The impact of the year-on-year variation in the intensity of solar radiation on the energy intensity of low-energy and passive houses

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Abstract. Solar radiation is a significant segment of heat gains in the operation of buildings. The importance of this segment is highlighted by lowering the energy performance of buildings. The current condition of assessment considers the standard values of solar radiation but these are often very different from the fair values. In the contribution it draws attention to not only to on-year variation in solar fluctuations in the intensity of solar radiation and its significant long-term deviation from the standard values but also to the impact to energy building in reliance to its energy intensity. The attention will be focused also to different values in standards valid in the Czech Republic. This specification of energy assessment of buildings is not only necessary to approximate calculations of real state, but mainly because we can expect more disputes about if a building has declared calculating the parameters of a building with nearly zero-energy or passive house.

1 Current condition in the Czech Republic

Energy performance of buildings is assessed by calculations according to valid European standards taking into consideration the climatic data in the Czech Republic. Those are given by CSN 73 0540 (CSN = Czech Technical Standard) and TNI 73 0331 (TNI = Technical Standards Information) and they should be based on long-term average. Even though TSI is just a recommended information usually the values listed there are used for assessment of buildings. Although the information differs in both standards and mainly in global radiation perpendicular surface oriented to different cardinal points. Comparison for the winter season is shown in Table 1 where there is a noticeable difference both in individual months, and within different orientation to cardinal points. These different values lead to according TNI it is less necessary to consider the orientation of windows to different cardinal points than when evaluation by CSN. Another source of values of global solar radiation for the region of the Czech Republic can be obtained from the Internet, namely from the computational programs for calculation of electricity from photovoltaic power plants.

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In Table 2 shows the comparison of results of several houses and different assessment according to these standards.

2 Real climate data

To determine the actual status of global radiation the data were purchased from ČHMÚ (Czech Hydrometeorological Institute) which performs long-term measurements. Values for Hradec Králové are listed in Table 3 [1]. This table shows that global solar radiation over the past 10 years is higher than the long-term average which is given in CSN, although the global radiation does not correspond with average temperatures for that period.

Table 1. Comparison of values listen in TNI 73 0331 and CSN 73 0540-3.

source	Monthly dose irradiation H [kWh/(m ² •month)]							
	January	February	March	April	October	November	December	Total per year
Horizon								
ČSN	23,06	36,75	76,12	110,53	52,74	25,53	18,62	343,35
TNI	20,8	37,0	72,2	113,8	56,5	25,2	14,9	340,4
difference	90 %	101 %	95 %	103 %	107 %	99 %	80 %	99 %
South								
ČSN	41,94	53,31	89,73	88,42	71,57	41,07	30,95	416,99
TNI	34,2	51,1	74,4	84,7	74,4	45,4	29,0	393,2
difference	82 %	96 %	83 %	96 %	104 %	111 %	94 %	94 %
Southeast, Southwest								
ČSN	32,2	41,17	76,16	84,33	57,61	31,99	23,86	347,32
TNI	26,8	41,0	64,7	86,4	60,3	33,8	23,1	336,1
difference	83 %	100 %	85 %	102 %	105 %	106 %	97 %	97 %
East, West								
ČSN	15,01	22,21	48,89	65,84	32,23	15,87	11,18	211,23
TNI	14,1	25,5	46,9	74,2	38,7	18,0	11,2	228,6
difference	94 %	115 %	96 %	113 %	120 %	113 %	100 %	108 %
Northeast, Northwest								
ČSN	6,42	9,55	23,25	38,3	14,06	6,98	5,09	103,65
TNI	8,2	14,8	29,8	50,4	21,6	9,4	6,0	140,2
difference	128 %	155 %	128 %	132 %	154 %	135 %	118 %	135 %
North								
ČSN	5,21	7,26	15,6	24,04	10,36	5,52	4,03	72,02
TNI	8,2	13,4	25,3	36,0	18,6	9,4	6,0	116,9
difference	157 %	185 %	162 %	150 %	180 %	170 %	149 %	162 %

Table 2. Comparison of assessment Building Energy Performance for heating depending on weather data according to ČSN 73 0540 and according to TNI 73 0331 [GJ].

