Journal of
MECHANICAL and ENERGY
ENGINEERING

ISSN: 2544-0780 | e-ISSN: 2544-1671
Vol. 2(42) | No. 4 | December 2018 | pp. 317-328
DOI: 10.30464/jmee.2018.2.4.317

ENERGY AUDIT OF THE RESIDENTIAL BUILDING

Małgorzata SIKORA[1*], Krystian SIWEK[1],

[1*]Faculty of Mechanical Engineering, Department of Energy, Koszalin University of Technology, Raclawicka 15-17, 75-620, Koszalin, Poland, e-mail: malgorzata.sikora@tu.koszalin.pl

(Received 2 November 2018, Accepted 14 December 2018)

Abstract: One of the ways to reduce the energy consumption from conventional sources is the introduction of an energy audit, which aims to inform the owner / user of a building about its energy consumption and possible ways of its reduction. For this purpose, the coefficients EK (annual demand for final energy) and EP (the amount of non-renewable primary energy to satisfy the energy needs of the building) were introduced. Their maximum values are deter-mined in accordance with the regulations of the Minister of Infrastructure for each type of building covered by the energy audit obligation. Audit is an expertise designed to gain knowledge about energy consumption in a given building, a set of buildings, a system or an installation. It is to provide information on how to save an energy and their results. The following article presents the purpose and methodology of performing the energy audit for residential buildings.

Keywords:energy audit, primary energy EP, final energy EK, energetic efficiency, methodology

1. INTRODUCTION

Audit is an expertise designed to gain knowledge about energy consumption in the building, a set of buildings, a farm or an installation. It should provide information about ways of energy savings and their results. Performing an energy audit is called auditing. It is a set of activities covering the assessment of the existing state of energy use in the investigated building. A person who performs this type of audit is called an energy auditor. He is a specialist in the scope of technical means of saving energy and environmental protection as well as in the field of economic efficiency assessment of energy-saving investments, working as an independent, objective adviser [1, 2, 16]. It is import ant to be noted that the auditor is treated as an expert. His task, except the assessment of the existing state, is to propose the ways of saving energy, providing approximate costs of their introduction and the resulting profits.

One of the ways to reduce the costs of obtaining energy is the use of renewable energy sources. This direction of the power engineering is more popular for some time due to the innovativeness of this type of energy generation. What is more, it is a cost-effective method for people using buildings in which renewable energy sources are used. In addition, the European Union insists on development of RES in accordance with Directive 2009/28 / EC [4, 6]. The emphasize of the European Union is related to the amount of CO_2 emitted during energy production, which affects the deterioration of the natural environment state around the world from one year to another. High emission of greenhouse gases affects the growth of the ozone hole. This directive aims to completely reduce the consumption of energy from conventional sources by 20%. At the same time, this goals have been broken down into the partial-goals at the national levels, taking into account different starting positions of individual Member States [3]

Similarly to the White Book, the European Commission emphasizes in the directive the necessity to undertake actions to protect the environment, mitigate climate change and to fulfill the global RES target set by the White Book. In this case, it should be achieved by in-creasing energy production from renewable energy sources. In addition to the assumption of 20% of energy from renewable sources, the aim of the directive was also to reduce green-house gas emissions by 20% [8].

One of the ways to reduce energy consumption from conventional sources is the introduction of an energy audit, which aims to inform the owner / user of a building about its energy consumption and possible ways of its reduction. For this purpose, coefficients EK (annual demand for final energy) and EP (the amount of non-renewable primary energy to meet the energy needs of the building) were introduced. Their maximum values are deter-mined in accordance with the ordinances of the Minister of Infrastructure [7,10,11] for each type of building covered by the energy audit obligation.

The energy audit is performed by a person called an auditor in the form of a detailed report. There are currently various types of audits that can be divided as follows:

- due to the level of detail:
  - preliminary,
  - detailed,
- due to the position of the ordering person:
  - for the user (investor),
  - for the bank,
- due to the scope:
  - fragmentary (for a separate installation),
  - detailed (covering the entire facility and all issues related to it),
- due to the contractor:
  - performed by an auditor,
  - performed by an user (eg. in the case of mass shares),
- depending on the facility on which the audit is carried out:
  - a residential building,
  - industrial facility,
  - energy management of the community.

2. METHODOLOGY FOR CONDUCTING AN ENERGY AUDIT

The methodology of conducting the energy audit together with the example of energy performance certificates are presented in the Regulations of the Minister of Infrastructure [4,10,11]. These documents contain detailed formulas for determining the energy demand for specific purposes throughout the year.

The determination of energy efficiency can be divided into four stages. The individual stages are illustrated and described in the diagram shown in Figure 1. The first one consists in analyzing the current state of affairs. Depending on the type of audit, this stage will vary in steps of proceeding. If it is an audit of a designed building, calculations of the demand for particular types of energy should be carried out based on project data obtained from the investor. This type of audit is aimed at checking the compliance of the project with the requirements for newly constructed buildings.

