DETERMINATION AND APPLICATION OF THE DATA USED IN ENERGY ESTIMATION METHODS FOR İSTANBUL

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1. Abstract

In this study, the data used in degree-day and bin methods are determined for Istanbul. Heating degree-day values are calculated at 14, 16, 18, 20, and 22 ^{o}C base temperatures and cooling degree-days for base temperatures of 18, 20, 22, 24, and 26 ^{o}C. In the calculations, the daily maximum and the minimum temperatures recorded by The State Meteorological Affairs General Directorate (DMİ) between the years 1981 and 1996 (16 years) are used. Monthly and yearly degree-day values are given in tabular form and they are analysed. Bin data for dry-bulb temperature from -9 ^{o}C to 39 ^{o}C with 3 ^{o}C increments are calculated in six daily 4-h shifts (1-4, 5-8, 9-12, 13-16, 17-20 and 21-24 hours) for İstanbul. Monthly and yearly bin data are presented in tables and on graphs. The bin data are obtained using the hourly dry-bulb temperatures measured during 16 years between 1983 and 1998. Energy analysis of a sample building in İstanbul is performed using the degree-day and the bin values obtained in this study.

2.Nomenclature

Q	:	Annual energy requirement [W.day]
DD	:	Degree-day [^{o}C.day]
HDD	:	Heating degree-day [^{o}C.day]
CDD	:	Cooling degree-day [^{o}C.day]
K_{tot}	:	Total heat transfer coefficient of building [W/ ^{o}C]
T_b	:	Base temperature [^{o}C]
η	:	Efficieny
T_m	:	Daily mean temperature [^{o}C]
h	:	Heating
c	:	Cooling
T_O	:	Centre temperature of temperature bin [^{o}C]
N_{bin}	:	Number of hours [h]
i	:	Temperature interval
m	:	Total number of temperature bins
tot	:	Total
U	:	Heat transfer coefficient [W/m^2 ^{o}C]
A	:	Area [m^2]

3. Introduction

A significant portion of energy is consumed in buildings to provide thermal comfort conditions. Due to growing concerns on production and consumption of energy, energy analysis plays an important role in the design and operation of buildings and especially selecting a suitable air-conditioning system. Various energy analysis methods have been developed ranging from simplified manual methods to detailed computer simulations. In spite of tremendous developments in computer technologies, degree-day and bin methods are still widely used in many developed countries, since they are the simplest methods and well-established tools for energy analysis. The monthly and/or annual cooling and heating requirements of specific buildings in different locations can be estimated by means of degree-day concept [1,2]. Energy analyses methods are not very well known in Turkey. Although there have been some independent studies on bin data and especially on degree-days for Turkey in recent years [3-12], energy estimating methods have not been handled properly. In this study, detailed degree-day and bin data for İstanbul were determined and analysed. Heating and cooling energy consumption of a sample building in İstanbul was estimated using the degree-day and the bin values obtained in this study.

4. Degree-day

Degree-day method is a simple method and a well-established tool for energy analysis, if the utilization of the building, the efficiency of the HVAC equipment, the indoor temperature and the internal gains are relatively constant. The method assumes that the energy needs for a building are proportional to the difference between the daily mean temperature and a base temperature. The base temperature is the outdoor temperature below or above which heating or cooling is needed. Traditionally, heating degree-days are calculated at a base temperature of 18 °C and cooling degree-days are determined at a base temperature of 22 °C for a typical uninsulated building [1,2].

The annual or monthly energy consumption, Q [W.day] can be calculated as;

$$Q = \frac{K_{tot}}{\eta} DD \tag{1}$$

where Ktot is the total heat transfer coefficient of the building in W/°C, η is the efficiency of the HVAC equipment and DD is the value of degree-days for heating or cooling. Heating degree-days (HDD) and cooling degree-days (CDD) can be determined using the following expressions;

$$\text{HDD} = (1\ \text{day}) \sum_{days} (T_b - T_m)^+ \tag{2}$$

$$\text{CDD} = (1\ \text{day}) \sum_{days} (T_m - T_b)^+ \tag{3}$$

in which, T_b is the base temperature and T_m is the daily mean outdoor temperature. The plus signs above the parentheses of Eqs. 2 and 3 indicate that only positive values are to be counted. Using HDD and CDD, annual heating consumption, Q_h, and annual cooling requirements, Q_c, in terms of kWh can be calculated, respectively as;

$$Q_h = \frac{K_{tot}}{\eta} HDD \frac{24}{1000} \tag{4}$$

$$Q_c = \frac{K_{tot}}{\eta} CDD \frac{24}{1000} \tag{5}$$

In this study, heating and cooling degree-day values were determined for İstanbul using the daily maximum and minimum temperatures that were recorded by The State Meteorological Affairs General Directorate (DMİ) between 1981 and 1996 (16 years) in Göztepe weather station.

