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Comparison of Methods in the Definition of Home Energy Characteristics in the Context of the European Union Directives

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Abstract

Energy characteristics were estimated for an exemplary single-family detached house on the basis of four calculation methods (according to the Directive 2010/31/EU on energy characteristics of detached houses) such as: the method based on the actually consumed amount of energy, the method based on the actually consumed amount of energy calculated for the standard weather conditions and the calculation method compatible with methodology from 2009 with its newest version of 2014 as well. Then the comparison analysis of the method based on the energy actually consumed with the calculation methods for the standard weather conditions was conducted. While comparing needs for final energy for building heating, one can notice a great discrepancy between values of relative errors of estimation. The value of estimation error in comparison with the total energy consumption for heating and preparing hot usable water amounts to 70% if you compare it to the calculation method (according to the methodology of 2014) with the actual energy consumption, whereas 36% if compared to the conversion conditions. The application of calculation models contained in the methodology of 2008 gives better results, because the estimating error is from 38% (compared with the actual energy consumption) to 11% (compared with real consumption taking into consideration the standard conditions). The method used to determine the characteristics will depend on whether the house meets the criteria in rules concerning minimal demands indicating the unit need for initial energy IE max. If the energy characteristics certificate is made on the basis of the method based on the real energy quantity consumption, it will show that a house will fulfill demands, while in the case where energy characteristics will be prepared based on calculation method compatible with the methodology of 2014 the house won't fulfill demands and it won't be accepted. If you want to accept as objective the proposed methodology of fulfilling energy certificates, energy characteristics defined on the actual consumed quantity of energy should include a notation of the need to calculate results for the conditions of the standard season.

Keywords: methodology of energy characteristics definition, real energy consumption, final energy, the heating season number of days counting for decreases of heat

Introduction

Energy consumption in the European construction sector is about 45% of the total energy needs of the European Union and 50% of the pollution put into the atmospheric air comes from this sector (Ballarini and Corrado 2009). As noted by Chan, Riffat and Zhu (2010), the construction sector consumes 35,3% of the needs for final energy. Therefore the energy consumption reduction in this area is a priority in the aims of "20–20–20" in the range of energy effectiveness. In the aim of improvement of energy exploitation effectiveness for building heating and air conditioning and in the aim of reducing greenhouse gas emission, the European Parliament and European Union Council accepted the Directive in the case of building energy characteristics.[1] It inscribes guidelines concerning the energy effectiveness augmentations and it proposes guidelines for membership countries concerning building energy characteristics. In the guidelines two possibilities of energy

1. See: Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings. OJ L 1, 4.1.2003, p. 65–71.

estimate of buildings were allowed — the calculation and exploitive methods. Poland as a rightful member of the European Union was obliged to introduce the decisions contained in the Directives[2] on energy certification of buildings. The Act on the change of the Construction Law from 2007 was a general basis to prepare energy certificates. The detailed methodology of preparing energy characteristic certificates for buildings, parts of buildings and apartments was set into the Infrastructure Minister Regulation in 2008. In this regulation the calculations were established that must be made within the framework of building estimates of energy needs (i.e., the theoretical quantitative forecast of energy consumption in the scale of one year). This quantification makes an objective estimation of the energy quality of the building. This quality can differ from the measured quality of consumed energy because this quality depends also on the manner of exploitation (Regulation 2008). Heating needs are calculated by assuming normative usable conditions that is:

- temperature in rooms established in the Regulation on technical conditions as to what the building should be like and where equipment should be situated (Regulation 2013),
- the most unfavorable temperatures established for a climatic zone in the PN-82/B-02403 norm,[3]
- average external monthly temperatures and qualities of the solar radiation for particular months — after the average of many years of data defined for the closest meteorological station,
- quality of the ventilation air flux according to the PN-B/83–03430 norm.[4]

Calculations concerning the energy needs in the homes should include:

- energy consumption for heating and ventilation
- energy consumption for preparation of hot water (further called h.u.w.), compared with the quantity of water consumed by inhabitants or other users

Energy need is calculated in turn for: usable energy (consumed directly), final energy (supplied to a building including waste of energy as a result from the efficiency of installation systems) and initial energy (that takes into consideration waste of energy during its production and transmission, and the type of energy carrier). Estimation of usable energy needs for heating, ventilation and cooling is made with the monthly balance-sheet method according to the PN-EN ISO 13790:2008 norm.[5]

The Law of building energy characteristics was introduced in 2014.[6] This Law defined rules for:

- creating energy characteristic certificates,
- heating and air conditioning system control in buildings,
- a central register of building energy characteristics,
- the development of the national plan for increasing the construction and local planning for the number of buildings with low energy consumption.

