Tomasz SZUL
University of Agriculture in Krakow
Department of Power Engineering and Automation of Agricultural Processes
ul. Balicka 116B, 30-149 Kraków, Poland
e-mail: Tomasz.Szul@ur.krakow.pl

THE INFLUENCE OF APPLIED HEAT SOURCES ON THE VALUE OF ENERGY PERFORMANCE OF BUILDING IN VIEW OF THE NEW REGULATIONS ON ENERGY EFFICIENCY

Summary

It was calculated energy performance of residential building which meets the requirements for heat-transfer rate for the building envelope, then the result was compared with the values of the maximum primary energy demand for heating, ventilation and usable water heating, for predicted time schedule (years: 2014, 2017, 2021) presented in a draft regulation on technical conditions obligatory for buildings and their location. Calculations were made for three variants of heating, i.e.: gas, coal and biomass. In addition, the calculations considered a variant in which hot water is prepared using a solar panel installation. Meeting performance requirements for buildings after the year 2014, and also after 2017 will be possible if a gas boiler and a biomass boiler are used, independently of solar panel set applied to prepare u.h.w. In case of coal heating, meeting the regulation on PE will be possible if hot water is prepared also by solar panel set. The maximum values of unit coefficient of demand for non-renewable PE after 2021 will cause that building equipped in a coal-fired boiler will not meet the requirements, even if the solar panel set is used for hot water preparation. In the case of heating using gas boiler, meeting regulations will be possible only when hot water will be prepared with a solar panel set.
***Key words**: energy consumption in buildings, comparison of energy performance EP, energy standards of residential buildings*

WPŁYW ZASTOSOWANEGO ŹRÓDŁA CIEPŁA NA CHARAKTERYSTYKĘ ENERGETYCZNĄ BUDYNKU MIESZKALNEGO W ŚWIETELE NOWYCH REGULACJI DOTYCZĄCYCH EFEKTYWNOŚCI ENERGETYCZNEJ

Streszczenie

Obliczono charakterystykę energetyczną dla przykładowego budynku mieszkalnego jednorodnego, który będzie spełniał planowane wymagania dotyczące ochrony cieplej przegród zewnętrznych (Umax), a następnie porównano ją z maksymalnymi wartościami wskaźnika zapotrzebowania na energię pierwotną EP_{H+W} na potrzeby ogrzewania, wentylacji i przygotowania ciepłej wody użytkowej, zgodnie z harmonogramem czasowym (rok: 2014, 2017, 2021) przedstawionym w projekcie rozporządzenia dotyczącego warunków technicznych, jakim powinny odpowiadać budynki i ich usytuowanie. Obliczenia wykonano dla trzech wariantów ogrzewania tj. gazowego, węglowego oraz na biomasę. Dodatkowo w obliczeniach uwzględniono wariant, w którym ciepła woda użytkowa jest przygotowywana za pomocą instalacji solarnej. Spełnienie wymagań stawianych budynkom w po roku 2014, a także po 2017 będzie możliwe w przypadku zastosowania kotła gazowego, oraz na biomasę niezależnie od tego czy będzie zastosowany zestaw solarny do przygotowania c.w.u. W przypadku zastosowania ogrzewania węglowego, spełnienie przepisów dotyczących $EP_{H+W(max)}$ będzie możliwe pod warunkiem, że ciepła woda użytkowa będzie przygotowywana dodatkowo przez zestaw solarny. Wartości graniczne jednostkowego współczynnika zapotrzebowania na nieodnawialną energię pierwotną $EP_{H+W(max)}$ po roku 2021 spowodują, że budynek wyposażony w węglowe źródło ciepła nie spełni wymagań, nawet w przypadku zastosowania zestawu solarnego do przygotowania ciepłej wody użytkowej. W przypadku ogrzewania wykorzystującego kocioł gazowy, wypełnienie warunku zapisanego w rozporządzeniu będzie możliwe jedynie wtedy, gdy ciepła woda użytkowa będzie przygotowywana za pomocą zestawu solarnego.
***Słowa kluczowe**: zużycie energii w budynkach, standardy energetyczne budynków, wskaźnik jednostkowego zapotrzebowania na energię pierwotną EP*

