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How Pro-Environmental Legal Regulations Affect the Design Process and Management of Multi-Family Residential Buildings in Poland

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Abstract: This article addresses issues related to the quality of design and subsequent management of multi-family residential buildings in the context of their energy supply. The framework of the analysis carried out here are pro-environmental legal regulations currently in force in Poland. This article describes the impact of these regulations on the design process and the role of the designer. The requirements have been defined and the constraints have been identified. A number of factors directly related to the nature and parameters of the designed buildings and their location have been taken into consideration. On the basis of this study, the impact of legal regulations both on the method of energy supply in the buildings and on their later use and management have been presented. Positive and negative aspects of the analyzed regulations have been indicated and directions for their evaluation and optimization have been proposed. The research was carried out using real buildings, both completed and in the design phase. This article is based on the authors' extensive experience in designing multi-family residential buildings in Poland.

Keywords: design; management; energy efficiency; energy performance of buildings; multi-family buildings; energy policy; architecture

1. Introduction

For many years, the issue of reducing energy consumption has become increasingly important both in the European Union (EU) and worldwide. According to the European Commission data, energy consumption in buildings is 40% and they generate 36% of CO_2 emissions in the EU [1]. One of the first directives of the European Parliament and the Council on the energy performance of buildings was directive 2010/31/EU [2], introduced in 2010. The primary objective of this directive was to reduce energy consumption and CO_2 emissions by construction works. In 2018, it was replaced by a new directive (2018/844) [3], which tightens the regulations in this area. Its main objective is to decarbonize the existing building stock in the EU by 2050. The result of these directives is the introduction of local legislation in this area by individual EU members. In Poland some new legal regulations have been created [4,5] and appropriate changes have been introduced to the existing regulations [6–8].

Successively introduced pro-environmental regulations have resulted in changes in the process of construction, mainly in terms of building materials, technologies used, energy sources, and methods and principles of their design. A number of studies have been developed in this field, including the analysis of the existing condition [9], location conditions of buildings [10,11] as well as optimal material [12–15], technological [7,16–18], and design solutions [19–22]. There are also several studies on the evaluation and modernization of existing facilities [23–27] as well as on global system solutions aimed at increasing the energy efficiency of buildings [28,29]. Manufacturers of materials and technological systems are also following current regulations and analysis offering increasingly advanced materials and technologies. The issues of energy management in the building industry are obviously not only a European domain, these issues are analyzed worldwide, as exemplified by studies [30–32].

All the above mentioned areas related to energy efficiency are reflected in the design process. Designers in particular countries have to meet increasingly strict requirements, while at the same time they struggle with local conditions, regulatory shortcomings, and investor expectations. Thus, a designer cannot remain only a creator today. He should also be an economist, a manager, a lawyer, and a psychologist capable of reacting creatively to the ever-changing realities and formal and legal requirements, skillfully balancing between professionals, investors, officials, etc. A detailed analysis of these relationships clearly shows how much of his duties and responsibilities have expanded, and thus how his space for creation has been radically reduced. Therefore, it seems reasonable to ask how these issues affect the design process on the example of shaping contemporary multifamily buildings in Poland.

2. Design Reality and Binding Formal and Legal Conditions

Many years of experience and professional practice related to the design of residential multi-family buildings allows us to state that the main external factors, which have a significant impact on the design process in the case of this type of facilities, undoubtedly include the designer's relations with the investor and the applicable legal regulations which the designer is obligated to observe. The whole is, of course, completed by the designer's creation in the understanding of his creative statement on the project's vision, and the ability to link it with the investor's expectations and the imposed formal and legal rigors.

It is obvious that the starting point of each project is signing a contract with the investor whose main goal is usually financial success. In the case of multi-family residential buildings, this usually means achieving the highest possible rate of development, i.e., obtaining and selling as many meters of usable floor area (UFA) as possible, assuming the lowest possible investment costs. Standard contracts assume multi-stage and complex design process, as a result of which the investor can intervene extensively in the proposed design solutions basically at the level of each project stage which consists of:

- The analysis concerning the assessment of a possible value of the development intensity ratio;
- A preliminary concept confirming the possibility of obtaining the declared value of this indicator;
- Target concept that forms the basis for the construction project;
- Multi-discipline construction project with energy characteristics;
- Obtaining a building permit;
- Executive design including details of the design solutions, work quantities, and cost estimates;
- As-built documentation considering the changes introduced during the implementation phase;
- Energy certificate and obtaining a permit to use.

In addition, the contract specifies detailed design guidelines for each industry with respect to the layout of the structure and size of the apartments, their percentage share, possible design, and material solutions acceptable to the investor, and often the cost of construction of 1 m^2 of usable area of the apartments, which cannot be exceeded by the designer. Such a large number of components result in the necessity for the designer to make numerous compromises of both aesthetic nature, in the face of direct confrontation with the investor, but also ethical and moral, due to the need for absolute application of complex, often incoherent and contradictory formal and legal issues, also in the field of pro- environmental regulations. Thus, the designer's freedom of expression and creation is often limited to their proper interpretation.

One of the most important legal acts in Poland in the field of planning is the Act on Spatial Planning and Development [33], which defines, among other things, the procedure and drawing preparation, and adopting one of the basic legal acts from the point of view of the design process, namely the local spatial development plan. The Act, in accordance with the relevant ordinance [34], also allows, on the basis of an urban planning analysis, to issue decisions on development conditions. Equally important legal acts in force in Poland are the Building Law Act [8] together with the relevant regulations, including the basic one concerning the technical conditions obligatory for the buildings and their location [6]. They define as precisely as possible all requirements related to the design of construction works. As a result, as in the case of local development plans, they impose a certain scheme of action in terms of specific and obligatory guidelines, to which the designer must absolutely apply, i.e., fulfill all strictly defined parameters related mainly to the location and development project, requirements concerning the building itself, and technical infrastructure solutions.

Starting in 2009, the legal regulations related to the project process, which are in force in Poland, began to evaluate intensively toward pro-environmental solutions. The changes introduced in the Construction Law [8] and the regulations [4–7] imposed an obligation on the designer to develop an energy performance and rationalization of energy use as an integral part of the construction project. The requirement to develop energy performance has become obligatory for practically all designed buildings, except for small domestic buildings, inventory, and storage facilities.