4.1. Heating Degree-day

Heating degree-day values are calculated at 14, 16, 18, 20, and 22 °C base temperatures for İstanbul. Table 1 shows the monthly and the annual heating degree-days.

Table 1. The monthly and the annual heating degree-days for İstanbul

Month	**Base Temperature [°C]**				
	14	16	**18**	20	22
January	239	301	363	425	487
February	230	285	341	397	453
March	195	254	315	377	439
April	72	118	171	229	288
May	11	31	65	112	167
June	0	1	3	13	41
July	0	0	0	2	9
August	0	0	0	1	7
September	0	1	6	21	54
October	17	41	79	130	187
November	104	154	213	272	332
December	186	247	309	371	433
Annual	1054	1433	1865	2350	2897

As can be seen from Table 1, heating requirement is maximum in January (363 [^{o}C-day] at T_b=18 ^{o}C). Figure 1 shows variation of the annual heating degree-days with base temperature for İstanbul. The heating degree-days increase almost linearly with increasing base temperature.

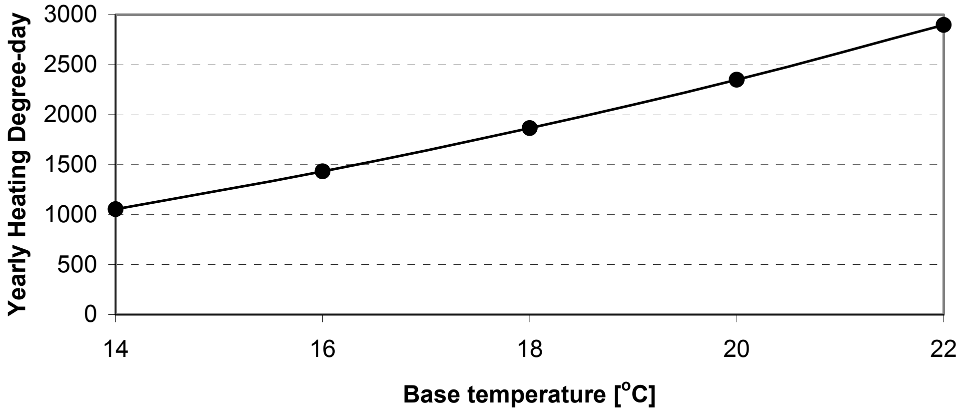

Figure 1. Variation of annual heating degree-days with base temperature

4.2. Cooling Degree-day

Monthly and annual cooling degree-days for base temperatures of 18, 20, 22, 24, and 26 ^{o}C are given in Table 2.

Table 2. Monthly and yearly cooling degree-days at various base temperature for İstanbul

Month	**Base Temperature [^{o}C]**				
	18	20	**22**	24	26
January	0	0	0	0	0
February	0	0	0	0	0
March	0	0	0	0	0
April	3	1	0	0	0
May	25	10	3	1	0
June	103	53	21	5	1
July	170	110	55	17	3
August	180	119	63	21	2
September	88	43	15	3	0
October	18	6	2	0	0
November	1	0	0	0	0
December	0	0	0	0	0
Yearly	588	342	159	47	6

In İstanbul, the highest cooling degree-day occurs in August (63 [^{o}C-day] at T_b=22 ^{o}C) as seen from Table 2. Variation of the annual cooling degree-days with base temperature is shown in Figure 2. The value of cooling degree-days increases significantly with the decrease of base temperature.