1. Introduction

Energy consumption by European buildings sector accounts for about 45% of the total energy needs of the European Union, whereas 50% of atmospheric air pollutants comes from this sector [1]. According to [4], buildings sector uses 35.3% of energy final demand. In order to improve the efficiency of energy consumption for heating and air-conditioning in buildings and to reduce greenhouse gas emission, the European Parliament and the Council adopted Directive 2002/91/EC [5] on the energy performance of buildings. On 19May, 2010 it was replaced by Directive 2010/31/UE [6] to strengthen the previous provisions. Lower energy consumption and wider use of renewable energy sources should lead to better safety of energy supplies and supporting technical development in respective countries. Limiting energy consumption and the use of energy from renewable sources in the residential buildings sector is a priority in the European Union member states. These measures allow for an efficient and sustainable use of fossil fuels potential and for reducing emission of gaseous and particulate pollution originating in the process of fuel burning. Constantly increasing prices of energy generating products also necessitate an improvement of energy performance of a building, particularly a newly constructed one. The measures determined in the directive should contribute to an improvement of energy performance of buildings in Poland. Materials presented in the specialist journals illustrate the state of energy demands for the existing and designed buildings in Poland. Analyses presented in the papers [2, 7, 8, 19] reveal that a mean value of final energy demand indicator in Poland fluctuates, depending on the kind of building, from 85.80 to 343.69 [kWh/(m^2· year], however single family and multiplex houses reach values much high than the European average. In residential buildings the most significant area of final energy consumption is heating, which accounts for 76% of the total consumption. Modernisation of the heating system and minimising heat losses may improve energy efficiency in residential buildings. Analyses conducted in Poland [3] demonstrated that the obligatory technical conditions [15] do not guarantee energy consumption on an optimal, energy-efficient level. On the basis of certificates issued in 2009 and 2012 it has been stated that fulfilment of the condition of the required value of non-renewable primary energy (PE) consumption does not guarantee rational use of energy or heat. Anyways, among single family or multiplex houses, on average 38% of buildings meet the requirements for limit PE condition indicator [14]. It results from an alternative regulation of technical conditions which allows to fulfil the requirement of energy consumption on a rationally low level in two ways. In compliance with art.329 WT2008, par.2, item 1 and 2 [15], meeting the boundary condition for PE value as energy efficiency condition is considered equivalent to meeting the requirements for thermal insulation of the building, i.e. heat load. Implementation of the Union regulations has been incorporated into Polish legislation. Toughened and specified requirements concerning heat retention for newly designed residential buildings were determined in a draft amending the regulation about technical conditions for buildings and their location [17]. Amended regulation determines among others time schedule and minimal values of heat transfer coefficient U_{max} for walls, floors on the ground, ceilings, flat roofs, windows, French windows and front doors, but also new standards for primary energy requirements expressed by PE indicator. Importantly, new regulations specify the requirements for energy consumption of newly commissioned buildings. So, art.328, par.1 shall read: a building and its heating, ventilation and hot usable water installations (...) should be designed and constructed so that the amount of heat, cool air and electricity necessary for the building functioning met the minimum requirements. The requirements are considered as fulfilled if (329):

1) the value of PE indicator [kWh·(m^2·year)$^{-1}$] determining the annual calculated requirement for primary energy for heating, ventilation, cooling and preparation of usable hot water (…) calculated according to the regulations concerning the methodology for calculating energy performance of buildings, is lower than the limit values stated in the regulations (Table 1),

2) the envelopes and installation technique of the building correspond to at least insulating power values stated in the regulations (Table 2).