Article 15 of this Law states that:

- The proper Minister for construction, local planning, spatial development and housing policy will define, by the way of regulation, the methodology of establishing building energy characteristics, the way of making documentation and models of energy characteristic certificates.
- The proper Minister for construction, local planning, spatial development and housing policy issuing the regulation, mentioned in Point 1, will take into consideration:
  - building or part of building construction technical parameters,
  - kinds of technical systems in the building or part of the building,
  - the methodology of energy characteristics defined based on the standard way of using a building or a part of the building,
  - the methodology of energy characteristics defined based on the actually consumed quantity of energy.

2. See: Directive 2002/91/EC... and Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings. OJ L 153, 18.6.2010, p. 13–35.

3. PN-82/B-02403 Temperatury obliczeniowe zewnętrzne.

4. PN-83/B-03430/AZ3:2000 Wentylacja w budynkach mieszkalnych, zamieszkania zbiorowego i użyteczności publicznej. Wymagania.

5. PN-EN ISO 13790:2009 Energetyczne właściwości użytkowe budynków — Obliczanie zużycia energii na potrzeby ogrzewania i chłodzenia.

6. See: Rozporządzenie Ministra Infrastruktury i Rozwoju z dnia 3 czerwca 2014 r. w sprawie metodologii obliczania charakterystyki energetycznej budynku i lokalu mieszkalnego lub części budynku stanowiącej samodzielną całość techniczno-użytkową oraz sposobu sporządzania i wzorów świadectw charakterystyki energetycznej. DzU z 2014 r. poz. 888.

By this law the Infrastructure end Development Minister issued new regulation on the methodology for buildings, homes or their part making a separate technically-usable unit for energy characteristic calculation, the method of documentation and the models of certificates of energy characteristics (further called the methodology). In this methodology two ways of making energy characteristics were introduced — i.e., based on a standard way of using energy and on the climate data based on the nearest meteorology station, and secondly, based on the actual quality of the consumed energy (Regulation 2014).

The first manner in the part concerning energy consumption for heating and ventilation calculation doesn't meaningfully differ from the notations of previous regulation. The change followed in the way of estimating ventilation flux. It is compared with a building's usable area now and it is defined with an indicative method. Values for the efficiency of production, accumulation, distribution and heating transfer were changed (or modified). The indicators for the value of expenditure necessary to calculate the qualities of initial energy consumption were also changed. The notation on the necessity of calculation for seasonal fuel consumption and also pollution emission was introduced. The Regulation assumes calculation needs for h.u.w. by indicating a method related to a m^2 of area. Indicator qualities of efficiency of preparation for hot usable water were changed in this case, too.

In the case of the exploitative method the annual need for final energy supplied to a building for heating and hot usable water is defined on the basis of documents confirming actual consumption of network heat or natural gas for heating needs and for hot usable water preparation. The value Q_{W+Hk}, expressed in kWh/year is average consumption of network heat or natural gas over the last 3 years. Annual consumption of hot usable water is calculated as a product of demands for final energy supplied to a building for the heating system as the average total efficiency of the heating system. Initial energy consumed is calculated in the same way as in the detailed method. Quality of pollution is calculated in the same way. The methodology doesn't assume a calculation (correction) counting the values for a standard year, so that in an objective way one can determine the building energy quality. Therefore the target of this work is to make a comparative analysis of the method based on actually consumed energy with by calculating a method for standard climatic conditions. The quality of needs for usable, final and initial energy will be defined. We'll examine also the influence of the observed calculating method on the value of the home energy characteristics.

