**2<=t<=4**	**4<=t<=6**	**6<=t<=8**	**8<=t<=10**	**10<=t<=12**	**12<=t<=14**	**14<=t<=16**	**16<=t<=18**	**18<=t<=20**	**20<=t<=22**	**22<=t<=24**	**Total**
-12>=T>=-14	0	0	0	0	0	0	0	0	0	0	0	0	0
-10>=T>=-12	0	2	2	0	0	0	0	0	0	0	0	0	4
-8>=T>=-10	1	0	0	1	0	0	0	0	0	0	1	2	5
-6>=T>=-8	0	0	0	1	2	0	0	0	1	4	3	2	13
-4>=T>=-6	1	5	7	8	5	1	1	2	3	0	1	0	34
-2>=T>=-4	9	16	18	18	11	7	4	1	1	4	5	9	103
0>=T>=-2	11	24	27	27	18	11	7	4	8	10	16	21	184
2>=T>=0	15	30	25	24	27	12	12	12	16	23	23	30	249
4>=T>=2	16	35	36	46	34	29	16	20	18	31	43	38	362
6>=T>=4	14	31	30	20	29	28	33	30	36	38	31	28	348
8>=T>=6	17	22	23	21	20	30	23	24	25	20	22	21	268
10>=T>=8	6	17	15	17	15	18	25	19	18	19	20	24	213
12>=T>=10	10	21	27	18	21	16	20	25	21	16	18	18	231
14>=T>=12	10	21	25	14	14	22	16	15	17	18	18	13	203
16>=T>=14	17	35	36	32	13	18	24	19	13	13	17	23	260
18>=T>=16	12	33	33	30	11	14	9	15	16	19	21	28	241
20>=T>=18	18	25	25	36	18	9	15	18	16	21	34	35	270
22>=T>=20	13	34	29	26	26	16	19	10	23	24	25	24	269
24>=T>=22	11	11	10	15	32	21	18	21	16	21	26	34	236
26>=T>=24	2	4	0	13	24	32	15	20	15	23	29	13	190
28>=T>=26	0	0	0	1	30	25	32	29	29	24	14	3	187

30>=T>=28	0	0	0	0	17	31	22	20	19	26	1	0	136
32>=T>=30	0	0	0	0	1	25	36	27	34	12	0	0	135
34>=T>=32	0	0	0	0	0	3	20	33	20	2	0	0	78
36>=T>=34	0	0	0	0	0	0	1	4	3	0	0	0	8
38>=T>=36	0	0	0	0	0	0	0	0	0	0	0	0	0
40>=T>=38	0	0	0	0	0	0	0	0	0	0	0	0	0
42>=T>=40	0	0	0	0	0	0	0	0	0	0	0	0	0
44>=T>=42	0	0	0	0	0	0	0	0	0	0	0	0	0

S. Yılmaz, *Development of a typical meteorological year and climate data library for Türkiye for building energy analysis*, Ph.D. dissertation, Graduate School of Natural Sciences, Marmara University, Istanbul, Türkiye, 2015.

Table 17. *BinData-based hourly temperature frequency distribution for the ASHRAE-weighted TMY dataset of Kocaeli (2020–2024).*

Kocaeli	**0≤t<2**	**2≤t<4**	**4≤t<6**	**6≤t<8**	**8≤t<10**	**10≤t<12**	**12≤t<14**	**14≤t<16**	**16≤t<18**	**18≤t<20**	**20≤t<22**	**22≤t<24**	**Total**
-8≤T<-6	0	0	0	0	0	0	0	0	0	0	0	0	0
-6≤T<-4	0	0	0	0	0	0	0	0	0	0	0	0	0
-4≤T<-2	0	0	0	0	0	0	0	0	0	0	0	0	0
-2≤T<0	0	0	0	0	0	0	0	0	0	0	0	0	0
0≤T<2	14	17	18	11	3	2	2	5	7	3	3	4	89
2≤T<4	33	38	35	24	15	10	12	9	12	24	32	32	276
4≤T<6	50	44	50	40	21	15	15	26	31	29	33	50	404
6≤T<8	45	56	53	53	40	34	30	27	38	46	55	49	526
8≤T<10	90	91	81	68	47	32	27	34	36	56	59	68	689
10≤T<12	73	79	85	69	71	50	45	50	69	72	82	85	830
12≤T<14	71	69	62	58	51	67	59	60	66	86	74	69	792
14≤T<16	66	65	66	58	53	37	49	68	81	62	63	63	731
16≤T<18	52	40	37	53	67	63	65	69	62	57	56	64	685
18≤T<20	72	79	59	36	54	64	57	53	46	46	61	59	686
20≤T<22	54	77	76	48	41	62	61	47	44	65	60	61	696
22≤T<24	86	60	73	44	40	34	40	40	53	66	77	91	704
24≤T<26	21	15	30	83	45	40	42	40	61	77	61	30	545
26≤T<28	3	0	4	50	49	50	45	55	70	34	14	5	379
28≤T<30	0	0	0	30	62	60	67	54	40	6	0	0	319
30≤T<32	0	0	1	4	50	47	39	58	12	1	0	0	212
32≤T<34	0	0	0	1	15	45	45	27	2	0	0	0	135
34≤T<36	0	0	0	0	6	13	27	8	0	0	0	0	54
36≤T<38	0	0	0	0	0	5	3	0	0	0	0	0	8
38≤T<40	0	0	0	0	0	0	0	0	0	0	0	0	0
40≤T<42	0	0	0	0	0	0	0	0	0	0	0	0	0
42≤T<44	0	0	0	0	0	0	0	0	0	0	0	0	0

