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Renewable Energy Sources in the Processes of Thermal Modernization of Buildings—Selected Aspects in Poland

Daria Moskwa-Bęczkowska [1,*] and Andrzej Moskwa [2]

[1] Department of Economics and Finance, Faculty of Management and Computer Modelling, Kielce University of Technology, 25-314 Kielce, Poland
[2] Independent Researcher, 27-400 Ostrowiec Świętokrzyski, Poland; fordm51@wp.pl
* Correspondence: dariam@tu.kielce.pl

Abstract: The article presents selected aspects of the energy modernization process of a single-family building, carried out in accordance with the legal regulations of Poland. One of the elements of this process is the use of renewable energy sources in the selection of heat sources. Two variants of thermo-modernization solutions for the tested facility were generated using the CERTO and the Aterm computer program. One was a heat pump, and the second was hybrid, in which the heat pump is supplied with electricity from photovoltaic panels. The key point of considerations was to conduct a comparative analysis of the operating costs of applied solutions. All variants were based on the same output data including the same building materials from which the thermal modernization process was carried out. The only difference was in the use of different types of thermal energy sources. The aim of the article was, therefore, to carry out a comparative analysis of variants of heat sources used in a single-family residential building—heating in a traditional way and through the use of photovoltaic panels and a heat pump. The results of the analysis in the context of benefits obtained from using renewable energy sources for heating residential buildings are discussed. The analysis showed that the simultaneous application of a heat pump and solar collectors in the analyzed building effectively influenced the values of indicators of annual demand for usable, primary, and final energy. The main conclusion of this research is that the amount of final energy demand in the analyzed case decreased from 86.04 kWh/(m^2/year) with natural gas to 40.46 kWh/(m^2/year) with a heat pump and a solar collector.

Keywords: renewable energy; thermal modernization; energy performance of buildings

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1. Introduction

The energy sector in Poland is currently one of the sectors of the Polish economy considered to be inefficient [1–3]. This is influenced by the different conditions of the sector taking into account geological, historical, climatic, and economic conditions [4]. In Poland, electricity is generated by high-emission units fueled mainly by hard coal and lignite, which results in high CO_2 emissions and contradicts the assumptions of the global climate policy. A big problem is also the outdated technology, often 30 years old, which turns out to be, firstly, much less effective and efficient in relation to the current state of technology and, secondly, in need of frequent and highly capital-intensive repairs and overhauls [5]. Therefore, for several years, the Polish energy sector has been undergoing deep transformation processes whose main objective is to reduce the overall share of conventional, i.e., primarily coal-based, power generation in favor of innovative solutions, including the implementation of low- and zero-emission sources of electricity [6,7]. Actions taken in this area are to ensure Poland's energy security and economic efficiency in the coming years [8]. It is worth noting, however, that this is extremely difficult due to the fact that the vast majority of electricity generators in Poland are burdened with the carbon footprint associated with traditional fuel-based power generation. Moreover, the structure of generation assets limits the investment potential of these entities in the segment of low- and zero-emission sources, which slows down the pace of Poland's energy transformation [9,10].

The issues of improving energy efficiency in Poland can be considered from two angles: macro- and micro-energy. The macro-energy perspective refers to the entire energy sector and concerns the implementation of tools and mechanisms to improve its efficiency resulting from the EU law, i.e., among others, the strategy of the European Green Deal [11,12] and national law, including the strategy of the Energy Policy of Poland until 2040 [9]. However, due to the aforementioned conditions, this process is extremely difficult and costly. Therefore, it is reasonable to take action to improve the analyzed efficiency on a micro level, i.e., in relation to individual houses and detached buildings, public buildings, and industrial plants. This is also justified by the fact that the vast majority of electricity consumers (about 88%) are private consumers [13]. Therefore, when it comes to achieving one of the overarching goals of the abovementioned strategies, i.e., increasing the share of renewable energy sources in the Polish energy sector, the focus should be on implementing these solutions in this particular sector.