The design solutions contained in the construction documentation, reflected in the results of the analysis carried out as part of the designed energy performance, must not forget to consider:

- Requirements relating to the value of the non-renewable primary energy indicator EP calculated according to the preparation methodology for energy performance certificates (comprehensive choice rationalization of heating system);
- Requirements for the limit values for the heat-transfer coefficient of the building envelope $U \leq Umax$;
- Checking the temperature coefficient f_{Rsi} in relation to the building envelope;
- Checking interlayer condensation;
- Checking the condition of water vapor condensation on the internal surface of the building envelope;
- Checking the total solar energy transmittance g_{tot} (solar factor) of transparent parts of building envelope;
- Determination of heat load for central heating, hot water, cooling installations, lighting, and auxiliary equipment, respectively;
- Determination of the annual average efficiency for central heating, hot water, and cooling installations;
- Checking the possibility of using renewable energy sources.

From the designer's perspective, it can be concluded that meeting most of the above mentioned conditions, as defined in the designed energy performance, does not pose major problems. The use of certified, relatively typical for multi-family buildings, construction, installation, and material solutions available on the market usually ensures that these requirements are met. However, it may turn out to be a problem to maintain at the required level the most important parameter of the designed energy performance, i.e., non-renewable primary energy, the so-called EP. In many cases it turns out to be quite complicated and problematic, and in some cases even controversial. This is not about problems with appropriate design solutions but about contradictions with other applicable regulations. To sum up, the requirement not to exceed certain EP values has a significant impact on the whole project process.

The value of EP is expressed in kWh per year per unit area of temperature-controlled space—(kWh/(m^2·year)). The maximum/limit value of EP is calculated according to the formula below [6]:

$$EP = EP_{H+W} + \Delta EP_L; [\mathrm{kWh}/(\mathrm{m}^2 \cdot \mathrm{year})] \quad (1)$$

where:
EP_{H+W}—partial value of EP index for heating, ventilation and domestic hot water preparation;
ΔEP_C—partial EP value for cooling;
ΔEP_L—partial EP value for lighting.

For multi-family residential buildings, the lighting component is not included. The component for heating, ventilation, and domestic hot water preparation is 85 (kWh/(m^2·year)), while the component for cooling is calculated based on the formula [6]:

$$\Delta EP_C = 10A_{f,C}/A_f; (\text{kWh}/(\text{m}^2\cdot\text{year})) \quad (2)$$

where:
A_f—area of rooms with regulated air temperature (heated or cooled), determined in accordance with the regulations issued under Article 15 of the Act of 29 August 2014 on the energy performance of buildings (m^2);
$A_{f,C}$—area of rooms with controlled air temperature (cooled), determined according to the above mentioned regulations (m^2).

In Poland, multi-family residential buildings equipped with air-conditioning are a fraction of the investments. In this article, buildings without air conditioning were tested. For such buildings the EP limit value is currently set at 85 (kWh/(m^2·year)).

The EP to be determined at the design stage for a building takes into account the final energy demand of the building and the additional energy input needed for fuel production, transport, storage, etc. Final energy (EK) is the energy delivered to a building for its technical and technological systems, calculated for each building individually. Its value depends mainly on the type of building, material parameters, its shape, location, and the technical and technological systems used. In the design process, the EK value is calculated on the basis of the methodology specified in the Regulation [6]. In order to determine the value of EP, the obtained EK value should be multiplied by the input factor of non-renewable primary energy needed to produce and deliver the energy carrier or energy to the building, i.e., the so-called w factor. The value of this factor, depending on the type of energy source used, has been determined by the legislator in a tabular form—see Table 1, included in the above-mentioned Ordinance [6]. In the case of a building where energy comes from different sources (e.g., network energy, local biomass, etc.), EP is the sum of the EK value for the individual energy sources multiplied by the corresponding value of w for the given source.

Table 1. The values of the non-renewable primary energy input factor on the generation and delivery of an energy carrier or energy for technical systems w [6].

No	Method of Supplying the Building with Energy	Type of Energy	w
1	Local energy generation in the building	Fuel oil	1.10
2		Natural gas	
3		Liquid gas	
4		Hard coal	
5		Brown coal	
6		Solar energy	0.00
7		Wind energy	
8		Geothermal energy	
9		Biomass	0.20
10		Biogas	0.50
11	District heating from cogeneration	Hard coal or gas	0.80
12		Biomass, biogas	0.15
13	District heating from heating stations	Hard coal	1.30
14		Gas or fuel oil	1.20
15	System power network	Electrical energy	3.00

According to the legal regulations in Poland, the EP value is one of the basic parameters determining the energy efficiency and ecological attractiveness of the designed object. That is why it is not difficult to notice how important the w value is in determining it. However, its values, given in the table above and assigned to the way of supplying the building or its part with energy, give rise to a number of controversies. They promote, on an equal level, the use of systems based both on hard coal, heating oil, and gas, for which w = 1.10, practically eliminating the possibility of using systems that make extensive use of electricity supplied from the system power network, for which w = 3.0. In Poland, electricity is largely produced in coal power plants and therefore it is considered as "dirty energy." But why does the problem related to the w coefficient value fall on the designer and investor who have no influence on the Polish energy system? The w values in general indicate a lack of consistency of the legislator with regard to the broadly understood assumptions of pro-environmental policy. For example, in the automotive industry, the solutions based on electricity obtained mainly from the power network are extremely strongly promoted. At the same time, efforts are being made to phase out vehicles powered by refined petroleum fuels. In the construction industry, taking into account the values of the w coefficient specified in the Regulation [6], it is quite the opposite. The w value for heating oil ranges from 1.1 to 1.2 and for system electricity is 3.0! It may seem that the legislator, through the w factor parameters contained in Table 1, defines the preferred installation and technological solutions that may be applied in the construction industry not fully consistent with the pro-environmental idea. This is a proposal based on major simplifications but shows a general lack of consistency in the existing legislation.