Tablo 18. Kocaeli (1989 – 2012) Bindata

Kocaeli	**Hourly Time Interval**												
	0<=t<=2	**2<=t<=4**	**4<=t<=6**	**6<=t<=8**	**8<=t<=10**	**10<=t<=12**	**12<=t<=14**	**14<=t<=16**	**16<=t<=18**	**18<=t<=20**	**20<=t<=22**	**22<=t<=24**	**Total**
-6>=T>=-8	0	0	0	0	0	0	0	0	0	0	0	0	0
-4>=T>=-6	0	0	0	0	0	0	0	0	0	0	0	0	0
-2>=T>=-4	0	0	0	0	0	0	0	0	0	0	0	0	0
0>=T>=-2	1	2	3	5	2	0	0	0	0	1	1	0	15
2>=T>=0	10	24	28	27	20	7	3	5	6	8	10	12	160
4>=T>=2	22	48	45	46	44	28	15	8	11	14	25	41	347
6>=T>=4	26	47	58	58	53	48	33	30	38	63	69	59	582
8>=T>=6	25	56	45	43	37	45	52	45	47	36	27	32	490
10>=T>=8	28	56	73	66	48	29	31	40	36	37	44	55	543

12>=T>=10	40	83	80	77	62	45	35	35	40	54	62	76	689
14>=T>=12	33	66	69	70	72	66	52	48	56	66	88	73	759
16>=T>=14	34	78	74	70	60	54	44	49	52	48	38	50	651
18>=T>=16	36	64	53	59	46	54	60	52	44	56	71	64	659
20>=T>=18	20	41	42	40	63	43	49	44	63	66	59	67	597
22>=T>=20	23	63	75	58	35	57	50	61	50	51	50	32	605
24>=T>=22	42	70	58	69	39	49	53	49	41	43	37	65	615
26>=T>=24	11	13	6	16	68	38	58	57	53	40	76	72	508
28>=T>=26	0	0	0	0	48	53	37	41	42	62	54	6	343
30>=T>=28	0	0	0	0	3	68	42	48	48	47	4	0	260
32>=T>=30	0	0	0	0	0	22	58	42	51	15	0	0	188
34>=T>=32	0	0	0	0	0	2	28	31	23	2	0	0	86
36>=T>=34	0	0	0	0	0	0	6	19	3	0	0	0	28
38>=T>=36	0	0	0	0	0	0	1	2	0	0	0	0	3
40>=T>=38	0	0	0	0	0	0	0	0	0	0	0	0	0
42>=T>=40	0	0	0	0	0	0	0	0	0	0	0	0	0
44>=T>=42	0	0	0	0	0	0	0	0	0	0	0	0	0

S. Yılmaz, *Development of a typical meteorological year and climate data library for Türkiye for building energy analysis*, Ph.D. dissertation, Graduate School of Natural Sciences, Marmara University, Istanbul, Türkiye, 2015.

Table 19. *BinData-based hourly temperature frequency distribution for the ASHRAE-weighted TMY dataset of Sakarya (2020–2024).*

