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THE EFFECT OF THE FUEL TYPE ON THE VALUE OF PRIMARY ENERGY AND EMMISSION OF POLLUTANTS

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Key words: certificate of energetic characteristic, energetic audit, emission of pollutants to atmosphere, alternative sources of energy.

Abstract

The aim of this paper is to present the interdependence of the value of non-renewable primary energy and the emission of pollutants to the atmosphere depending on the type of fuel used. The analysis of the existing building object dating from 2005, in its present state using natural gas with a high methane content for the purpose of heating and preparing hot utility water. Other, alternative types of fuel have been proposed and the amounts of the primary energy index and emitted pollutants have been compared. Liquefied petroleum gas and biomass have been proved to be the most ecological fuel.

WPŁYW RODZAJU PALIWA NA WARTOŚĆ ENERGII PIERWOTNEJ I EMISJĘ ZANIECZYSZCZEŃ

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Słowa kluczowe: świadectwo charakterystyki energetycznej, audyt energetyczny, emisja zanieczyszczeń do atmosfery, alternatywne źródła energii.

Abstrakt

W pracy przedstawiono zależność wartości nakładu nieodnawialnej energii pierwotnej oraz emisji zanieczyszczeń do atmosfery w zależności od użytego rodzaju paliwa. Przeprowadzono analizę istniejącego obiektu budowlanego z 2005 roku, wykorzystującego gaz ziemny wysokometanowy na ogrzewanie i przygotowanie ciepłej wody użytkowej. Zaproponowano inne, alternatywne rodzaje paliwa oraz porównano wartości wskaźnika EP oraz ilość emitowanych zanieszyczeń. Wykazano, że najbardziej ekologicznym paliwem jest gaz płynny oraz biomasa.

Introduction

Starting on 01.01.2009, on the strength of the Ordinance of the Minister of Infrastructure dated 6.11.2008 concerning the methodology of calculating the energetic characteristic of a building and dwelling or part of a building constituting an independent technical and usable whole as well as the method of drawing up and the formats of certificates of their energetic characteristic (Dz.U. 2008 nr 201 poz. 1240), an obligation to draw up certificates of energetic characteristic of buildings was introduced. This practice results from the Directive of the European Parliament and the Council of the European Union 2002/91/EC (Journal of Law U. W. E. L 1/65 of 2002) concerning the energetic characteristic of buildings of 16 December 2002, which compels the community member states to reduce energy-consumption in building engineering, both in new and repaired buildings. Such a formulation is supposed to attract the attention of investors and immovable property owners to the problem of energy-consumption by building objects, and thus, a negative effect on the natural environment.

The role of the certificate of energetic characteristic

The certificate of energetic characteristic is an independent estimation of the market value and the use value of a building or quarters. This document can be issued only by an authorised specialist. The requirement for energy necessary to maintain the use comfort is determined at three levels, which are the use, final and primary ones. The requirement for energy includes: heating (in all objects), hot water (in all objects), ventilation and air conditioning (if a building is equipped with a cooling system), and also lighting in public buildings.

Use energy is energy used directly in a building, serving the purpose of heating or obtaining hot water. Its value is determined on the basis of heat loss through external partitions surrounding the regulated temperature cubature and ventilation. Final energy is balanced at the boundary of a building. It expresses the requirement for energy which should be delivered to a building including all the loss resulting from the efficiency of installation systems. The requirement for non-renewable primary energy determines the total effectiveness of a building. Apart from final energy, it includes additional inputs of non-renewable primary energy for supplying a building boundary with every energy carrier used (e.g. coal, fuel oil, gas, electric energy, renewable energies, etc.) and support energy, necessary for auxiliary devices' drive.