1 Object of the research and methodology

The calculations were made for a detached house built in 2010, located in the rural area in Bochnia commune in Malapolska district. The house was fitted with a system of central heating working in a closed system (separated pipes) with aluminum linked heaters (fitted with thermostatic valves with a proportional working of $P = 2K$ supplied with a gas condensation boiler of 3–13 kW power used with a weather regulator. Hot usable water is prepared for three inhabitants through a gas condensation boiler working with an h.u.w. tank. Water is supplied to scooping valves through water circulation (separated pipes). In the analyzed house gas is used strictly for heating and h.u.w. preparation. Basic data concerning the analyzed object are compared in table 1.

The building, despite being built in 2010, fulfills the actual technical demands contained in the regulations of the warm filtering coefficient for the outside partitions U_{max} (Regulation 2013).

The monthly readings of the level of gas from the gas meter (readings confirmed by invoices for gas) were conducted in the analyzed building. In table 2 a year-long gas consumption of the preceding three years certification are compared. The year-long gas consumption for heating and h.u.w. preparation in respective years fluctuates from approximately 960–1 270 m^3 with an approximate value of 1 080 m^3.(7) The defining of the year-long demand for usable, final and initial energy in the building was the next stage of calculation. The comparative calculations were made according to the methodology from 2008 (Regulation 2008) and actual regulation from the year 2014 (Regulation 2014).

7. [In the journal European practice of number notation is followed — for example, 36 333,33 (European style) = 36 333.33 (Canadian style) = 36,333.33 (US and British style). — Ed.]

Tab. 1. Building basic data

Building heated area Af (m^2)	136,26
Cubage of the heated part of the building	341,30
Coefficient of heat filter U (W/m^2K)	
Outsider walls	0,25
The floor on the soil.....................	0,24
The structural ceiling under the attic..........	0,20
Heated roof	0,20
Windows..............................	1,00
Area of all outside partitions of the building A (m^2)	307,17
Coefficient A/Ve	0,90

Tab. 2. Gas consumption for heating and h.u.w. preparation in the years 2012–2014 (C_{H+W}; in m^3)

Month	2012	2013	2014	Average of three years
January	137	229	172	179,4
February	157	199	161	172,4
March	107	138	101	115,4
April	55	85	81	73,7
May	40	57	51	49,4
June	22	35	27	28,0
July	22	37	27	28,7
August	28	46	30	34,7
September	30	38	34	34,0
October	69	78	69	72,0
November	131	163	86	126,7
December	165	173	161	166,4
Total	963	1278	1000	1080,8

In the method based on the actual consumed energy, heat combustion of gas supplied to the building (the heat serves in the final energy calculation) was taken from information for the Heat Combustion Counting Area (HCCA) in the Polish Gas Company Sp. z o.o. (Ltd.) for the station OK9 in the commune of Bochnia. For the analyzed years it is on average 11,116 kWh/m^3.[8] Although the methodology (Regulation 2014) doesn't assume a conversion (correction) of real energy consumption for needs of heating and ventilating for the standard seasonal conditions, in this work calculations like that were made. We took advantage of interelations:

$$Q_{K,H} = \sum_{i=1}^{3} \frac{Sd(t_b)_i}{Sd(t_b)_0} \cdot Q_{K,H_i} \cdot \frac{1}{3}, \tag{1}$$

where:
$Q_{K,H}$ — demand for final energy for heating in a standard season (kWh),
$Sd(t_b)_0$ — number of degree- days in a standard heating season (°Cd),
$Sd(t_b)_i$ — number of degree-days for a given year (°Cd),
Q_{K,H_i} — final energy consumption for heating in the season for a given year (kWh).
Climatic data based on which the calculations were made were taken from the climatic database for the station Kraków-Balice for the standard year[9] and for the years 2012, 2013, 2014.[10] They served to define the degree — days of the heating season $Sd(15°C)[Sd = Dd]$ in the standard year

8. Obszary Rozliczeniowe Ciepła Spalania. [@:] http://www.psgaz.pl/dlaklienta/18869/21361.
9. See: Wskaźniki emisji i wartości opałowe paliwa oraz typowe lata meteorologiczne i statystyczne dane klimatyczne dla obszaru Polski do obliczeń energetycznych budynków. [@:] http://www.mir.gov.pl/strony/zadania/budownictwo/dane-do-swiadectw-charakterystyki-energetycznej-budynkow.
10. Data published at http://www.wunderground.com/.

