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HEATING DEGREE DAY IN HUNGARY

Zoltán Verbai*, **István Lázár, Ferenc Kalmár**

University of Debrecen, Faculty of Engineering, 4028 Debrecen, Ótemető u. 2-4, Hungary

Abstract

In Central European countries, heating represents approximately 75% of the total energy use of a residential building, with average thermal characteristics of the envelope. The expected energy use can be determined using complex simulation programs, but an easier way is to use specific degree day values. Degree day values should be calculated as precisely as possible. At present in Hungary, the degree day values that are used for simplified energy calculations were determined several decades ago.
The aim of our research was to determine the degree day values based on the last 60 years for different Hungarian settlements. Using the CarpathClim database and elaborating the degree day values for 25 Hungarian cities, differences of 10% have been found compared with the values used previously for energy calculations.

Key words: heating, energy use, degree day, CarpathClim

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1. Introduction

In the European Union, approximately 40% of the total energy consumption is used by buildings (EC Directive, 2010), two-thirds of which is given by heating and cooling systems. Approximately 70% of 4.3 million flats do not fulfill the requirements established by the building energy performance regulation (Ministry of National Development, 2012). In the case of public buildings, similar ratios can be obtained.

The heat utilization in Hungary between years 1990-2007 is shown in Fig. 1, (Ministry of National Development, 2012). It can be observed that district heating systems and natural gas give approximately 65% of the total heat that is consumed. This huge amount of energy is used, especially during the winter period, by heating systems. By enhancing the thermal insulation of buildings and the efficiency of central heating systems, the energy consumption will decrease considerably.

Analyzing the energy savings obtained by building energy refurbishment practices has shown that usually energy savings of 10-45% are obtained. However, using the available technologies, even energy savings of 85% can be realized.

The heat delivered by district heating systems decreased in the analyzed period from 12% to 8%. This result is caused by the cut-off of buildings from district heating systems on one hand and by building refurbishments on the other hand. At present, approximately 660,000 of flats (17%) are connected to district heating systems.

The determination of the energy use of a building is a complex task and can be solved using simulation programs, measuring instruments or simplified calculation methods. Unfortunately, at present, the measurement of energy consumption is not available for every building and every flat.

At the same time, the variation of environmental parameters, the accuracy of used instruments and the customer habits can affect the correctness of the measurements. There are complex simulation programs that can give useful results, but the meteorological data, which constitutes the basis of such calculations, should be well known.

* Author to whom all correspondence should be addressed: e-mail: verbai@eng.unideb.hu; Phone: +36 52 415155; Fax: +36 52 418643

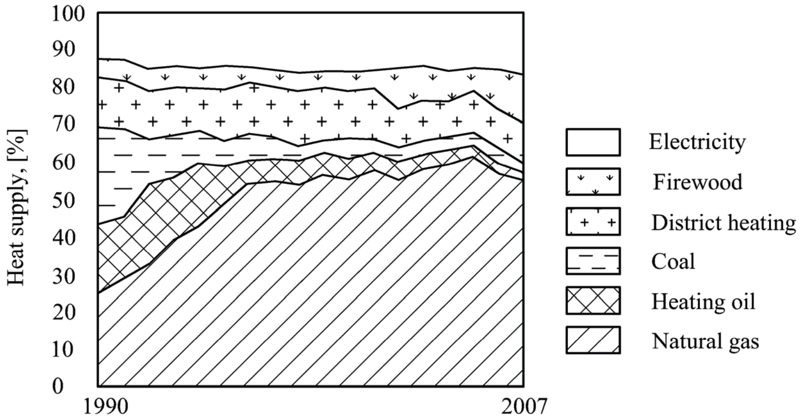

Fig. 1. Heat consumption in Hungary by source (1990-2007)

A simplified method for the calculation of energy use in buildings is given by Regulation 7/2006 TNM (2006). This regulation was modified in 2012 and 2014, and the indoor parameters, the efficiency of different heat sources and the outdoor parameters are given by these regulations.