It shows that in the light of amended regulations, each building commissioned for use will have to fulfil two criteria. So far it was enough if it met one of the two criteria, because of the “or” used the text of the regulation. More specific formulation of the regulations will require deeper than hitherto analyses, because the energy consumption of the building depends not only on the thermal insulation of its internal partitions, but also on the efficiency of technical systems used in the building and the fuels used. Therefore, the estimation must comprise several variants of heating systems, including those supported with the energy from renewable sources, to meet the requirements concerning the maximum value of the indicator of requirement for non-renewable primary energy (PE).

Table 1. Energy standards of residential buildings - statement of parameters [17]

No.	Specification	Maximum values of PE_{H+W} indicator for heating, ventilation and hot water preparation [kWh•(m^2•year)$^{-1}$]		
		From 1 January 2014	From 1 January 2017	From 1 January 2021
1	Single family house	120	95	70
2	Multiplex house	110	90	70

Source: own study

Table 2. Time schedule and limits of heat transfer coefficient U for the envelope

No.	Specification	Heat transfer coefficient U_{max} [W•(m^2•K)$^{-1}$]		
		From 1 January 2014	From 1 January 2017	From 1 January 2021
1	External walls	0.25	0.23	0.20
2	Roofs, flat roofs and ceilings under non-heated attics or over passages	0.2	0.18	0.15
3	Floors on the ground	0.3	0.3	0.3
4	Ceilings over non-heated rooms	0.25	0.25	0.25
5	Windows (except roof windows), French windows and non-opening transparent surfaces	1.3	1.1	0.9
6	Roof windows	1.5	1.3	1.1
7.	Doors in the interior particles	1.7	1.5	1.3

Source: own study

2. Aim and scope of the work

The objective of the paper is calculation of energy performance (determined by PE indicator) for a residential building, which will meet the requirements of heat retention by envelopes (U_{max}), and then comparing it with the maximum values of PE indicator for the needs of heating, ventilation and preparation of usable hot water, according to the time schedule presented in the draft regulation on the technical conditions which buildings and their location should meet.

The scope of the work comprises calculations of usable energy (UE), final energy (FE) and primary energy (PE) demand for three variants of heating system, i.e. central heating combined with:

- gas condensing boiler,
- automatic coal-fired boiler with retort furnace and

automatic boiler equipped with a biomass (oat grain) burning furnace.

The computations for the building assumed an additional source of heat, i.e. wood fired hearth with forced air system. These systems are not combined with one another. The following proportions of heat sources in the central heating system were assumed: the boiler 70%, the hearth 30%.

Usable hot water is prepared in a accumulator system, where two variants of heat source are:

- monovalent system with a boiler (c.h.+w.u.w) as a basic source of heat, preparing usable hot water all year round,
- bivalent system of usable hot water preparation a boiler (c.h +u.h.w) and a solar panel set with flat collectors. During the heating season water is heated only by the boiler, whereas after the season it is heated by the solar panel set.

3. The object of research and the computation method

The simulation research was conducted on a detached single family house with a natural ventilation system inhabited by four persons. Its usable floor area, with regulated temperature A_f is 141 m^2, volume V_e = 484 m^2. The building compactness indicator A/V_e is 0.78 [1/m].The building is situated in the third climatic zone. Figures 1-2 present horizontal sections of the ground floor and attic, and the vertical section of the building with the basic dimensions.