(Dopke 2014) and for a given year that were calculated based on the Hitchin formula (Degree-Days: Theory and... 2006):

$$Sd(t_b) = \sum_{i=1}^{9} Sd(t_b)_m = \frac{t_b - t_{śr}}{1 - e^{-k\cdot(t_b - t_{śr})}} \cdot L_m, \tag{2}$$

where:

$Sd(t_b)$ — number of degree-days of the heating season (°Cd),
$Sd(t_b)m$ — number of degree-days for a given month of a heating season (°Cd), according to methodology (Resolution 2008, 2014) a heating season lasts for 9 months (i.e., from January to May and from September to December),
t_b — assumed base temperature (15°C) (Dopke 2012),
$t_{śr}$ — average monthly temperature (°C),
k — constant, to Cracow = 0,821 (Dopke 2011),
L_m — number of days in a month (d).

The number of degree-days in the standard heating season $Dd(tb)_0$ is 3 615,9 (°Cd), while in years 2012, 2013, 2014 was adequately $Dd(tb)_i$: 2 789,1; 2 766,9; 2 422,6 (°Cd) which gives an average of 3 years on the level of 2 659,5 (°Cd). Comparing the results we can note that the number of degree-days of a standard season is greater on average about 36% of the time in comparison with the number degree-days in the measured period (years 2012–2014).

Energy consumption was calculated by four methods. They were defined as follows:

A — the method based on the actually consumed quantity of energy
B — the calculative method compatible with the methodology of 2014
C — the calculative method compatible with the methodology of 2008, and additionally
D — the method based on actual quantity of consumed energy, counted for standard seasonal conditions

2 Results of the research and analysis

Calculations that were done allowing for the definition of seasonal demand for usable, final and initial energy for heating and h.u.w. preparation. In the method based on real energy consumption it was necessary to separate two fluxes of energy: usable and initial. It was necessary in turn to define usable and initial energy consumed for heating and h.u.w. preparation. In summer months (i.e., June, July, August, natural gas was consumed strictly to prepare h.u.w.). So one can precisely estimate final energy consumption $Q_{K.W}$ for this period. It was assumed in calculations that in the months of the heating season final energy $Q_{K.W}$ that serves to prepare h.u.w. will be an average value of the three month of the summer season. This provided a way to calculate usable and final energy consumption according to the methodology contained in attachment 2 regulation.

The results of a calculation for annual demand for final energy $Q_{K,H}$, $Q_{K.W}$ dividing for processes were compared in table 2, while demand for usable energy $Q_{H,nd} + Q_{W,nd}$ and initial energy $Q_{P,H} + Q_{P,W}$ for the analyzed building was done in the table 3. In this table were also compared values of the unit indicator for the demand for initial energy IE. For comparison the method based on real energy consumed with the calculation methods relative error was defined according to the formula 3 and the results are shown in table 4.

$$\delta = \frac{|x_0 - x|}{x_0} \cdot 100, \tag{3}$$

where:

δ — relative error of the estimated final energy consumption (%),
x_0 — real value of the final energy consumption (kWh),
x — value of the final energy consumption estimated by the calculation method (kWh).