In the case of an existing building (renovation audit), the procedure in stage I involves systematic collection of data, inspections of the tested object condition (analysis of thermal bridges and leaks in eg. using infrared camera) and consumption of media using various types of meters and sensors. Water, gas and electricity bills are also helpful in the analysis, allowing to determine the consumption of energy carriers and, as a result, the consumption of energy. In addition, reviewed should be to building partitions, the installation and the heat sources. The second stage of the audit is to determine the reliability of the data obtained. It consists in verifying the obtained data, determining the final energy consumption and primary energy from non-renewable sources. These values, after made the calculations are compared with limit values of EK and EP coefficients for a given type of building [13].

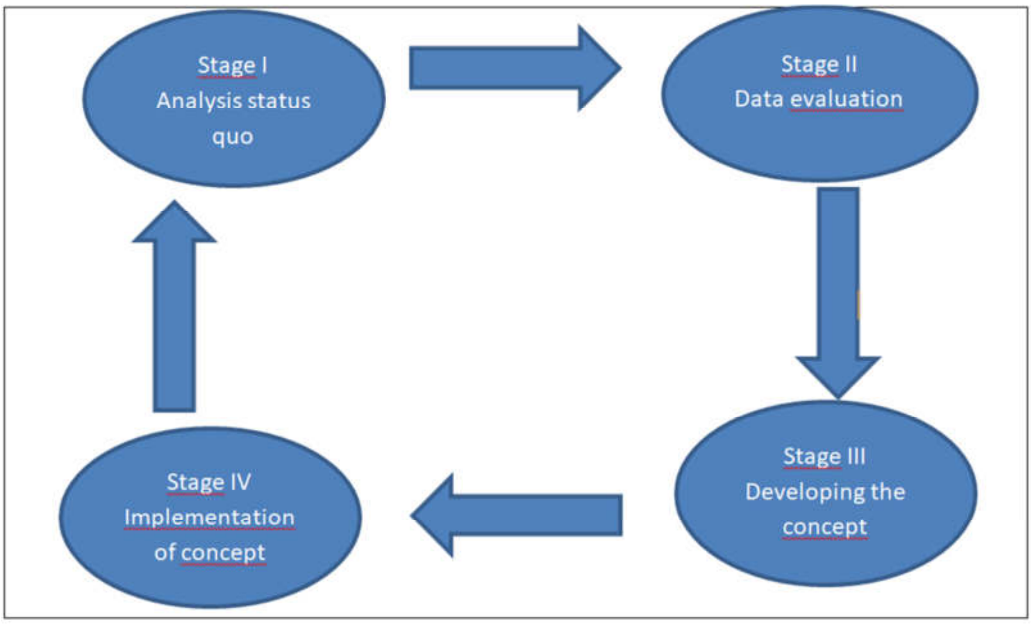


Fig. 1. The ideological scheme of methodology during proceeding of the energy audit of a building or its part [12]

Based on the audit results, the auditor is required to present several optional concepts that will allow the reduction of the EK and EP coefficients, presenting the results of the implementation of the concept, its costs and the possibility of co-financing from various sources. The next step is developing the concept. It consists in considering hypothetical threats in its implementation. Typical obstacles that interfere with the development of the concept are the lack of technical knowledge, negligible market knowledge, lack of time (unavailable contractors), lack of capital, limited information of decision makers, energy and technology costs, unallocated fixed costs. The last step is to implement the chosen concept. In the case of an enterprise, it proceeds according to the following stages: changing the company's vision in the area of energy, improving the energy management system, motivating and sensitizing employees, monitoring and controlling the energy management system [12].

2.1. Calculation of energy demand

The main values in the energetic audit of a single-family house are the demand of energy for heating and hot water preparing. The demand for usable energy for cooling and lighting in the case of a single-family home may be omitted. The cooling demand is calculated only if there is a cooling installation that supports more than one room, and for lighting purposes only in public buildings. Calculations aimed at determining the annual demand for final energy should be made as a ratio of the demand for usable energy (which is determined by a heat balance of building) by the seasonal efficiency of a given technical system. The calculations are aimed at estimation the demand of energy for heating purposes and are given by equation (1):

$$Q_{K,H} = \frac{Q_{H,nd}}{\eta_{H,tot}} \left[\frac{kWh}{year}\right], \quad (1)$$

where:

$Q_{K,H}$ – demand for usable energy (useful heat) for the building (residential premise) for heating, [kWh / year], $\eta_{H,tot}$ – average seasonal overall efficiency of the building's heating system.

In addition to the energy required for heating purposes, the preparation of hot water should also be taken into account using the dependence (2):

$$Q_{K,W} = \frac{Q_{W,nd}}{\eta_{W,tot}} \left[\frac{\text{kWh}}{\text{year}}\right], \quad (2)$$

where:

$Q_{W,Nd}$ – demand for useful heat to prepare hot water, [kWh / year], $\eta_{W,tot}$ – average seasonal total efficiency of the hot water preparation system.

All the formulas described so far lead to the calculation of the most important coefficient EK and EP. The final energy demand coefficient is calculated from the dependence (3):

$$EK = \frac{Q_{K,H}+Q_{K,W}}{A_f} \left[\frac{\text{kWh}}{\text{m}^2\cdot\text{year}}\right], \quad (3)$$

where:

A_f – heating or cooling area (with regulated temperature) of building or local, [m^2].