Nevertheless, the simplified method contains a single degree day curve. This degree day curve was elaborated based on meteorological data registered several decades ago. In our opinion, even in the case of simplified calculation methods, to determine as precisely as possible the energy demand for heating, a single degree day curve and a single degree day value for heating in Hungary is not enough (Fig. 2).

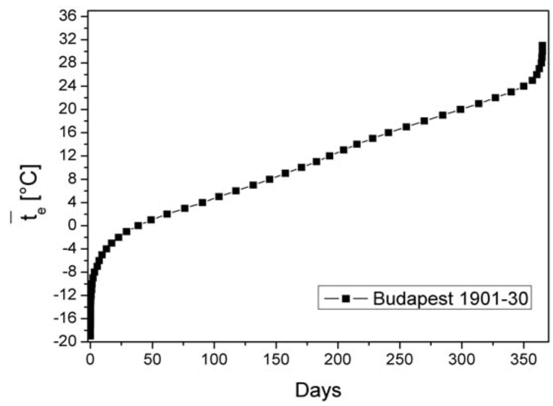

Fig. 2. Theoretical degree day curve

The degree day curve used for the energy calculations cannot be determined using one year of temperature data. In Greece and Turkey, the degree day was determined for all of the regions in the country (Büyükalaca et al., 2011; Matzarakis and Balafoutis, 2004; Papakostas and Kiriakis, 2005). The aim of our research was to establish degree day values for different regions in Hungary. First, we used data from Agro-Meteorological Observatory Debrecen (DE METEO) and the degree day curve specific for Debrecen was determined. Thereafter, based on temperature data given by the CarpathClim project, the degree day curves and values specific for different Hungarian localities have been determined. In the case of Debrecen, the CarpathClim database was compared statistically with data given by DE METEO.

2. Comparison of CarpathClim and DE METEO data

The temperature data measured at Agro-Meteorological Observatory Debrecen are available for 1963-2012. The daily mean temperature values have been determined based on the hourly mean temperature values. In the case of the CarpathClim project, the main aim was to improve the basis of climate data in the Carpathian Region for applied regional climatological studies, such as a Climate Atlas and/or drought monitoring, to investigate the fine temporal and spatial structure of the climate in the Carpathian Mountains and the Carpathian basin with unified methods (Szalay et al., 2013).

The project used a 10 km-10 km grid, and based on the daily minimum and maximum temperature values, the daily mean temperature was determined. Climatological grids cover the area between latitudes 44°N and 50°N, and longitudes 17°E and 27°E. The timeframe is 1961-2010. In the case of DE METEO, because the daily mean temperature values are determined based on the hourly mean values, the database can be considered to be more accurate.

Nevertheless, such a database is not available for the whole country; therefore, I decided to use the CarpathClim database for the degree day analysis. First and foremost, I made a statistical analysis and comparison of these two databases for Debrecen. For this comparison, the period of 1981-2010 was taken into consideration. The GPS coordinates of the DE METEO station are: 21.581 / 47.576 and 125 m height with reference to the Baltic Sea level. The closest point in the CarpathClim database (2471) has the GPS coordinates: 21.60 / 47.60 and 129 m height with reference to the Baltic Sea level. The results of statistical analysis are presented in Fig. 3.

It can be observed that the two point-set given by these two meteorological databases have high similarity. However, in the following, I checked the CarpathClim grid points situated in the nearby of the DE METEO. The GPS coordinates and height of the measuring points are given in Table 1. The differences between the basic statistical data of the CarpathClim point-sets and DE METEO point-set are presented in Table 2.