Annual final energy consumption for heating in the analyzed building runs from 7,9 to 12 MWh. The consumption delimited based on the method of actual consumed energy is 7,9 MWh, meanwhile after calculation based on a standard heating season with Formula 2 it is 10,8 MWh. For the

Tab. 3. Quantity of the demand for final energy for heating and preparation of hot usable water

Calculation method	Annual demand for final energy kWh		
	Heating: $Q_{K,H}$	Hot usable water: $Q_{K,W}$	Total: $Q_{K,H} + Q_{K,W}$
A	7 952,4	4 061,6	12 014
B	12 058,0	5 136,0	20 320
C	11 983,0	3 094,0	16 648
D	10 851,4	4 061,6	14 913

preparation h.u.w. it runs from 3 to 5 MWh. Annual demand for final energy for heating and h.u.w. preparation runs from 12 to 20,3 MWh. The calculation results for demand for final energy defined by the method based on the real energy consumption and the calculation methods served to define the value of the relative error of estimating δ (tab. 4) for three premises that were as follows:

- the comparison of the real final energy consumption for the preparation of h.u.w. $Q_{K.W}$ with the results obtained from the methodologies of 2014 and 2008
- the comparison of the real final energy consumption for heating $Q_{K,H}$ (real energy consumption and counted for a standard season) with the results obtained from calculations in the methodologies of 2014 and 2008,
- the comparison of the real final energy consumption for heating and h.u.w. preparation $Q_{K,H}$ (the real energy consumption calculated for a standard season) with the results obtained by the calculations contained in the methodologies of 2014 and 2008. Analyzing the results obtained in table 4 one can affirm that in the case of h.u.w. preparation the discrepancy between the real and calculated demand for final energy is ca. +/— 20% while in the method based on the methodology of 2014 consumption of water is reappraised, while in the method contained in the methodology of 2008 it is underestimated

Tab. 4. Values of relative estimating of error comparing the methods of the calculations of final energy consumption

Calculation method	δ%				
	A/D ($Q_{K,W}$)	A ($Q_{K,H}$)	D ($Q_{K,H}$)	A ($Q_{K,H} + Q_{K,W}$)	D ($Q_{K,H} + Q_{K,W}$)
B	26,5	51,6	11,1	69,1	36,3
C	23,8	50,7	10,4	38,6	11,6

These discrepancies result first of all from the individual method of using h.u.w. by consumers. A no less important aspect of the comparison is the difference between the two calculation methods. This difference is as much as 50%. The only explanation is the method of estimation of consumption of h.u.w., where the methodology of 2008 accepts values of unit water consumption per person while in the newest methodology this consumption is related to the building usable area — so it has nothing in common with the quantity of users.

In the case of comparing demand for final energy for building heating we can notice a great discrepancy between the values of errors. Comparing consumption based on real energy consumption with calculating methods this error is about 50% while correction of the value of actual consumed energy in conditions of a standard season and compared this way obtained results with a relative error of estimation on the of about 10% to 11%. The relatively low value of error comes from the fact that in this case every compared method (exploitative and calculative) compares energy consumption to standard conditions.

The value of the estimating error in the case of comparing the total energy consumption for heating and h.u.w. preparation is close to 70% if we compare the calculation method (by the methodology of 2014) to real energy consumption, while 36% while we relate it to the calculation conditions. Using the calculation methods contained in the methodology of 2008 gives better results. The estimated error in this case is from 38% (compared with the real energy consumption) to 11% (compared with the real consumption and calculation for standard conditions).

The quantity of the usable energy consumption and initial energy which additionally takes into consideration electric energy consumption supplied for the driving force of the auxiliary devices of the heating and h.u.w. preparation systems was put together in table 5. The electric energy consumption was counted according to the guidelines of the Regulation 2014. Depending on the calculation method seasonal needs for usable energy is from 8,9 MWh to 15,3 MWh while demand for non- renewable initial energy includes the interval from 14 MWh to 23 MWh.

Tab. 5. Quantity for annual demand for usable and initial energy

Calculation method	Year-long demand for energy		Coefficient of unit demand for initial energy
	Usable $Q_{H,nd} + Q_{W,nd}$	Initial $Q_{P,H} + Q_{P,W}$	$kWh/(m^2 \cdot year)$ IE
A	8 906	14 037,4	103,00
B	15 341	23 196,8	170,23
C	13 790	19 088,6	140,08
D	11 211	17 226,3	126,42

If we compare demand for initial energy with the building's usable area we'll obtain a synthetic indicator SI (i.e., unit demand for initial energy). For the analyzed building it ranges on a scope 103–170 $kWh/(m^2 \cdot year)$ depending on the method. Lesser values relate to the methods based on the real energy consumption and larger values to the calculation methods. Indicator value SI referred to the notes contained in Regulation 2013 "Technical terms that the building and its location should be matched to" as of 2014 (in abbreviation WT 2014 (TS2014) regarding the allowable value for detached houses IE_{max}. It gives an objective opinion for the building energy quality. According to WT2014 the indicator value should be 120 $kWh/(m^2 \cdot year)$. The value of energy characteristics for the analyzed building depending on the calculation method is shown in figure 1.