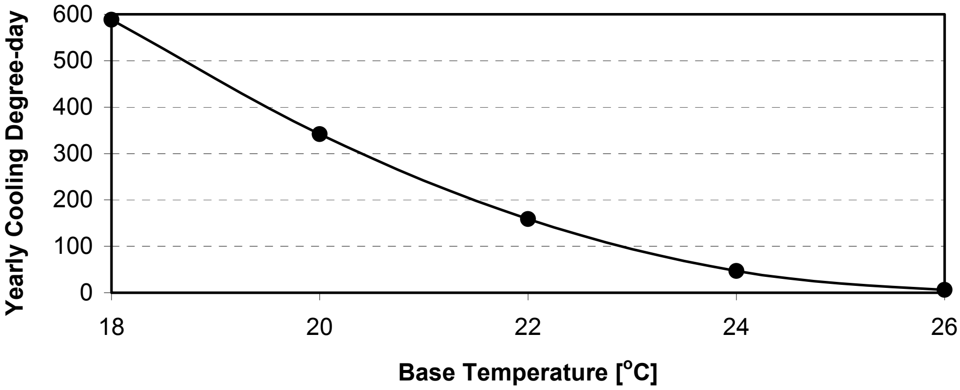

Figure 2. Variation of annual cooling degree-days with base temperature

5. Bin Method

Annual or monthly energy consumption can be determined easily using bin method, if different temperature intervals and time periods are evaluated separately. Bin method is used in many applications if the utilization of building, the efficiency of the HVAC equipment, the base temperature and the total heat transfer coefficient of the building are not constant. Since bin method is based on hourly weather data, rather than daily averages, it is more accurate than the degree-day method [13]. Bin method is based on the calculation of the energy consumption for different values of the outdoor temperature ($T_{o,i}$) and multiplying it by the corresponding number of hours ($N_{bin,i}$) in the temperature interval (bin) centred on that temperature [12] :

$$Q_{bin,i} = N_{bin,i} \frac{K_{tot}}{\eta} \left(T_b - T_{o,i}\right)^{\pm} \quad \textbf{(6)}$$

The plus subscript on the parenthesis of Eq. (6) is for heating and indicates that only positive values are to be counted. For cooling, only negative values should be considered. $Q_{bin,i}$ values are calculated separately using Eq. (6) for each temperature interval (bin) and summed to obtain total energy consumption :

$$Q_{tot} = \sum_{i=1}^{m} Q_{bin,i} \quad \textbf{(7)}$$

where m is the total number of the temperature intervals (bins).

In this study, bin data for dry-bulb temperature from -9 °C to 39 °C with 3 °C increments were calculated in six daily 4-h shifts (1-4, 5-8, 9-12, 13-16, 17-20 and 21-24 hours) for İstanbul. Bin data were determined using hourly dry-bulb temperatures measured by DMİ in İstanbul (Göztepe) during a period of 16 years (between 1983 and 1998). Monthly bin data for İstanbul are given in Table 3 in 4-h periods. The smallest temperature bin observed in İstanbul is –4.5 °C (-6 °C /-3 °C) with 11 h in February, whilst the maximum bin observed is 34.5 °C (33 °C /36 °C) with 3 h in July. Annual N_{bin} values for six separate time periods of the day are presented in Table 4. As can be seen from the table, the maximum yearly total N_{bin} value is 1144 h in 7.5 °C (6 °C/9 °C) temperature interval.

Figure 3 shows distribution of monthly total N_{bin} values for İstanbul. Heating and cooling seasons can be estimated from the figure. As can be seen from the figure, while winter months locate at the left of the graph (low temperature bins), the summer months are at the right (high temperature bins). Transitions from winter to summer and summer to winter take place at the middle of the graph (medium temperature bins). Cumulative distribution of yearly bin data for İstanbul is shown in Figure 4. From the figure, one can get approximately the number of hours for heating season or cooling season by choosing a base temperature. For example, it can be easily determined that the heating season is 6200 h for T_b=18 °C and cooling season is 980 h for T_b=22 °C.

Table 3. Monthly total N_{bin} values [h/month] for İstanbul.