The coefficient of primary energy demand is calculated using the annual primary energy demand, which is the sum of energy demand for:

– heating,
– hot water preparation,
– cooling and ventilation for cooling rooms,
– lighting.

EP coefficient of the annual primary energy demand is calculated from the dependence (4):

$$EP = \frac{Q_p}{A_f} \left[\frac{\text{kWh}}{\text{m}^2\cdot\text{year}}\right], \quad (4)$$

where:

A_f – heating or cooling area (with regulated temperature) of building or local, $[m^2]$. Q_p – annual demand for primary energy.

The annual demand is calculated from formula (5):

$$Q_p = Q_{P,H} + Q_{P,W} + Q_{P,C} + Q_{P,L} \left[\frac{\text{kWh}}{\text{year}}\right], \quad (5)$$

where:

$Q_{P,H}$ – annual demand for primary energy through the heating and ventilation system for heating and ventilation, [kWh / year], $Q_{P,W}$ – annual primary energy demand by the system for preparing hot water, [kWh / year], $Q_{P,C}$ annual demand for primary energy through a cooling and ventilation system for room and air cooling, [kWh / year], $Q_{P,L}$ annual primary energy demand by a lighting system (only included in public buildings), [kWh / year] [8].

2.2. Energy demand of the building (gains and losses)

To determine the energy demand of the building, the energy balance of the building should be made. Taking into account the direction of the flow of energy balance components, they are divided into gains and losses. To the gains are included energy provided by the heat transfer through divisions, solar energy from insolation of transparent divisions in the form of windows, glazing or doors, and insolation of opaque partitions, energy from people in the room, thermal energy being a side effect of mechanical and electronic working devices located in the room. Energy losses include losses due to heat transfer through the partitions (winter), ventilation, and transmission losses (networks and installations) [8].

The pie chart presented in Fig. 2 shows the distribution of energy components brought to a single-family home. The largest part of the supplied energy is from fuel, then from the sun, and on the end energy of the person and the device. The largest part of the energy supplied is obtained due to the use of high energy raw material (fuel) or depending on the type of installation, from the use of electricity. The effect of using this energy is its conversion into the form of thermal energy. Solar energy is a much smaller percentage of energy in relation to fuel, most often it comes from insolation of transparent divisions.

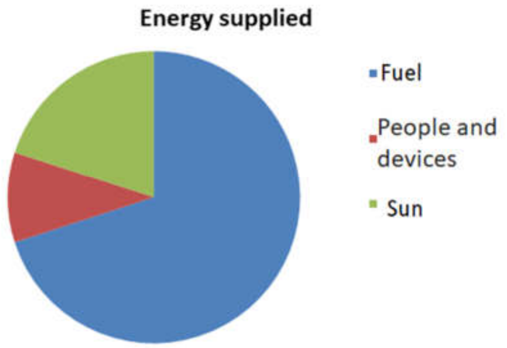


Fig. 2. Distribution of energy components supplied in the average house with an energy demand index of 150 kWh / (m2a), according to Reinmuth [9]

Fig. 3 presents a pie chart of thermal energy loss in a single-family home. The biggest part of losses comes from windows. These losses can be aggravated by the wrong selection of windows and their incorrect placement. In order to minimize heat loss through the windows, the spaces between the glass are filled with gas, in eg. argon. However, the most heat is conducted through the window frames.

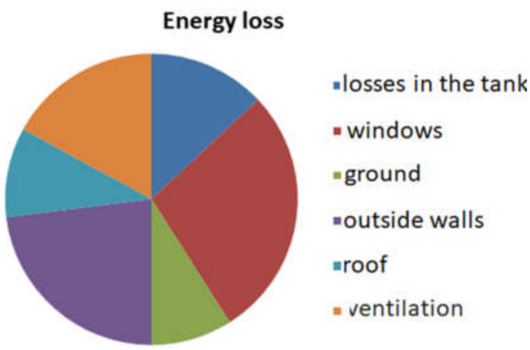


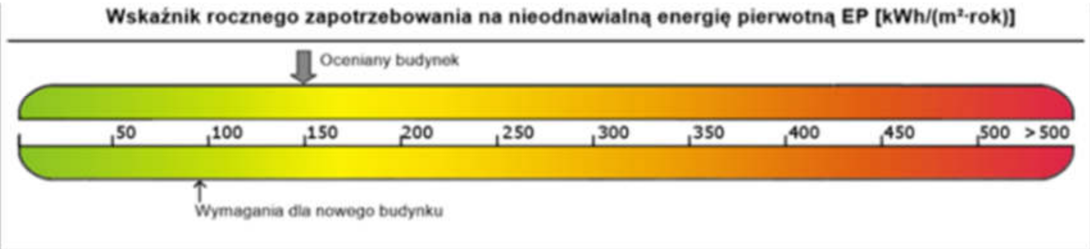
Fig. 3. Distribution of components of energy losses in the average home with an energy demand index of 150 kWh / (m2a), according to Reinmuth [9]

According to Fig.3, heat transfer through the partitions is the second largest heat loss. To reduce the amount of heat losses due to this, it is necessary to compensate thermal bridges and increase the thickness of wall insulation. There is a problem regarding the identification of a thermal bridge in a building partition. To detect thermal bridge, an infrared camera can be used. The higher the temperature difference between the inside of the house and the outside environment, the more visible is the bridge on the thermovision image. Therefore, the most favorable time of year for this type of diagnostics is winter.

