COOLING DEGREE DAY ANALYSIS AS A CLIMATE IMPACT INDICATOR FOR DIFFERENT LOCATIONS OF POLAND AND INDIA

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Abstract - Energy analysis plays an important role in developing an optimum and cost effective design of HVAC system for a building. Although there are different energy analysis methods, which vary in complexity, the degree-day methods are the simplest methods and well-established tools. Energy consumption increases as the number of heating and cooling degree days increases and falls as the number of heating and cooling degree days falls. The value of degree-days is a measure used to indicate the demand for energy to heat or cool buildings. The monthly or annual cooling and heating requirements of specific buildings in different locations can be estimated by means of the degree-days concept. The base temperature is the outdoor temperature below or above which heating or cooling is needed. Cooling degree-days enable better benchmarks to be developed for air-conditioned buildings, allow improved Building Energy Management System operation and produce better energy estimating methods. These three factors could make real contribution to energy efficiency and CO_2 emission targets. In this study the degree days for period 2008-2012 were calculated for Poland (5 cities) and India (5 cities) in each country. Cooling Degree Days for India were calculated for base temperature from 18 ^oC till 26^oC. The Cooling Degree Days for Poland were calculated for base temperaturę from 18 till 28^oC.The average annual value of CDD_{18} for Indian cities is CDD_{18} for Chennai is 4108, for Kolkata CDD_{18}=3360, for New Delhi CDD_{18}=3015, for Mumbai CDD_{18}=3469, for Mangalore CDD_{18}=3449. The average annual value of CDD_{18} for Polish cities is Suwałki CDD_{18}=99 for Zielona Gora CDD_{18}=75, Zakopane CDD_{18}=43, Gdansk CDD_{18}=62, Warsaw CDD_{18}=182.

Keywords - Building Energy Conservation, Cooling Degree Days, India, Poland.

I. INTRODUCTION

Degree-days are well known important climatic indicator used in the HVAC industry to estimate the demand for heating and cooling services. The degree days are the summation of temperature differences between average outdoor air temperature and base temperature, which is referred as the outdoor temperature at which heating or cooling systems do not need to the run.When outdoor temperature is below the base temperature, the heating system needs to provide the heat. On the other hand cooling systems needs to operate when the outdoor temperature is above the base temperature. The cooling degree days are the difference between average outdoor temperature and base temperature.
Monjur Mourshed (2012) [1] developed an equation for calculating degree-days from low-resolution temperature days by exploring the relationship between degree days and annual mean temperature of 5511 locations around the world using the multiple non-linear regression, K. Papakostas, T. Mavromatis, N. Kyriakis (2010) [2] calculated cooling degree days for two main cities of Greece (Athens and Thessaloniki) from 19883 to 2002. M. Christenson, H. Manz, D. Gyalistras (2006) [3] estimated heating degree days and cooling degree day for four representative Swiss locations for the period 1901-2003.Kevin Baumert, M. Selman (2003) [4] summarizes the methodologies used by the World Resources
Institute for calculating annual heating degree days (HDD) and cooling degree days (CDD) for 171 countries.O. Buyukalaca, H. Bulut, T. Yilmaz (2001) [5] calculated heating and cooling degree days for different base temperatures for Turkey. F. Jiang, X. Li, B. Wei, R. Wu, Z. Li [6] used to detect annual and seasonal variations of heating and cooling degree-days in Xinjiang, China, by using the Mann – Kendall trend test and linear regression techniques for 1959-2004. W.J. Roltsch, F. G Zalom et. al (1998) [7] used seven methods of estimating degree days at each of nine locations during 2 years in California and compered to degree-day values calculated by hourly summation. WI big [8] calculated heating and cooling degree days for Lodz, Poland for the period 1931-2001.
The literature survey confirms that degree days are important climate indicator, which is still a subject of study. By using degree-day method climate in the countries of Poland and India were compared and analyzed during the period 2008-2013. In every country 5 different locations were taken under consideration. The most advanced city in the North, South East and West.

II. STUDY AREA

A. Poland

Warsaw
Warsaw is situated in central part of Poland. The figure [1] shows the location Warsaw in Poland.
North Latitude: 52-25N
East Longitude: 21E
Altitude:106 m.

Gdansk

Gdansk is situated in the North of Poland at the Baltic Sea

North Latitude: 54-22-58N
East Longitude: 18-28-01E
Altitude: 138 m.

Zielona Góra

Zielona Góra is situated in the West of the Poland

North Latitude: 51-55-58N
East Longitude: 15-31-58E
Altitude: 192 m

Zakopane

Zakopane is situated in the south in the Poland in the Tetra Mountains

North Latitude: 49-17-59N
East Longitude: 19-58-01E
Altitude: 857 m.

Suwałki

Suwałki are situated on the East of the Poland

North Latitude: 54-07-58N
East Longitude: 22-56-59E
Altitude: 186 m.