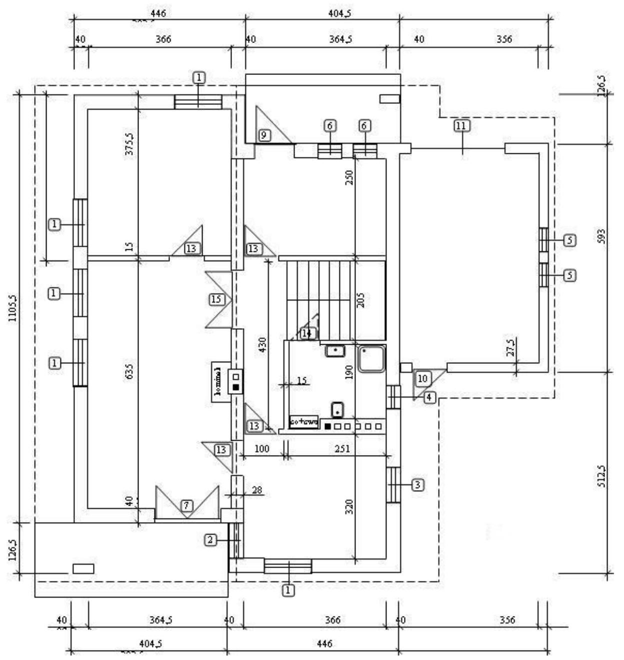

Fig. 1. Ground floor projection

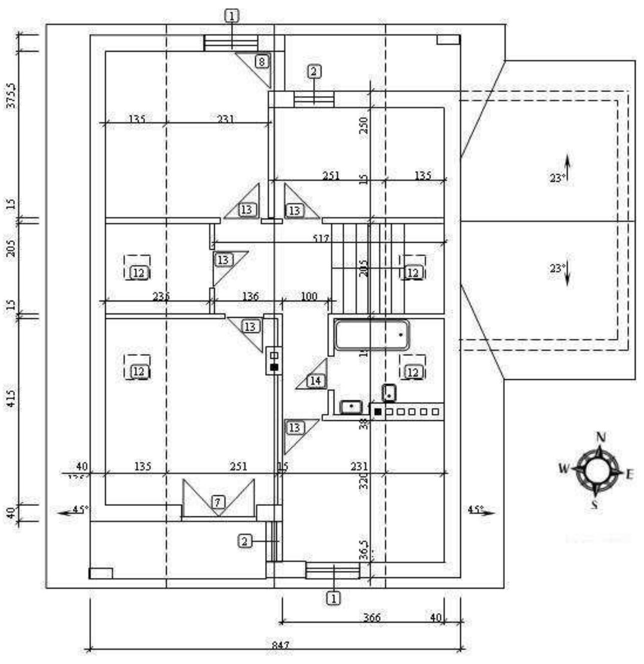

Fig. 2. Attic projection

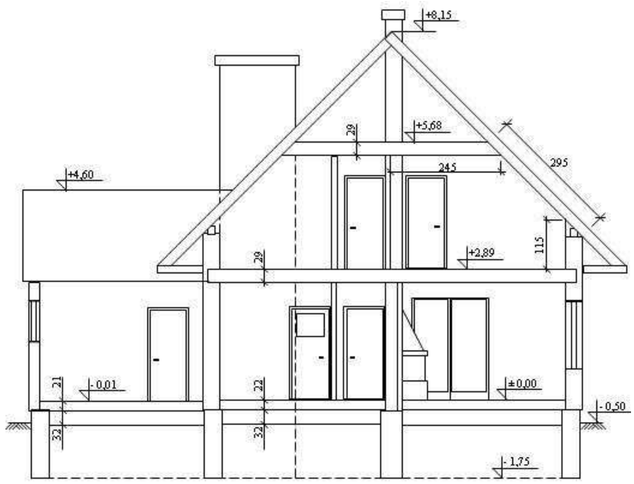

Fig. 3. Vertical section of the building

The external walls of the building are constructed from foamed concrete blocks with a density of 400kg/m^3, and 60cm long, 36.5cm wide and 20cm high. The walls are covered using thin joint masonry, with and additional outer insulating layer of rock wool covered by a glue layer with reinforced fabric and thin coat plaster. The internal lime and cement plastering is a traditional one, c.a.1.5cm thick. The internal walls are built of chequer bricks and covered on both sides by a lime and cement plaster. The wall on the ground floor, situated on the building axis is the supporting wall, supporting the ceiling in the central part. It is built of brick and after plastering is 28cm thick. The ceiling over the ground floor is constructed as a monolithic reinforced concrete slab, insulated from the top by a styrofoam layer. The knee wall and gable walls are constructed in the same way as the basic external wall described above. The gable walls are masonry walls up to the collar beams. The house has a rafter framing (8x16cm) with collar beams (5x20cm) fastened in pairs on both sides of the rafter. The thermal insulation between the rafters is made of 15cm thick rock wool with an additional layer of wool on the level of gypsum and cardboard slab supporting framework. Traditional ceramic tiles are lain in the outer layer of the hipped roof. The wooden ceiling over the attic is insulated in the same way as the hipped roof. Zero concrete floor is lain on a gravel bed and insulated from above by a styrofoam layer and then by a cement floor and floor panel.

Energy performance of the building was computed using the methodology described in the Decree of the Minister of Infrastructure, Journal of Laws, No.201, item 1240 [16]. Heat transfer coefficient was computed according to the standard PN-EN ISO6946 [10] so that its value was lower or equal to U_{max} limit value (Table 2). Therefore, the thickness of insulation layer on the walls and under rafters on the plane of supporting framework was changed for individual variants. Heat losses to the ground were established on the basis of PN-EN ISO 13370:2008 [13]. Heat transfer coefficients for windows and doors were calculated precisely in compliance with PN-EN ISO 10077-1:2007 [11] and linear heat loss coefficients ψ for thermal bridges – with reference to the outer dimensions, using numerical calculations, in compliance with PN-EN ISO 1021:2008 [12]. Ventilation airflow was determined on the basis of Polish standard PN-83/B-03430/AZ3:2000 [9]. Efficiency of central heating and water heating installations was adopted according to the Journal of Laws, No. 201, item 1240 [16]. The volume of hot water container (250 dm^3) and the minimum surface of flat solar collectors (3.4 m^2) were determined on the basis of [18]. The heat demand necessary for hot water preparation by the solar installation (for the Kraków-Balice meteorological station) was calculated using KOLEKTOREK 2.0 computer programme.

4. Results and discussion

On the basis of calculations made for the analyzed residential building, a unit consumption of usable (UE) and final (FE) energy was estimated for individual heating variants. The results of computations were compiled in Table 3.

Usable energy consumption by the building after 2021 will be lower by 32% as compared with 2014. Usable energy (UE) demand indicator will be changing from 97 to 66 [kWh•(m^2•year)$^{-1}$]. Final energy consumption depends on the applied heating variant. The lowest indicator of final energy consumption characterizes the building heated by a gas condensing boiler and, depending on the assumed reference period, FE indicator value changes from 123 to 86 [kWh•(m^2•year)$^{-1}$]. The highest final energy consumption was noted for the building equipped with automatic boiler with biomass burning furnace; in this case FE indicator value will fluctuate from 142 to 103 [kWh•(m^2•year)$^{-1}$].

Subsequently, the calculations determined the non-renewable primary energy (EP) demand indicator which was then compared with the recommendations stated in the amended regulations concerning $EP_{H+W\ (max)}$. Results of calculations for the successive time intervals, for which the regulations determined the maximum values of non-renewable primary energy demand indicator $EP_{H+W\ (max)}$, were presented in Figures 4-6.

Demand for non-renewable primary energy for heating and hot water preparation expressed by means of $PE_{H+W\ (max)}$ indicator for the analyzed residential building, whose envelopes meet the requirements of the maximum U_{max} coefficient value, will be fulfilled if a gas condensing boiler or an automatic boiler with biomass burning furnace is installed, irrespectively of the application of solar panel set for usable hot water preparation. If a coal heating is applied, meeting the requirements concerning $EP_{H+W\ (max)}$ will be possible in a bivalent system (coal fired boiler + solar panel set). It refers to the regulations coming into force from January 2014 (Fig. 4) and their toughened version in 2017 (Fig. 5).