Month	Time	Temperature Bin [^oC]															
		-9/-6	-6/-3	-3/0	0/3	3/6	6/9	9/12	12/15	15/18	18/21	21/24	24/27	27/30	30/33	33/36	36/39
January	1-4	0	0	4	26	43	29	17	4	1	0	0	0	0	0	0	0
	5-8	0	0	4	29	40	31	16	4	0	0	0	0	0	0	0	0
	9-12	0	0	1	16	37	36	21	11	2	0	0	0	0	0	0	0
	13-16	0	0	1	11	34	36	23	15	4	0	0	0	0	0	0	0
	17-20	0	0	2	17	42	34	20	8	1	0	0	0	0	0	0	0
	21-24	0	1	2	22	44	30	18	6	1	0	0	0	0	0	0	0
	Total	0	1	14	121	240	196	115	48	9	0	0	0	0	0	0	0
February	1-4	0	2	11	23	39	22	12	3	0	0	0	0	0	0	0	0
	5-8	0	2	11	25	39	20	12	3	0	0	0	0	0	0	0	0
	9-12	0	2	6	15	26	32	17	11	3	0	0	0	0	0	0	0
	13-16	0	1	6	13	21	30	19	15	6	1	0	0	0	0	0	0
	17-20	0	2	8	15	33	27	15	10	2	0	0	0	0	0	0	0
	21-24	0	2	10	17	39	24	14	5	1	0	0	0	0	0	0	0
	Total	0	11	52	108	197	155	89	47	12	1	0	0	0	0	0	0
March	1-4	0	1	4	20	45	30	18	5	1	0	0	0	0	0	0	0
	5-8	0	1	4	20	44	30	18	6	1	0	0	0	0	0	0	0
	9-12	0	0	3	7	27	38	24	15	8	2	0	0	0	0	0	0
	13-16	0	0	2	6	21	35	26	14	13	6	1	0	0	0	0	0
	17-20	0	1	2	9	36	33	20	14	7	2	0	0	0	0	0	0
	21-24	0	0	3	14	46	30	19	10	2	0	0	0	0	0	0	0
	Total	0	3	18	76	219	196	125	64	32	10	1	0	0	0	0	0
April	1-4	0	0	0	1	14	37	39	22	6	1	0	0	0	0	0	0
	5-8	0	0	0	1	11	34	41	22	8	3	0	0	0	0	0	0
	9-12	0	0	0	0	3	16	29	28	25	14	4	1	0	0	0	0
	13-16	0	0	0	0	2	12	22	24	27	20	9	3	1	0	0	0
	17-20	0	0	0	0	4	19	32	26	22	11	5	1	0	0	0	0
	21-24	0	0	0	0	7	31	38	27	11	5	1	0	0	0	0	0
	Total	0	0	0	2	41	149	201	149	99	54	19	5	1	0	0	0
May	1-4	0	0	0	0	0	7	26	47	32	10	2	0	0	0	0	0
	5-8	0	0	0	0	0	4	21	42	35	16	5	1	0	0	0	0
	9-12	0	0	0	0	0	0	4	20	32	36	21	9	2	0	0	0
	13-16	0	0	0	0	0	0	3	13	25	34	29	14	5	1	0	0
	17-20	0	0	0	0	0	1	8	24	33	31	18	7	2	0	0	0
	21-24	0	0	0	0	0	3	17	40	38	21	4	1	0	0	0	0
	Total	0	0	0	0	0	15	79	186	195	148	79	32	9	1	0	0
June	1-4	0	0	0	0	0	0	1	9	48	50	11	1	0	0	0	0
	5-8	0	0	0	0	0	0	1	6	28	54	26	5	0	0	0	0
	9-12	0	0	0	0	0	0	0	1	4	24	46	34	10	1	0	0
	13-16	0	0	0	0	0	0	0	1	2	12	38	39	23	5	0	0
	17-20	0	0	0	0	0	0	0	1	5	31	45	27	10	1	0	0
	21-24	0	0	0	0	0	0	1	2	26	57	29	5	0	0	0	0
	Total	0	0	0	0	0	0	3	20	113	228	195	111	43	7	0	0

Table 3. (Continued) Monthly total N_{bin} values [h/month] for İstanbul.