Sakarya	0≤t<2	2≤t<4	4≤t<6	6≤t<8	8≤t<10	10≤t<12	12≤t<14	14≤t<16	16≤t<18	18≤t<20	20≤t<22	22≤t<24	Total
-8≤T<-6	0	0	0	0	0	0	0	0	0	0	0	0	0
-6≤T<-4	0	0	0	0	0	0	0	0	0	0	0	0	0
-4≤T<-2	0	0	0	0	0	0	0	0	0	0	0	0	0
-2≤T<0	6	10	17	7	0	2	0	0	0	0	1	5	48
0≤T<2	19	21	14	13	5	0	2	2	4	4	8	12	104
2≤T<4	32	38	40	17	12	2	3	8	9	18	24	27	230
4≤T<6	66	58	56	52	24	17	9	18	29	37	54	67	487
6≤T<8	56	67	64	41	43	34	34	36	54	78	72	66	645
8≤T<10	74	70	77	81	43	45	41	48	61	58	55	62	715
10≤T<12	66	71	68	59	67	42	40	49	59	65	73	66	725
12≤T<14	80	73	62	61	55	53	57	51	52	64	58	74	740
14≤T<16	60	64	52	51	71	72	61	65	68	60	78	66	768
16≤T<18	50	54	57	47	50	54	52	57	67	60	54	45	647
18≤T<20	57	74	56	43	38	59	62	57	42	45	30	49	612
20≤T<22	85	69	77	49	44	38	41	48	44	43	63	79	680
22≤T<24	67	48	62	63	41	49	55	30	36	56	93	89	689
24≤T<26	12	8	18	89	48	35	42	52	74	90	60	23	551
26≤T<28	1	2	3	38	82	42	40	53	71	33	7	2	374
28≤T<30	0	0	0	20	60	74	65	70	37	8	2	0	336
30≤T<32	0	0	0	1	32	63	60	47	17	2	0	0	222
32≤T<34	0	0	0	0	14	26	32	23	6	0	0	0	101
34≤T<36	0	0	0	0	1	19	22	14	1	0	0	0	57
36≤T<38	0	0	0	0	0	6	11	2	1	0	0	0	20
38≤T<40	0	0	0	0	0	0	1	2	0	0	0	0	3
40≤T<42	0	0	0	0	0	0	0	0	0	0	0	0	0
42≤T<44	0	0	0	0	0	0	0	0	0	0	0	0	0

Tablo 20. Sakarya (1989 – 2012) Bindata

	Hourly Time Interval												
Sakarya	**0<=t<=2**	**2<=t<=4**	**4<=t<=6**	**6<=t<=8**	**8<=t<=10**	**10<=t<=12**	**12<=t<=14**	**14<=t<=16**	**16<=t<=18**	**18<=t<=20**	**20<=t<=22**	**22<=t<=24**	**Total**
-8>=T>=-10	2	0	0	0	0	0	0	0	0	0	0	0	2
-6>=T>=-8	0	0	0	0	0	0	0	0	0	0	0	0	0
-4>=T>=-6	0	0	0	0	0	0	0	0	0	0	0	0	0
-2>=T>=-4	0	0	0	0	0	0	0	0	0	0	0	0	0
0>=T>=-2	0	5	10	15	3	0	0	0	0	0	0	0	33
2>=T>=0	17	39	39	42	30	9	2	1	0	3	6	14	202
4>=T>=2	19	39	46	44	40	17	7	9	14	17	33	43	328
6>=T>=4	33	67	71	63	54	43	27	17	22	64	69	65	595
8>=T>=6	33	72	74	67	44	57	47	48	70	51	49	59	671
10>=T>=8	30	62	57	59	56	51	54	50	41	46	47	54	607
12>=T>=10	31	67	67	63	57	36	44	35	41	53	66	71	631
14>=T>=12	35	63	65	72	71	52	45	53	52	58	72	59	697
16>=T>=14	28	65	78	69	51	56	42	48	55	67	50	52	661
18>=T>=16	44	92	91	77	51	57	56	53	59	50	50	76	756
20>=T>=18	35	68	56	66	66	58	61	62	54	63	88	80	757
22>=T>=20	28	40	43	44	63	46	52	55	50	59	60	61	601
24>=T>=22	20	35	24	32	55	69	43	57	63	54	50	56	558
26>=T>=24	9	15	9	16	48	59	70	46	42	47	56	25	442
28>=T>=26	1	0	0	1	30	49	55	60	48	44	27	15	330
30>=T>=28	0	0	0	0	9	43	45	50	46	39	7	0	239
32>=T>=30	0	0	0	0	0	23	38	36	45	14	0	0	156
34>=T>=32	0	0	0	0	0	3	30	32	22	1	0	0	88
36>=T>=34	0	0	0	0	0	0	11	18	4	0	0	0	33
38>=T>=36	0	0	0	0	0	0	0	0	0	0	0	0	0
40>=T>=38	0	0	0	0	0	0	0	0	0	0	0	0	0
42>=T>=40	0	0	0	0	0	0	0	0	0	0	0	0	0
44>=T>=42	0	0	0	0	0	0	0	0	0	0	0	0	0

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Table 21. *BinData-based hourly temperature frequency distribution for the ASHRAE-weighted TMY dataset of Tekirdağ (2020–2024).*