Presented Figures show a considerable difference between the values of EP for biomass boiler and gas or coal-fired boilers. It is due to the fact, that the methodology of calculating building energy performance biomass as a renewable energy source, is determined by a coefficient of non-renewable primary energy outlay on generating and supply of energy source material to the building "w_1" of the value of 0.2, whereas the coefficient for gas is higher, i.e.1.1 [7].

Table 3. Usable and final energy demand indicators according to the regulations on energy standards

No.	Specification	Unit energy demand indicator	Energy standard from 1 January 2014	Energy standard from 1 January 2017	Energy standard from 1 January 2021
1	Building heated by gas boiler	UE [kWh•(m^2•year)$^{-1}$]	97	72	66
		FE [kWh•(m^2•year)$^{-1}$]	123	92	86
2	Building heated by coal fired boiler	UE [kWh•(m^2•year)$^{-1}$]	97	72	66
		FE [kWh•(m^2•year)$^{-1}$]	138	108	102
3	Building heated by biomass boiler	UE [kWh•(m^2•year)$^{-1}$]	97	72	66
		FE [kWh•(m^2•year)$^{-1}$]	142	111	103

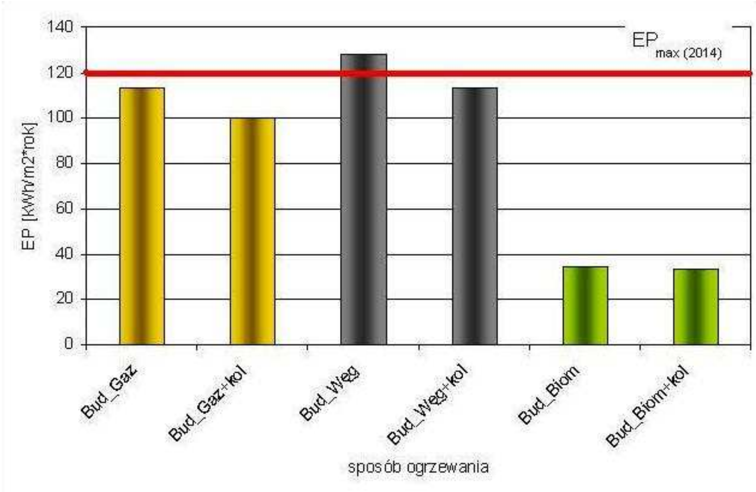

Fig. 4. Comparison of energy performance EP for different heating systems with maximum values of $EP_{H+W\ (max)}$ obligatory from 2014

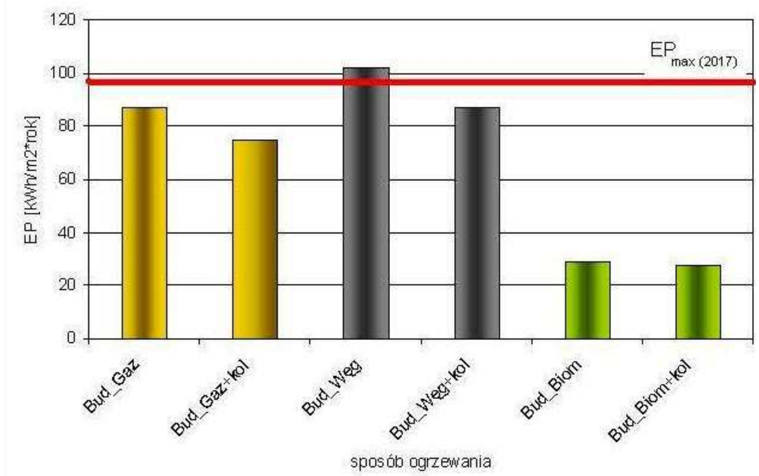

Fig. 5. Comparison of energy performance EP for different heating systems with maximum values of $EP_{H+W\ (max)}$ obligatory from 2017