	A4	B4	C4
ČSN	32,5	31,4	30,4
TNI	31,3	30,0	29,2
difference %	4	4	4

3 Comparison of the calculated values

To determine the difference of the actual climate data was chosen reference building with dimensions of 10 x 10 m and 6 m in height with windows of 20 m² facing south, 4 m² north and after 8 m² on the east and west. This building was considered a total of 12 variants, according to storage capacity of construction:

- A) Lightweight construction, heat capacity 110 kJ/(K·m²),
- B) Medium-heavy construction, heat capacity 165 kJ/(K·m²),
- C) Heavy construction, heat capacity 260 kJ/(K·m²).

And also according to quality of thermal insulations. There were chosen values required by standard of 1964 [2], by standard of 1977 and also recommended values for passive houses by standard from 2011. These values are listen in Table 4, where ale also listed characteristic values of the glazing. Ventilation in the first two cases is considered natural, in the latter two cases is considered as a forced recovery.

Table 3. Global solar radiation for years 2005 - 2014 measured in Hradec Králové.

Global solar radiation E_m [kWh/(m ² •month)]									How much more sunlight strikes against ČSN [%]	How many degree-days were warmer comparing to the long-term average [%]
year	01	02	03	04	10	11	12	Total year		
2005	28,20	43,80	100,22	135,25	73,92	22,65	15,27	419,30	122 %	107 %
2006	32,48	44,55	79,49	120,45	68,51	25,45	19,64	390,56	114 %	113 %
2007	23,99	39,45	81,48	165,44	58,55	26,35	15,69	410,95	120 %	126 %
2008	23,93	47,34	82,08	114,97	56,65	26,24	19,49	370,69	108 %	117 %
2009	24,73	33,47	64,51	162,50	41,40	29,44	17,31	373,35	109 %	118 %
2010	26,29	40,49	86,35	140,36	67,89	24,64	17,71	403,72	118 %	98 %
2011	25,21	47,80	102,62	127,84	61,22	30,11	17,63	412,42	120 %	118 %
2012	26,60	48,24	99,32	124,66	53,06	25,02	20,69	397,59	116 %	117 %
2013	18,46	34,40	76,87	105,94	67,91	24,25	20,41	348,24	101 %	111 %
2014	23,82	48,46	96,43	126,57	56,90	21,34	15,86	389,38	113 %	138 %
ČSN	23,06	36,75	76,12	110,53	52,74	25,53	18,62	343,35	100 %	

Table 4. Considered in the calculation of thermal properties of the reference building.

construction	heat transfer coefficient U_N [W/(m ² ·K)]			
	CSN 73 0540 of 1964	CSN 73 0540 of 1977	CSN 73 0540-2 recommended values	CSN 73 0540-2 recommended values for passive houses
	1	2	3	4
on the ground floor	1,5	1,15	0,3	0,15
wall	1,4	0,89	0,25	0,12
window	2,4	2,4	1,1	0,9
flat floor	0,93	0,51	0,16	0,1
solar transmittance glass g [-]:	0,81	0,81	0,52	0,6

Table 5. Calculated energy performance of buildings according to climate conditions CSN 73 0540 and according to climate data in each years for region Hradec Králové [GJ].

	A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	C3	C4
2005	184,7	126,1	46,9	28,8	182,2	123,5	45,1	27,7	179,2	120,2	43,2	26,9
2006	183,8	125,8	46,8	28,9	181,4	123,3	45,1	27,8	178,2	120,1	43,3	26,9
2007	164,6	111,9	40,2	25,6	162,1	109,1	38,3	24,1	159,2	106,4	37,2	23,2
2008	164,3	111,5	39,6	24,6	162,0	109,1	38,1	23,2	159,2	106,1	36,8	21,9
2009	179,5	123,1	47,0	30,0	177,3	121,0	45,5	29,2	174,6	118,7	43,3	28,5
2010	195,6	134,6	50,9	32,8	193,4	132,3	49,2	30,9	190,3	129,6	47,5	29,7
2011	178,7	121,4	44,3	26,4	176,2	118,4	42,4	25,1	173,2	115,6	40,6	23,7
2012	181,5	123,5	45,3	26,3	179,2	120,8	43,5	24,9	176,5	118,3	41,9	23,6
2013	189,1	130,2	49,0	31,1	186,6	127,7	47,4	29,6	184,4	125,5	45,9	28,3
2014	151,0	101,3	36,5	22,4	148,6	99,0	34,6	20,4	145,7	96,3	33,0	19,1
CSN	182,7	127,1	49,1	32,5	180,8	125,2	47,8	31,4	178,7	122,7	46,7	30,4

Fig. 1. Calculated energy performance of buildings according to climate conditions CSN 73 0540 and according to climate data in each years for region Hradec Králové [GJ].