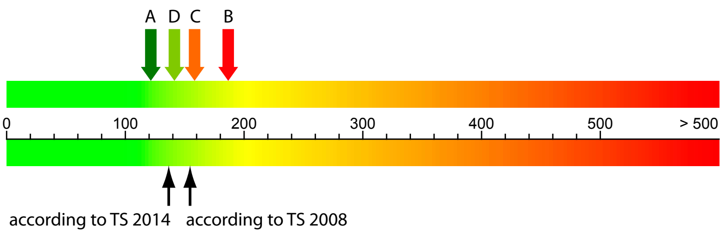

Fig. 1. Building energy characteristics

We can note a great discrepancy if we compare the indicator of unit demand for initial energy IE with a reference level IE max depending on the method used to establish building energy characteristics. The method used affects opinion as to whether this building will fulfill criteria of rules concerning the minimal demands for the IEmax indicator. It can influence technical acceptance for a newly built house. Using the method based on real energy consumption will show that this building undoubtedly will fulfill minimal demands. We can classify it even among the group of the energy-saving buildings. The problem will occur at the moment when energy characteristics will be established based on the calculation method according to the methodology of 2014. In this case it will occur if it has a higher IE indicator value that significantly surpasses the limit permitted by the rules and even though it will fulfill maximum value indicators of heat penetration for outer partitions U_{max} it won't obtain technical acceptation. If energy characteristic would be defined according to rules of the method of 2008, there would be better results. The value of the IE defined with the method based on the actual consumed quantity of energy and calculated on the conditions of a standard season insignificantly -6 $kWh/(m^2 \cdot year)$ surpasses the value of IE_{max}.

Conclusions

Comparative analysis of the method based on the actual consumed energy with the calculation methods for standard climatic conditions done in this study allowed for statement of the following conclusions.

Comparing demand for final energy for building heating we can notice a great discrepancy among the values of relative errors of estimation. If comparing consumption based on actual energy consumption with calculation methods the error is c. 50%, while the correction of actual consumed energy with standard seasonal conditions and compared this way obtained results with calculation methods gives a relative error of estimation on the level of c. 10 to 11%.

The value of the estimating error comparing total energy consumption for heating and h.u.w. preparation is almost 70% if we compare the calculation method (by the methodology of 2014) with the real energy consumption and 36% when we compare it with the calculation conditions. Better results are obtained using calculation models contained in the methodology of 2008. The estimating error is then from 38% (compared with the actual energy consumption) to 11% (compared with the actual consumption calculated on the standard conditions).

Final energy consumption for hot usable water preparation in the exploitative method depends on the individual manner of use by consumers. In the analyzed building the discrepancy between real and calculated demand for final energy is ca. +/– 20%.

It depends on the method used to establish building energy characteristics whether the building fulfills criteria set down in the rules in relation to demands concerning the IEmax indicator. The building will fulfill demands if certificattion of energy characteristics is done based on the method based on real energy consumption. The problem will appear at the moment when energy characteristics are established on the base of the calculation method of 2014. In this case it will show that the building will have a higher indicator of the IE value. Thus it will significantly surpass the limit allowe by the rules and in spite of fulfilling demands concerning maximal values of coefficients of heat penetrating the outer partitions Umax, it won't accepted.

We are not able to accept the method suggested of defining energy characteristics based on the actual consumed quantity of energy if it doesn't compare with the note about the necessity of calculation results for standard seasonal conditions. For the climatic station Kraków-Balice the number of degree-days of a standard season is higher on average ca 36% compared with the number of degree-days in the calculation period (2012–2014 years).

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