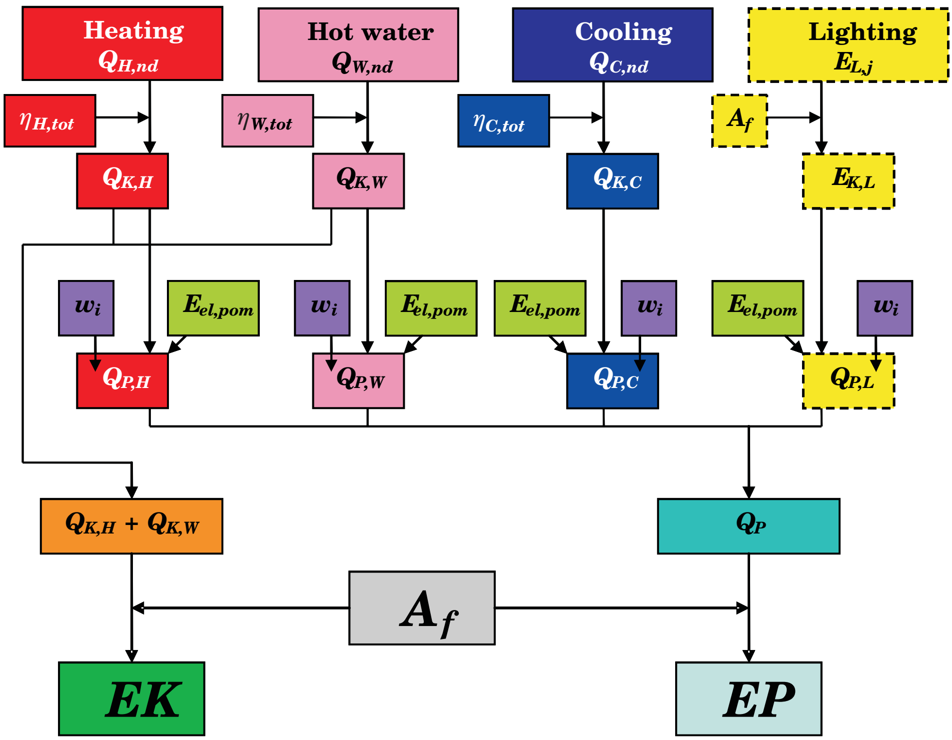

Fig. 1 Diagram for calculating the energetic characteristic
Source: authors' data

Primary energy for the heating and ventilation system is calculated according to the following equation:

$$Q_{P,H} = w_H \cdot Q_{K,H} + w_{el} \cdot E_{el,pom,H} \text{ [kWh/year]} \quad (1)$$

$Q_{K,H}$ – annual requirement for final energy by the heating and ventilation system for heating and ventilation [kWh/year],

w_i – coefficient of the non-renewable primary energy input for producing and delivering a final energy carrier (or energy) for an estimated building (w_{el}, w_H, w_W),

$E_{el,\mathrm{pom},H}$ – annual requirement for electric energy for auxiliary devices' drive of the heating and ventilation system [kWh/year].

Primary energy for the system of hot utility water preparation is calculated according to the following equation:

$$Q_{P,W} = w_w \cdot Q_{K,W} + w_{el} \cdot E_{el,\mathrm{pom},W} \text{ [kWh/year]} \qquad (2)$$

$Q_{K,W}$ – annual requirement for final energy by the hot utility water system [kWh/year],
w_i – coefficient of the non-renewable primary energy input for producing and delivering a final energy carrier (or energy) for an estimated building (w_{el}, w_H, w_W),
$E_{el,\mathrm{pom},W}$ – annual requirement for electric energy for auxiliary devices' drive of the hot utility water preparation system [kWh/year].

Primary energy for the cooling system is calculated according to the following equation:

$$Q_{P,C} = w_C \cdot Q_{K,C} + w_{el} \cdot E_{el,\mathrm{pom},C} \text{ [kWh/year]} \qquad (3)$$

$Q_{K,C}$ – annual requirement for final energy by the cooling and ventilation system for room and air cooling [kWh/year],
w_i – coefficient of the non-renewable primary energy input for producing and delivering a final energy carrier (or energy) for an estimated building (w_{el}, w_H, w_W),
$E_{el,\mathrm{pom},C}$ – annual requirement for electric energy for auxiliary devices' drive of the cooling and ventilation system [kWh/year].

Annual requirement for primary energy by a built-in lighting system is calculated according to the following equation:

$$Q_{P,L} = w_{el} \cdot E_{K,L} + w_{el} \cdot E_{el,\mathrm{pom},L} \text{ [kWh/year]} \qquad (4)$$

$E_{K,L}$ – annual requirement for final energy by built-in lighting [kWh/year],
w_i – coefficient of the non-renewable primary energy input for producing and delivering a final energy carrier (or energy) for an estimated building (w_{el}, w_H, w_W),
$E_{el,\mathrm{pom},L}$ – annual requirement for electric energy for auxiliary devices' drive of the built-in lighting system [kWh/year].