Currently, the audit can be carried out using specialized programs such as ArCADIA-TERMOCAD from Intersoft, which allows to enter geometry and thermal parameters of the building and individual rooms in order to make a thermal balance of the building. The pro-gram contains climate data for individual zones of the country. The program also has an option to model the building in 3D where it has the ability to determine the thickness of the walls and the number of storeys, etc. The audit aims to improve the energy efficiency that can be obtained through thermo-modernization projects. Examples are: the improvement, which reduces the energy demand for heating and hot water preparing in residential buildings, complexes of buildings and buildings owned by local government units.

Another goal is to reduce the consumption of primary non-renewable energy. This objective can be obtained by making a technical connection to a centralized heat source, due to the liquidation of the local heat source, resulting in a reduction in the cost of acquiring heat delivered to the buildings. Another method is the total or partial change of energy sources to renewable sources or the use of high-efficiency cogeneration [15]. Figures 4 and 5 present the printout of the calculation results of the final energy demand coefficient EK, usable energy coefficient EU and nonrenewable primary energy coefficient EP from the ArCADia-TERMOCAD program. The printout also includes a graph of the permissible value of the EP coefficient. The figures show the results of an energy audit for the same building taking into account different energy sources. In the audit presented in Fig. 4, the coal-fired boiler was assumed as the source of heat, and the biomass boiler was used In building from figure 5.

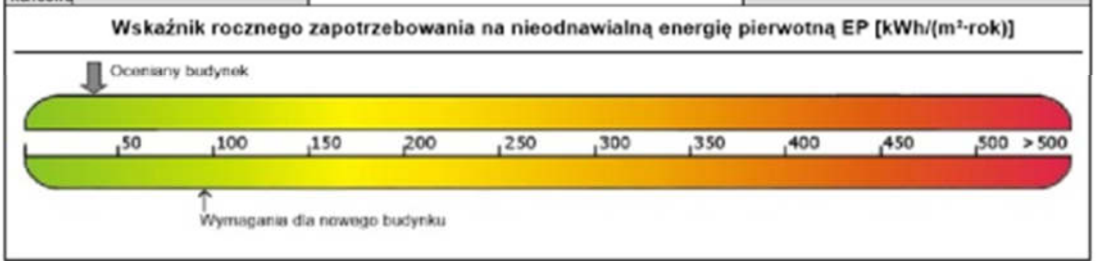
Figure 6-9 shows the printout of selected pages of the energy audit for the above-described building with a biomass boiler as a source of heat. The document contains, in addition to building data and calculated values of EK, EU and EP coefficients, the results of heat transfer coefficient U calculation for individual partitions as well as calculations for individual heating systems.



Obliczeniowa roczna ilość zużywanego nośnika energii lub energii przez budynek 12)			
System techniczny	**Rodzaj nośnika energii lub energii**	**Ilość nośnika energii lub energii**	**Jednostka/(m^2·rok)**
Ogrzewania	Miejscowe wytwarzanie energii w budynku - Węgiel kamienny	11,17	kg/(m^2·rok)
	Sieć elektroenergetyczna systemowa - Energia elektryczna	0,87	kWh/(m^2·rok)
Przygotowania ciepłej wody użytkowej	Miejscowe wytwarzanie energii w budynku - Węgiel kamienny	9,84	kg/(m^2·rok)
	Sieć elektroenergetyczna systemowa - Energia elektryczna	0,88	kWh/(m^2·rok)

Fig. 4. Printout of an energy audit fragment from the ArCADia-TERMOCAD program for a building with a coal-fired boiler

Ocena charakterystyki energetycznej budynku 10)		
Wskaźniki charakterystyki energetycznej	**Oceniany budynek**	**Wymagania dla nowego budynku według przepisów techniczno-budowlanych**
Wskaźnik rocznego zapotrzebowania na energię użytkową	EU= 57,3 kWh/(m^2·rok)	
Wskaźnik rocznego zapotrzebowania na energię końcową 11)	EK= 139,7 kWh/(m^2·rok)	
Wskaźnik rocznego zapotrzebowania na nieodnawialną energię pierwotną 11)	EP= 37,2 kWh/(m^2·rok)	EP= 95,0 kWh/(m^2·rok)
Jednostkowa wielkość emisji CO_2	E_{CO2}= 0,00059 t CO_2/(m^2·rok)	
Udział odnawialnych źródeł energii w rocznym zapotrzebowaniu na energię końcową	U_{OZE}= 98,76 %	



Obliczeniowa roczna ilość zużywanego nośnika energii lub energii przez budynek 12)			
System techniczny	**Rodzaj nośnika energii lub energii**	**Ilość nośnika energii lub energii**	**Jednostka/(m^2·rok)**
Ogrzewania	Miejscowe wytwarzanie energii w budynku - Biomasa	18,46	kg/(m^2·rok)
	Sieć elektroenergetyczna systemowa - Energia elektryczna	0,85	kWh/(m^2·rok)
Przygotowania ciepłej wody użytkowej	Miejscowe wytwarzanie energii w budynku - Biomasa	13,39	kg/(m^2·rok)
	Sieć elektroenergetyczna systemowa - Energia elektryczna	0,88	kWh/(m^2·rok)

