The project of autonomous power single-family home with the use of renewable energy sources in the conditions of the Poland

Maciej Neugebauer, Janusz Piechocki, Piotr Sołowiej,

Abstract: *As part of the work we carried out an energy audit selected, representative of a detached house in accordance with EN-12831. It sets annual flows of heat loss and energy requirements of the building. On this basis, the project made building power into electricity and heat in a variety of configurations from renewable energy sources. There has also been energy and economic analysis of selected solutions*
Key words: *renewable energy sources, energy efficiency, photovoltaik*

INTRODUCTION

Along with growing prices of energy (heat, electricity, gas, etc.) appears more and more people wanting to change their house in home energy self-sufficient. Performing such a task requires, to begin an accurate energy audit, and then with recognized energy needs - choosing of some devices in order to get a complete energy self-sufficiency of the building. As part of the calculation, be taken into account whenever the specificity of the building - its location, energy needs, construction (heat loss), the number of people residing permanently in the building, use of renewable energy sources like. Then, all that data should be collected into one coherent system.

DESCRIPTION OF THE BUILDING;

Building for which the calculation was made, is located in central Poland. The cross-section (with dimensions) is shown in Figure 1.

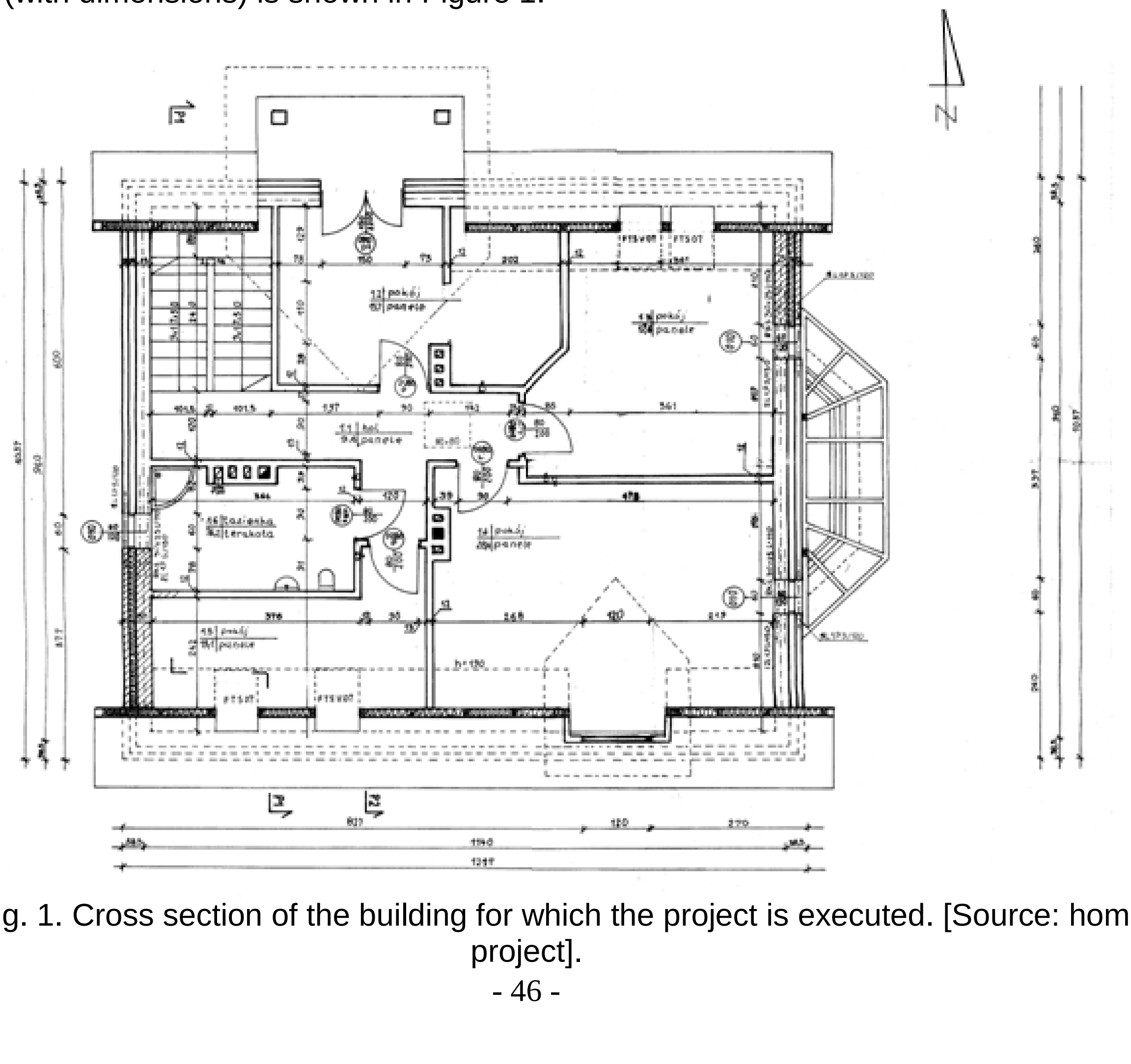

Fig. 1. Cross section of the building for which the project is executed. [Source: home project].

Figures 2 and 3 shows the view of the four facades.

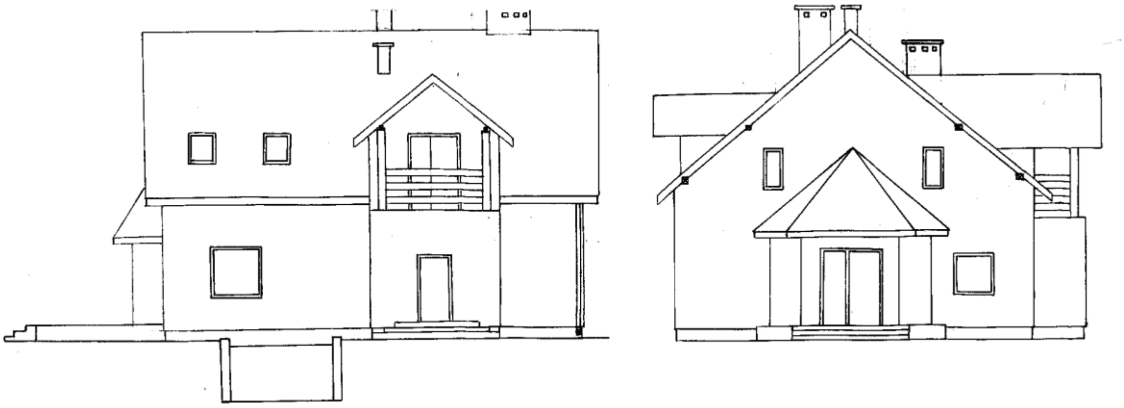

Fig. 2. View of the facade from the east and north [Source: home project].

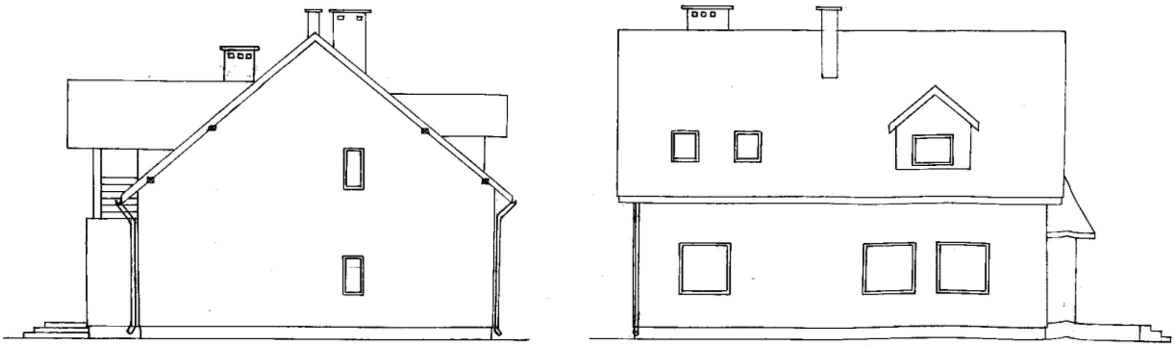

Fig. 3. View of the facade from the west and south [Source: home project]

For the calculations the climatic data (temperature outside and annual average outside temperature and sunlight) for zone III - Polish central.