The lack of consistency of the legislator can also be seen in the context of determining the w value, for the heat carrier which is the so-called district heating. This issue is particularly important in the design of multi-family residential buildings where district heating is very often a source of energy. Multi-family residential buildings are mostly designed and constructed in large and medium-sized towns, where it is usually possible or even necessary to connect them to existing district heating networks. In many cases, the designer is obliged by law to use district heating. This results, among others, from the provisions contained in local regulations—local spatial development plans or decisions on development conditions. Additionally, the legislator, in accordance with Art. 33 pt. 2 ppk. 10 of the Building Law [8], imposes the necessity to use the district heating if it is available, requiring the designer to attach to the design documentation a statement concerning the possibility of connecting the designed object to the existing heating network. At the same time, the legislator determines the values of the coefficient w for district heating, for which items 11 to 14 in Table 1 are provided, which, in the case of energy obtained from hard coal, gas, or fuel oil, make it practically impossible to obtain EP coefficient values at the required level. In design practice, the values given in the table above are rarely used for district heating. They are taken into account only if the value of this factor has not been provided by the supplier of heat. Currently, most producers and suppliers of district heating, due to the fact that system heat is produced using different technologies and fuels, determine the value of the w coefficient individually and publish its value. Based on this data, the EP value for the designed building is then determined.

The research described in this article focuses on multi-family residential buildings, where the primary energy carrier is the so-called district heating. Its use seems right and justified, but in effect it largely limits the designer's freedom to choose alternative energy sources. This, in turn, causes complications in the design process associated with meeting the requirements set out in the Polish regulations on energy requirements, which has been shown in this study. Many Polish researchers have dealt with the energy efficiency of multi-family residential buildings and district heating, among others [12,23,35–37]. The analysis was mainly focused on overall energy efficiency, the materials used, the technology, as well as the energy sources (including system energy), but not enough attention was paid to the coupling and contradictions in the current regulations on the use of district heating. There are also no analysis of Polish contemporary design realities and how the work of the designer, architect faces the need to protect the natural environment changes.

3. Objective and Research Methodology

The design process as well as binding formal and legal conditions require continuous optimization in order to introduce the principles of sustainable development in an efficient way. It is particularly important while designing multi-family housing due to scale of impact on society. The conducted research oriented mainly toward a practical application of the results obtained in the investment process fits into a trend of introducing sustainable development principles. The basic aim of the research was to determine the design consequences of the need to meet legal requirements for pro-environmental solutions. A practical goal was to obtain the necessary data to elaborate on the tool supporting the decision-making in the design process as well as rationalize the process of creation of laws within the scope of pro-environmental solutions. The research used the set of source materials—mainly legal acts in force, a number of project documentation and analysis of specific cases. The research was carried out on actual original designs of multi-family residential buildings, both those already completed and those under construction or at an advanced design stage. It allowed for a detailed analysis of the issue, because only at the advanced stage of the construction project, after receiving the technical connection conditions from the utility managers, as well as the known usable areas and the structure of the premises, a reliable energy performance of the designed building is possible.

From the available research (design) material, multi-family residential buildings powered by district heating, designed and constructed over the last decade, were initially selected:

- Multi-family housing at Baltycka Street in Swinoujscie. Completion 2010;
- Multi-family housing "Nautica" at Raginisa Street in Szczecin. Completion 2013–2018;
- Multi-family housing at Gen. Sikorskiego Street in Drawsko Pomorskie. Completion 2015;
- Multi-family housing "Chabrowe I" at Zniwna Street in Szczecin. Completion 2015;
- Multi-family housing at Pancerna Street in Lodz. Project 2016;
- Multi-family housing "Chabrowe II" at Zniwna Street in Szczecin. Completion 2018;
- Multi-family housing at Sadowskiego Street in Szczecin. Completion 2019;
- Multi-family housing at Barnima Street in Stargard. Project 2018;
- Multi-family housing at Akacjowa Street in Goleniow. Project 2019;
- Multi-family housing at Emilii Plater Street in Szczecin. Project 2019.

The calculations, made for the buildings, which initially qualified for the study, showed that EK calculation values for multi-family buildings, powered by a heat distribution network, differed from each other to a small extent. On this basis, the ranges of the individual components of the EK values relating to multi-family buildings were determined (Table 2).

Table 2. The range of EK values for typical multi-family buildings designed according to current standards equipped with a heat substation supplied from the municipal heating network.

	Heating and Ventilation	Hot Water	Auxiliaries	Total
EK value kWh/(m^2·year)	29 ÷ 39	48 ÷ 59	4.2 ÷ 4.9	80.2 ÷ 102.9

Taking into account that in the majority of facilities in Poland the auxiliary equipment is supplied with mains electricity, coefficient w = 3.0, the table above shows that in order to meet the condition EP ≤ 85 (kWh/(m^2·year)) it is necessary to use system energy with a coefficient w value of less than one or other alternative solutions.

In order to obtain possible highly measurable research results, multi-family residential buildings with the most similar and comparable characteristics were selected for further detailed analysis which meet the following criteria:

- Buildings designed in a similar period, i.e., over the last three years;
- Buildings with a residential function;
- Buildings of similar dimensions with an underground garage;
- Buildings where heat is supplied from district heating networks;
- Buildings located in various places within the West Pomeranian voivodeship in Poland.

Based on these criteria, three multi-family buildings were selected for further research:

- The multi-family building at Sadowskiego Street in Szczecin;
- The multi-family building at Barnima Street in Stargard;
- The multi-family building at Akacjowa Street in Goleniow.

The multi-family building at Sadowskiego Street in Szczecin (Figure 1).

(a) (b) (c) (d)

Figure 1. The building at Sadowskiego Street in Szczecin. (**a**) Visualization 01; (**b**) visualization 02; (**c**) floor plan; (**d**) cross section and east elevation.

Project: 2017 Completion 2017–2019.

Based on the current Local Spatial Development Plan, a single-staircase, multi-family residential building was designed and constructed. The building with an L-shaped base has four above-ground storeys, including the last floor with a mezzanine, partially retracted from the front of the building. Underneath the building and partly outside its outline there is a multi-stand underground garage.

Basic data:

- Development surface: 829.75 m^2
- Building height: 14.98 m

- Number of above-ground storeys: 4
- Number of underground storeys: 1
- Usable surface: 3853.76 m^2
- Building cubature: 14,450.0 m^3
- Number of apartments: 42

The multi-family building at Barnima Street in Stargard (Figure 2).

Project: 2019. In progress.

Based on the current Local Spatial Development Plan, a two-staircase, multi-family residential building was designed. The building with an L-shaped base has three storeys above the ground. Under the building there is a multi-stand underground garage.