Annual requirement for electric energy for auxiliary devices' drive includes all equipment necessary for reliable operation of heating, ventilation, hot utility water and built-in lighting systems.

The value of total primary energy id calculated according to the following equation:

$$Q_P = Q_{P,H} + Q_{P,W} + Q_{P,C} + Q_{P,L} \text{ [kWh/year]} \quad (5)$$

Two ratios are the final effect of the calculations:

– requirement for final energy *EK*:

$$EK = (Q_{K,H} + Q_{K,W})/A_f \text{ [kWh/m}^2\text{/year]} \quad (6)$$

– requirement for primary energy *EP*:

$$EP = Q_p/A_f \text{ [kWh/m}^2 \cdot \text{year]} \quad (7)$$

A_f – area of regulated temperature rooms (heated or cooled) [m^2].

Value *EP*, which is obtained after making a number of calculations, is compared with reference values determined according to the Ordinance of the Minister of Infrastructure of 12 April 2002 concerning technical conditions which must be complied with by buildings and their location (Dz.U. nr 75 poz. 690) and the Ordinance of the Minister of Infrastructure of 6 November 2008 amending the ordinance concerning technical conditions which must be complied with by buildings and their location (Dz.U. nr 201 poz. 1238).

The aim of energetic certificates is to stimulate the development of energy-saving building engineering supplied by renewable fuels of low emission of environmentally harmful chemical compounds. The type of fuel has an influence on the value of the non-renewable primary energy input ratio and thus on the value of indices EK and EP. The lower the EP value, the more an object is estimated as energy saving, emitting less harmful chemical substances to the atmosphere

Characterization of an object

A simulation has been carried out for a building object located in Szczecin, in a medium shaded area situated on the edge of a residential area of detached houses. It is an inner one-family segment of a terraced house. The construction of the building is traditional, made of brick with reinforced concrete foundation, a gable roof based on a traditional rafter framing, covered with cement tiles on wooden laths. The body of the building is complemented by a one-car, heated garage, the roof over the garrage is used as a terrace. A 4-person family lives in the building. The construction of this building was started in 2003, and finished in 2005. The building was put into service in 2006.

A gas two-run furnace with an open combustion chamber of the power of 24 kW is the source of heat. It is controlled by a room controller placed on the ground floor. No hot utility water container and no circulation. Temperature of hot water at the drawing valves 55°C. Central heating and hot utility water conduits are made of plastics conducted under floors, insulated according to the requirements of the Technical Conditions. Natural gas with a high methane content (w_i = 1,1) constitutes fuel in actual state. The building is equipped with a natural – gravitational ventilation system, without a leak proof test.

Typical PCV windows with a double-pane pack of a declared heat-transfer coefficient of U = 1,1 W/m$^2 \cdot$ K were used.

A layer entrance door complying with the requirement of maximum heat-transfer coefficient $U_{\max}$ = 2,6 W/m$^2 \cdot$ K. Garage door designed for non-heated garages is improperly additionally protected from the cold.

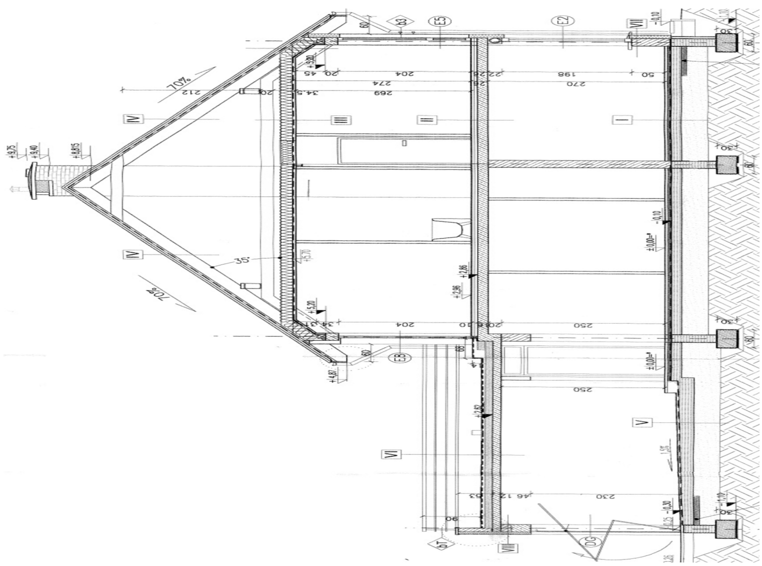

Fig. 2. Cross-section of the estimated building
Source: design documentation made available by the owner of the building

Basic technical parameters of the building
– outer cubature: 689 m^3;
– ventilated cubature: 443 m^3;
– heated area (with controlled temperature): 164.2 m^2;
– building area: 111.4 m^2.