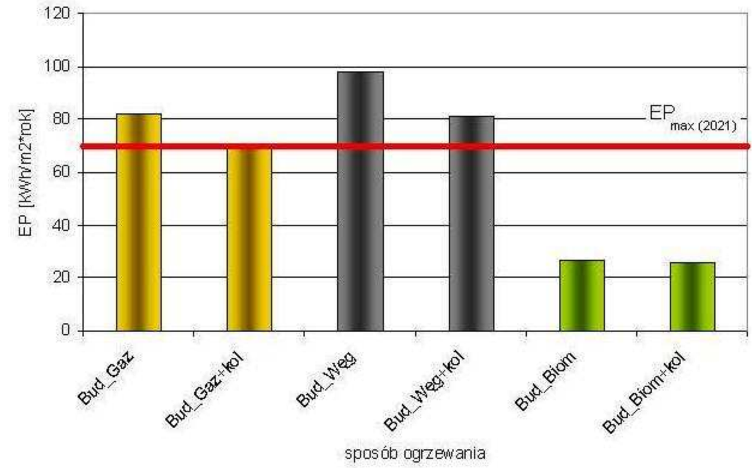

Fig. 6. Comparison of energy performance EP for different heating systems with maximum values of $EP_{H+W\ (max)}$ obligatory from 2021

Toughening of the regulations on $EP_{H+W\ (max)}$ after 2021 (Fig.6) will result in the fact that the building equipped with coal burning source of heat will not meet the rigorous requirements of EP≤ 70 [kWh•(m^2•year)$^{-1}$], even when the solar panel set for water heating is applied. In the variant when gas condensing boiler is used for building heating, the requirements will be satisfied only if water is heated in the bivalent system (gas boiler +solar panel set). When biomass burning source of heat is applied, PE coefficient value is approximately three times lower than the permissible $EP_{H+W\ (max)}$ value.

5. Conclusions

- Unit usable energy (UE) demand indicator will be changing from about 97 [kWh•(m^2•year)$^{-1}$]for the building constructed according to the standard planned for 2014 to 66 [kWh•(m^2•year)$^{-1}$] for the house built in compliance with the regulations after 2021.

- Final energy (FE) demand indicator depends on the applied heat source and will be changing during the time interval adopted in the regulations from 123 to 86 [kWh•(m^2•year)$^{-1}$] for gas condensing boiler; from138 to 102 [kWh•(m^2•year)$^{-1}$], when an automatic coal fired boiler with retort furnace is installed and from 142 to 103 [kWh•(m^2•year)$^{-1}$] when an automatic boiler with biomass burning furnace is used.
- Fulfilling the conditions concerning the maximum value of non-renewable primary energy demand indicator $PE_{H+W\ (max)}$ obligatory from January 2014, but also after 2017, will be possible if a condensing gas boiler is applied, irrespective of the application of solar panel set for water heating. In case when coal fired heating system is used, meeting the requirements specified for $EP_{H+W\ (max)}$ will be possible on condition that hot water will be prepared in a bivalent system (coal fired boiler + solar panel set).
- Limit values of unit non-renewable primary energy (EP) demand coefficient $PE_{H+W\ (max)}$ after 2021 will cause that the building equipped with a coal fired source of heat will not satisfy the rigorous demands EP≤ 70 [kWh•(m^2•year)$^{-1}$], even if a solar panel set is installed for heating usable water. In case of heating system using gas condensing boiler, the regulations will be obeyed if hot water will be prepared in a bivalent system (gas boiler + solar panel set).
- The building in which the heat source will be automatic boiler with biomass burning furnace will comply with all demands concerning the maximum value of $EP_{H+W\ (max)}$, irrespectively of the year in which they are in force. It results from advantageous provisions in the Decree of the Minister of infrastructure on the methodology of estimating energy performance of buildings, where biomass is promoted as a clean fuel.