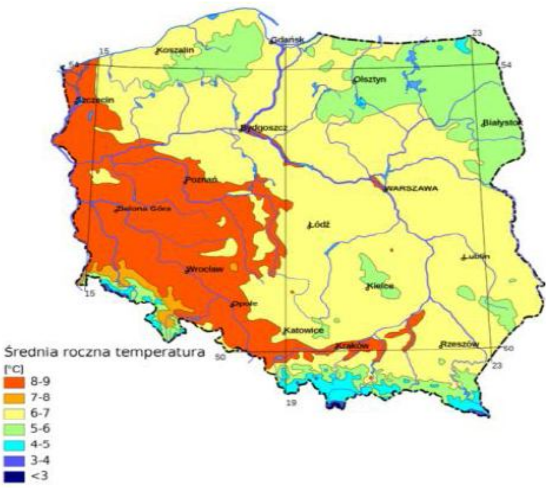


Figure 1- Annual Temperature In Poland

Poland climate can be described as a temperate climate with relatively cold winters and warm summers, which is greatly influenced by oceanic air currents from the west, cold polar air from Scandinavia and Russia, as well as warmer, sub-tropical air from the south. In winter, polar-continental fronts often dominate, bringing cold, frosty weather with temperatures far below zero and sometimes heavy snowfall. The late summer and autumn months are often influenced by dry, sub-tropical, continental air mass that brings plenty of warm days. The average air temperatures amount to 6 - 8.5°C for a year, the annual rainfall is 500 - 700 mm, of which snow constitutes only 5 - 20%. Heating season lasts from 6 to 8 months. It starts in October/ November and ends in March/ April. The heating season starts when indoor temperature is 16oC al least 3 days. Moreover during hot summers there is need to provide cooling. The cooling season last from July to August

B.India

Mangalore

Mangalore is situated in south part of India in Karnataka state, on Malabar coast at the Arabian Sea and nearly to Western Ghats mountains. The figure [2] shows the location Mangalore in India.

North Latitude: 12-55-01N
East Longitude: 074-52-58E
Altitude: 102 m.

New Delhi

North Latitude: 28-34-01N
East Longitude: 77-07-01E
Altitude: 233 m

Chennai

North Latitude: 13-00-00N
East Longitude: 80-10-58E
Altitude: 16 m.

Kolkata

North Latitude: 22-38-59N
East Longitude: 88-27-00E
Altitude: 6 m

Mumbai

North Latitude: 19-07-01N
Longitude: 72-50-59E
Altitude: 14 m

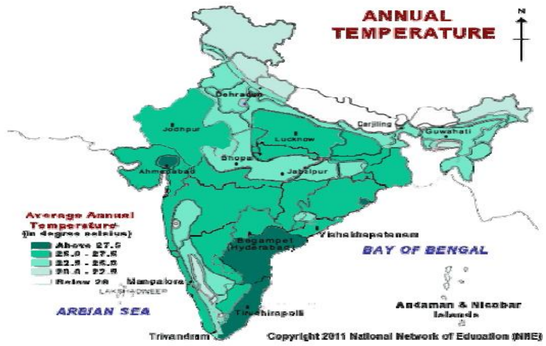


Figure 2- Annual Temperature In India

The India has three seasons in climate. Winters (December to February) are very pleasant, the humidity and temperatures are low. During day times, temperature falls below 34°C and night time temperature falls below 20°C. Summers (March to May) are hot with a maximum temperature of 39°C. The climate is hot and humid. During the Monsoons (June to September) the rainfalls are very strong.

The cooling needs to be provided during the whole year.

III. METHODOLOGY

$$CDD_d = \begin{cases} 0.5(T_{max} + T_{min}) - T_b & T_{min} \geq T_b \\ 0.5(T_{max} - T_b) - 0.25(T_b - T_{min}) & T_{min} > T_b \, and (T_{max} - T_b) > (T_b - T_{min}) \\ 0.25(T_{max} - T_b) & T_{min} < T_b \, and (T_{max} - T_b) < (T_b - T_{min}) \\ 0 & T_{max} \leq T_b \end{cases}$$

To estimate cooling degree days, it is required to measure maximum and minimum outside air temperature (T_{max} and T_{min}). Base temperature is set by user and T_{base} is outdoor temperature at which heating or cooling systems do not need to the run. Thera are four possible relationships between the base temperature and diurnal temperature variation, resulting in four different scenarios. Depending on this four scenarios, daily cooling degree days CDD, is calculated from the base temperature T_b and daily minimum and maximum temperatures respectively using the equation [1] below:

Daily cooling degree days, CDD can be calculated using the same parameters

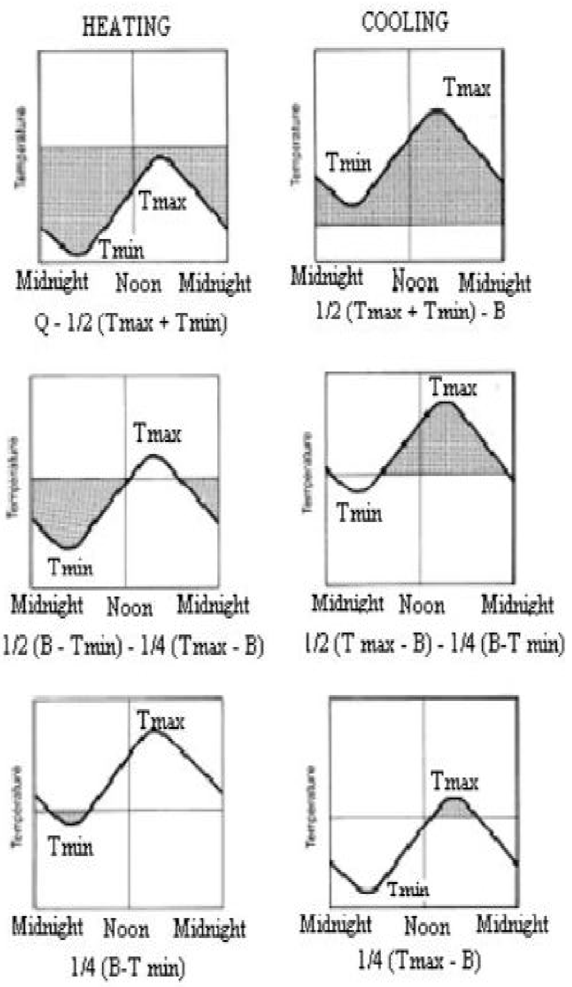


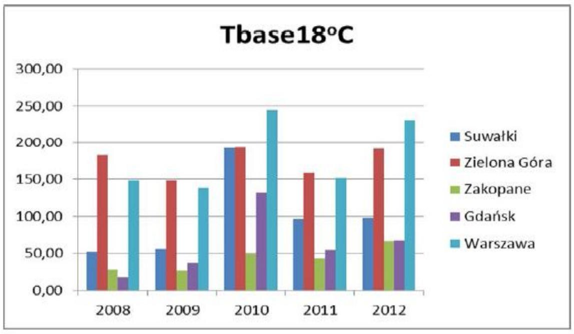
Figure 3- Degree Day Formula [11]

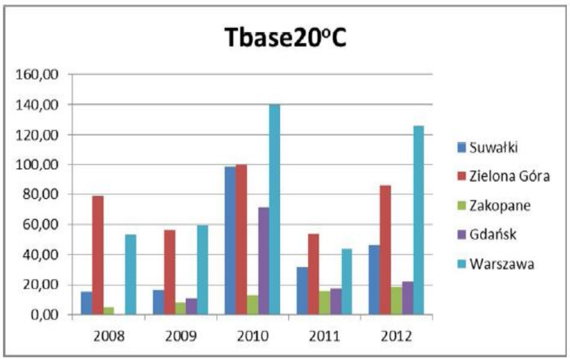
Figure[3] shows the graphical representation of formula used to calculate heating and cooling degree days.

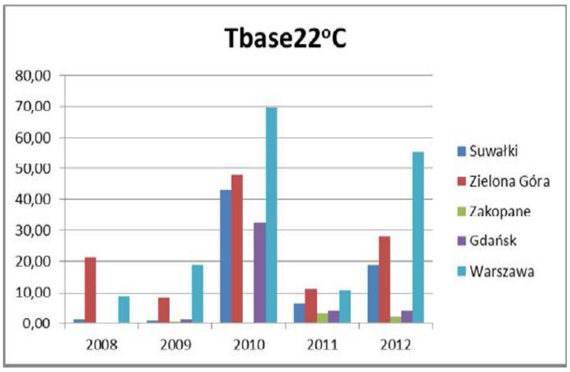
IV. RESULTS OBTAINED

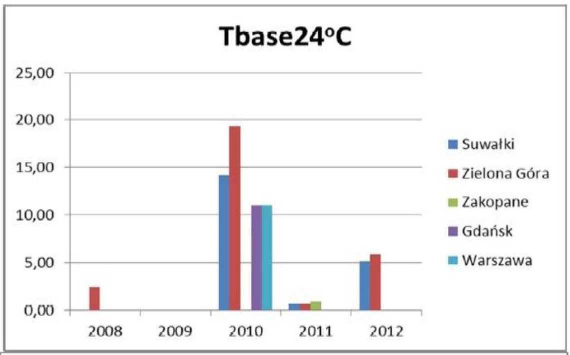
A.Comparsion of Cooling Degree Days in Polish cities

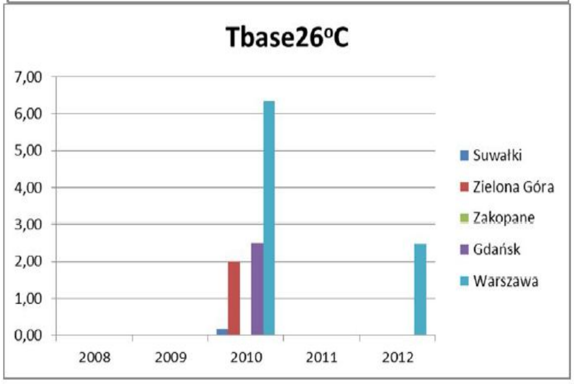
Cooling degree days for different locations of Poland for different base temperatures from 18°C to 26°C