Table 1

List of rooms in the estimated building

Number/Name of room	Design temperature $\theta_{int,i}$ [°C]	Room area A_i [m^2]	Inner cubature V_i [m^3]
1 WC	20.00	1.31	3.55
2 Charring room / Drying room	20.00	5.31	14.34
3 Office	20.00	12.60	34.02
4 Sitting room	20.00	30.07	81.19
5 Hall	20.00	13.93	37.62
6 Kitchen	20.00	5.43	14.66
7 Vestibule	16.00	4.54	11.34
8 Individual garage	5.00	18.45	50.92
10 Sitting room	20.00	22.70	61.06
11 Bedroom W	20.00	16.00	43.03
12 Bedroom E	20.00	13.89	37.36
13 Hall	20.00	12.01	32.32
14 Bathroom	24.00	7.99	21.50
Total		164.23	442.91

Source: authors' data

The outer walls are made of PHOROTERMU 25 on cement and lime mortar, additionally protected from cold by foamed polystyrene plates EPS 70-040 FASADA (12 cm), with a thin-layer acrylic elevation plaster outside, plastered with gypsum plaster inside.

The construction of the floor consists of: polyethylene sheeting, cement floor (4 cm), foamed polystyrene plate EPS 200-036 FLOOR (6 cm), insulating asphalt tar (2 cm), concrete of mean density of 1800 kg/m^3 (15 cm) and sand bed (30 cm).

The construction of the roof over the functional attic – wooden, rafter and collar beam, additionally protected from cold by mineral wool (20 cm), covered by plane tiles.

The analysis of the present state

The collected data were introduced into the ArCadia Thermo PRO 2.4 programme, educational version. Based on the calculations, the value of the requirement for primary energy at the present state is: EP = 153,9 kWh/m^2 · · year, with the reference value according to the Technical Conditions of 2008: 124,24 kWh/m^2 · year for a newly built building.

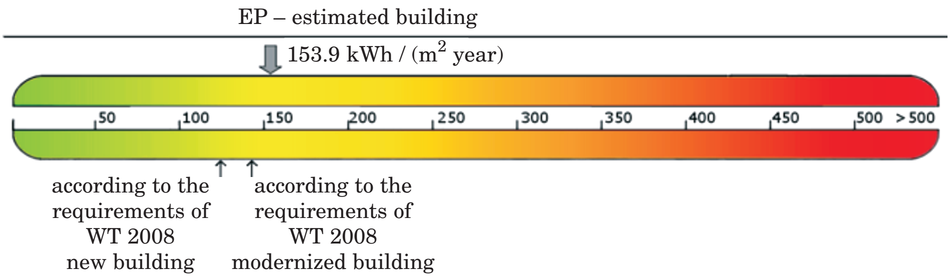

Fig. 3 Value of the non-renewable primary energy input for the estimated building
Source: ArCadia Thermo PRO,educational version, Intersoft)

The value of final energy for the present state and the amount of fuel necessary to heat and prepare hot utility water for standard assumptions is presented below.

Table 2

Value of final energy for the present state

Type of fuel – central heating	Share %	$\eta_{H,\mathrm{tot}}$	H_u	Unit	$Q_{K,H}$ [kWh/year]	Fuel consumption B	Unit
Fuel – natural gas	100.0	0.73	9.97	kWh/m^3	15645.4	1569.2	m^3/year
Type of fuel – hot utilitywater	Share %	$\eta_{W,\mathrm{tot}}$	H_u	Unit	$Q_{K,W}$ [kWh/year]	Fuel consumption B	Unit
Fuel – natural gas	100.0	0.42	9.97	kWh/m^3	5735.1	575.2	m^3/year

H_u – calorific value
Source: authors' data,based on ArCadia Thermo PRO,educational version, Intersoft

Alternative variants – a comparison of the EP value and the amount of fuel

For comparison, the following have been suggested as alternative fuels:
– central heating and hot utility water – liquefied petroleum gas (w_i = 1.1) – variant I,

- central heating – hard coal (w_i = 1.1), hot utility water – liquefied petroleum gas (w_i = 1.1) – variant II,
- central heating – biomass (w_i = 0.2), hot utility water – liquefied petroleum gas (w_i = 1.1) – variant III,
- central heating and hot utility water – electric energy (w_i = 3.0) – variant IV.