Month	Time	Temperature Bin [°C]															
		-9/-6	-6/-3	-3/0	0/3	3/6	6/9	9/12	12/15	15/18	18/21	21/24	24/27	27/30	30/33	33/36	36/39
July	1-4	0	0	0	0	0	0	0	1	13	57	49	4	0	0	0	0
	5-8	0	0	0	0	0	0	0	0	8	39	57	19	1	0	0	0
	9-12	0	0	0	0	0	0	0	0	1	5	24	57	32	5	0	0
	13-16	0	0	0	0	0	0	0	0	0	4	12	44	48	14	2	0
	17-20	0	0	0	0	0	0	0	0	1	8	42	50	18	4	1	0
	21-24	0	0	0	0	0	0	0	0	5	33	71	14	1	0	0	0
	Total	0	0	0	0	0	0	0	1	28	146	255	188	100	23	3	0
August	1-4	0	0	0	0	0	0	0	1	13	50	55	5	0	0	0	0
	5-8	0	0	0	0	0	0	0	0	10	38	56	19	1	0	0	0
	9-12	0	0	0	0	0	0	0	0	1	5	21	58	34	5	0	0
	13-16	0	0	0	0	0	0	0	0	0	4	10	42	54	13	1	0
	17-20	0	0	0	0	0	0	0	0	1	9	42	54	16	2	0	0
	21-24	0	0	0	0	0	0	0	0	4	31	73	15	1	0	0	0
	Total	0	0	0	0	0	0	0	1	29	137	257	193	106	20	1	0
September	1-4	0	0	0	0	0	0	3	19	46	42	9	1	0	0	0	0
	5-8	0	0	0	0	0	0	3	17	41	43	15	1	0	0	0	0
	9-12	0	0	0	0	0	0	0	1	8	26	45	31	8	1	0	0
	13-16	0	0	0	0	0	0	0	1	5	19	38	35	19	3	0	0
	17-20	0	0	0	0	0	0	0	5	17	43	37	15	3	0	0	0
	21-24	0	0	0	0	0	0	0	12	35	51	20	2	0	0	0	0
	Total	0	0	0	0	0	0	6	55	152	224	164	85	30	4	0	0
October	1-4	0	0	0	0	0	7	30	44	30	12	1	0	0	0	0	0
	5-8	0	0	0	0	1	6	29	43	31	11	3	0	0	0	0	0
	9-12	0	0	0	0	0	2	11	20	36	36	13	5	1	0	0	0
	13-16	0	0	0	0	0	2	8	18	30	37	18	8	3	0	0	0
	17-20	0	0	0	0	0	3	14	33	41	22	9	2	0	0	0	0
	21-24	0	0	0	0	0	6	23	42	37	13	3	0	0	0	0	0
	Total	0	0	0	0	1	26	115	200	205	131	47	15	4	0	0	0
November	1-4	0	0	0	4	15	31	34	27	8	1	0	0	0	0	0	0
	5-8	0	0	0	4	15	30	34	28	8	1	0	0	0	0	0	0
	9-12	0	0	0	1	7	21	30	29	24	7	1	0	0	0	0	0
	13-16	0	0	0	1	5	17	28	30	25	12	2	0	0	0	0	0
	17-20	0	0	0	1	10	26	34	29	17	3	0	0	0	0	0	0
	21-24	0	0	0	2	14	28	35	29	10	2	0	0	0	0	0	0
	Total	0	0	0	13	66	153	195	172	92	26	3	0	0	0	0	0
December	1-4	0	0	3	14	30	42	23	10	2	0	0	0	0	0	0	0
	5-8	0	0	3	16	29	43	23	9	1	0	0	0	0	0	0	0
	9-12	0	0	1	9	20	44	29	18	3	0	0	0	0	0	0	0
	13-16	0	0	1	7	19	38	33	19	7	0	0	0	0	0	0	0
	17-20	0	0	1	10	24	45	28	14	2	0	0	0	0	0	0	0
	21-24	0	0	2	13	27	42	26	12	2	0	0	0	0	0	0	0
	Total	0	0	11	69	149	254	162	82	17	0	0	0	0	0	0	0

Table 4. Yearly total N_{bin} values [h/year] for six separate time periods of day for İstanbul

Time	Temperature Bin [°C]															
	-9/-6	-6/-3	-3/0	0/3	3/6	6/9	9/12	12/15	15/18	18/21	21/24	24/27	27/30	30/33	33/36	36/39
1-4	0	3	22	88	186	205	203	192	200	223	127	11	0	0	0	0
5-8	0	3	22	95	179	198	198	180	171	205	162	45	2	0	0	0
9-12	0	2	11	48	120	189	165	154	147	155	175	195	87	12	0	0
13-16	0	1	10	38	102	170	162	150	144	149	157	185	153	36	3	0
17-20	0	3	13	52	149	188	171	164	149	160	198	156	49	7	1	0
21-24	0	3	17	68	177	194	191	185	172	213	201	37	2	0	0	0
Total	0	15	95	389	913	1144	1090	1025	983	1105	1020	629	293	55	4	0