Basic data:

- Building height: 10.17 m
- Number of above-ground storeys: 3
- Number of underground storeys: 1
- Usable surface: 3031.82 m^2
- Building cubature: 17,802.04 m^3
- Number of apartments: 61

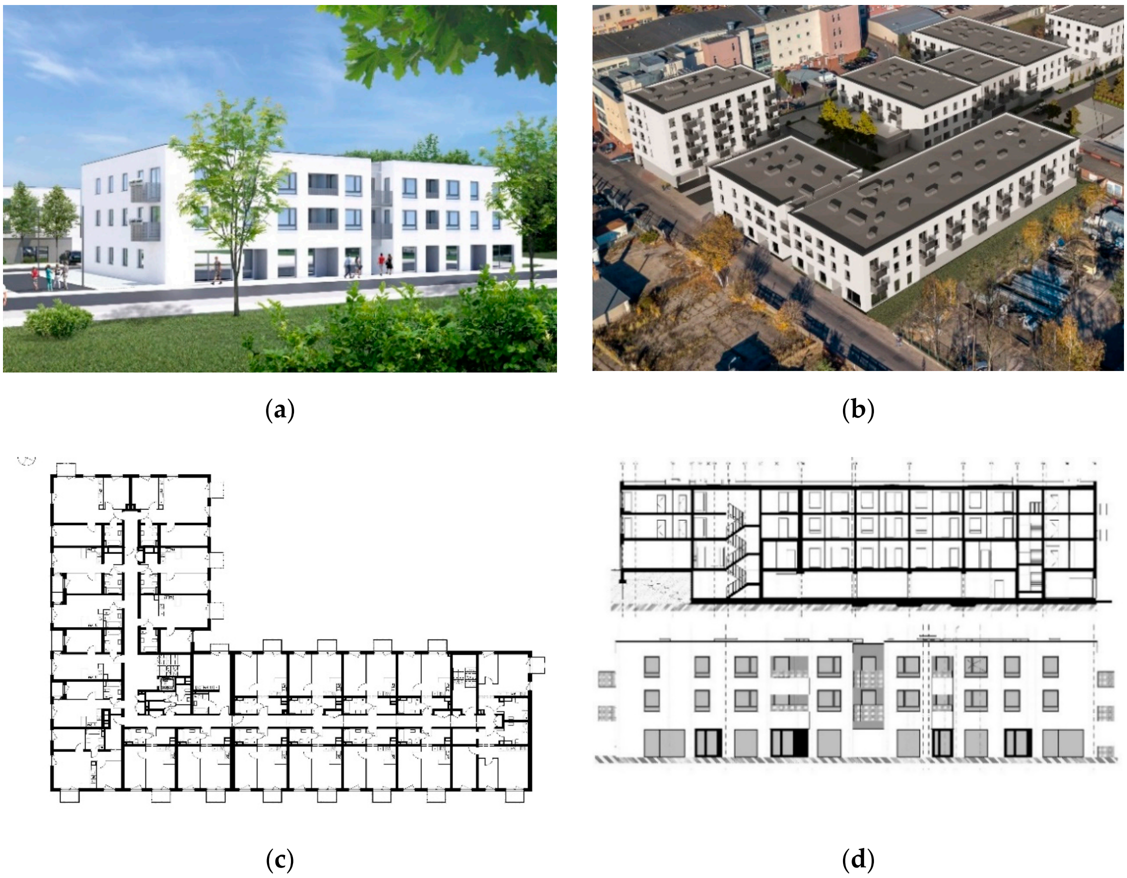

Figure 2. The building at Barnima Street in Stargard. (**a**) Visualization 01; (**b**) visualization 02; (**c**) floor plan; (**d**) cross section and east elevation.

The multi-family building at Akacjowa Street in Goleniow (Figure 3).

Project: 2020. In progress.

Based on the decision on development conditions, a two-staircase, multi-family residential building was designed. The building has an L-shaped base and has five storeys above ground. Under the building there is a multi-stand underground garage.

Basic data:

- Development surface: 1037.00 m^2
- Building height: 16.40 m
- Number of above-ground storeys: 5
- Number of underground storeys: 1
- Usable surface: 3303.35 m^2
- Building cubature: 21,880.00 m^3
- Number of apartments: 50