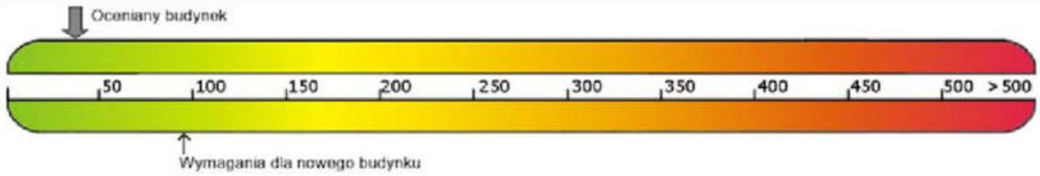
Fig. 5. Printout of an energy audit fragment from the ArCADia-TERMOCAD program for a building with a biomass boiler

ŚWIADECTWO CHARAKTERYSTYKI ENERGETYCZNEJ BUDYNKU	
Numer świadectwa 1)	1

Oceniany budynek		
Rodzaj budynku 2)	Mieszkalny	
Przeznaczenie budynku 3)	Dom jednorodzinny	
Adres budynku	78-220 Tychowo ul. Akacjowa 9	
Budynek, o którym mowa w art. 3 ust. 2 ustawy 4)	Tak	
Rok oddania do użytkowania budynku 5)	2002	
Metoda wyznaczania charakterystyki energetycznej 6)	metoda obliczeniowa dla przyjętego sposobu użytkowania i standardowych warunków klimatycznych	
Powierzchnia pomieszczeń o regulowanej temperaturze powietrza (powierzchnia ogrzewana lub chłodzona) A_f [m ^{2}] 7)	220,00 m ^{2}	
Powierzchnia użytkowa [m ^{2}]	220,00 m ^{2}	
Ważne do (rrrr-mm-dd) 8)	20.03.2023	
Stacja meteorologiczna, według której danych jest wyznaczana charakterystyka energetyczna 9)	Koszalin	

Ocena charakterystyki energetycznej budynku 10)		
Wskaźniki charakterystyki energetycznej	**Oceniany budynek**	**Wymagania dla nowego budynku według przepisów techniczno-budowlanych**
Wskaźnik rocznego zapotrzebowania na energię użytkową	EU= 57,3 kWh/(m^2·rok)	
Wskaźnik rocznego zapotrzebowania na energię końcową 11)	EK= 139,7 kWh/(m^2·rok)	
Wskaźnik rocznego zapotrzebowania na nieodnawialną energię pierwotną 11)	EP= 37,2 kWh/(m^2·rok)	EP= 95,0 kWh/(m^2·rok)
Jednostkowa wielkość emisji CO_2	E_{CO2}= 0,00059 t CO_2/(m ^{2}·rok)	
Udział odnawialnych źródeł energii w rocznym zapotrzebowaniu na energię końcową	U_{OZE}= 98,76 %	

Wskaźnik rocznego zapotrzebowania na nieodnawialną energię pierwotną EP [kWh/(m²·rok)]



Obliczeniowa roczna ilość zużywanego nośnika energii lub energii przez budynek 12)			
System techniczny	**Rodzaj nośnika energii lub energii**	**Ilość nośnika energii lub energii**	**Jednostka/(m^2·rok)**
Ogrzewania	Miejscowe wytwarzanie energii w budynku - Biomasa	18,46	kg/(m^2·rok)
	Sieć elektroenergetyczna systemowa - Energia elektryczna	0,85	kWh/(m^2·rok)
Przygotowania ciepłej wody użytkowej	Miejscowe wytwarzanie energii w budynku - Biomasa	13,39	kg/(m^2·rok)
	Sieć elektroenergetyczna systemowa - Energia elektryczna	0,88	kWh/(m^2·rok)
Chłodzenia	--	--	--
Wbudowanej instalacji oświetlenia 11)	--	--	--

Sporządzający świadectwo	
Imię i nazwisko: Krystian Siwek Nr wpisu do wykazu 13) Data wystawienia świadectwa: 20.03.2018	Podpis i pieczątka

ArCADia-TERMOCAD PRO 7.0 ArCADiasoft Chudzik sp. j. ul. Sienkiewicza 85/87, 90-057 Łódź, tel (42)689-11-11, e-mail: arcadiasoft@arcadiasoft.pl, www.arcadiasoft.pl
Licencja dla: student Krystian Siwek ;czasowa,niekomercyjna [L01]

Fig. 6. Selected cards of energy audit from the ArCADia-TERMOCAD program for a building with a biomass boiler (example 1)