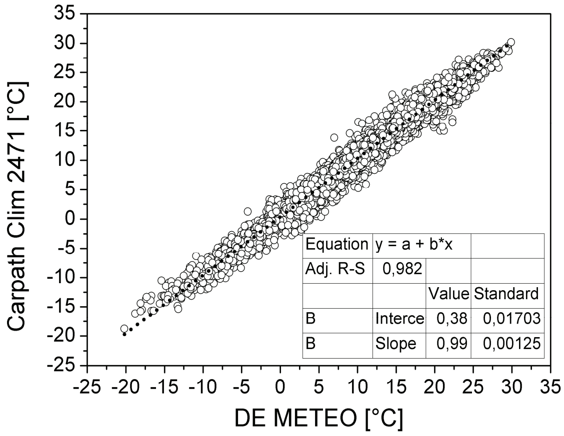

Fig. 3. Analysis of temperature data (CarpatCLIM-DE METEO)

Based on the temperature values of the two databases, the degree day curve was built, and the degree day was calculated assuming an internal set-point temperature of 20^{o}C and balance point temperature of 12^{o}C. The obtained values are shown in Table 3. The differences between databases are approximately 3%. In the following, the degree day values have been calculated using the CarpathClim database.

3. Degree day values in Hungary

Macskásy drew the first degree day chart of Hungary (Fig. 4) (Macskásy, 1952). Because daily mean temperatures were not available at that time, the degree day values have been calculated using monthly mean outdoor temperature values. The iso-degree day curves, presented in Fig. 4, actually correspond to the localities with heights lower than 150 m with reference to the Baltic Sea level and has been calculated for a building with an indoor set point temperature of 20 ^{o}C and a balance point temperature of 12 ^{o}C. Using the CarpathClim database, the degree day curves of different settlements have been built and for buildings with a similar set point and balance point temperature, the degree day values were determined.

Using the daily mean values for the last 50 years, degree day values were determined for 25 settlements. The GPS coordinates and heights of different cities were identified using Google Earth. Thereafter, in the CarpathClim database, the proper data set was identified and used to build up the degree day curve.

Usually, that data set was used for a settlement, which was measured in the closest observatory point. Nevertheless, the specific height of the settlement and observatory point were always compared because the height has an important influence on air temperatures. The calculated new degree day values and the difference compared with previously used theoretical values are presented in Table 4.

Table 1. GPS coordinates and heights of analyzed CarpathClim measuring points

Carpath-2369 (GPS 21.50 / 47.70) height: 106m	Carpath-2370 (GPS 21.60 / 47.70) height: 131m	Carpath-2371 (GPS 21.70 / 47.70) height: 140m
Carpath-2470 (GPS 21.50 / 47.60) height: 131m	***Carpath-2471*** ***(GPS 21.60 / 47.60)*** ***height: 129m***	Carpath-2472 (GPS 21.70 / 47.60) height: 130m
Carpath-2571 (GPS 21.50 / 47.50) height: 106m	Carpath-2572 (GPS 21.60 / 47.50) height: 109m	Carpath-2573 (GPS 21.70 / 47.50) height: 122m

Table 2. Deviations between CarpathClim data and DE METEO data

	Carpath-2369		***Carpath-2370***		***Carpath-2371***	
Min	0.00	-6.81	0.00	-6.84	0.00	-6.98
Max	6.81	6.13	6.84	6.20	6.98	6.24
Mean	0.95	-0.34	0.94	-0.30	0.95	-0.35
	Carpath-2470		***Carpath-2471***		***Carpath-2472***	
Min	0.00	-6.80	0.00	-6.82	0.00	-6.78
Max	6.82	6.15	6.82	6.17	6.78	6.36
Mean	0.94	-0.35	0.93	-0.33	0.92	-0.21
	Carpath-2571		***Carpath-2572***		***Carpath-2573***	
Min	0.00	-7.07	0.00	-7.31	0.00	-6.93
Max	7.07	6.10	7.31	6.47	6.93	6.29
Mean	1.01	-0.57	0.96	-0.45	0.94	-0.37

Table 3. Degree day and number of days in a heating season

30 year	*Degree day, [Kd]*	*Number of days in a heating season*
CarpathClim 2471	3156.4	187.43
DE METEO	3262.76	193
Difference [%]	-3.37	-2.97