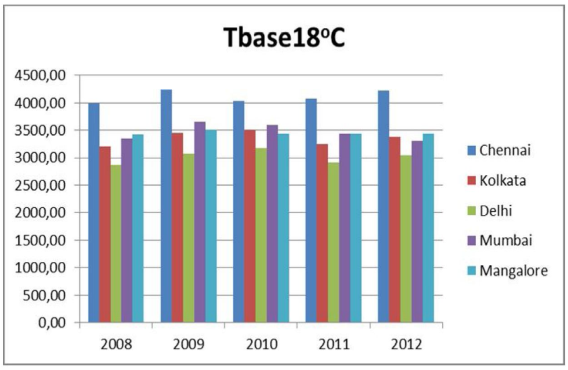


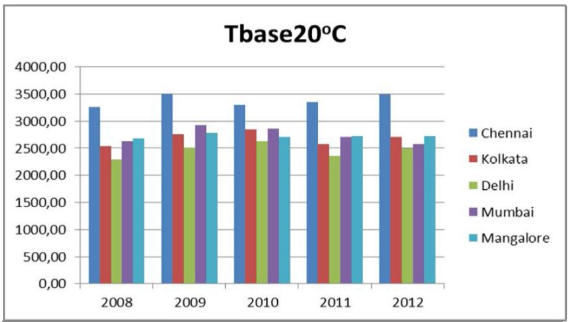


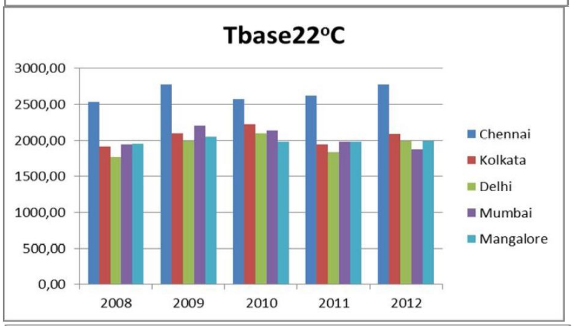


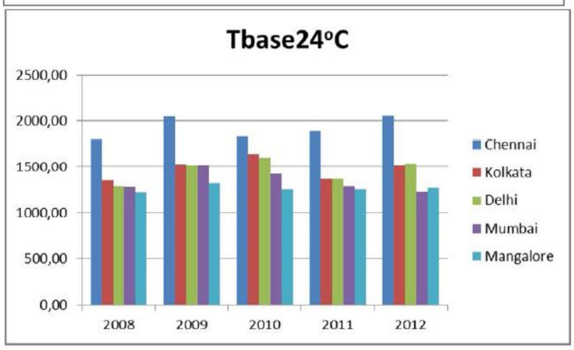
B. Comparsion of Cooling Degree Days in Indian cities

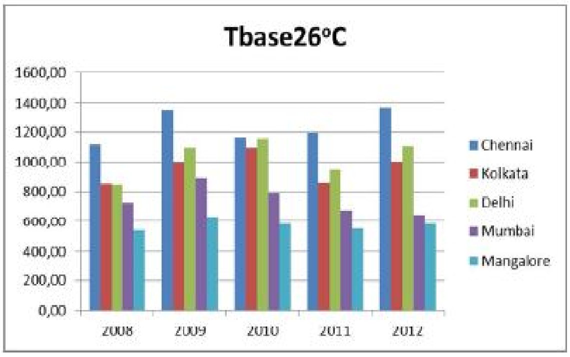
Cooling degree days for different locations of India for different base temperatures from 18°C to 26°C











C. Energy Loss Calculation Fabric Loss

The U-value of a material or structure is the rate at which heat will pass through a given area for a given temperature difference. It is a property of the material in a structure and is usually measured in watts per square metre per degree Celsius ($W/m^2/^0C$).

Cooling Energy Lost = kWh/year/m^2 1000 24 * CDDAnnual * U

The specification of walls, roofs in India and their U values should be taken into consideration.

Base temperature =18^0C then annual cooling degree days =4078.36

If minimum U value of .8W/m^2/˚C is considered for walls then cooling Energy loss = 78.3 kWh/year/m^2.

If maximum of U value of wall 4.12 W/˚C is considered cooling energy loss is 403.3 kWh/year/m^2.

No. of units saved per year/m^2 =325.Percentage savings in energy is 80.6.

C. Energy Loss Calculations for India **(CDD)**

Chennai				
2008				
Tbase	**CDD**	**Energy loss with U=0,8**	**Energy Loss with U=4,12**	**Energy saved**
°C	-	-	-	kWh/year/m^2
18	3992,78	76,66	114,992	38,33
20	3260,78	62,61	93,9104	31,30
22	2528,78	48,55	72,8288	24,28
24	1796,83	34,50	51,7488	17,25
26	1116,50	21,44	32,1552	10,72
2009				
Tbase	**CDD**	**Energy loss with U=0,8**	**Energy Loss with U=4,12**	**Energy saved**
°C	-	-	-	kWh/year/m^2
18	4232,17	81,26	121,8864	40,63
20	3502,17	67,24	100,8624	33,62
22	2772,17	53,23	79,8384	26,61
24	2043,81	39,24	58,8616	19,62
26	1356,50	26,04	39,0672	13,02
2010				
Tbase	**CDD**	**Energy loss with U=0,8**	**Energy Loss with U=4,12**	**Energy saved**
°C	-	-	-	kWh/year/m^2
18	4026,89	77,32	115,9744	38,66
20	3296,89	63,30	94,9504	31,65
22	2566,89	49,28	73,9264	24,64
24	1839,06	35,31	52,9648	17,65
26	1167,28	22,41	33,6176	11,21
2011				
Tbase	**CDD**	**Energy loss with U=0,8**	**Energy Loss with U=4,12**	**Energy saved**
°C	-	-	-	kWh/year/m^2
18	4077,33	78,28	117,4272	39,14
20	3347,33	64,27	96,4032	32,13
22	2617,33	50,25	75,3792	25,13
24	1889,06	36,27	54,4048	18,13
26	1195,50	22,95	34,4304	11,48
2012				
Tbase	**CDD**	**Energy loss with U=0,8**	**Energy Loss with U=4,12**	**Energy saved**
°C	-	-	-	kWh/year/m^2
18	4213,08	80,89	121,3368	40,45
20	3493,08	67,07	100,6008	33,53
22	2773,08	53,24	79,8648	26,62
24	2055,39	39,46	59,1952	19,73
26	1372,50	26,35	39,528	13,18