The source of heat for heating and preparing hot utility water in variant I is a condensation boiler up to 50 kW (for central heating with parameters 70/55°C).

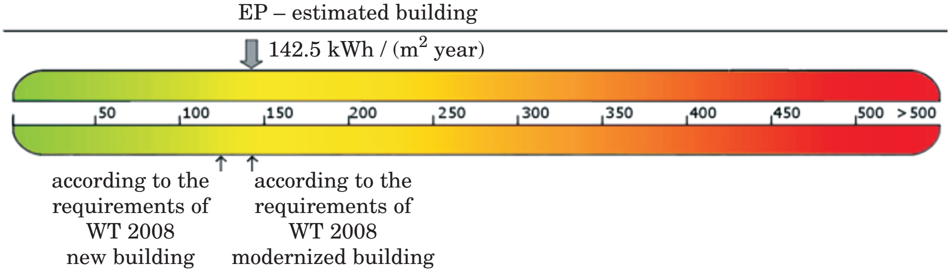

Fig. 4 Value of non-renewable primary energy input for variant I
Source: ArCadia Thermo PRO, educational version, Intersoft

Table 3

Value of final energy for variant I

Type of fuel – central heating	Share %	$\eta_{H,\text{tot}}$	H_u	Unit	$Q_{K,H}$ [kWh/year]	Fuel consumption B	Unit
Fuel – liquefied petroleum gas	100.0	0.75	6.65	kWh/m^3	15115.4	2273.0	m^3/year
Type of fuel – hot utility water	Share %	$\eta_{W,\text{tot}}$	H_u	Unit	$Q_{K,W}$ [kWh/year]	Fuel consumption B	Unit
Fuel – liquefied petroleum gas	100.0	0.53	6.65	kWh/m^3	4562.0	686.0	m^3/year

Source: authors' data,based on ArCadia Thermo PRO,educational version, Intersoft

In variant II, coal boiler produced after 2000 was assumed as a heat source for heating while the source of hot utility water was maintained from variant I.

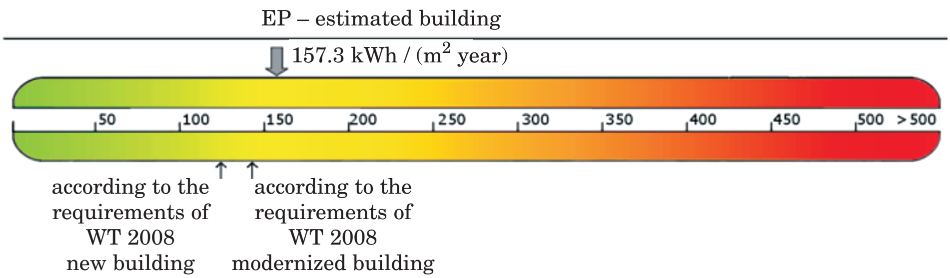

Fig. 5 Value of non-renewable primary energy input for variant II
Source: ArCadia Thermo PRO, educational version, Intersoft

Table 4

Value of final energy for variant II

Type of fuel – central heating	Share %	$\eta_{H,\mathrm{tot}}$	H_u	Unit	$Q_{K,H}$ [kWh/year]	Fuel consumption B	Unit
Fuel – hard coal	100.0	0.66	7.70	kWh/kg	17327.4	2250.3	kg/year
Type of fuel – hot utility water	Share %	$\eta_{W,\mathrm{tot}}$	H_u	Unit	$Q_{K,W}$ [kWh/year]	Fuel consumption B	Unit
Fuel – liquefied petroleum gas	100.0	0.53	6.65	kWh/m^3	4562.0	686.0	m^3/year

Source: authors' data, based on ArCadia Thermo PRO,educational version, Intersoft

In variant III, biomass boiler, wood fired, with manual service of the power up to 100kW was assumed as the heat source for heating while the source of hot utility water was maintained from variant I.