However, it is worth remembering that one of the conditions for the effective use of renewable energy sources in buildings is their thermal modernization, i.e., a comprehensive change of their energy properties in order to reduce heat losses [14]. A properly conducted thermal modernization process requires the selection of an effective method of heating the facility. Today, a great emphasis is put on the "electrification of heating", i.e., the use of so-called "heat pumps" powered by energy from solar collectors [15,16]. This is a very interesting issue, not only in its technical aspects, but also in its economic aspects. Knowing the level of costs for electricity consumption, with energy prices currently rising, is extremely important.

In the context of the above considerations, the aim of this paper was a multivariant comparative analysis of the impact of selected devices and installations of renewable energy sources in the heating system of a single-family building on its energy performance. Three variants of using heat sources in a single-family residential building were analyzed: heating in a traditional way, with natural gas, and in a hybrid way, i.e., by using only a heat pump and by using a heat pump and solar collectors at the same time. The realization of the aim of the paper required the formulation of a research hypothesis that electric energy obtained from a solar collector and then used to power a heat pump would be a more energy-efficient solution than conventional sources. The verification of the research hypothesis formulated in this way made it possible to demonstrate the energy and, thus, economic benefits obtained when using renewable energy sources to heat residential buildings. The proposed concept also fits into the current trend of replacing conventional energy sources with alternative solutions. The research procedure carried out in this article enabled the verification of the hypothesis and the realization of the set objective. The obtained results, due to their extensive nature, are synthetically presented in the corresponding sections of the conducted considerations. The remainder of this paper is organized as follows: after this introduction section, Section 2 presents the methods and data, Section 3 describes the analytical results, and Section 4 provides a discussion of the results. Lastly, Section 5 presents the conclusion and policy implications.

1.1. Photovoltaic Market in Poland—Current State of Affairs

According to the assumptions of "Poland's Energy Policy until 2040", one of the key areas for improving the country's energy efficiency is increasing the production of electricity from renewable energy sources. It is assumed that, in 2030, the share of these sources in gross final energy consumption will be at least 23% [9]. At present, the main generators of renewable energy in Poland are wind power plants, which account for nearly 60% of all electric energy sources of renewable origin. Table 1 shows the structure of renewable energy installations in Poland.

Table 1. Installations of renewable energy sources in Poland as of 31 December 2021.

Type of Installation	Number of Installations	Energy Produced (MW)
Biogas power plants	345	257
Biomass power plants	45	1248
Photovoltaic power plants	2400	1693
Wind power plants	1292	7158
Hydroelectric power plants	786	990
Co-firing technology	10	169

Source: Own elaboration based on data from the Energy Regulatory Office [17].

Wind power plants are located mainly in northwestern Poland. These are mainly the Zachodniopomorskie (716.8 MW), Pomorskie (246.9 MW), and Wielkopolskie (245.3 MW) voivodeships. On the other hand, from the point of view of power generation capacity, photovoltaic power plants, as well as individual prosumer installations, occupy second place. Between 2013 and 2020, the capacity of photovoltaic plants in Poland increased from 4 MW in 2013 to 3960 MW in 2020 (see Figure 1).

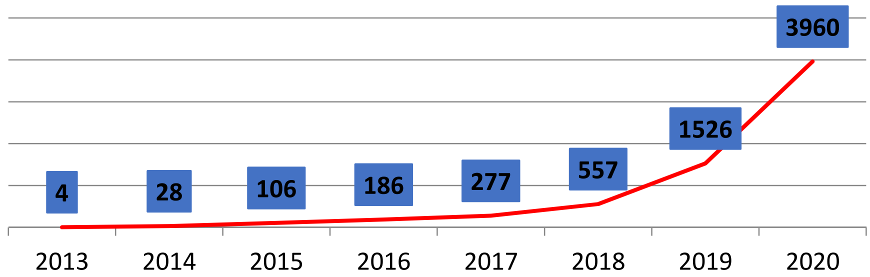

Figure 1. Photovoltaic power plant capacity in Poland in 2013–2020 (data in MW). Source: own elaboration based on Energy Market Agency data [18].