Mumbai				
2008				
Tbase	CDD	Energy loss with U=0,8	Energy Loss with U=4,12	Energy saved
°C	-	-	-	kWh/year/m²
18	3353,61	64,39	96,584	32,19
20	2624,92	50,40	75,5976	25,20
22	1946,53	37,37	56,06	18,69
24	1281,53	24,61	36,908	12,30
26	726,06	13,94	20,9104	6,97
2009				
Tbase	CDD	Energy loss with U=0,8	Energy Loss with U=4,12	Energy saved
°C	-	-	-	kWh/year/m²
18	3659,94	70,27	105,4064	35,14
20	2929,94	56,25	84,3824	28,13
22	2199,94	42,24	63,3584	21,12
24	1518,11	29,15	43,7216	14,57
26	892,61	17,14	25,7072	8,57
2010				
Tbase	CDD	Energy loss with U=0,8	Energy Loss with U=4,12	Energy saved
°C	-	-	-	kWh/year/m²
18	3593,42	68,99	103,4904	34,50
20	2863,42	54,98	82,4664	27,49
22	2136,61	41,02	61,5344	20,51
24	1426,22	27,38	41,0752	13,69
26	792,00	15,21	22,8096	7,60
2011				
Tbase	CDD	Energy loss with U=0,8	Energy Loss with U=4,12	Energy saved
°C	-	-	-	kWh/year/m²
18	3438,61	66,02	99,032	33,01
20	2708,61	52,01	78,008	26,00
22	1981,06	38,04	57,0544	19,02
24	1288,86	24,75	37,1192	12,37
26	674,42	12,95	19,4232	6,47
2012				
Tbase	CDD	Energy loss with U=0,8	Energy Loss with U=4,12	Energy saved
°C	-	-	-	kWh/year/m²
18	3299,25	63,35	95,0184	31,67
20	2582,61	49,59	74,3792	24,79
22	1874,53	35,99	53,9864	18,00
24	1234,94	23,71	35,5664	11,86
26	646,31	12,41	18,6136	6,20

Kolkata				
2008				
Tbase	CDD	Energy loss with U=0,8	Energy Loss with U=4,12	Energy saved
°C	-	-	-	kWh/year/m²
18	3202,53	61,49	92,2328	30,74
20	2533,61	48,65	72,968	24,32
22	1917,64	36,82	55,228	18,41
24	1353,75	25,99	38,988	13,00
26	848,14	16,28	24,4264	8,14
2009				
Tbase	CDD	Energy loss with U=0,8	Energy Loss with U=4,12	Energy saved
°C	-	-	-	kWh/year/m²
18	3453,19	66,30	99,452	33,15
20	2752,42	52,85	79,2696	26,42
22	2100,50	40,33	60,4944	20,16
24	1531,00	29,40	44,0928	14,70
26	1000,03	19,20	28,8008	9,60
2010				
Tbase	CDD	Energy loss with U=0,8	Energy Loss with U=4,12	Energy saved
°C	-	-	-	kWh/year/m²
18	3514,36	67,48	101,2136	33,74
20	2841,86	54,56	81,8456	27,28
22	2224,53	42,71	64,0664	21,36
24	1644,72	31,58	47,368	15,79
26	1098,61	21,09	31,64	10,55
2011				
Tbase	CDD	Energy loss with U=0,8	Energy Loss with U=4,12	Energy saved
°C	-	-	-	kWh/year/m²
18	3247,36	62,35	93,524	31,17
20	2580,64	49,55	74,3224	24,77
22	1944,58	37,34	56,004	18,67
24	1367,72	26,26	39,3904	13,13
26	856,75	16,45	24,6744	8,22
2012				
Tbase	CDD	Energy loss with U=0,8	Energy Loss with U=4,12	Energy saved
°C	-	-	-	kWh/year/m²
18	3384,69	64,99	97,4792	32,49
20	2709,11	52,01	78,0224	26,01
22	2086,61	40,06	60,0944	20,03
24	1521,89	29,22	43,8304	14,61
26	1004,33	19,28	28,9248	9,64