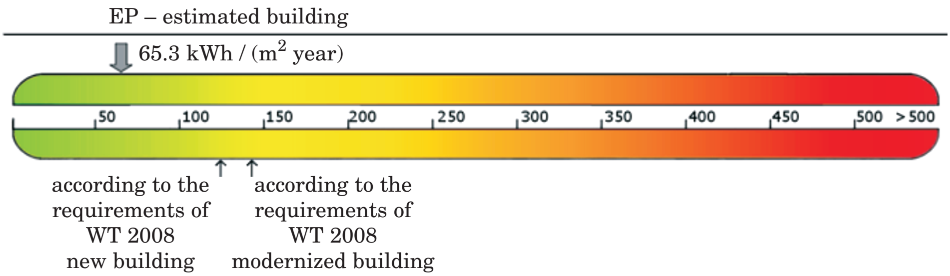

Fig. 6 Value of non-renewable primary energy input for variant III
Source: ArCadia Thermo PRO, educational version, Intersoft

Table 5

Value of final energy for variant III

Type of fuel – central heating	Share %	$\eta_{H,\mathrm{tot}}$	H_u	Unit	$Q_{K,H}$ [kWh/year]	Fuel consumption B	Unit
Fuel – biomass	100.0	0.58	4.28	kWh/kg	19734.0	4610.8	kg/year
Type of fuel – hot utility water	Share %	$\eta_{W,\mathrm{tot}}$	H_u	Unit	$Q_{K,W}$ [kWh/year]	Fuel consumption B	Unit
Fuel – liquefied petroleum gas	100.0	0.53	6.65	kWh/m^3	4562.0	686.0	m^3/year

Source: authors' data, based on ArCadia Thermo PRO,educational version, Intersoft

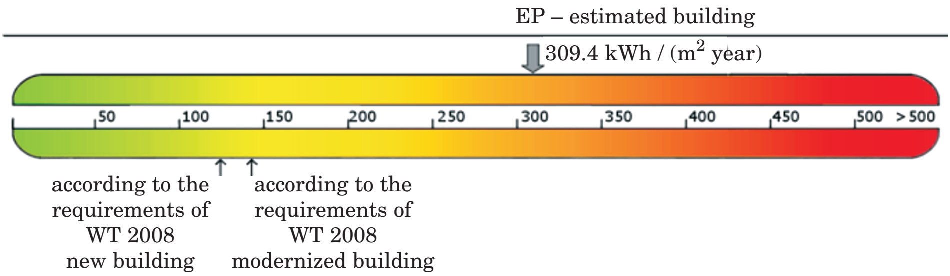

Fig. 7. Value of non-renewable primary energy input for variant IV
Source: ArCadia Thermo PRO, educational version, Intersoft

Table 6

Values of final energy for variant IV

Type of fuel – central heating	Share %	$\eta_{H,tot}$	H_u	Unit	$Q_{K,H}$ [kWh/year]	Fuel consumption B	Unit
Electric energy – mixed production	100.0	0.92	1.00	kWh/ kWh	12339.1	12339.1	kWh/ year
Type of fuel – hot utility water	Share %	$\eta_{W,tot}$	H_u	Unit	$Q_{K,W}$ [kWh/year]	Fuel consumption B	Unit
Electric energy – mixed production	100.0	0.60	1.00	kWh/ kWh	4014.5	4014.5	kWh/ year

Source: authors' data, based on ArCadia Thermo PRO,educational version, Intersoft

Thus, the value of primary energy changes depending on the fuel supplying the central heating and hot utility water systems.

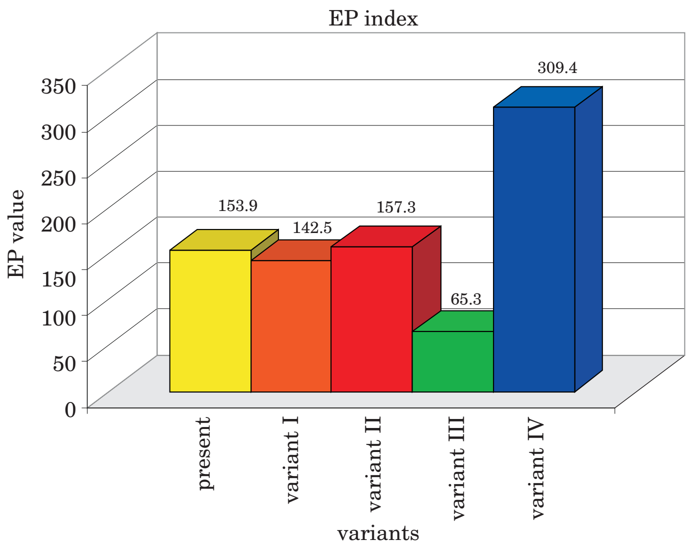

Fig. 8. Comparison of primary energy values depending on the applied combination of fuels
Source: authors' data