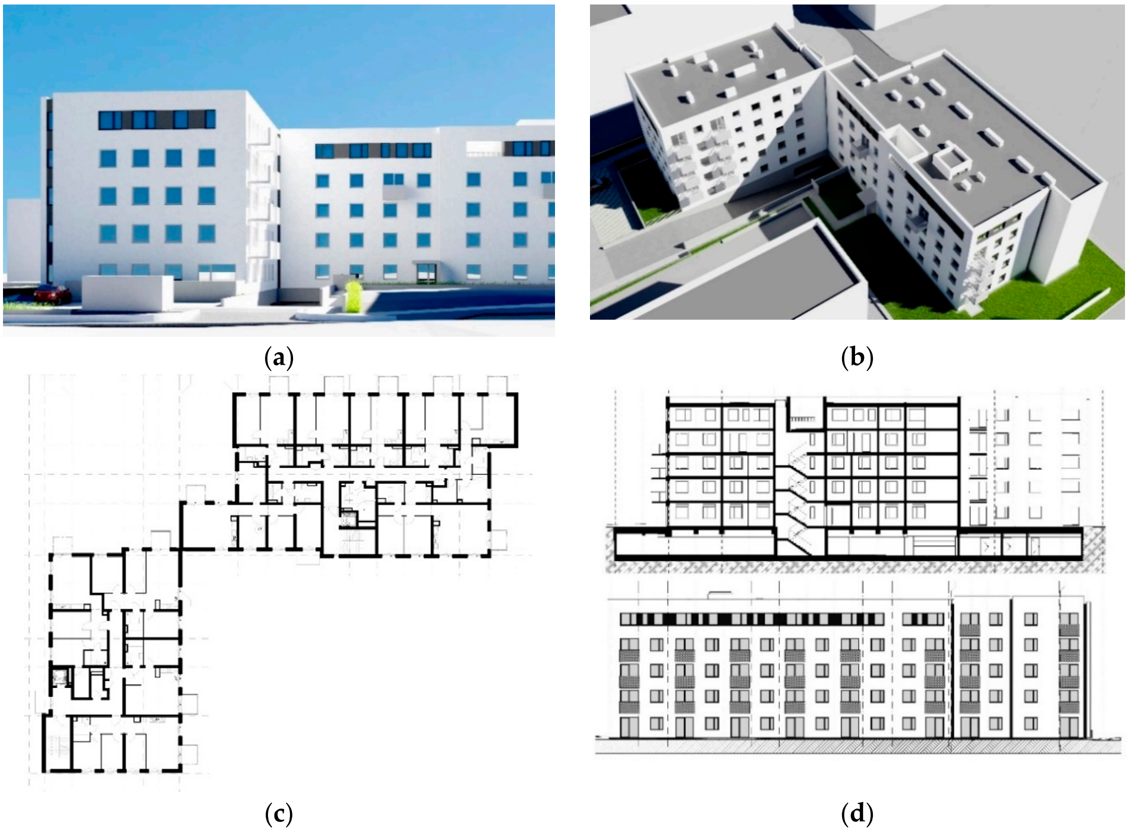

Figure 3. The building at Akacjowa Street in Goleniow. (**a**) Visualization 01; (**b**) visualization 02; (**c**) floor plan; (**d**) cross section and east elevation.

Technical and functional solutions adopted in the design process of individual buildings were analyzed in detail in relation to the demand for energy used for:

- Heating and ventilation;
- Preparing of domestic hot water;
- Powering the auxiliary equipment.

Similar structure and materials of similar thermal insulation were used in the buildings, as well as the same type of transparent parts of the building envelope which met the thermal insulation requirements specified in [6]. Increasing the thermal insulation of the external building envelope above the required minimum has very little impact on the final EP result. It ranges from 1 ÷ 2 (kWh/(m^2·year)). In the discussed investments, the final thickness of the thermal insulation was determined after the selection of thermal insulation sources on the basis of the optimization process with cost criteria. The conducted research made it possible to determine the differences in the design process of very similar buildings, resulting only from their location within one voivodeship. The calculations and analysis of numerous options available and a setup of design and technological solutions in the field of energy supply were made for each of the buildings. The requirements resulting from binding legal regulations were taken into consideration.

4. Results

The first stage of the analysis for the selected buildings was the EP calculation taking into account the use of only available district heating as the main and only source of thermal energy. The calculations assume that the auxiliary equipment will be supplied with mains electricity for which the coefficient $w = 3$, while the coefficients w for district heating were adopted in accordance with the values provided by individual heat suppliers. The results of the calculations are shown in the table below (Tables 3–8).

The multi-family building at Sadowskiego Street in Szczecin.

Table 3. The annual final energy demand (kWh/(m^2·year)) for the multi-family building at Sadowskiego Street in Szczecin.

Energy Carrier	Heating and Ventilation	Hot Water	Auxiliaries	Total
District heating (w = 0.71)	32.70	58.94	0.00	98.65
Mains electricity (w = 3.0)	0.00	0.00	4.62	4.62

The multi-family building at Barnima Street in Stargard.

Table 4. The annual primary energy demand EP (kWh/(m^2·year)) for the multi-family building at Sadowskiego Street in Szczecin.

	Heating and Ventilation	Hot Water	Auxiliaries	Total
EP value (kWh/(m^2·year))	23.22	41.85	13.87	78.94

Table 5. The annual final energy demand EK (kWh/(m^2·year)) for the multi-family building at Barnima Street in Stargard.

Energy Carrier	Heating and Ventilation	Hot Water	Auxiliaries	Total
District heating (w = 0.92)	28.44	48.33	0.00	98.65
Mains electricity (w = 3.0)	0.00	0.00	4.63	4.62

Table 6. The annual primary energy demand EP (kWh/(m^2·year)) for the multi-family building at Barnima Street in Stargard.

	Heating and Ventilation	Hot Water	Auxiliaries	Total
EP value (kWh/(m^2·year))	26.16	44.46	13.88	84.50

The multi-family building at Akacjowa Street in Goleniow.

Table 7. The annual final energy demand EK (kWh/(m^2·year)) for the multi-family building at Akacjowa Street in Goleniow.

Energy Carrier	Heating and Ventilation	Hot Water	Auxiliaries	Total
District heating (w = 0.92)	29.37	50.56	0.00	81.25
Mains electricity (w = 3.0)	0.00	0.00	3.89	4.62

Table 8. The annual primary energy demand EP (kWh/(m^2·year)) for the multi-family building at Akacjowa Street in Goleniow.

	Heating and Ventilation	Hot Water	Auxiliaries	Total
EP value (kWh/(m^2·year))	38.18	65.72	11.66	115.56

The studies have shown as follows:

The multi-family building at Sadowskiego Street in Szczecin, during the process of design and obtaining a building permit in 2017, met the requirements related to the required maximum value of EP. However, at that time the *w* value given for the district heating in Szczecin was 0.71. Currently, in 2020, the value of the *w* coefficient for the Szczecin thermal power industry is 0.93. Therefore, the building constructed on the basis of the 2017 project at this point in time does not meet the requirements of the EP threshold.

The multi-family building at Barnima Street in Stargard, during the design and obtaining a building permit in 2018, as well as currently, meets the requirements related to the required maximum value of EP.

The multi-family building at Akacjowa Street in Goleniow, as the only one of the analyzed, at the stage of the construction project did not meet the binding regulations concerning the required value of EP and significantly exceeding it. In this case, the reason was also the relatively high value of the *w* factor, given for the district heating in Goleniow, which in this case was 1.3.

The tests have shown that meeting the requirements for the maximum value of EP $\leq$ 85 (kWh/(m^2·year)) for the analyzed multi-family buildings powered exclusively by district heating depends mainly on the *w* value. The expected *w* values should be clearly below one, i.e., energy should be generated in a cogeneration system or using renewable energy sources or both. Unfortunately, in many towns, especially medium and small ones, thermal power generation is based on typical coal-fired or gas-fired plants. This causes the *w* factor to reach such a high level as in Goleniow. This makes it impossible to design a multi-family residential building powered exclusively by district heating, mainly due to the technology and type of heating material of the local system energy producer.