ŚWIADECTWO CHARAKTERYSTYKI ENERGETYCZNEJ BUDYNKU	
Numer świadectwa 1)	1

Podstawowe parametry techniczno-użytkowe budynku	
Liczba kondygnacji budynku	4
Kubatura budynku [m ^{3}]	780,11m ^{3}
Kubatura budynku o regulowanej temperaturze powietrza [m ^{3}]	780,11m ^{3}
Podział powierzchni użytkowej budynku 14)	222 m powierzchni użytkowej, 78 m powierzchni nieużytkowej (strych, garaż)
Temperatury wewnętrzne w budynku w zależności od stref ogrzewanych	Pomieszczenia ogrzewane 20 stopni, pomieszczenia podpiwniczane nieogrzewane 12 stopni, garaż ogrzewany 12 stopni, strych nieogrzewany 12 stopni.
Rodzaj konstrukcji budynku	PBU-59

Przegrody budynku	Nazwa przegrody	Opis przegrody	Współczynnik przenikania ciepła przegrody U [W/(m ^{2}•K)]	
			Uzyskany	Wymagany 15)
	Balkon 90x235-Okno zewnętrzne	Szerokość: 0,9m, Wysokość: 2,35m	0,23	1,10
	BRAMA 240x220-Drzwi zewnętrzne	Szerokość: 2,4m, Wysokość: 2,2m	0,00	1,50
	D 1-Dach	Blacha trapezowa-ocynkowana (0,001 m, λ=50,000 W/(m•K)); Łaty (0,08 m, λ=0,200 W/(m•K)); Kontrłaty (0,02 m, λ=0,200 W/(m•K)); Folia dachowa paroprzepuszczalna (0,002 m, λ=0,019 W/(m•K)); Krokwie (0,2 m, λ=0,200 W/(m•K)); Blacha trapezowa-ocynkowana (0,001 m, λ=50,000 W/(m•K)); Folia dachowa paroprzepuszczalna (0,002 m, λ=0,019 W/(m•K)); Łaty (0,08 m, λ=0,200 W/(m•K))	0,61	0,70
	Drzwi front 16st-Drzwi zewnętrzne	Szerokość: 0,9m, Wysokość: 2m	0,23	1,50
	Drzwi pirwnica 8st-Drzwi zewnętrzne	Szerokość: 2,6m, Wysokość: 0,6m	0,45	1,50
	DW 1-Drzwi wewnętrzne	Szerokość: 0,9m, Wysokość: 2m	0,23	1,50
	łazienka 60x150-Okno zewnętrzne	Szerokość: 0,6m, Wysokość: 1,5m	0,23	1,10
	Okno dachowe 70x110-Okno połaciowe	Szerokość: 0,7m, Wysokość: 1,1m	0,23	1,30
	PG 1-Podłoga na gruncie	Pospółka (0,4 m, λ=1,950 W/(m•K)); Beton o średniej gęstości (0,1 m, λ=1,350 W/(m•K)); Papa asfaltowa na goraco (0,002 m, λ=0,175 W/(m•K)); Styropian (0,2 m, λ=0,045 W/(m•K)); Beton o średniej gęstości (0,1 m, λ=1,350 W/(m•K)); Płytki ceramiczne (0,005 m, λ=1,300 W/(m•K))	0,20	0,30
	Piwnica 90x40-Okno zewnętrzne	Szerokość: 0,9m, Wysokość: 0,4m	0,45	1,10
	Poddasze-Strop wewnętrzny	Tynk lub gładź cementowo-wapienna (0,005 m, λ=0,820 W/(m•K)); Płyta gipsowo kartonowa (0,01 m, λ=0,230 W/(m•K)); Wełna mineralna granulowana 40 (0,3 m, λ=0,050 W/(m•K)); Deska Dachowa (0,003 m, λ=0,033 W/(m•K))	0,16	0,18
	SG 1 pod ziemia - Ściana na gruncie	Tynk (0,2 m, λ=0,800 W/(m•K)); Styropian (0,05 m, λ=0,045 W/(m•K)); Papa asfaltowa izolacyjna gr	0,24	Bez wymagań

ArCADia-TERMOCAD PRO 7.0 ArCADiasoft Chudzik sp. j. ul. Sienkiewicza 85/87, 90-057 Łódź, tel (42)689-11-11, e-mail: arcadiasoft@arcadiasoft.pl, www.arcadiasoft.pl
Licencja dla: student Krystian Siwek ;czasowa,niekomercyjna [L01]

Fig. 7. Selected cards of energy audit from the ArCADia-TERMOCAD program for a building with a biomass boiler (example 2)