The influence of the fuel type on the emission of pollutants to the atmosphere

Significant changes in legal provisions concerning air protection were introduced in 2001. The basic legal act is the Environmental Protection Act of 27.04.2001 (Dz.U. nr 61, poz. 627, 2001). The guiding principle of this law is:
– Maintaining the level of substances in the air below the levels permissible for them or at least at these levels,
– Reducing the levels of substances in the air at least to the permissible ones when they are not met.

It is consistent with legal acts of the European Union expressed in Directive 96/62/EC of 27.09.1996 concerning the air quality estimation and management.

In order to simulate the amounts of pollutants emitted to the environment depending on the variant of adopted fuel supplying central heating and hot utility water, a cover plate Ecological effect of the programme ArCadia Thermo PRO educational version was used; based on introduced data, it calculates the amount of pollutants emitted to the atmosphere – SO_2, NOX, CO, CO_2, dust, soot, B-a-P. Such an analysis is necessary when we do audit for EU subsidies or the Environmental Protection Fund. At the stage of drawing up a certificate of energetic characteristic, it makes it possible to estimate the effect of the adopted system of heating and preparing hot utility water on the environment on the basis of the amount of pollutants. The calculations of the pollutants emission are based on the information and instruction materials of the Ministry of Environmental Protection, Natural Resources and Forestry 1/96 "Indices of the emission of polluting substances introduced into the air from the processes of energetic combustion of fuels". The results below also include auxiliary electric defices necessary for the operation of the central heating and hot utility water system.

Table 7

Emission of pollutants

Total emission in the building – present state	Unit	SO_2	NO	CO	CO_2	DUST	SOOT	B-a-P
	kg/year	533.2464	4.0927	1.1763	4797.7392	0.9111	0.0016	0.0000
Total emission in the building – variant I	Unit	SO_2	NO_x	CO	CO_2	DUST	SOOT	B-a-P
	kg/year	533.2464	1.3478	0.4043	585.9850	0.8790	0.0016	0.0000
Total emission in the building – variant II	Unit	SO_2	NO_x	CO	CO_2	DUST	SOOT	B-a-P
	kg/year	576.4525	3,5981	101.6686	5086.6211	24.5073	0.7892	0.0315
Total emission in the building – variant III	Unit	SO_2	NO_x	CO	CO_2	DUST	SOOT	B-a-P
	kg/year	536.4278	93.4246	5.7989	585.9850	4.0604	0.0016	0.0000
Total emission in the building – variant IV	Unit	SO_2	NO_x	CO	CO_2	DUST	SOOT	B-a-P
	kg/year	15415.0895	38.9612	11.6884	16939.6588	25.4095	0.0457	0.0009

Source: authors' data, based on ArCadia Thermo PRO,educational version, Intersoft

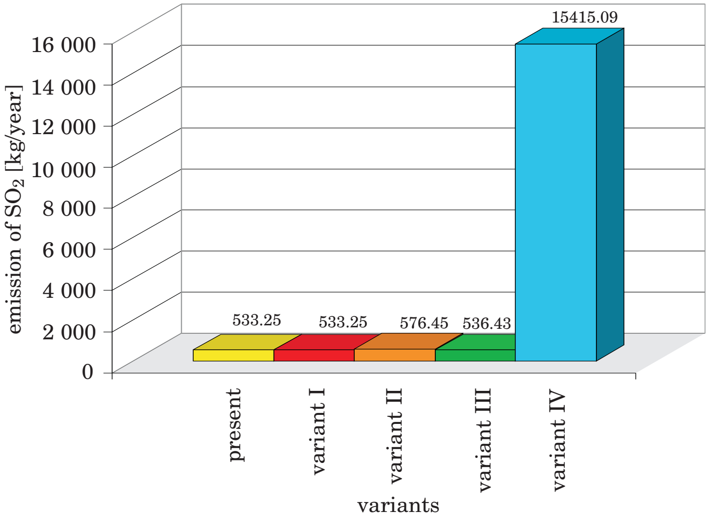

Fig. 9. Comparison of emission of SO_2 based on the data from table 7
Source: authors' data