According to the Energy Market Agency, the total value of investments in photovoltaic panels in Poland in 2020 was nearly 10 billion PLN, of which the vast majority (as much as 6.5 billion PLN) was invested by households, and about 3 billion PLN was invested by businesses and local government units. Therefore, it is reasonable to analyze the problem of energy efficiency improvement in Poland from the micro perspective, i.e., in relation to individual prosumers of the energy services market. This is also confirmed by data from the report "Rynek Fotowoltaiki w Polsce 2021" ("Photovoltaic Market in Poland 2021"), according to which the largest share in the energy market is held by micro-installations (i.e., installations with a total installed capacity not exceeding 50 kW), installed mainly in households [19]. They accounted for as much as 77% of installed photovoltaic capacity in 2020. It is worth noting here that the dynamic growth in the level of popularity of this technology among Polish prosumers is the result of, among other things, the forms of support offered within the framework of the government program "Mój prąd" aimed at subsidizing photovoltaics or grants awarded within the framework of regional operational programs. These efforts have put Poland in fourth place in terms of new photovoltaic capacity growth in 2020 (see Figure 2).

The development of the photovoltaic market in Poland, as of 2019, remains at a high level, making it one of the European leaders. As shown in Figure 2, compared to Poland, only three countries—Germany, the Netherlands, and Spain—reported larger growth in installed photovoltaic capacity in 2020 (Germany with 4.74 GW, the Netherlands with 3 GW, and Spain with 2.8 GW of new capacity). With a growth of 2.4 GW, Poland is in fourth place, ahead of France (0.9 GW) whose share of new PV installations declined. According to the estimates of the Institute of Renewable Energy, the photovoltaic market in Poland will continue to grow rapidly in the coming years. In 2023, from the perspective of total installed capacity, it is estimated that the prosumer photovoltaic installations market will equal that of solar farms, which will positively impact the sustainable development of the entire renewable energy sector in Poland.

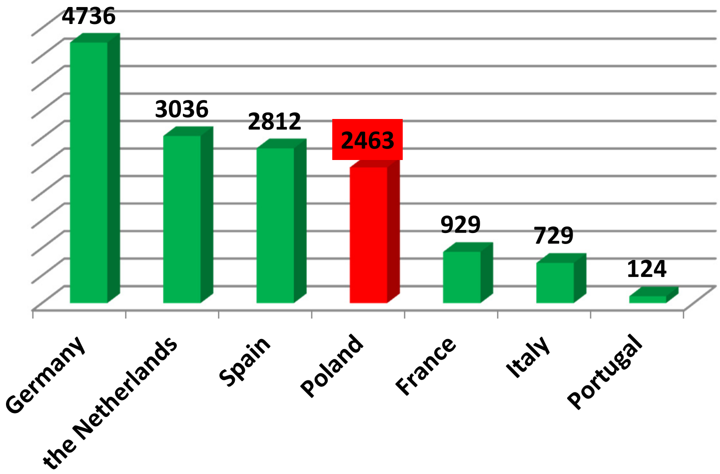

Figure 2. Growth of installed photovoltaic capacity in selected European Union countries in 2020, (data in MW). Source: own elaboration based on Energy Market Agency data [19].

Photovoltaic systems are also developing rapidly in global markets [20,21]. This situation mainly affects European Union member states, due to their climate policies [22,23]. A major contributor to solar energy production in Europe is Germany [24,25]. In 2021, the country generated a total of 60.6 GW of electricity from solar photovoltaic systems [26,27]. In contrast, China (308.3 GW), the United States (122.9 GW), Japan (77.6 GW), and India (60.1 GW) are the top markets in the world [28,29].

1.2. Legal Regulations for Processes of Thermal Modernization of Buildings in Poland

The effective utilization of photovoltaic installations, particularly for individual prosumers, depends on the technical condition of a given building. This requires comprehensive measures for thermal modernization of existing buildings. According to the provisions of the Act of 21 November 2008, on supporting thermal modernization and renovations, thermal modernization processes consist of the following:

- reduction in the energy demand for heating buildings and heating and domestic hot water,
- reduction in primary energy losses in local heating networks and the local heat sources supplying them,
- making technical connections to a centralized heat source, in association with liquidation of a local heat source,
- complete or partial change to renewable energy sources.