The calculations showed that in the case of the building project in Goleniow, it turned out to be necessary to introduce changes to the project in order to analyze the possibility of using other, alternative to district heating, energy sources allowing to meet the binding, pro-environmental legal requirements. Four variants of heat sources that can be used were analyzed in detail:

- Option 1. A gas boiler room located in the building, supplying residential heat distribution centers.
- Option 2. Gas boiler room located in the building supplying residential heat substations together with an additional photovoltaic installation for supplying auxiliary equipment.
- Option 3. Cascade of air heat pumps with photovoltaic installation.
- Option 4. Ground source heat pump with photovoltaic installation.

The results of the calculation of the EP values for the above variants are presented below, taking into account the building parameters and the design solutions used.

Option 1. A gas boiler room supplying residential heat distribution centers. The analyzed solution assumes placing the boiler room in the building. The calculation resulted as follows (Tables 9 and 10):

Table 9. The annual final energy demand (kWh/(m^2·year)) for the multi-family building at Akacjowa Street in Goleniow (gas boiler room).

Energy Carrier	Heating and Ventilation	Hot Water	Auxiliaries	Total
Gas boiler room (*w* = 1.1)	28.51	40.01	0.00	68.52
Electricity	0.00	0.00	4.12	4.12

Table 10. The annual primary energy demand (kWh/(m^2·year)) for the multi-family building at Akacjowa Street in Goleniow (gas boiler room).

	Heating and Ventilation	Hot Water	Auxiliaries	Total
EP value (kWh/(m^2·year))	31.36	44.01	12.35	87.73

Option 2. Gas boiler room. The analyzed solution assumes placing the boiler room in the building and locating the photovoltaic panels on the roof. The calculation resulted as follows (Tables 11 and 12):

Table 11. The annual final energy demand (kWh/(m^2·year)) for the multi-family building at Akacjowa Street in Goleniow (gas boiler room + photovoltaic system for auxiliary equipment).

Energy Carrier	Heating and Ventilation	Hot Water	Auxiliaries	Total
Gas boiler room (w = 1.1)	28.51	40.01	0.00	68.52
Photovoltaics energy (w = 0)	0.00	0.00	4.12	4.12

Table 12. The annual primary energy demand (kWh/(m^2·year)) for the multi-family building at Akacjowa Street in Goleniow (gas boiler room + photovoltaic system for auxiliary equipment).

	Heating and Ventilation	Hot Water	Auxiliaries	Total
EP value (kWh/(m^2·year))	31.36	44.01	0.00	75.38

Option 3. The cascade of air heat pumps with photovoltaic installation. The analyzed solution assumes placing the main technology of pumps and photovoltaic installation on the building roof. The maximum power of the photovoltaic installation (determined by the available space, taking into account the location of the cascade of pumps on the roof) was obtained with an installation of 40 kWp. The cascade of air/water heat pumps of the monoblock type was adopted as the heat source. The calculations resulted as follows (Tables 13 and 14):

Table 13. The annual final energy demand (kWh/(m^2·year)) for the multi-family building at Akacjowa Street in Goleniow (Cascade of air heat pumps with photovoltaic installation).

Energy Carrier	Heating and Ventilation	Hot Water	Auxiliaries	Total
Air heat pump (network energy w = 3)	17.21	8.41	0.00	25.62
Air heat pump (photovoltaic w = 0)	0.00	8.41	4.62	13.04

Table 14. The annual primary energy demand (kWh/(m^2·year)) for the multi-family building at Akacjowa Street in Goleniow (Cascade of air heat pumps with photovoltaic installation).

	Heating and Ventilation	Hot Water	Auxiliaries	Total
EP value (kWh/(m^2·year))	51.63	25.24	0.00	76.86

Option 4. Ground source heat pumps (vertical collectors, minimum 150 m) with photovoltaic installation. The analyzed solution assumes placing a photovoltaic installation on the roof of the building. The maximum power of the photovoltaic installation (determined by the available space) is 68 kWp. As a source of heat, a ground heat pump with vertical collectors was adopted (the drilling depth is min. 150 m). The calculations resulted as follows (Tables 15 and 16):

Table 15. The annual final energy demand (kWh/(m^2·year)) for the multi-family building at Akacjowa Street in Goleniow (ground source heat pump with photovoltaic installation).

Energy Carrier	Heating and Ventilation	Hot Water	Auxiliaries	Total
Air heat pump (network energy $w = 3$)	7.31	0.00	0.00	7.31
Air heat pump (photovoltaic $w = 0$)	0.00	14.72	4.62	19.34

Table 16. The annual primary energy demand (kWh/(m^2·year)) for the multi-family building at Akacjowa Street in Goleniow (ground source heat pump with photovoltaic installation).

	Heating and Ventilation	Hot Water	Auxiliaries	Total
EP value (kWh/(m^2·year))	21.94	0.00	0.00	21.94

The conducted research has shown that, apart from option 1, the remaining alternative heat source variants proposed for the analyzed building meet the requirements of the regulations on pro-environmental solutions concerning the non-extendible reference value EP ≤ 85 (kWh/(m^2·year)). In addition, for options 2, 3, and 4, CO_2 emissions were calculated. The calculations were made using published data from the National Center for Emissions Management to the End User (KOBiZE 2020). KOBiZE is a Center within the structures of the Institute of Environmental Protection and maintains, among others, a database in which data on the emission of greenhouse gases and other substances, and related parameters necessary to perform this type of calculations are collected. The results obtained are presented in Table 17.

Table 17. The annual CO_2 emissions depending on the accepted heat source of the multi-family building at Akacjowa Street in Goleniow.

	Gas Boiler Room + Photovoltaics for Auxiliary Equipment	Cascade of Air Heat Pumps with Photovoltaic Installation	Ground Source Heat Pump with Photovoltaic Installation
ECO_2 CO_2/(m^2·year)	0.0137 (t)	0.0260 (t)	0.0169 (t)
ECO_2 CO_2/(year)	45.256443 (t)	85.88814 (t)	55.827291 (t)
Share of renewable energy sources (RES)	5.67%	67.60%	93.14%

The solution based on gas boiler and a photovoltaic installation for supplying auxiliary equipment, i.e., option 2, turned out to be the most advantageous in terms of CO_2 emissions. The solution based on gas boiler results in the lowest CO_2 emissions to the atmosphere. This is due to the fact that electricity used partly in the remaining solutions, i.e., options 3 and 4, is produced in Poland mainly using coal. Over time, during the operation of the building, the situation will probably change in favor of solutions based on heat pumps, because Poland, like every EU country, is obliged to reduce CO_2 emissions, and will mainly support the elimination of power plants and coal-fired cogeneration plants. Recently, a positive accent in Poland has been the resignation by PKN Orlen (of which the State Treasury is the majority shareholder) after the acquisition of Energa Capital Group company, from the construction of unit C of Ostroleka power plant in coal technology in favor of gas technology.