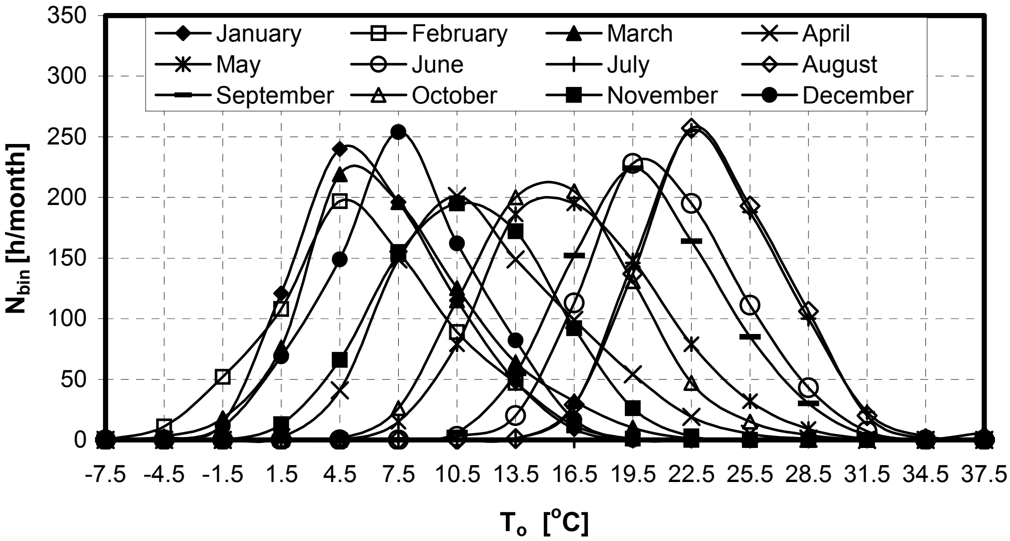

Figure 3. Variation of monthly total N_{bin} values for İstanbul

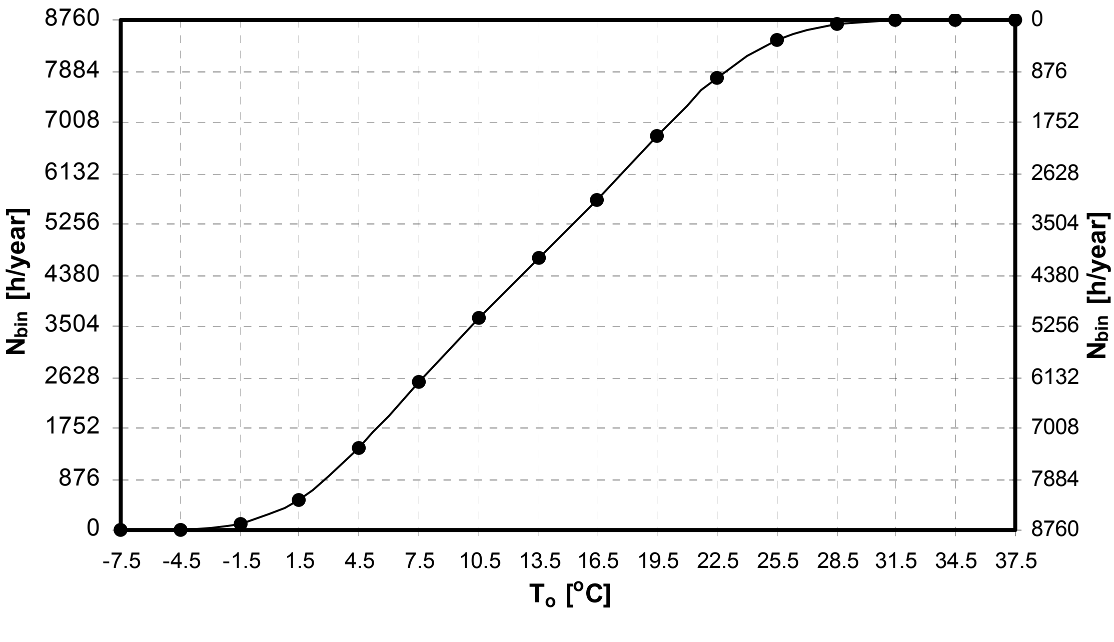

Figure 4. Cumulative distribution of yearly total bin data for İstanbul

6. Calculation of Energy Requirements for a Sample Building

In this study, annual energy requirements of a sample building located in İstanbul were calculated. The sample building has 1555.1 m^2 total floor area (floor height 3.52 m) and consists of 3 floors. The building provides the insulation requirement imposed by Turkish Standard-TS 825, " Thermal Insulation in Buildings". Table 5 shows physical and thermal characteristics of the building. The efficiency of heating system was chosen 0.92 (natural gas) and the performance of cooling system 3.8. The base temperatures were 18 ^oC for heating and 22 ^oC for cooling. The building is occupied 7 days a week, between 07^{00}-20^{00} hours and unoccupied otherwise. The air exchange rate of the building is 1 per hour.

Table 5. The physical and thermal properties of the sample building

Element	Area [m^2]	U-factor [$W/m^2\,^oC$]	*UA* [$W/^oC$]
Outer walls (20 cm foamed concrete + 2 cm insulation)	702.4	0.52	365.2
Windows (Double-glazed)	330.6	2.70	892.6
Roof (8 cm insulation)	610	0.38	231.8
Air exchange	-	-	1264.4
		K_{tot}[$W/^oC$]	2754.1

6.1 Calculation of annual heating energy requirement with degree-day method

Reading HDD=1865 [^{o}C-day] for T_b=18 ^oC from Table 1 and inserting this into Equation 4, annual heating energy requirement is found to be Q_h=133993 kWh. If natural gas (heating value = 34534.5 kJ/m^3) is used as fuel, annual gas consumption is 13968 m^3.

6.2. Calculation of annual cooling energy requirement with degree-day method

If CDD=159 [^{o}C-day] is taken for T_b=22 ^oC from Table 2 and inserted into Equation 5, annual cooling energy requirement is calculated as Q_c=2766 kWh.