The literature distinguishes three degrees of thermal modernization of buildings, classified on the basis of two criteria: comprehensiveness of the measures and achieved effects (see Table 2).

As can be seen from the information presented in Table 2, the application of the third level of thermal modernization of the building—comprehensive modernization—will fully improve its energy efficiency. It is also worth remembering here the principle of Trias Energetica, according to which the use of renewable energy sources, such as photovoltaic panels, must be preceded by processes to reduce energy losses while maintaining comfort of living [31]. The use of renewable energy sources makes sense for buildings with minimum energy demand. This approach has a number of environmental, economic, and social benefits. From the perspective of the purpose of this article, the economic benefits are the most significant. In fact, according to the Buildings Performance Institute Europe, annual energy savings achieved through comprehensive thermal modernization processes may reach between 5% and 26% of consumption in 2030 compared to 2013. A comprehensive modernization could also reduce heating costs by up to 60%.

In summary, thorough thermal modernization of a building is aimed at reducing its operating costs, which are gradually increasing under current economic conditions. Therefore, in such decisions, it is necessary to carry out an analysis of the economic efficiency of the undertaken undertaking, also taking into account the costs of its implementation.

Table 2. Degrees of thermal modernization of the building.

Degree of Thermal Modernization of the Building	Measures to Achieve the Desired Degree of Modernization
Slight thermal modernization	• Modernization or replacement of the heating system including replacement or modernization of the heat source
Average thermal modernization	• Modernization or replacement of the heating system including replacement or modernization of the heat source • Replacement of window and door woodwork • Insulation of external walls • Roof insulation
Comprehensive thermal modernization	• Modernization or replacement of the heating system including replacement or modernization of the heat source • Using renewable energy sources • Upgrading or replacing the domestic hot water system • Replacement of external window and door woodwork • Insulation of all building envelopes (facades, flat roof, and ceiling/floor) • Elimination of thermal bridges, e.g., as a result of balcony renovation • Modernization of the ventilation system.

Source: [30].

2. Materials and Methods

This study was conducted on the basis of the key energy performance of buildings. The whole comparative analysis, due to the limited volume of the article, is presented in synthetic terms.

The research object is a single-family residential building located in climate zone III. This building was built in 1991, using a traditional brick technique, with three-layer external walls with air cavities. The usable area of the analyzed building is 140 m^2. The analyzed building is equipped with a gravity ventilation system, and its external partitions are characterized by a low heat transfer coefficient, amounting to U = 0.190 W/(m^2K), with a useful energy demand for heating and ventilation of 38.93 kWh/(m^2/year). The heat source for the building is a natural gas-fired boiler. As property owners plan to begin the process of average thermal modernization, one of the key decisions is choosing an alternative heat source.

According to the current Polish legal regulations, all existing buildings that will be expanded or modernized after 31 December 2020 must meet the requirements arising from the Regulation of the Minister of Infrastructure of 12 April 2002 on technical conditions to be met by buildings and their location [32,33]. The main goal of the new regulations is to promote energy-efficient construction and for "old" buildings to achieve minimum energy performance standards. The drastic tightening of the current building regulations is a consequence of the pro-environmental policy of the European Union and the adoption of three standard postulates, called the 3 $\times$ 20 package of climate laws, i.e., reduction in energy consumption by 20%, reduction in carbon dioxide emissions by 20%, and increase in renewable energy production by 20% [34–37]. The changes introduced relate—above all—to reducing the thermal conductivity coefficient of the building's structural elements, reducing energy demand, and modernizing heating furnaces. From the point of view of achieving the objective of this article, it is important to reduce the thermal conductivity coefficient (EP) by modernizing the heat source. The consequences of tighter thermal conductivity values and energy demand would be reflected in the ways buildings are heated. Because it is not possible to achieve the required EP coefficient value with traditional coal, oil, or gas boilers, It will be necessary to use renewable energy sources in such buildings. Increasing the share of renewable energy sources in the energy balance of the building will facilitate compliance with the 2021 technical conditions referred to in the aforementioned regulation [32].