Table 4. Calculated degree day values and deviations

Mean indoor temperature 20°C					*Carpath Clim*	*Google Earth*	*GPS coordinates*
Balance point temperature 12°C							
1981-2010	[days]	[%]	[Kd]	[%]	[m]	[m]	
Budapest 1901-1930	193.2	0	3080.44	0			
Budapest (Budaörs)	198.9	-2.95	3294.49	-6.95	226	150	47.46 / 18.95
Budapest (Airport)	185.8	3.85	3016.24	2.08	117	147	47.43 / 19.26
Baja	185.5	3.97	3035.22	1.47	113	94	46.18 / 18.95
Békéscsaba	183.4	5.06	3036.85	1.42	83	85	46.67 / 21.09
Debrecen	189.2	2.06	3187.11	-3.46	109	120	47.53 / 21.63
Dunaújváros	186.9	3.26	3042.73	1.22	122	138	46.96 / 18.94
Eger	196.0	-1.43	3328.9	-8.07	233	179	47.90 / 20.38
Gyöngyös	201.7	-4.41	3412.76	-10.79	188	176	47.78 / 19.93
Győr	192.1	0.59	3132.83	-1.70	113	111	47.69 / 17.65
Kaposvár	187.3	3.08	3040.72	1.29	137	153	46.36 / 17.80
Kecskemét	186.2	3.64	3060.58	0.64	110	114	46.90 / 19.69
Kékestető	215.3	-11.41	3513.33	-14.05	672	1014	47.87 / 20.01
Mátraháza	215.3	-11.43	3514.44	-14.09	410	712	47.87 / 19.98
Miskolc	192.2	0.53	3253.59	-5.62	115	178	48.10 / 20.76
Mosonmagyaróvár	191.3	0.97	3110.12	-0.96	120	122	47.87 / 17.27
Nagykanizsa	206.1	-6.69	3420.59	-11.04	170	157	46.46 / 16.99
Nyíregyháza	191.8	0.73	3241.2	-5.22	109	109	47.95 / 21.72
Pápa	188.5	2.44	3034.37	1.50	164	150	47.33 / 17.47
Pécs	195.3	-1.09	3244	-5.31	170	141	46.00 / 18.20
Salgótarján	199.9	-3.44	3355.62	-8.93	242	264	48.09 / 19.80
Szeged	181.8	5.93	2989.29	2.96	73	77	46.25 / 20.14
Szolnok	184.8	4.37	3055.74	0.80	83	87	47.16 / 20.18
Tatabánya	200.5	-3.78	3359.09	-9.05	194	154	47.57 / 18.40
Veszprém	193.7	-0.25	3169.7	-2.90	216	246	47.10 / 17.91
Záhony	198.7	-2.85	3392.03	-10.12	102	104	48.40 / 22.18

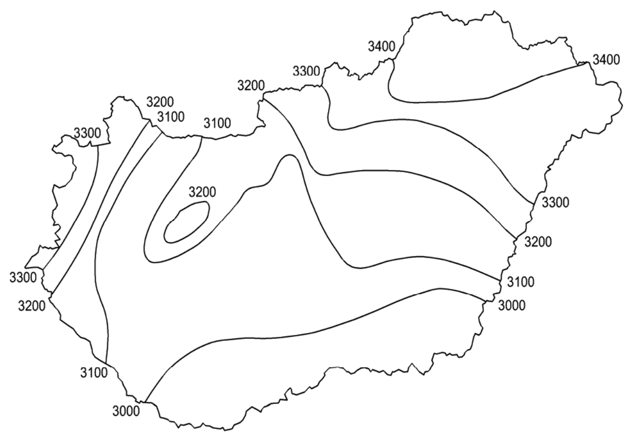

Fig. 4. Degree day chart of Macskásy (1952)

The differences are calculated taking the degree day curve currently used as the reference. Differences between -10% and +3% can be identified for analyzed settlements.