The application of any of the proposed alternative heat sources which met the environmental requirements had a number of design consequences and forced significant changes in the advanced design of the building. Therefore, the individual solutions were subjected to a detailed analysis with regard to their technical feasibility and costs related to their application. Because of the failure to meet the applicable environmental requirements, option 1 was not further analyzed.

In case of using option 2, i.e., a gas boiler room located in the building, supplying residential heat substations together with the photovoltaic installation used for auxiliary equipment, it was necessary to significantly interfere with the structure and functional system of the building. Because of the height of the designed building (five storeys) and applicable regulations (PN-B-2431-1 standard 2.3.1), the gas boiler room could be located only on the last storey of the building. For this reason, it was necessary to arrange an additional room for the boiler room, at the expense of the already designed living space. This resulted in changes in the structural layout of a fragment of the building and a change in the dimensions of the installation shafts in order to allow the heating medium to be fed from the boiler room to the garage and then distributed to the residential heat substations located on individual floors. In the case of this solution, it was also necessary to analyze the number and distribution of photovoltaic panels on the roof of a building with a rather specific shape.

The decision to exclude the use of option 3, i.e., cascades of air heat pumps with photovoltaic installation, was mainly due to economic analysis, but also to technical difficulties related to the location of necessary equipment. The specific shape of the plot and land development used to the maximum extent the development parameters included in the decision on development conditions made it impossible to locate any installations in the area because of lack of free space. Therefore, the only possibility was to locate the cascade of air pumps and photovoltaic panels exclusively on the roof of the building. It was therefore necessary to analyze the number and distribution of air pumps and photovoltaic panels on the building roof. As a consequence, their location forced the necessity to redesign both the roof of the building, in order to enable the location of the necessary devices on them, taking into account their significant size and weight, as well as to redesign the installation shafts, and thus the fragments of apartments through which they run, in order to enable the heating medium to be supplied from the devices located on the roof to the technical rooms located in the garage.

When analyzing option 4, i.e., ground source heat pumps with vertical heat exchangers of min. 150 m with photovoltaic installation, it has been assumed that the main source of heat will be a heat pump unit with a lower and upper source circuit. The lower source was to be geothermal energy obtained from the ground through a system of vertical ground exchangers. The heat pumps were planned to be located in technical rooms at garage level. However, due to the shape of the plot, the location of the building, the underground garage designed underneath and outside the building, and the fact that the whole building was founded on a foundation slab, it proved practically impossible to use ground source heat pumps, due to insufficient surface area of undeveloped land to be drilled and heat exchangers placed in it. The option of drilling and locating the exchangers under the building slab also proved to be unjustified mainly for economic reasons, as the interference of this solution in the structure of the building would be too large.

On the basis of a detailed analysis of three possible options of using an alternative heat source in relation to the district heating it turned out that for the investor, option 2, with a gas boiler room and a photovoltaic installation on the roof of the building, is the most reasonable and economically rational. Despite the need to introduce significant functional and structural changes to the project and the associated costs, as well as the measurable loss of profits resulting from the loss of part of the residential space, this solution proved to be the cheapest to implement at the construction stage. The analysis was dominated by the investor's arguments related to the need to reduce investment costs during the investment's execution in order to achieve maximum profits at the moment of selling the apartments. Investing in other, costly energy-saving solutions proved to be economically unjustified at this stage, as it would bring measurable financial benefits only over many years of operation and not at the time of selling the apartments.

However, at the stage of the decision on the building permit, it turned out that the adopted solution with a gas boiler room and photovoltaic installation on the roof of the building, alternative to the district heating, carries the risk of not meeting the requirements of the legal obligation to use the system heat in the face of the applicable regulations. The authority issuing the building permit referred to the provision of the decision on development conditions No. 424 issued by the mayor of Goleniow [38], i.e., point 2.5. concerning the conditions of service in the field of technical and communication infrastructure, which reads: 'In the field of heat supply—to the district heating network', despite the provision 'In the field of gas supply—there are technical possibilities of connecting to the gas network after obtaining the conditions for connection'. Additionally, a provision from the Construction Law Act was quoted [8] Journal of Laws 1994 No. 89, item 414, Art. 33.2.10, stating that the application for a building permit should be accompanied by 'designer's declaration concerning the possibility of connecting the designed building to the existing heating network, in accordance with the conditions set out in Art. 7b of the Energy Law of 10 April 1997 (Journal of Laws of 2019, item 755, as amended 4), ... submitted under pain of criminal liability' [39]. On this basis, the use of district heating to power the building proved to be mandatory, despite the impossibility of complying with the provisions on the EP limit value based on this type of heat source alone (see Tables 7 and 8). Therefore, it turned out to be necessary to change the design in order to analyze the possibility of applying additional technical solutions, this time to supplement the obligatory use of the district heating and to meet the applicable, pro-environmental legal requirements.

Taking into account all previously analyzed factors, spatial and economic limitations, in order to obtain the proper EP value for the designed building in Goleniow, four possible technical solutions were further analyzed to complement the obligatory system heat:

Option A: district heating with intake-exhaust mechanical ventilation with recovery.
Option B: district heating with intake-exhaust mechanical ventilation with recovery and additionally a photovoltaic system for supplying auxiliary equipment.
Option C: district heating with additional photovoltaic installation (max 68 kWp) for the supply of auxiliary equipment and part of the energy for domestic hot water preparation.
Option D: district heating plus photovoltaic installation (max 68 kWp) for supplying auxiliary equipment and partially for hot water preparation, and intake-exhaust mechanical ventilation with recovery.

Below are the results of EP value calculations for the analyzed additional technical solutions, taking into account the building parameters and applied design solutions (Tables 18–25).