6. Bibliography

[1] Ballarini, Corrado: Application of energy rating methods to the existing building stock. Analysis of some residential buildings in Turin. Energy and Buildings, 2009, 41(7), 790-800.

[2] BuildDesk Analytics. Czy budynki w Polsce są energooszczędne? Doradca energetyczny, 2010, nr 1.

[3] BuildDesk Polska.Warunki techniczne na przekór efektywności energetycznej. Energia i Budynek, 2011, nr 3.

[4] Chan, Riffat, Zhu: Review of passive solar heating and cooling technologies. Renewable and Sustain. Energy Rev., 2010, 14(2), 781-789.

[5] Dyrektywa Parlamentu Europejskiego i Rady 2002/91/UE z dnia 16 grudnia 2002 r. w sprawie charakterystyki energetycznej budynków.

[6] Dyrektywa Parlamentu Europejskiego i Rady 2010/31/UE z dnia 19 maja 2010 r. w sprawie charakterystyki energetycznej budynków.

[7] Kukla, Liszka, Wojtulewicz: Raport (cz. 1) – Analiza potencjału zmniejszenia zużycia energii w nowych budynkach w wyniku zastosowania wyższych standardów w zakresie izolacyjności przegród zewnętrznych. Energia i Budynek, 2010, nr 1-2.

[8] Kukla, Liszka, Wojtulewicz: Raport (cz. 2) – Analiza potencjału zmniejszenia zużycia energii w nowych budynkach w wyniku zastosowania wyższych standardów w zakresie izolacyjności przegród zewnętrznych. Energia i Budynek, 2010, nr 3.

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

[10] EN ISO 6946. Komponenty budowlane i elementy budynku. Opór cieplny i współczynnik przenikania ciepła. Metoda obliczania.

[11] PN-EN ISO 10077-1:2007 Cieplne właściwości użytkowe okien, drzwi i żaluzji. Obliczanie współczynnika przenikania ciepła. Część 1: Postanowienia ogólne.

[12] PN-EN ISO 10211:2008 Mostki cieplne w budynkach. Strumienie cieplne i temperatury powierzchni. Obliczenia szczegółowe.

[13] PN-EN ISO 13370:2008 Cieplne właściwości użytkowe budynków – Wymiana ciepła przez grunt – metoda obliczania.

[14] Praca zbiorowa. Stan energetyczny budynków w Polsce, Raport, BuildDesk Polska, 2011. www.builddesk.pl

[15] Rozporządzenie Ministra Infrastruktury z dnia 6 listopada 2008 roku w sprawie warunków technicznych, jakim powinny odpowiadać budynki i ich usytuowanie (zmiana). Dz.U. Nr 201, poz. 1238.

[16] Rozporządzenie Ministra Infrastruktury z dnia 6 listopada 2008 r. w sprawie metodologii obliczania charakterystyki energetycznej budynku stanowiącej samodzielną całość techniczno-użytkowa oraz sposobu sporządzania i wzorów świadectw ich charakterystyki energetycznej. Dz.U. 2008 nr 201 poz. 1240.

[17] Rozporządzenie Ministra transportu, budownictwa i gospodarki morskiej. Projekt z dnia 13.02.2013: zmieniający rozporządzenie w sprawie warunków technicznych, jakim powinny odpowiadać budynki i ich usytuowanie. http//: bip.transport.gov.pl/.../projekty.../projekty.../px_08032013_dokument6.

[18] Recknagel, Schramek: Kompendium wiedzy. Ogrzewnictwo, klimatyzacja, ciepła woda, chłodnictwo - Recknagel, Sprenger, Schramek, Wyd. 3, 2008, Omni Scala.

[19] Szul T.: Charakterystyka energetyczna budynków mieszkalnych na terenach wiejskich Polski południowej. Technika Rolnicza Ogrodnicza Leśna, 2009, nr 2, s. 19-21.