Using the Macskasy's degree day chart, the new values can be plotted (Fig. 5).

4. Case study

In the following, let us analyze the energy consumption and CO_2 emissions of a typical residential building. The family house was built in 1980 using brick with vertical holes.

The overall heat transfer coefficient of the external wall is U_{wall} = 1.81 W/m^{2}K. The slab is steel concrete provided with an insulation layer from expanded polystyrene of 5 cm. The overall heat transfer coefficient of the slab is U_{slab} = 1.53 W/m^{2}K.

The floor is not insulated and its fictive linear heat transfer coefficient is Ψ = 1.55 W/mK. The windows have an overall heat transfer coefficient U_{window} = 2.5 W/m^{2}K. The door was replaced, and the heat transfer coefficient of the new door is U_{door} = 1.8 W/m^{2}K.

The net floor area of the building is 114.5 m^2, and the heated volume is 309.1 m^3. The heat loss of this building calculated for the indoor set point temperature and outdoor design temperature is 18.9 kW. The specific heat loss is calculated using Eq. (1) (Regulation 7/2006 TNM, 2006):

$$q = \frac{\sum AU - \frac{Q_{sd}}{72}}{V} \quad (1)$$

where ΣAU is the sum of the building element area and corresponding overall heat transfer coefficient products; Q_{sd} – is the direct solar gain; and V is the heated volume.

The specific heat loss of the building is 1.68 W/m^3K. The average value of the indoor set point temperature in the building is 17.6 ^oC. The temperature difference between the indoor set point temperature and the balance point temperature of the building is calculated using Eq. (2) (Regulation 7/2006 TNM, 2006):

$$\Delta t_b = \frac{Q_{sd} + Q_{sid} + A_n q_b}{\sum AU + \sum l\Psi + 0.35ACHV} + 2 = 3.5°C \quad (2)$$

where Q_{sid} is the solar indirect gain; A_n is the net floor area; q_b is the specific internal heat gain; Σl is the sum of the widths of the external walls in contact with floor slab; and ACH is the air change rate.

The balance point temperature of this building is:

$$t_b = \bar{t}_{i.} - \Delta t_b = 14.1°C \quad (3)$$

The net energy demand for heating can be determined using Eq. (4) (Regulation 7/2006 TNM, 2006):

$$Q_F = HV(q + 0.35 \cdot ACH)\sigma - Z_F A_N q_b \quad (4)$$

where H is the heating degree day; q is the specific heat loss; σ is a correction factor, which takes into account the intermittent operation of heating system; and Z_F is the number of hours in the heating period.

The primary energy consumption for heating can be determined using Eq. (5), where: q_F is the specific energy demand for heating; $q_{f,h}$ is the specific heat loss caused by the improper control of delivered heat; $q_{f,v}$ is the specific heat loss of the distribution pipes; $q_{f,s}$ is the specific heat loss of the heat storage system; C_k is the coefficient of performance of the used heat generator; α is the time ratio afferent for a certain heat generator (in the case of more than one heat generator); e_h is the primary energy transformation factor appropriate for the used heat carrier; E_{FP} is the specific electricity used for pumping; E_{FS} is the specific electricity used by storage system (if any); $q_{k,v}$ is the specific electricity consumption of the heat generator; and e_v is the primary energy transformation factor of electricity (Regulation 7/2006 TNM, 2006):

$$E_F = (q_F + q_{f,h} + q_{f,v} + q_{f,s}) \cdot \sum (C_k \cdot \alpha_k \cdot e_h) + (E_{FP} + E_{FS} + q_{k,v})e_v \quad (5)$$