The calculations of energy demand for the purpose of this paper were carried out for climate base III—Kielce Suków. According to the analysis and evaluation of the technical conditions of the studied structure, it was determined that its annual energy demand for heating and ventilation is 38.93 kWh/(m^2/year).

In order to facilitate the decision on selection or modernization of the heat source in the analyzed building, the following technological variants of the central heating and ventilation system were analyzed (see Figure 3):

1. Air/water heat pump fully covering the CH demand,
2. Air/water heat pump covering 100% of the CH demand, powered by solar collectors.

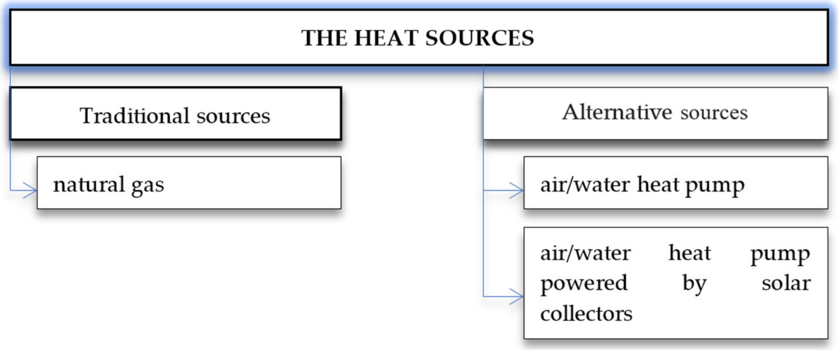

Figure 3. Traditional and alternative heat sources. Source: own elaboration.

In both cases, the heat pipes were insulated, and the heat source was located inside the heated building.

All necessary calculations were performed using CERTO 2015 and Aterm computer software [38,39]. The results made it possible to identify important elements of the energy performance of the analyzed building in terms of the obtained indicators of annual demand for usable energy, primary energy, and final energy.

The useful energy demand contains important information about the energy quality of a building. It shows the status of thermal insulation of the building envelope, the degree of elimination of thermal bridges, and their impact on heat loss, and it determines the type of ventilation used (with or without heat recovery) [40]. From the energy demand, it is possible to deduce how the building body was designed (compact or expansive) and how the solar gain coming in through the transparent envelopes was used.

Primary energy, on the other hand, is a parameter defining the value of demand for nonrenewable energy coming mainly from fossil energy resources (coal, oil, or gas) [40]. It is used for heating, ventilation, and domestic hot water in a building.

From the building occupant's point of view, on the other hand, the amount of final energy demand is the most important. This is the energy that should be delivered to the building in the form of a heating medium, fuel, or electricity [40]. Its size allows estimating the costs of energy supply for heating and ventilation, air conditioning, domestic hot water, and lighting of the building, as well as comparing costs using other supply methods.

Tables 3–5 present synthetic results of demand for usable, primary, and final energy for the investigated single-family building, taking into account the analyzed heat sources, i.e., natural gas boiler, heat pump, and heat pump powered by solar collectors. Thus, Table 3 shows the key energy performance indicators for a building powered by a traditional heat source, i.e., natural gas. The table also shows an annual primary energy demand (EP) index of 70.00 kWh/(m^2/year), effective from 2021. This is the value resulting from the standards adopted in the aforementioned Technical Conditions 2021 for newly constructed buildings [32].

Table 3. Energy performance of a building using non-renewable heat sources (natural gas).

Energy Performance Index	Values Obtained for the Analyzed Building	Requirements for a New Building
Annual useful energy demand index	EU = 63.02 kWh/(m^2/year)	
Annual final energy demand index	EK = 86.04 kWh/(m^2/year)	
Annual primary energy demand index	EP = 94.65 kWh/(m^2/year)	EP = 70.00 kWh/(m^2/year)
Specific emission of CO_2	ECO_2 = 0.0174t CO_2/(m^2/year)	
Share of renewable energy sources in annual final energy demand	Uoze = 0.00%	

Source: own elaboration based on data from CERTO 2015 and Aterm [38,39].