Mangalore				
2008				
Tbase	CDD	Energy loss with U=0,8	Energy Loss with U=4,12	Energy saved
°C	-	-	-	kWh/year/m^2
18	3416,94	65,61	98,408	32,80
20	2684,94	51,55	77,3264	25,78
22	1952,94	37,50	56,2448	18,75
24	1223,19	23,49	35,228	11,74
26	541,92	10,40	15,6072	5,20
2009				
Tbase	CDD	Energy loss with U=0,8	Energy Loss with U=4,12	Energy saved
°C	-	-	-	kWh/year/m^2
18	3510,61	67,40	101,1056	33,70
20	2780,61	53,39	80,0816	26,69
22	2050,61	39,37	59,0576	19,69
24	1321,42	25,37	38,0568	12,69
26	635,61	12,20	18,3056	6,10
2010				
Tbase	CDD	Energy loss with U=0,8	Energy Loss with U=4,12	Energy saved
°C	-	-	-	kWh/year/m^2
18	3440,69	66,06	99,092	33,03
20	2710,69	52,05	78,068	26,02
22	1980,69	38,03	57,044	19,01
24	1254,00	24,08	36,1152	12,04
26	584,42	11,22	16,8312	5,61
2011				
Tbase	CDD	Energy loss with U=0,8	Energy Loss with U=4,12	Energy saved
°C	-	-	-	kWh/year/m^2
18	3442,81	66,10	99,1528	33,05
20	2712,81	52,09	78,1288	26,04
22	1982,81	38,07	57,1048	19,03
24	1252,81	24,05	36,0808	12,03
26	551,75	10,59	15,8904	5,30
2012				
Tbase	CDD	Energy loss with U=0,8	Energy Loss with U=4,12	Energy saved
°C	-	-	-	kWh/year/m^2
18	3433,69	65,93	98,8904	32,96
20	2713,69	52,10	78,1544	26,05
22	1993,69	38,28	57,4184	19,14
24	1273,69	24,45	36,6824	12,23
26	582,94	11,19	16,7888	5,60

New Delhi				
2008				
Tbase	CDD	Energy loss with U=0,8	Energy Loss with U=4,12	Energy saved
°C	-	-	-	kWh/year/m^2
18	2864,17	54,99	82,488	27,50
20	2296,56	44,09	66,1408	22,05
22	1770,78	34,00	50,9984	17,00
24	1284,89	24,67	37,0048	12,33
26	846,92	16,26	24,3912	8,13
2009				
Tbase	CDD	Energy loss with U=0,8	Energy Loss with U=4,12	Energy saved
°C	-	-	-	kWh/year/m^2
18	3072,78	59,00	88,496	29,50
20	2514,11	48,27	72,4064	24,14
22	1988,72	38,18	57,2752	19,09
24	1513,67	29,06	43,5936	14,53
26	1099,25	21,11	31,6584	10,55
2010				
Tbase	CDD	Energy loss with U=0,8	Energy Loss with U=4,12	Energy saved
°C	-	-	-	kWh/year/m^2
18	3180,53	61,07	91,5992	30,53
20	2624,64	50,39	75,5896	25,20
22	2093,03	40,19	60,2792	20,09
24	1603,53	30,79	46,1816	15,39
26	1159,81	22,27	33,4024	11,13
2011				
Tbase	CDD	Energy loss with U=0,8	Energy Loss with U=4,12	Energy saved
°C	-	-	-	kWh/year/m^2
18	2912,03	55,91	83,8664	27,96
20	2354,67	45,21	67,8144	22,60
22	1839,78	35,32	52,9856	17,66
24	1370,36	26,31	39,4664	13,16
26	940,83	18,06	27,096	9,03
2012				
Tbase	CDD	Energy loss with U=0,8	Energy Loss with U=4,12	Energy saved
°C	-	-	-	kWh/year/m^2
18	3045,86	58,48	87,7208	29,24
20	2496,28	47,93	71,8928	23,96
22	1995,08	38,31	57,4584	19,15
24	1541,67	29,60	44,4	14,80
26	1110,06	21,31	31,9696	10,66

D. Energy loss calculations for Poland (CDD)

Gdańsk				
2008				
Tbase	CDD	Energy loss with U=0,8	Energy Loss with U=4,12	Energy saved
°C	-	-	-	kWh/year/m²
18	18,00	0,35	0,5184	0,17
20	0,00	0,00	0	0,00
22	0,00	0,00	0	0,00
24	0,00	0,00	0	0,00
26	0,00	0,00	0	0,00
2009				
Tbase	CDD	Energy loss with U=0,8	Energy Loss with U=4,12	Energy saved
°C	-	-	-	kWh/year/m²
18	37,50	0,72	1,08	0,36
20	10,50	0,20	0,3024	0,10
22	0,00	0,00	0	0,00
24	0,00	0,00	0	0,00
26	0,00	0,00	0	0,00
2010				
Tbase	CDD	Energy loss with U=0,8	Energy Loss with U=4,12	Energy saved
°C	-	-	-	kWh/year/m²
18	132,50	2,54	3,816	1,27
20	0,00	0,00	0	0,00
22	0,00	0,00	0	0,00
24	0,00	0,00	0	0,00
26	0,00	0,00	0	0,00
2011				
Tbase	CDD	Energy loss with U=0,8	Energy Loss with U=4,12	Energy saved
°C	-	-	-	kWh/year/m²
18	54,50	1,05	1,5696	0,52
20	0,00	0,00	0	0,00
22	0,00	0,00	0	0,00
24	0,00	0,00	0	0,00
26	0,00	0,00	0	0,00
2012				
Tbase	CDD	Energy loss with U=0,8	Energy Loss with U=4,12	Energy saved
°C	-	-	-	kWh/year/m²
18	67,50	1,30	1,944	0,65
20	22,00	0,42	0,6336	0,21
22	0,00	0,00	0	0,00
24	0,00	0,00	0	0,00
26	0,00	0,00	0	0,00