6.3. Calculation of annual heating energy requirement with bin method

Since the building is occupied between 07^{00}-20^{00} hours, the base temperature was taken 18 ^oC in this period, and 20 ^oC during the unoccupied period. Ventilation system is shut off during the unoccupied period and therefore, load due to air exchange is zero and K_{tot} is reduced to 1489.7 $W/^oC$. Inserting the N_{bin} values taken from table 4 into Equations 6 and 7, annual heating energy requirement was obtained as Q_h=119590 kWh. In this case, annual natural gas consumption is 12466 m^3. Heating energy requirement for each temperature bin and time periods is given in Table 6.

Table 6. Heating energy requirement for each temperature bin and time periods

Time	Temperature Bin (^{o}C)																Total [kWh]
	-9/-6	-6/-3	-3/0	0/3	3/6	6/9	9/12	12/15	15/18	18/21	21/24	24/27	27/30	30/33	33/36	36/39	
1-4	0	119	766	2636	4668	4149	3123	2021	1133	181	0	0	0	0	0	0	18796
5-8	0	60	383	1423	2246	2004	1523	947	485	83	0	0	0	0	0	0	9153
9-12	0	236	1284	4717	8467	9053	5927	3287	1044	0	0	0	0	0	0	0	34015
13-16	0	67	584	1877	4122	5344	3637	2021	647	0	0	0	0	0	0	0	18298
17-20	0	202	759	2568	6022	5909	3839	2209	669	0	0	0	0	0	0	0	22178
21-24	0	119	592	2037	4442	3927	2938	1947	975	172	0	0	0	0	0	0	17149
Total [kWh]	0	803	4368	15259	29967	30385	20987	12432	4953	436	0	0	0	0	0	0	**119590**

6.4. Calculation of annual cooling energy requirement with bin method

Taking T_b=22 ^oC and K_{tot} = 2754.1 $W/^oC$ during occupied hours, and T_b=24 ^oC and K_{tot}=1489.7 $W/^oC$ during unoccupied hours, and reading bin values from Table 4, annual cooling energy requirement is obtained Q_c=3466 kWh from Equations 6 and 7. Cooling energy requirement for each temperature bin and time periods is given in Table 7.

Table 7. Cooling energy requirement for each temperature bin and time periods

Time	Temperature Bin (°C)																Total [kWh]
	-9/-6	-6/-3	-3/0	0/3	3/6	6/9	9/12	12/15	15/18	18/21	21/24	24/27	27/30	30/33	33/36	36/39	
1-4	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	6
5-8	0	0	0	0	0	0	0	0	0	0	0	13	2	0	0	0	15
9-12	0	0	0	0	0	0	0	0	0	0	93	552	415	83	0	0	1142
13-16	0	0	0	0	0	0	0	0	0	0	57	469	721	248	27	0	1522
17-20	0	0	0	0	0	0	0	0	0	0	72	396	231	48	9	0	756
21-24	0	0	0	0	0	0	0	0	0	0	0	22	3	0	0	0	25
Total [kWh]	0	0	0	0	0	0	0	0	0	0	221	1458	1371	379	36	0	**3466**

6.5. Calculation of yearly heating energy according to TS 825

Annual heating energy requirement of the sample building was calculated 93871 kWh using the method given in TS 825, compulsory Turkish Standard for Thermal Insulation in Buildings [14]. Annual heating energy requirement of a building should be smaller than a limit value according to TS 825. The limit value is a function of the ratio of the total heat loosing area to the total volume of the building and equations are given in the standard to calculate the limit value. The limit value for the annual heating energy requirement of the sample building was found to be 96338 kWh. Since the annual heating energy requirement of the sample building (93871 kWh) is less than the limit value (96338 kWh), it was concluded that the sample building is in accordance with TS 825.

6.6. Comparison of Results

Annual heating and cooling energy requirements of the sample building estimated from degree-day and bin methods and from TS 825 are compared in Table 8. The annual heating energy requirement calculated from degree-day method is 11% higher than the value obtained from bin method for heating and %20 smaller in the case of cooling. The values obtained from bin method are more realistic than the ones obtained from degree-day method, since bin method is based on hourly data, rather than daily mean temperatures and it also takes into account of utilization of building. Annual heating energy requirement calculated from TS 825 is smaller than the values obtained from the other methods. Indoor temperature was chosen 20 °C in the calculation of heating energy according to TS 825 in which concept of base temperature is not utilized. However, base temperature (T_b) is very important in degree-day and bin methods [2]. As can be seen from Table 1, value of degree-days changes significantly with base temperature, and this affect directly annual heating energy requirement. This is also valid for bin method. In the energy calculations for the sample building, T_b was taken 18 °C in degree-day method. In the case of bin method, T_b=18 °C during occupied hours and T_b=20 °C during unoccupied period. Since base temperature is a function of many parameters such as desired indoor temperature, total heat transfer coefficient of the building, and indoor and solar heat gains, a more detailed study is needed to be able to evaluate the exact value of base temperature for the sample building. Base temperature of 18 °C in heating and 22 °C in cooling should be employed with caution [2].