ŚWIADECTWO CHARAKTERYSTYKI ENERGETYCZNEJ BUDYNKU	
Numer świadectwa 1)	1

	wewnętrzna	λ=0,820 W/(m•K)); Bloczek betonowy komórkowy 590x120x240 (0,12 m, λ=0,140 W/(m•K)); Tynk lub gładź cementowo-wapienna (0,02 m, λ=0,820 W/(m•K))		
	SW 24cm -Ściana wewnętrzna	Tynk lub gładź cementowo- wapienna (0,02 m, λ=0,820 W/(m•K)); Bloczek betonowy komórkowy 590x240x240 (0,24 m, λ=0,140 W/(m•K)); Styropian 10 (0,1 m, λ=0,045 W/(m•K)); Tynk lub gładź cementowo-wapienna (0,02 m, λ=0,820 W/(m•K))	0,24	0,30
	Sypialnia 180x150-	Szerokość: 1,8m, Wysokość: 1,5m	0,23	1,10
	SZ 1 parter I piętro -Ściana zewnętrzna	Tynk strukturalny Cersit CT 36-ziarno 2,0 mm (0,002 m, λ=1,000 W/(m•K)); Styropian (0,15 m, λ=0,045 W/(m•K)); Bloczki betonowy komórkowy 590x240x240 (0,24 m, λ=0,190 W/(m•K)); Tynk ceramiczno-wapienny (0,02 m, λ=0,820 W/(m•K))	0,21	0,23
	SZ nad ziemia piwnica-Ściana zewnętrzna	Tynk mozaikowy (0,002 m, λ=0,300 W/(m•K)); Styropian (0,1 m, λ=0,045 W/(m•K)); Papa asfaltowa izolacyjna gr 5 mm (0,005 m, λ=0,180 W/(m•K)); Bloczek fundamentowy betonowy (0,24 m, λ=0,090 W/(m•K)); Tynk wapienno-piaskowy (0,02 m, λ=0,800 W/(m•K)); Gładź cementowo-wapienna (0,005 m, λ=0,820 W/(m•K))	0,20	0,23
	Tarasowe 180x235-	Szerokość: 1,8m, Wysokość: 2,35m	0,23	1,10
	Wykusz 236x150-	Szerokość: 2,36m, Wysokość: 1,5m	0,23	1,10
	Wykusz boczne 90x150-	Szerokość: 0,9m, Wysokość: 1,5m	0,23	1,10
System ogrzewania 16)	Elementy składowe systemu	Opis		Średnia sezonowa sprawność
	Nazwa źródła ciepła: Nowe źródło ogrzewania			
	Wytwarzanie ciepła	Kotły na biomasę (słoma), wrzutowe, z obsługą ręczną, o mocy do 100kW		0,60
	Przesył ciepła	C.o. wodne z lokalnego źródła ciepła usytuowanego w ogrzewanym budynku z zaizolowanymi przewodami, armaturą i urządzeniami, które są zainstalowane w przestrzeni ogrzewanej		0,96
	Akumulacja ciepła	Zasobnik ciepła w systemie ogrzewania o parametrach 70/55°C w przestrzeni ogrzewanej		0,93
	Regulacja i wykorzystanie ciepła	Ogrzewanie wodne z grzejnikami członowymi lub płytowymi w przypadku regulacji centralnej bez automatycznej regulacji miejscowej		0,77
System przygotowania ciepłej wody użytkowej 16)	Elementy składowe systemu	Opis		Średnia roczna sprawność
	Nazwa źródła ciepła: Nowe źródło ciepłej wody			
	Wytwarzanie ciepła	Węzeł cieplny kompaktowy z obudową, o mocy nominalnej do 100 kW		0,70
	Przesył ciepła	Centralne podgrzewanie wody — systemy z obiegami cyrkulacyjnymi z pionami instalacyjnymi nieizolowanymi i izolowanymi przewodami rozprowadzającymi		0,60
	Akumulacja ciepła	System przygotowania ciepłej wody użytkowej bez zasobnika ciepłej wody użytkowej		1,00
System chłodzenia 16)	Elementy składowe systemu	Opis		Średnia sezonowa sprawność

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Fig. 8. Selected cards of energy audit from the ArCADia-TERMOCAD program for a building with a biomass boiler (example 3)

ŚWIADECTWO CHARAKTERYSTYKI ENERGETYCZNEJ BUDYNKU	
Numer świadectwa 1)	1

Wskaźnik rocznego zapotrzebowania na energię użytkową EU [kWh/(m 2•rok)] 17)					
	Ogrzewanie i wentylacja	Ciepła woda użytkowa	Chłodzenie	Oświetlenie wbudowane	Suma
Suma [kWh/(m 2•rok)]	32,99	24,36	0,00		57,35
Udział [%]	57,52	42,48	0,00		100,00
Wskaźnik rocznego zapotrzebowania na energię użytkową EU: 57,35 [kWh/(m 2•rok)]					

Wskaźnik rocznego zapotrzebowania na energię końcową EK [kWh/(m 2•rok)] 17)					
Rodzaj nośnika energii lub energii	Ogrzewanie i wentylacja	Ciepła woda użytkowa	Chłodzenie	Oświetlenie wbudowane11)	Suma
Miejscowe wytwarzanie energii w budynku - Biomasa	79,98	58,00	0,00	0,00	137,98
Sieć elektroenergetyczna systemowa - Energia elektryczna	0,85	0,88	0,00	0,00	1,73
Suma [kWh/(m 2•rok)]	80,83	58,89	0,00	0,00	139,71
Udział [%]	57,85	42,15	0,00	0,00	100,00
Wskaźnik rocznego zapotrzebowania na energię końcową EK: 139,71 [kWh/(m 2•rok)]					