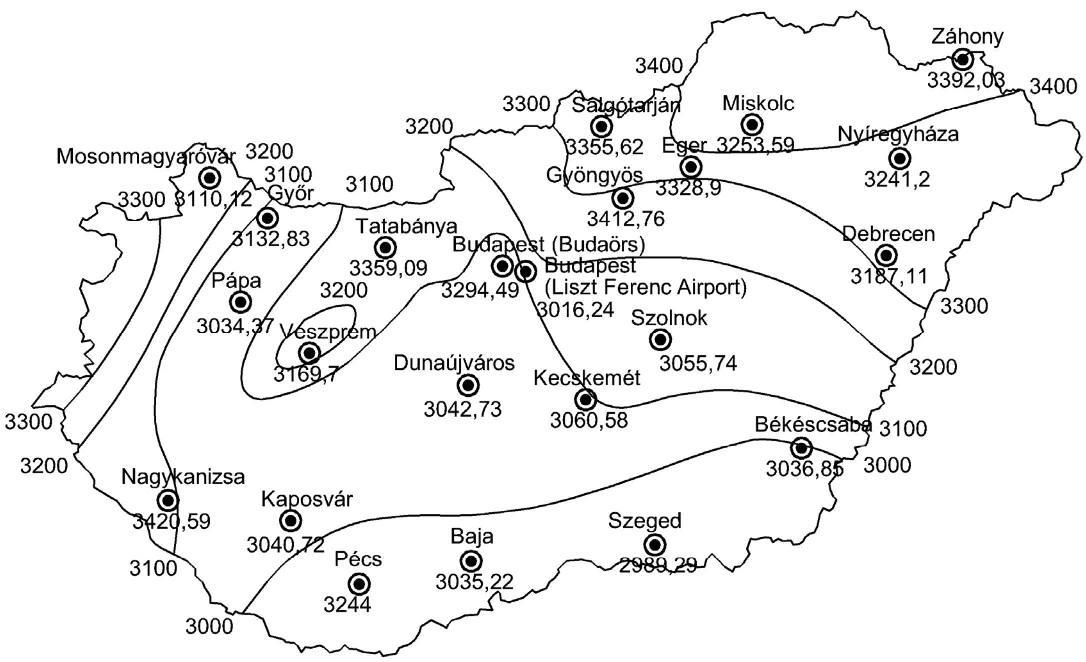

Fig. 5. Degree day chart with new degree day values

Table 5. Heating energy consumption data

	Budapest	***Nyíregyháza***	***Nagykanizsa***	***Kékestető***
Degree day	2599.90	2902.60	3063.32	3147.99
Deviation of degree day	-	-11.64	-17.82	-21.08
Heating days	214.91	218.59	236.47	248.62
Deviation of heating days	-	-1.71	-10.03	-15.69
Energy demand for heating	31677.12	35658.44	37553.52	38514.36
Specific energy demand for heating	384.66	429.17	450.35	461.10
Yearly total energy consumption for heating	44043.77	49139.87	51565.56	52795.44
Yearly heat consumption	43316.70	48412.79	50838.49	52068.37
Yearly CO_2 emission	8.79	9.83	10.32	10.57
Yearly gas consumption	4586.47	5126.06	5382.90	5513.12
Deviation of gas consumption	-	-11.76	-17.36	-20.20
Electricity consumption (by heating system)	727.08	727.08	727.08	727.08
Yearly CO_2 emission equivalent of consumed electricity	0.27	0.27	0.27	0.27

The energy calculations were done along with the theoretical degree day value for three different locations using WinWatt software. The results are presented in Table 5. It can be observed that the deviations of the degree day are similar to the deviations obtained in the case of gas consumption.

5. Conclusions

Currently, in the building sector, the largest amount of work is given by building refurbishments. In the case of energy refurbishments of buildings, the payback time is calculated by taking the expected energy savings into account. Energy savings cannot be determined correctly if the degree day data are not precisely identified.

It was shown that differences of even 10% can be registered throughout the country taking the currently used degree day curve as the reference. These differences can lead to significant errors in determining the payback time of investments. Using the CarpathClim database, the degree day was determined for different regions in Hungary.

Acknowledgments

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