Table 8. Comparison of annual heating and cooling energy requirements

Method		Annual Heating Energy [kWh]	Annual Cooling Energy [kWh]
Degree-day		133993	2766
Bin		119590	3466
TS 825	Calculation	93871	-
	Limit Value	96338	-

7. Conclusion

In this study, heating degree-day values at 14, 16, 18, 20, and 22 °C base temperatures and cooling degree-days for base temperatures of 18, 20, 22, 24, and 26 °C were calculated for İstanbul. Bin data for dry-bulb temperature from -9 °C to 39 °C with 3 °C increments were also determined in six daily 4-h shifts (1-4, 5-8, 9-12, 13-16, 17-20 and 21-24 hours). The data obtained were presented in tables and figures. Annual heating and cooling energy requirements of a sample building in İstanbul were estimated using the degree-day and the bin values obtained in this study. It was seen that the annual heating energy requirement obtained from bin method is less than the value calculated from degree-day method for heating but higher in the case of cooling. It was also found that the annual heating energy requirement calculated from TS 825 is less than the values obtained from bin and degree-day methods.

8. References

1. ASHRAE- Fundamentals, Chapter 28- Energy Estimating Methods, Atlanta, 1993.
2. J. F. Kreider and A. Rabl, Heating and Cooling of Buildings-Design Efficiency, Chapter-8, McGraw-Hill, Inc., 1994.
3. Satman A., Altun G. and Göktekin, A., 1990. The Usage Potential of Natural Gas For Heating of Residences in Turkey, Proceedings of the Fifth Turkish Energy Congress, Vol. 2. pp. 133-144, Ankara. (In Turkish)
4. Kılkış, B. and Okutan, C., 1990. Rational Use of Energy with High Technology Systems in Heating and Cooling, Proceedings of the Fifth Turkish Energy Congress, Vol. 2. pp. 389-402, Ankara. (In Turkish)
5. İleri, A. and Üner, M., 1998. Typical Weather Data of Main Turkish Cities. Engineer and Machinery, Vol. 39, No:463, pp. 31-42.(In Turkish)
6. Dağsöz, A. K. and Bayraktar, K. G., 1999. Number of Degree-Days in Turkey and Energy Politics, Journal of Sanitary Engineering, July-August 1999, pp. 32-40. (In Turkish)
7. Büyükalaca, O., Bulut, H. and Yılmaz, T., 2000. Degree-day Values for Some Provinces of Turkey, Conference Proceeding of 12. Turkish National Conference on Thermal Sciences and Technologies with International Participation, Sakarya, Turkey, Vol. 1, pp.107-112. (In Turkish)
8. Bulut, H., Büyükalaca, O., and Yılmaz T., 2000. Detailed Meteorological Data for Energy Analysis of Buildings in Adana, Proceedings of 6. National Congress on Refrigeration and Air-Conditioning Techniques, pp. 325-332, Adana. (In Turkish)
9. Gümrah, F., Katırcıoğlu, D., Okumuş, S., Aykan, Y., and Kılınçer, N., 2000. Modeling of Demand for Natural Gas for Ankara with Degree-day Concept, Proceedings of 8. Turkish Energy Congress, pp. 73-87, Ankara. (In Turkish)
10. TTMD, 2000. Turkish Weather Data. Technical Publication of Turkish Society of HVAC & Sanitary Engineers (TTMD), Ankara. (In Turkish)
11. Büyükalaca, O., Bulut, H. and Yılmaz, T., 2001. Analysis of Variable-Base Heating and Cooling Degree-Days for Turkey. Applied Energy, Vol. 69, No: 4, pp. 269-283.
12. Bulut, H., Büyükalaca, O., and Yılmaz, T., 2001. Bin Weather Data for Turkey. Applied Energy, Vol. 70, No: 2, pp. 135-155.
13. Al-Homoud, M. S., 2001. Computer-Aided Building Energy Analysis Techniques. Building and Environment, Vol. 36, pp. 421-433.
14. TS 825, 1998. Thermal insulation in buildings. Turkish Institute of Standards, Ankara. (In Turkish)

9. Short CV

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