ENERGY AUDIT

For the above-mentioned building energy audit was performed. At the beginning inventory was made of the premises and building partitions (internal and external) and adopted the design room temperature - Table 1.

Table 1.
Internal computational temperatures

room	**Temperature** $\Theta_{i,e}$ **°C**
garage	8
corridor in the basement	8
basement	8
a boiler room	16
laundry	16
vestibule (unheated)	8
hall	20
room	20
kitchen	20
bathroom	24

[Source: Regulation of the Polish Minister of Infrastructure of 12 April 2002. on the technical conditions to be met by buildings and their location (Dz. U. of 2002 No. 75, item. 690, as amended**)]**

According to the draft slope of the roof - 45^0, the number of living people - four. The total building area is Ab = 182 m^2 and total volume Vb = 395 m^3.

An energy audit was made in the following calculation steps.

- Heat transfer coefficients were calculated the baffle separating heated space of the building from the outside and unheated spaces - in accordance with PN EN ISO 6946: 2007 [1] with the adjustments to the air voids. The calculation was performed according to the methods for homogeneous and heterogeneous partitions (floors, walls lucarne etc.).
- By PN EN 14683: 2008 [2] was calculated heat loss of heat bridges. Identified the following thermal bridges - Table 2

Table 2

Thermal bridges in the audited building

	baffle	elements	bridges symbol	value Ψ_e W/mK	length l_e m	Ψ_e*l_e W/K
windows	O6	frame, lintel	W1	0	4,2	**0**
	O10	frame, lintel	W1	0	14,4	**0**
	O34	frame, lintel	W1	0	24	**0**
	O32	frame, lintel	W1	0	5,4	**0**
	FTS07	frame, lintel	W1	0	18,4	**0**
	OBD4	frame, lintel	W1	0	7,4	**0**
	OBD12	frame, lintel	W1	0	8	**0**
doors	OO3 90	frame, lintel	W1	0	6,1	**0**
walls	SZ	outside corner	C1	-0,05	29	**-1,45**
	SPG-SG	ceiling	IF1	0	46,7	**0**
	SZ	ceiling	IF1	0	43	**0**
	SZ-D2	wall-roof	R1	0,55	20	**11**
	SZ-D2	wall-roof (plate)	R9	-0,05	25,54	**-1,277**
	D2-SJ	roof-ceiling	R9	-0,05	39,8	**-1,99**
	SZ	Inside corner	C5	0,05	11,4	**0,57**
	SL	outside corner	C4	-0,15	2,6	**-0,39**
	SZ-SW	wall internal/external	IW1	0		**0**
	D2-SW	wall internal/external	IW5	0		**0**
	SZ-SJ	external wall-ceiling	R5	0,6	11,6	**6,96**

- calculated heat loss through the woodwork (doors and windows);
- On this basis, the rate of heat loss through the building envelope infiltration – eqitation 1 by PN EN ISO 12831:2003 [3]:

$$H_{tr} = \Sigma[b_{tr,i} (A_i U_i + \Sigma l_i \Psi_i)] \text{ W/K} \quad (1)$$

$$H_{tr} = 159,76 \text{ W/K}$$

- determined coefficient of heat loss by ventilation;
- Calculated heat gains from the sun (through the window) and electrical equipment;
- calculated the total heat loss through infiltration and ventilation using monthly balances (average monthly temperature data taken by a weather station for the selected location;

- determined annual useful heat demand
- calculated (taking into account the efficiency of the entire heating and heat transfer) annual final energy demand to heat the house:

$$Q_{K,H} = 23\ 269 \text{ kWh}$$

- Calculation of the annual energy needs final for the preparation of hot water (also having regard to the efficiency):

$$Q_{K,W} = 7\ 527{,}25 \text{ kWh}$$

- On this basis, the estimated annual demand for non-renewable primary energy was calculated:

$$\mathbf{EP = 174{,}99\ [kWh/m^2 \cdot rok]}$$

The calculations are the basis for selection of the heating system and the possibility to cover the energy needs of the building using PV panels.