Suwałki				
2008				
Tbase	CDD	Energy loss with U=0,8	Energy Loss with U=4,12	Energy saved
°C	-	-	-	kWh/year/m²
18	52,44	1,01	1,5104	0,50
20	0,00	0,00	0	0,00
22	0,00	0,00	0	0,00
24	0,00	0,00	0	0,00
26	0,00	0,00	0	0,00
2009				
Tbase	CDD	Energy loss with U=0,8	Energy Loss with U=4,12	Energy saved
°C	-	-	-	kWh/year/m²
18	56,25	1,08	1,62	0,54
20	16,42	0,32	0,4728	0,16
22	0,00	0,00	0	0,00
24	0,00	0,00	0	0,00
26	0,00	0,00	0	0,00
2010				
Tbase	CDD	Energy loss with U=0,8	Energy Loss with U=4,12	Energy saved
°C	-	-	-	kWh/year/m²
18	192,28	3,69	5,5376	1,85
20	0,00	0,00	0	0,00
22	0,00	0,00	0	0,00
24	0,00	0,00	0	0,00
26	0,00	0,00	0	0,00
2011				
Tbase	CDD	Energy loss with U=0,8	Energy Loss with U=4,12	Energy saved
°C	-	-	-	kWh/year/m²
18	96,61	1,85	2,7824	0,93
20	0,00	0,00	0	0,00
22	0,00	0,00	0	0,00
24	0,00	0,00	0	0,00
26	0,00	0,00	0	0,00
2012				
Tbase	CDD	Energy loss with U=0,8	Energy Loss with U=4,12	Energy saved
°C	-	-	-	kWh/year/m²
18	97,50	1,87	2,808	0,94
20	46,47	0,89	1,3384	0,45
22	0,00	0,00	0	0,00
24	0,00	0,00	0	0,00
26	0,00	0,00	0	0,00

Zielona Góra				
2008				
Tbase	CDD	Energy loss with U=0,8	Energy Loss with U=4,12	Energy saved
°C	-	-	-	kWh/year/m^2
18	183,11	3,52	5,2736	1,76
20	0,00	0,00	0	0,00
22	0,00	0,00	0	0,00
24	0,00	0,00	0	0,00
26	0,00	0,00	0	0,00
2009				
Tbase	CDD	Energy loss with U=0,8	Energy Loss with U=4,12	Energy saved
°C	-	-	-	kWh/year/m^2
18	149,00	2,86	4,2912	1,43
20	56,03	1,08	1,6136	0,54
22	0,00	0,00	0	0,00
24	0,00	0,00	0	0,00
26	0,00	0,00	0	0,00
2010				
Tbase	CDD	Energy loss with U=0,8	Energy Loss with U=4,12	Energy saved
°C	-	-	-	kWh/year/m^2
18	193,53	3,72	5,5736	1,86
20	0,00	0,00	0	0,00
22	0,00	0,00	0	0,00
24	0,00	0,00	0	0,00
26	0,00	0,00	0	0,00
2011				
Tbase	CDD	Energy loss with U=0,8	Energy Loss with U=4,12	Energy saved
°C	-	-	-	kWh/year/m^2
18	158,89	3,05	4,576	1,53
20	0,00	0,00	0	0,00
22	0,00	0,00	0	0,00
24	0,00	0,00	0	0,00
26	0,00	0,00	0	0,00
2012				
Tbase	CDD	Energy loss with U=0,8	Energy Loss with U=4,12	Energy saved
°C	-	-	-	kWh/year/m^2
18	191,58	3,68	5,5176	1,84
20	85,78	1,65	2,4704	0,82
22	0,00	0,00	0	0,00
24	0,00	0,00	0	0,00
26	0,00	0,00	0	0,00

Warsaw				
2008				
Tbase	CDD	Energy loss with U=0,8	Energy Loss with U=4,12	Energy saved
°C	-	-	-	kWh/year/m^2
18	78,14	1,50	2,2504	0,75
20	0,00	0,00	0	0,00
22	0,00	0,00	0	0,00
24	0,00	0,00	0	0,00
26	0,00	0,00	0	0,00
2009				
Tbase	CDD	Energy loss with U=0,8	Energy Loss with U=4,12	Energy saved
°C	-	-	-	kWh/year/m^2
18	73,11	1,40	2,1056	0,70
20	1,42	0,03	0,0408	0,01
22	0,00	0,00	0	0,00
24	0,00	0,00	0	0,00
26	0,00	0,00	0	0,00
2010				
Tbase	CDD	Energy loss with U=0,8	Energy Loss with U=4,12	Energy saved
°C	-	-	-	kWh/year/m^2
18	178,14	3,42	5,1304	1,71
20	0,00	0,00	0	0,00
22	0,00	0,00	0	0,00
24	0,00	0,00	0	0,00
26	0,00	0,00	0	0,00
2011				
Tbase	CDD	Energy loss with U=0,8	Energy Loss with	Energy saved
°C	-	-	-	kWh/year/m^2
18	63,92	1,23	1,8408	0,61
20	0,00	0,00	0	0,00
22	0,00	0,00	0	0,00
24	0,00	0,00	0	0,00
26	0,00	0,00	0	0,00
2012				
Tbase	CDD	Energy loss with U=0,8	Energy Loss with U=4,12	Energy saved
°C	-	-	-	kWh/year/m^2
18	126,17	2,42	3,6336	1,21
20	32,33	0,62	0,9312	0,31
22	0,00	0,00	0	0,00
24	0,00	0,00	0	0,00
26	0,00	0,00	0	0,00