As can be seen from the data presented in the table above, the index of annual demand for primary energy is 94.65 kWh/(m^2/year), which significantly exceeds the allowable value of this index, resulting from the Technical Conditions 2021 [32]. This means that, when deciding on the scope of thermal modernization works for this building, it is necessary to take into account the replacement or modernization of the heat source.

An alternative to traditional gas boilers is—among others—a heat pump, which was analyzed to improve the energy performance of the analyzed building. The heat pump is one of the two solution variants proposed in the article. Table 4 shows the values of demand indices for energy extracted from the heat pump used in the analyzed building.

Table 4. Energy performance of a building using a heat pump in the heating system.

Energy Performance Index	Values Obtained for the Analyzed Building	Requirements for a New Building
Annual useful energy demand index	EU = 63.02 kWh/(m^2/year)	
Annual final energy demand index	EK = 60.27 kWh/(m^2/year)	
Annual primary energy demand index	EP = 50.95 kWh/(m^2/year)	EP = 70.00 kWh/(m^2/year)
Specific emission of CO_2	ECO_2 = 0.0094t CO_2/(m^2/year)	
Share of renewable energy sources in annual final energy demand	Uoze = 15.43%	

Source: own elaboration based on data from CERTO 2015 and Aterm [38,39].

Analysis of the data presented in the table above allows us to conclude that the use of a heat pump as an alternative to natural gas would make it possible to meet the applicable primary energy demand standards. Other indicators such as final energy demand and carbon dioxide emissions are also improved significantly compared to the data in Table 3.

Table 5 shows the values of energy performance indices for the analyzed building when using a heat pump and solar collectors in the heating system.

Table 5. Energy performance of a building using a heat pump and solar collectors in the heating system.

Energy Performance Index	Values Obtained for the Analyzed Building	Requirements for a New Building
Annual useful energy demand index	EU = 63.02 kWh/(m^2/year)	
Annual final energy demand index	EK = 40.46 kWh/(m^2/year)	
Annual primary energy demand index	EP = 28.80 kWh/(m^2/year)	EP = 70.00 kWh/(m^2/year)
Specific emission of CO_2	ECO_2 = 0.0098t CO_2/(m^2/year)	
Share of renewable energy sources in annual final energy demand	Uoze = 29.01 %	

Source: own elaboration based on data from CERTO 2015 and Aterm [38,39].

The comparative analysis of the data presented in Tables 3–5 allows concluding that the most advantageous solution from the point of view of energy demand in the investigated building would be the simultaneous application of a heat pump and solar collectors. The adopted solutions would also have a significant impact on reducing carbon dioxide emissions by about 46% in the case of the heat pump alone and by about 44% in the case of the heat pump and solar collectors. In addition, they would favorably increase the share of renewable energy sources in annual final energy demand to 15.43% for variant one and to 29.01% for variant two.

3. Results

The analysis showed that the simultaneous application of a heat pump and solar collectors in the analyzed building effectively influenced the values of indicators of annual demand for usable, primary, and final energy. Figure 4 shows a graphical representation of the results obtained.