HEATING THE BUILDING

One of the most ecological and economical to use heat sources are heat pumps [4, 5, 6]. In this case, the heat pump selection was made on the basis of the annual final energy demand to heat the house and hot water preparation. The demand for thermal power per 1m^2 of the building is $Z_g = 38$ W/m^2.

Due to the fact that the heat pump system will operate in dual-mode (also expected to install behind the heat pump electrical flow heater with a power $P_{biw} = 2000$W, actuated only during the peak demand for heat).

$$k_b = 1 - P_{biw}/(Z_g * A_b) = 0{,}71 \quad (2)$$

where:

P_{biw} – the power of bivalent source;

k_b – bivalence coefficient

Assumed power needed to heat the hot water for four people Pcwu = 500W.

Accordingly, the computational power of the heat pump is:

$$P_{gpc} = Z_g * A_b * k_b + P_{cwu} = 5410{,}36\text{W} \quad (3)$$

where:

P_g - the power of the heat pump;

Z_g - the demand for building thermal power;

A_b - area of the building;

P_{cwu} - the power to heat domestic hot water

Chosen heat pump with a heating output $P_g = 5500$W, cooling capacity of $P_{ch} = 4125$W and COP coefficient = 4.0. Lower heat source will provide two vertical ground heat exchangers with a depth of 70m each.

SELECTION OF THE PHOTOVOLTAIC INSTALLATION

Assumptions predict that photovoltaic and battery pack is intended to meet - at best - demand for electricity of the entire building throughout the year. The restrictions that exist in the present case is the architecture of the building and especially the roof. Thanks to modern modules to optimize the work of individual photovoltaic modules avoid the detrimental effects of shading, causing loss of performance of the whole series of interconnected photovoltaic modules (even if only one of the shaded cells).

The first step in designing the photovoltaic system is to estimate the daily consumption of electricity during the winter season. The excess produced during the summer season electricity will be sold to the grid.

To evaluate the daily electricity consumption adopted the use of energy-efficient lighting based on LED technology and devices used in the household (refrigerator, washing machine, etc.) With the highest energy-saving class. All of these devices are also added electric power of the heat pump. After applying the current rate of simultaneity use of equipment received during the winter electricity demand of 15 kWh/day. In summer demand for electricity is 9 kWh/day. Inclination of the roof oriented to the south - 45° area available for the installation of photovoltaic panels - 100m^2.

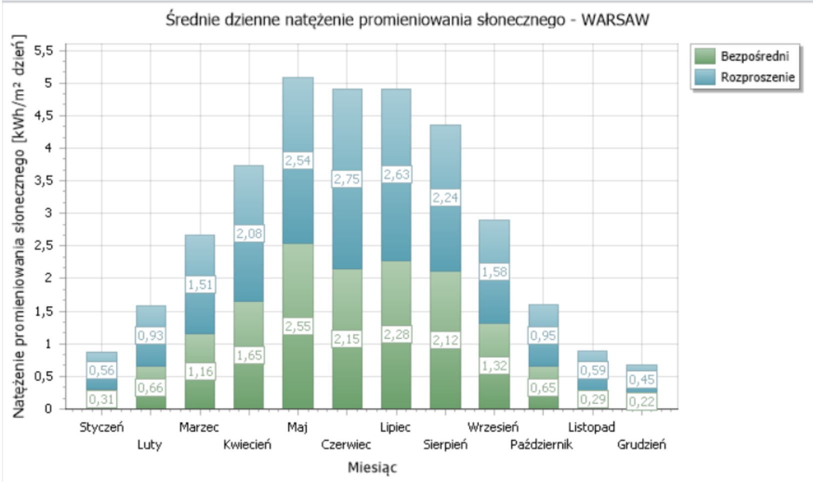

Fig. 4. Average monthly solar irradiance in Warsaw [source: own calculations in BlueSol].

The calculation of the size of the photovoltaic installation related to the month of December, which are the smallest energy yields from solar radiation. To meet the daily needs of the building in question (using the average daily solar radiation on a plane inclined at an angle of 45 ° Fig. 4) power plant should be at least P_i = 15 kWp.