Zakopane				
2008				
Tbase	CDD	Energy loss with U=0,8	Energy Loss with U=4,12	Energy saved
°C	-	-	-	kWh/year/m^2
18	28,03	0,54	0,8072	0,27
20	0,00	0,00	0	0,00
22	0,00	0,00	0	0,00
24	0,00	0,00	0	0,00
26	0,00	0,00	0	0,00
2009				
Tbase	CDD	Energy loss with U=0,8	Energy Loss with U=4,12	Energy saved
°C	-	-	-	kWh/year/m^2
18	27,33	0,52	0,7872	0,26
20	8,14	0,16	0,2344	0,08
22	0,00	0,00	0	0,00
24	0,00	0,00	0	0,00
26	0,00	0,00	0	0,00
2010				
Tbase	CDD	Energy loss with U=0,8	Energy Loss with U=4,12	Energy saved
°C	-	-	-	kWh/year/m^2
18	48,78	0,94	1,4048	0,47
20	0,00	0,00	0	0,00
22	0,00	0,00	0	0,00
24	0,00	0,00	0	0,00
26	0,00	0,00	0	0,00
2011				
Tbase	CDD	Energy loss with U=0,8	Energy Loss with U=4,12	Energy saved
°C	-	-	-	kWh/year/m^2
18	43,50	0,84	1,2528	0,42
20	0,00	0,00	0	0,00
22	0,00	0,00	0	0,00
24	0,00	0,00	0	0,00
26	0,00	0,00	0	0,00
2012				
Tbase	CDD	Energy loss with U=0,8	Energy Loss with U=4,12	Energy saved
°C	-	-	-	kWh/year/m^2
18	66,69	1,28	1,9208	0,64
20	18,33	0,35	0,528	0,18
22	0,00	0,00	0	0,00
24	0,00	0,00	0	0,00
26	0,00	0,00	0	0,00

CONCLUSION

Poland situated in central Europe has temperate climate with relatively cold winters and warm summer. During the summer there is need of cooling buildings, and during long winters there is high need to heat the buildings to provide thermal comfort for occupants. The heating system should run almost all year, what confirm the amount of Heating Degree Days in every city in Poland. The coldest place in Poland is Zakopane. The most warm place is Poland is Zielona Góra and Warsaw- the high amount of CDD confirms that. The air should be cooled during months of July and August.

India situated in South Asia has a three seasons in every season there is a need of using cooling systems. The hottest place in India is Chennai where yearly CDD is about 4300. The coldest city is New Delhi, where seasonally heating should be provided.

Degree day method is very useful to estimate the demand for heating and cooling services that is why it is used as important climatic indicator in the HVAC industry.

In this study the variable base CDD for India, CDD for Poland were checked by using long term (2008-2012) data. The base temperatures 18°C,20 °C,22 °C,24 °C,26 °C are chosen to calculate degree days. All results are given in tables. The average yearly degree day is with correlation to base temperature.

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REFERENCES

[1] M. Mourshed, Relationship between annual mean temperaturę and degree-days, Energy and Buildings 54 (2012) 418-425.

[2] K. Papakostas, T. Mavromatis, N. Kyriakis, Impact of the ambient temperature rise on the energy consumption for heating and cooling in residential buildings of Greece, Renewable Energy 35 (2010) 1376-1379.

[3] M. Christenson, H. Manz, D. Gyalistras Climate Warming impact on degree-days and building energy demand in Switzerland, Energy Conversation and Management 47 (2006) 671-686.

[4] Kevin Baumert, M. Selman, Heating and Cooling Degree Days, World RResources Institute (2003)

[5] O. Buyukalaca, H. Bulut, T. Yilmaz, ANalysys of variable-base heating and cooling degree days for Turkey, Applied Energy 69 (2001) 269-283.

[6] Fengqing Jiang , Xuemei Li, Binggan Wei, Ruji Hu, Zhen Li Observed trends of heating and cooling degree-days in Xinjiang Province, China, Theor Appl Climatol (2009) 97 349–360

[7] W.J. Roltsch, F. G Zalom, A.J. Strawn, Joyce. F. Strand, M.J. Pitcairn, Evaluation of several degree-day estimation method in California climates, , Int J Biometeorol (1999) 42:169-172.

[8] J. Wilbig Heating degree days and cooling degree days in Łódź in the period 1931-2000, University of Lodź.

[9] CIBSE,Climate Change and the Indoor Environment: Impacts and Adaptation,TM36, Chartered Institution of Building Services Engineers, London, UK, 2005.

[10] S. Shanmuga Priya, S. R. Rajkumar, M.Premalatha, Analysis of Cooling Degree Days for Tiruchirappalli a district in India, IJRRAS 8 (1) (2011) 44-56.

[11] Degree days fuel efficiency booklet 7, Department of the environment UK, 1996.

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