Wskaźnik rocznego zapotrzebowania na nieodnawialną energię pierwotną EP [kWh/(m 2•rok)] 17)					
Rodzaj nośnika energii lub energii	Ogrzewanie i wentylacja	Ciepła woda użytkowa	Chłodzenie	Oświetlenie wbudowane11)	Suma
Miejscowe wytwarzanie energii w budynku - Biomasa	16,00	11,60	0,00	0,00	27,60
Sieć elektroenergetyczna systemowa - Energia elektryczna	2,55	2,65	0,00	0,00	5,20
Suma [kWh/(m 2•rok)]	18,55	14,25	0,00	0,00	32,80
Udział [%]	56,55	43,45	0,00	0,00	100,00
Wskaźnik rocznego zapotrzebowania na nieodnawialną energię pierwotną EP: 37,16 [kWh/(m 2•rok)]					

Zalecenia dotyczące opłacalnej ekonomicznie i wykonalnej technicznie poprawy charakterystyki energetycznej budynku w zakresie 18)

1) przegród budynku w przypadku planowania robót budowlanych polegających na ociepleniu budynku, obejmujących ponad 25% powierzchni przegród zewnętrznych tego budynku

...

2) systemów technicznych w budynku w przypadku planowania robót budowlanych polegających na ociepleniu budynku, obejmujących ponad 25% powierzchni przegród zewnętrznych tego budynku

...

3) przegród budynku niezależnie od planowanych robót budowlanych, o których mowa w pkt 1

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Fig. 9. Selected cards of energy audit from the ArCADia-TERMOCAD program for a building with a biomass boiler (example 4)

3. SUMMARY

European Union directives are designed to force on Member States to reduce energy consumption, especially from non-renewable sources. They provide the basis and guidance for the legislation of the Member States of the European Union. Ways of achieving the set goal are not imposed on the Union, so each state has the possibility to implement projects in its own way. In Poland and in several other countries, one of the ways to achieve the goal of reducing energy consumption from non-renewable sources is to introduce energy audits of newly designed buildings as well as existing ones. The audit allows to determine if the de-signed building meets the standards related to low energy consumption set by the legislator. In the case of renovation audits, the project involves checking the condition of the building and installation, presenting ways to reduce energy consumption for heating and hot water preparing by carrying out thermo-modernization and reducing the consumption of primary non-renewable energy through the exchange of heat sources for renewable energy. On the basis of figures 4 and 5 can be determined a significant reduction of the EP coefficient value when as a heat source is using a biomass boiler. It fell by over 100 kWh/(m^2/year). Another indirect goal is to reduce CO_2 emissions. The reduction of energy consumption for heating purposes, especially those from fossil fuels, significantly reduces the emission of greenhouse gases. In addition to economic benefits, the energy audit of the building also brings environmental benefits [14].

Nomenclature

Symbols

$Q_{K,H}$ – Annual demand for final energy, $\left[\frac{\text{kWh}}{\text{year}}\right]$

$Q_{H,nd}$ – demand for usable energy, $\left[\frac{\text{kWh}}{\text{year}}\right]$

$\eta_{H,tot}$ – average seasonal overall efficiency of the building's heating system

$Q_{K,W}$ – energy required for heating purposes, (the preparation of hot water, $\left[\frac{\text{kWh}}{\text{year}}\right]$

$Q_{W,nd}$ – demand for useful heat to prepare hot water, $\left[\frac{\text{kWh}}{\text{year}}\right]$

$\eta_{W,tot}$ – average seasonal total efficiency of the hot water preparation system

A_f – heating or cooling area (with regulated temperature) of building or local, [m^2].

Q_p – The annual demand, $\left[\frac{\text{kWh}}{\text{year}}\right]$

$Q_{P,H}$ – annual demand for primary energy through the heating and ventilation system for heating and ventilation, $\left[\frac{\text{kWh}}{\text{year}}\right]$

$Q_{P,W}$ – annual primary energy demand by the system for preparing hot water, $\left[\frac{\text{kWh}}{\text{year}}\right]$

$Q_{P,C}$ – annual demand for primary energy through a cooling and ventilation system for room and air cooling, $\left[\frac{\text{kWh}}{\text{year}}\right]$

$Q_{P,L}$ – annual primary energy demand by a lighting system (only included in public buildings), $\left[\frac{\text{kWh}}{\text{year}}\right]$

Acronyms

EK – Final energy
EP – Primary energy

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Biographical notes

Małgorzata Sikora received her M.Sc. degree in Environmental Engineering (specialization: Heating and air conditioning) and next Ph.D (with honors) degree in Machinery Construction and Operation from Koszalin University of Technology, in 2008 and 2011 respectively. Since 2011 she has been an assistant in the Department of Heating and Refrigeration Engineering at the Koszalin University of Technology. Currently she works as an assistant professor in Department of Power Engineering. Her scientific interests concern a heat and flow phenomenon during refrigerants condensation, refrigeration, heat pumps, etc. She has participated a in 4 national research projects, 1 international education project (Tempus Energy). She presenting results of her work at 4 international and numerous national conferences, she published 4 articles in journals from the Philadelphia list and 15 articles in national magazines and 46 papers printed in national and international conferences materials. Dr. Eng. Małgorzata Sikora is also coauthor of 1 monograph published in English, and 1 didactic textbook.

Krystian Siwek – a graduate of the Energetic on Faculty of Mechanical Engineering (specialization of Renewable Sources of Energy) at the Koszalin University of Technology. Currently, he works as a CAD designer at Buglo. Author of several articles in the journals: Busses and Refrigeration (in polish).