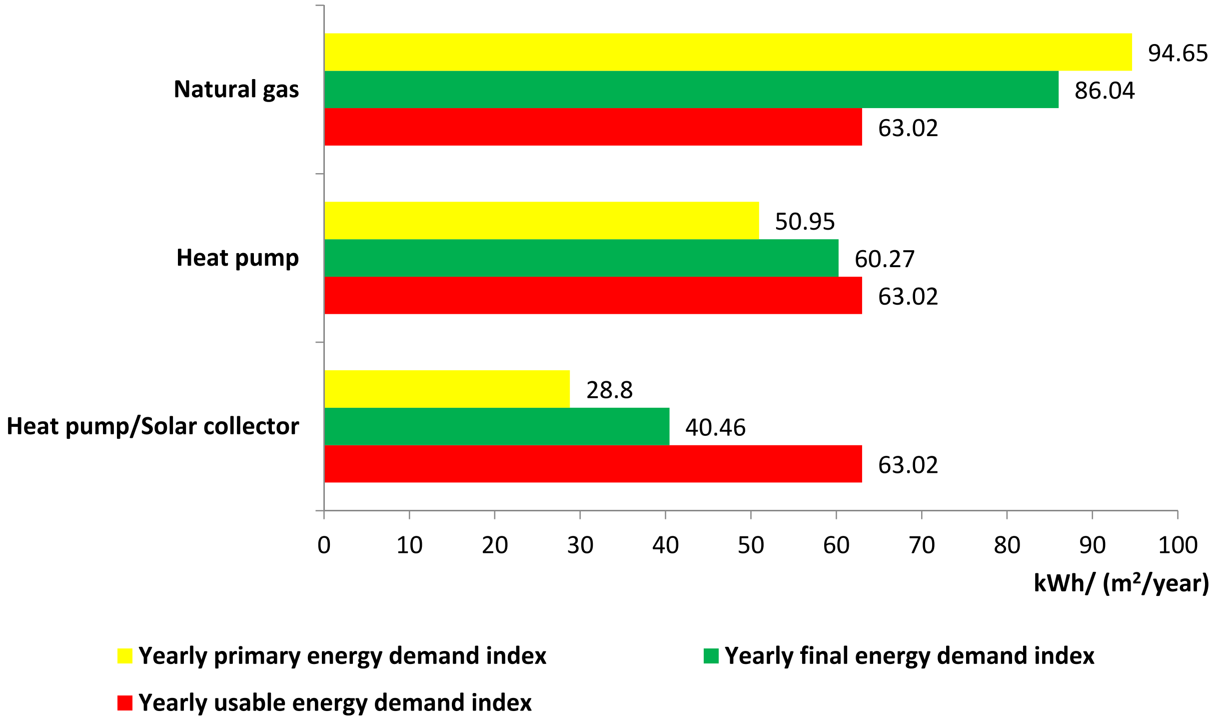

Figure 4. Energy performance indices of the analyzed building (data in kWh/(m^2/year)). Source: own elaboration based on data from Tables 3–5 [38,39].

The obtained results indicate that both the first variant (application of a heat pump) and the second variant (application of a heat pump together with a solar collector) showed significant reduction in the values of energy demand indices, compared to the traditional natural gas. The amount of final energy demand in the analyzed case decreased from 86.04 (kWh/(m^2/year) with natural gas to 40.46 (kWh/(m^2/year) with a heat pump and a solar collector. Primary energy demand, on the other hand, similarly dropped from 94.65 (kWh/(m^2/year) to 28.8(kWh/(m^2/year). The observed improvement in the energy performance of the analyzed building implies significant savings of nonrenewable primary energy resources.

The data obtained indicate that the modernization of the heat source in this building should be focused on installation of a hybrid solution, i.e., simultaneous application of a heat pump and a solar collector. It is worth noting that the proposed solution is also beneficial from the point of view of economic aspects, more specifically, the reduction of heating costs of the analyzed building. In fact, the basic indicator for determining the level of heating costs of a building is the amount of annual final energy demand. In the analyzed example, the final energy costs were lower by 29.95% when using the first variant, i.e., a heat pump, and by 52.97% when using a heat pump and solar collectors. The value of primary energy demand was also reduced by 46.17% for the heat pump and 69.57% for the heat pump and solar panels. Such a decrease in the value of the incurred costs of heating the building would give measurable economic benefits for its users. For example, for the purpose of this paper, the annual heating costs of the analyzed building were calculated on the basis of a natural gas price of 0.35 (PLN/kWh) with a calorific value of 10.972 (kWh/m^3) and a final energy rate of 86.04 (kWh/(m^2/year). Calculations were made using Equation (1).

$$\text{RKO} = \text{EK} \times \text{building heating area} \times \text{price per 1 kWh}, \tag{1}$$

where RKO is the annual cost of heating with natural gas, and EK is the final energy.