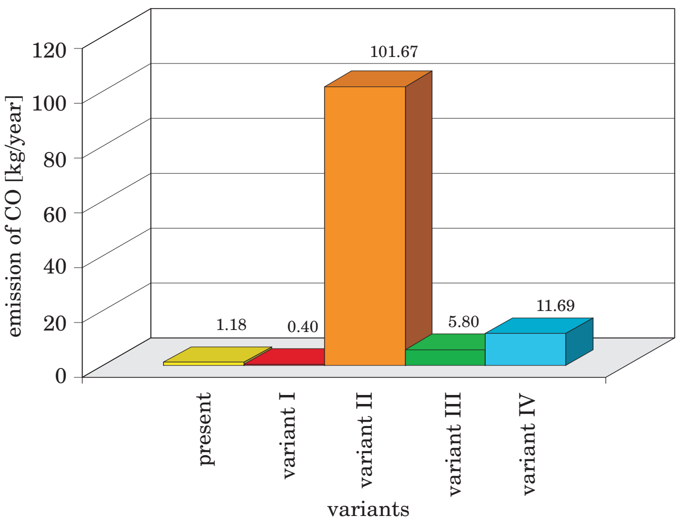

Fig. 10. Comparison of emission of CO based on the data from table 7
Source: authors' data

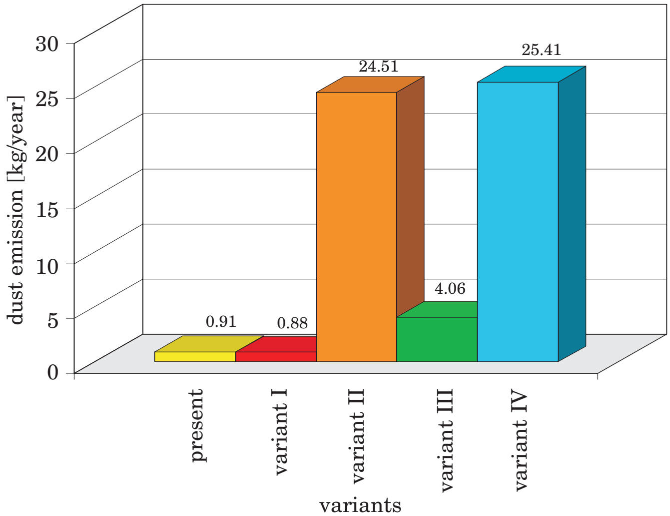

Fig. 11. Comparison of emission of dust based on the data from table 7
Source: authors' data

Conclusion

On the grounds of the analysis it can be concluded that the type of fuel has a significant effect on the value of the index of non-renewable primary energy input. The lower this value – the more energy-saving the building is. With an increase in primary energy the object becomes less attractive for the owner. The value obtained for every newly-built or modernized building should meet reference values specified in the Technical Conditions. The simulation has confirmed that the building in which electric energy from mixed production is used for heating and preparing hot utility water is the most costly in use. On the other hand, it is possible to build a house in which biomass energy is used for heating. With the application of the most frequently used fuels: liquefied petroleum gas, natural gas and hard coal, the primary energy value is maintained at a similar level.

It has been proved in the simulation that the use of electric energy from mixed prodution for supplying central heating and hot utility water is the least ecological one in terms of emission of pollutants to the atmosphere.

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Ustawa z dnia 27.04.2001 roku – Prawo ochrony środowiska (Dz.U. nr 61, poz. 627 z 2001 r. z późn. zm.).

Rozporządzenie Ministra Infrastruktury z dnia 12 kwietnia 2002 r. w sprawie warunków technicznych, jakim powinny odpowiadać budynki i ich usytuowanie (Dz.U. 2002 nr 75 poz. 690 z późn. zm.).

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).

Materiały informacyjno-instruktarzowe MOŚZNiL 1/96 „Wskaźniki emisji substancji zanieczyszczających wprowadzanych do powietrza z procesów energetycznego spalania paliw".

Materiały informacyjno-instruktażowe MOŚZNiL 1/96 „Wskaźniki emisji substancji zanieczyszczających wprowadzanych do powietrza z procesów energetycznego spalania paliw".