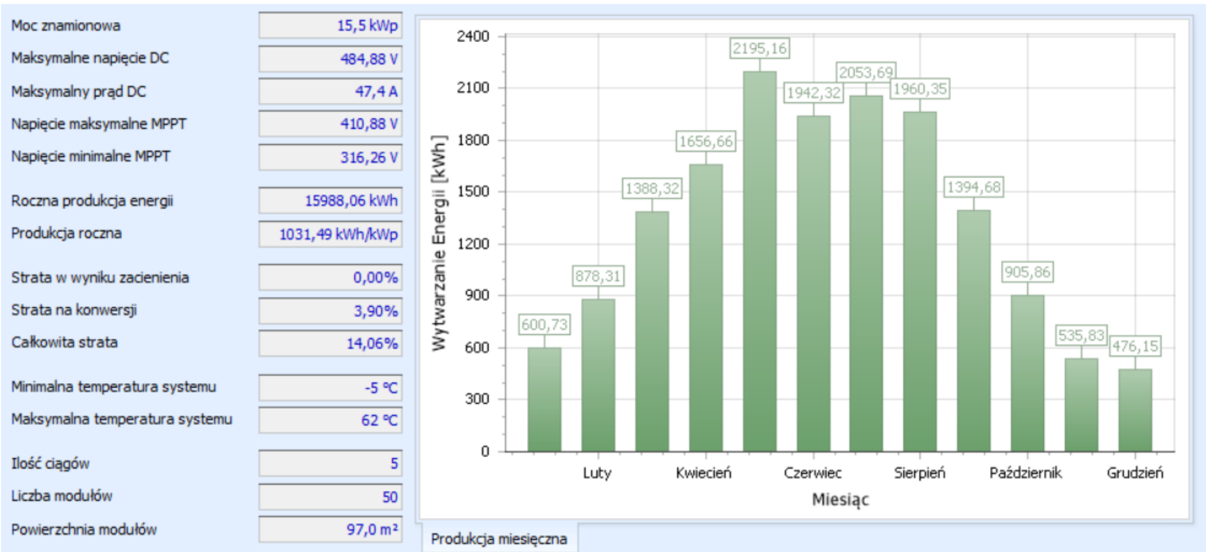

Fig. 5. Performance and the number of selected polycrystalline panels [source: own calculations in BlueSol].

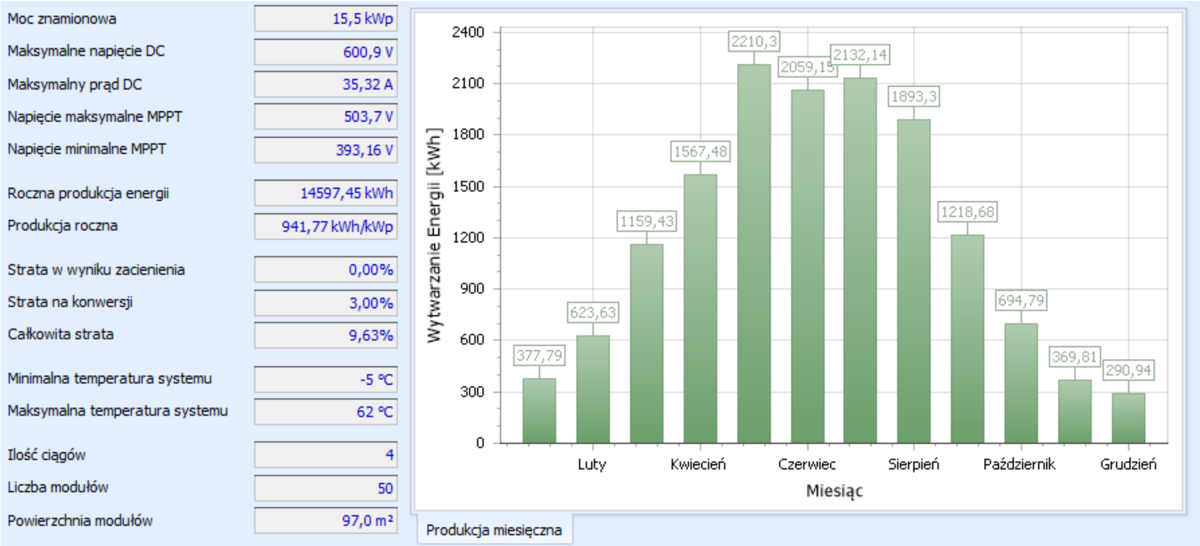

Fig. 6. Performance and the number of selected monocrystalline panels [source: own calculations in BlueSol].