Calculations of energy performance of buildings for heating were done according to CSN EN ISO 13790 and the result is 12 variants of calculation (from A1 to C4) for years 2005 – 2014. These results are listed in Table 5 and later in graph 1 [3].

In Table 6 and graph 2 are then calculated values in percentage relative to the values calculated according to the standard.

Table 6. Energy performance of buildings according to climate data in each years for the region Hradec Králové relative in percentage to values obtained under standardized climatic conditions [%].

	A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	C3	C4
2005	101,1	99,2	95,6	88,6	100,8	98,6	94,2	88,3	100,3	97,9	92,5	88,4
2006	100,6	98,9	95,5	88,9	100,3	98,5	94,3	88,6	99,8	97,8	100,2	95,1
2007	90,1	88,0	82,0	78,8	89,7	87,1	80,1	76,9	89,1	86,7	79,6	76,4
2008	90,0	87,7	80,7	75,8	89,6	87,1	79,7	73,9	89,1	86,5	78,6	72,2
2009	98,3	96,8	95,8	92,3	98,0	96,7	95,2	92,9	97,7	96,7	92,6	93,9
2010	107,1	105,9	103,8	101,1	106,9	105,7	102,8	98,3	106,5	105,6	101,6	97,7
2011	97,8	95,5	90,4	81,4	97,4	94,5	88,7	80,0	97,0	94,1	86,8	78,0
2012	99,4	97,1	92,4	81,1	99,1	96,5	91,0	79,4	98,8	96,4	89,6	77,6
2013	103,5	102,4	99,9	95,7	103,2	102,0	99,1	94,3	103,2	102,2	98,2	93,2
2014	82,7	79,7	74,5	68,8	82,2	79,1	72,3	65,0	81,5	78,5	70,6	62,9
CSN	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0

Fig. 2. Energy performance of buildings according to climate data in each years for the region Hradec Králové relative in percentage to values obtained under standardized climatic conditions [%].

Effect of changes in the intensity of solar radiation on energy consumption for heating is documented in Table 7 and graph 3. There is calculated energy consumption for heating according to values listed in the standard and then is considered the same temperature, however the intensity of solar radiation is higher by 20%.

Table 7. Energy performance of buildings according to climate data according to the standard and increase in the global solar radiation by 20 % for the region Hradec Králové listed in GJ and in % relative to standard values.

	A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	C3	C4
CSN [GJ]	182,7	127,1	49,1	32,5	180,8	125,2	47,8	31,4	178,7	122,7	46,7	30,4
Temperatures according to CSN, sun more by 20% [GJ]	176,6	121,1	45,7	29,3	174,4	118,2	44,3	28,1	171,8	116,1	42,8	27,0
Likewise %	103,5	105,0	107,3	111,0	103,7	105,9	108,1	111,9	104,0	105,8	109,3	112,7

Fig. 3. Energy performance of buildings according to climate data according to the standard and increase in the global solar radiation by 20 % for the region Hradec Králové listed in GJ and in % relative to standard values.

4 Conclusions

The results demonstrate clearly that the effect of fluctuations in solar radiation has a significant influence to energy performance of buildings for heating which increases especially with thermal insulation properties structure. In old buildings, the 20 % difference in the global radiation shows at model building the range of 3,5 to 4% depending on the heat capacity of the considered structure. For buildings with thermal insulation as recommended for passive houses, however, the difference is 11 to 12,7%. From this finding it implies knowledge that when assesing the measured energy consumption for heating is necessary, besides other things, také in account also global solar radiation, which is usually not performed, usually only takes into account the different temperatures in the heating season. Less significant impact on the energy performance of buildings have storage capabilities. Those at the model house ranged to 2,3%.

References

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