Tekirdağ	**0≤t<2**	**2≤t<4**	**4≤t<6**	**6≤t<8**	**8≤t<10**	**10≤t<12**	**12≤t<14**	**14≤t<16**	**16≤t<18**	**18≤t<20**	**20≤t<22**	**22≤t<24**	**Total**
-8≤T<-6	0	0	0	0	0	0	0	0	0	0	0	0	0
-6≤T<-4	1	2	5	1	0	0	0	0	0	0	0	0	9
-4≤T<-2	3	4	1	4	1	0	0	0	0	1	4	4	22
-2≤T<0	8	10	9	6	5	3	0	1	4	7	6	8	67
0≤T<2	9	6	11	7	5	7	11	13	13	12	9	8	111
2≤T<4	32	34	31	23	11	8	8	4	6	8	18	28	211
4≤T<6	35	44	43	25	17	8	6	12	19	34	31	32	306
6≤T<8	74	64	59	48	32	29	22	24	35	41	60	72	560
8≤T<10	71	68	73	85	67	66	62	59	93	94	81	79	898
10≤T<12	73	91	70	65	91	85	87	91	65	70	76	65	929
12≤T<14	100	91	85	55	69	72	69	63	54	57	86	94	895
14≤T<16	64	64	68	80	49	50	49	54	69	90	75	61	773
16≤T<18	37	37	38	53	62	70	71	69	75	53	33	40	638
18≤T<20	60	71	33	42	46	43	62	58	37	20	39	51	562
20≤T<22	65	57	66	30	53	51	37	34	30	57	57	58	595
22≤T<24	64	59	69	57	49	49	44	37	56	43	61	64	652
24≤T<26	16	14	37	63	50	58	51	64	51	64	61	52	581
26≤T<28	7	6	18	66	80	72	74	63	66	53	23	7	535
28≤T<30	1	1	3	18	35	52	63	65	46	13	5	2	304
30≤T<32	0	0	0	4	6	7	10	15	10	3	1	0	56
32≤T<34	0	0	0	0	2	0	1	4	0	1	1	0	9

34≤T<36	0	0	0	0	2	0	3	0	0	1	0	0	6
36≤T<38	0	0	0	0	0	1	0	0	0	0	0	0	1
38≤T<40	0	0	0	0	0	1	0	0	0	0	0	0	1
40≤T<42	0	0	0	0	0	0	0	0	0	0	0	0	0
42≤T<44	0	0	0	0	0	0	0	0	0	0	0	0	0

Tablo 22. Tekirdağ (1989 – 2012) Bindata

	Hourly Time Interval												
Tekirdağ	**0<=t<=2**	**2<=t<=4**	**4<=t<=6**	**6<=t<=8**	**8<=t<=10**	**10<=t<=12**	**12<=t<=14**	**14<=t<=16**	**16<=t<=18**	**18<=t<=20**	**20<=t<=22**	**22<=t<=24**	**Total**
-6>=T>=-8	0	0	0	0	0	0	0	0	0	0	0	0	0
-4>=T>=-6	0	0	0	0	0	0	0	0	0	0	0	0	0
-2>=T>=-4	2	4	5	8	3	0	0	0	0	0	2	1	25
0>=T>=-2	9	21	18	13	12	4	0	0	2	6	9	13	107
2>=T>=0	11	22	37	40	22	13	8	8	8	16	20	21	226
4>=T>=2	30	68	57	52	42	20	13	12	22	25	37	53	431
6>=T>=4	30	55	57	54	58	36	25	30	33	61	79	67	585
8>=T>=6	28	50	54	62	50	71	62	54	61	60	36	43	631
10>=T>=8	25	67	76	67	51	62	69	73	60	36	38	53	677
12>=T>=10	41	76	76	68	55	41	53	46	41	57	78	71	703
14>=T>=12	33	63	54	58	70	54	39	42	46	72	67	66	664
16>=T>=14	32	62	69	48	57	68	70	58	74	62	61	61	722
18>=T>=16	30	65	65	41	39	63	65	63	67	50	50	65	663
20>=T>=18	29	51	48	63	36	33	52	66	39	48	61	62	588
22>=T>=20	26	49	61	53	70	65	52	39	44	55	55	42	611
24>=T>=22	20	53	36	41	36	48	60	67	80	53	43	52	589
26>=T>=24	16	18	13	34	55	48	39	47	36	42	56	42	446
28>=T>=26	3	5	3	24	37	53	66	64	53	45	27	14	394
30>=T>=28	0	0	0	2	26	32	38	35	37	26	10	3	209
32>=T>=30	0	0	0	0	9	15	13	17	15	10	0	0	79
34>=T>=32	0	0	0	0	0	3	5	5	9	5	0	0	27
36>=T>=34	0	0	0	0	0	0	0	3	3	0	0	0	6
38>=T>=36	0	0	0	0	0	0	0	0	0	0	0	0	0
40>=T>=38	0	0	0	0	0	0	0	0	0	0	0	0	0
42>=T>=40	0	0	0	0	0	0	0	0	0	0	0	0	0
44>=T>=42	0	0	0	0	0	0	0	0	0	0	0	0	0

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