Taking into account the architectural possibilities and the required capacity of the system chosen installation consisting of 50 polycrystalline photovoltaic panels NA310W-P72-156 / J with power 310W each one. The structure of the system consists of five series of ten panels. Each series have power 3100kW$_p$. The total area of installation is 97 m^2. The total capacity of the installation is P_{ip} = 15,5kW$_p$. Simulated monthly production of electricity for the planned photovoltaic system is shown in Fig. 5

For comparison also shows a selection of monocrystalline panels AD310M6-Aa - figure 6.

SIZE SELECTION OF BATTERIES

The task of the accumulation system of electricity supply in the PV system single-family building is to offset the mismatch of supply of energy from the photovoltaic system to the needs of the household (the system produces electricity during the day and the highest consumption of this energy falls on the evening hours). To prolong battery life, it is advisable to cover the demand for energy provide 50% reserve in order to avoid the phenomenon of so-called deep discharge.

Capacity of the battery was calculated as follows:

$$C = \frac{2 \cdot w \cdot F}{U} = 10000 \text{ Ah} \qquad (4)$$

where:

w - Daily energy needs of 15 kWh;

F - factor energy reserves - for the winter = 4

U - system voltage of 12 V

The size electric energy storage of 10 kAh is quite large, but ensures the continuity of electricity supply for single-family home in question throughout the year.

CONCLUSIONS

Due to poor wind conditions (in the selected location) were not taken the wind turbine into consideration during the design and calculation autonomous home system of power electricity;

Calculations choice of photovoltaic panels monocrystalline and polycrystalline carried out for the same dimensions and power of panels - 310Wp - in order to be able to compare the results:

- The calculations show that the difference between the average daily production of electrical energy for both types of panels shows no significant differences;

- Monocrystalline panels produce less power in the autumn and winter, while polycrystalline panels produce less energy in the summer and spring – it is related to differences in conversion efficiency of direct and dispersed radiation;

For the selected location the difference in higher electricity production by monocrystalline panels do not outweigh higher purchase price - that's why for project implementation were selected polycrystalline PV panels.

REFERENCES

[1] PN EN ISO 6946:2007 Building components and building elements - Thermal resistance and thermal transmittance - Calculation method;

[2] PN EN 14683:2008 Thermal Bridges in building construction – linear thermal transmittance – Simplified methods and default values;

[3] PN EN ISO 12831:2006 Heating systems in buildings – Method for calculation of design heat load;

[4] Ommen, T., Markussen, W., Elmegaard, B. 2014. Heat pumps in combined heat and power systems. Energy 76 (1), 989-1000.

[5] Self, S.J., Reddy, B.V., Rosen, M.A., 2013. Geothermal heat pump systems: status review and comparison with other heating options, Appl. Energy 101, 341-348

[6] Zhai, X.Q., Qu, M., Yu, X., Yang, Y., Wang, R.Z. 2011. A review for the applications and integrated approaches of ground-coupled heat pump systems, Renew. Sust. Energy Rev. 15 (6) ,3133-3140.

ABOUT THE AUTHORS

PhD. Maciej Neugebauer, University of Warmia and Mazury in Olsztyn, Department of Electrical, Power, Electronic and Control Engineering, Str. Oczapowskiego 11, 10-736 Olsztyn, Poland; tel.: +4889 523 3639, e-mail: mak@uwm.edu.pl,

Prof. Janusz Piechocki, University of Warmia and Mazury in Olsztyn, Department of Electrical, Power, Electronic and Control Engineering, Str. Oczapowskiego 11, 10-736 Olsztyn, Poland; tel.: +4889 523 2303, e-mail: jpt@uwm.edu.pl,

Prof. Piotr Sołowiej, University of Warmia and Mazury in Olsztyn, Department of Electrical, Power, Electronic and Control Engineering, Str. Oczapowskiego 11, 10-736 Olsztyn, Poland; tel.: +4889 523 3639, e-mail: pit@uwm.edu.pl