Thus, the cost savings were calculated on the basis of Equation (2) when using a heat pump and Equation (3) when using a heat pump and solar collector.

$$\text{Cost savings with a heat pump} = (\text{RKO} \times 29.95\%)/100\%. \tag{2}$$

$$\text{Cost savings with a heat pump and solar collector} = (\text{RKO} \times 52.97\%)/100\%. \tag{3}$$

The obtained results are presented in Table 6.

Table 6. Value of annual heating costs.

Annual Final Energy Demand Index EK = 86.04 (kWh/m^2·year)	**Cost Savings**	
Natural gas 4215.96 PLN	Heat pump 1262.68 PLN	Heat pump/Solar collector 2233.19 PLN

Source: own elaboration based on data from CERTO 2015 and Aterm [38,39].

As can be seen from the data presented in Table 6, the value of heating costs of the analyzed building with natural gas is 4215.96 PLN per heating season. Modernization of the building consisting of the application of the first variant would allow for savings of almost 1300.00 PLN/year in heating costs. In turn, the heat pump and solar collectors would save users more than 2000.00 PLN/year. This confirms that the proposed solutions would not only improve the energy efficiency of the building, but also reduce its operating costs. It is also worth mentioning here that the proposed thermal modernization solutions are associated with specific investment outlays, the size of which is not the subject of this discussion. Detailed calculations of the investment costs incurred in upgrading a building's heating system and the return-on-investment period for this project will be analyzed in a separate article.

4. Discussion

The comparative analysis of the proposed heat sources carried out in the paper showed that the best solution for the analyzed building was the simultaneous application of a heat pump and solar collectors. This solution had a significant impact on the energy efficiency of the building, as confirmed by much lower values of the indicators of the annual demand for primary energy, usable energy, and especially final energy in comparison with the traditional source of heat (natural gas). Thoughtful selection of a heating system can reduce the operating costs associated with heating a building by more than 50%. The difference between heating the presented building with a gas boiler and a heat pump was over 2233.19 PLN per year.

However, from the point of view of avoiding heat losses in the process of thermo-modernization, replacement or modernization of structural elements of the building is also important. It is generally accepted that heat loss through the roof is between 10% and 30%, through the walls is between 20% and 30%, through the windows and the door frames is between 10% and 25%, through the basement is between 3% and 6%, and through ventilation is between 25% and 40% [30]. Thermal modernization processes, therefore, involve the use of appropriate insulation and construction materials and the proper selection of internal installations in modernized buildings [41].

According to this research, the solar-powered heat pump shows great potential to become a promising energy-efficient heating technology. The advantages of this solution have been widely discussed in the literature for some time [42–45]. Authors often stressed that, by combining two distinct energy sources for heating purposes, one would be offered great value for the money spent on property heating, whereas it would deliver a superior cost–performance ratio compared to traditional central heating systems [46]. In addition to the advantages, the analyzed solution has one major disadvantage, i.e., the high cost of installation, causing many residential building owners to opt out. In this context, a cognitively interesting issue is the analysis and evaluation of the costs and benefits of using a solar-powered heat pump, which will be considered in a future article.

5. Conclusions

The proper development of RES is inseparably connected with increasing the energy efficiency of buildings. Renewable energy prices are expected decline, while conventional energy sources, i.e., grid electricity and natural gas are on an upward trend. The use of installations based on renewable energy resources in the building industry has a significant impact on increasing energy security and achieving the required heat consumption standards at a lower operating cost.

Targeted and deliberate measures to improve the end-use energy efficiency of buildings must be necessary in a sustainable low-carbon economy. Improving the energy performance of a building, which has a significant impact on achieving significant savings in nonrenewable energy sources, requires systemic, broad state support. The modification of the existing regulations of the prosumer electricity and heat market, in accordance with Directive 2010/31/EC of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings, should lead to the design of buildings with nearly zero energy consumption [33].

Therefore, the use of hybrid solutions combining different energy sources (in this case, heat pumps and solar collectors) is in line with current energy policy trends in the European Union. The analysis of the proposed variants of solutions showed a significant improvement of the key indices of the energy performance of the building, which was also reflected in the costs of its heating. This is extremely important in light of current environmental and economic conditions, as well as rising energy prices, in Poland.

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