Option A

Table 18. The annual EK demand (kWh/(m^2·year)) for the multi-family building at Akacjowa Street in Goleniow (system heat (Goleniow) + intake-exhaust mechanical ventilation with recovery).

Energy Carrier	Heating and Ventilation	Hot Water	Auxiliaries	Total
District heating (w = 1.3)	9.92	50.56	0.00	60.47
Electrical energy (w = 3)	0.00	0.00	6.79	6.79

Table 19. The annual EP demand (kWh/(m^2·year)) for the multi-family building at Akacjowa Street in Goleniow (district heating (Goleniow) + intake-exhaust mechanical ventilation with recovery).

	Heating and Ventilation	Hot Water	Auxiliaries	Total
EP value (kWh/(m^2·year))	12.89	65.72	20.37	98.98

Option B

Table 20. The annual EK demand (kWh/(m^2·year)) for the multi-family building at Akacjowa Street in Goleniow (district heating (Goleniow) + mechanical supply and exhaust ventilation with recovery + photovoltaic installation for auxiliary equipment).

Energy Carrier	Heating and Ventilation	Hot Water	Auxiliaries	Total
District heating (w = 1.3)	9.92	50.56	0.00	60.47
Photovoltaic installation (w = 0)	0.00	0.00	6.79	6.79

Table 21. The annual EP demand (kWh/(m^2·year)) for the multi-family building at Akacjowa Street in Goleniow (district heating (Goleniow) + intake-exhaust mechanical ventilation with recovery).

	Heating and Ventilation	Hot Water	Auxiliaries	Total
EP value (kWh/(m^2·year))	12.89	65.72	0.00	78.62

Option C

Table 22. The annual EK demand (kWh/(m^2·year)) for the multi-family building at Akacjowa Street in Goleniow (district heating (Goleniow) + application of photovoltaic installation to supply auxiliary equipment and part of the energy for the preparation of the hot water).

Energy Carrier	Heating and Ventilation	Hot Water	Auxiliaries	Total
District heating (w = 1.3)	29.37	35.39	0.00	64.76
Photovoltaic installation (w = 0)	0.00	17.84	3.89	21.73

Table 23. The annual EP demand (kWh/(m^2·year)) for the multi-family building at Akacjowa Street in Goleniow (district heating (Goleniow) + application of photovoltaic installation to supply auxiliary equipment and part of the energy for the preparation of the hot water).

	Heating and Ventilation	Hot Water	Auxiliaries	Total
EP value (kWh/(m^2·year))	38.18	46.01	0.00	84.19

Option D

Table 24. The annual EK demand (kWh/(m^2·year)) for the multi-family building at Akacjowa Street in Goleniow (district heating (Goleniow) + application of photovoltaic installation (max 68 kWp) for supplying auxiliary equipment and partially for hot water preparation + mechanical ventilation with recovery).

Energy Carrier	Heating and Ventilation	Hot Water	Auxiliaries	Total
District heating (w = 1.3)	9.92	36.40	0.00	46.32
Photovoltaic installation (w = 0)	0.00	16.65	6.79	23.44

Table 25. The annual EP demand (kWh/(m^2·year)) for the multi-family building at Akacjowa Street in Goleniow (district heating (Goleniow) + installation (max) + ventilation with recovery).

	Heating and Ventilation	Hot Water	Auxiliaries	Total
EP value (kWh/(m^2·year))	12.89	47.32	0.00	60.21

Research carried out showed that, apart from option A, the other alternatives proposed comply with the requirements of the regulations on ecological solutions concerning the maximum reference value EP ≤ 85 (kWh/(m^2·year)). Additionally, for each of the proposed solutions, calculations were also made in terms of CO_2 emissions—Table 26. The calculations were made using the data published by KOBiZE.

From the point of view of CO_2 emissions, the solution based on district heating (PEC Goleniow) with photovoltaic installation (max 68 kWp) and intake-exhaust mechanical ventilation with recovery turned out to be the best solution.

The above solutions were also analyzed in detail in terms of their technical and economic applicability. The introduction of each of them, at this stage of the construction project, significantly interfered with the structure of the building and forced further changes in the design. The greatest consequences in the context of the change in design were the introduction of intake-exhaust mechanical ventilation with recovery. In addition to the high costs associated with the installation itself, together with the necessary equipment, a far-reaching interference with the structure and function of the building was necessary. It turned out to be necessary to introduce additional punctures in reinforced concrete walls and to enlarge the installation shafts enabling the supply of intake-exhaust pipes to each apartment. It was also necessary to arrange space for placing the recuperator in each apartment and to distribute the installation wires in the individual living quarters. Because of the provisions of the building and permit decision, it was not possible to increase the height of the building, and thus the height of the storey. It resulted in the necessity of enclosing the ventilation ducts at the junction of ceilings and walls, and also local lowering of rooms. As a result, it generated additional costs, while reducing the living space, as well as deteriorating the functionality and aesthetics of individual rooms.

Table 26. The annual CO_2 emissions depending on the accepted heat source for the multi-family building at Akacjowa Street in Goleniow.

	District Heating (Goleniow) + Photovoltaic Installation (Max 68 kWp) for Supplying Auxiliary Equipment and Partially for Hot Water Preparation	(District Heating (Goleniow) + Intake-Exhaust Mechanical Ventilation with Recovery + Photovoltaic Installation for Auxiliary Equipment)	District Heating (Goleniow) + Photovoltaic Installation (Max 68 kWp) + Intake-Exhaust Mechanical Ventilation with Recovery
ECO_2 $CO_2/(m^2 \cdot year)$	0.0222 (t)	0.0207 (t)	0.0159 (t)
ECO_2 $CO_2/(year)$	73.33526 (t)	68.38017 (t)	52.5239 (t)
RES share	25.12%	10.09%	33.61%

The option related to the use of photovoltaic panels, in turn, required that the necessary number and distribution of photovoltaic panels be determined depending on the option adopted. As indicated earlier, the development project prevented their deployment on the site. The only possible location was the slab roof. Of course, the number of panels needed resulted from the adopted solution. In the case of option B and D, i.e., mechanical ventilation with photovoltaic panels, their number was so small that it did not generate problems with their arrangement. On the other hand, if photovoltaic panels (variant C) were to be the only alternative, a detailed analysis and additional design concept regarding their number and arrangement, in the context of limited space and specific roof shape, was necessary (Figure 4).

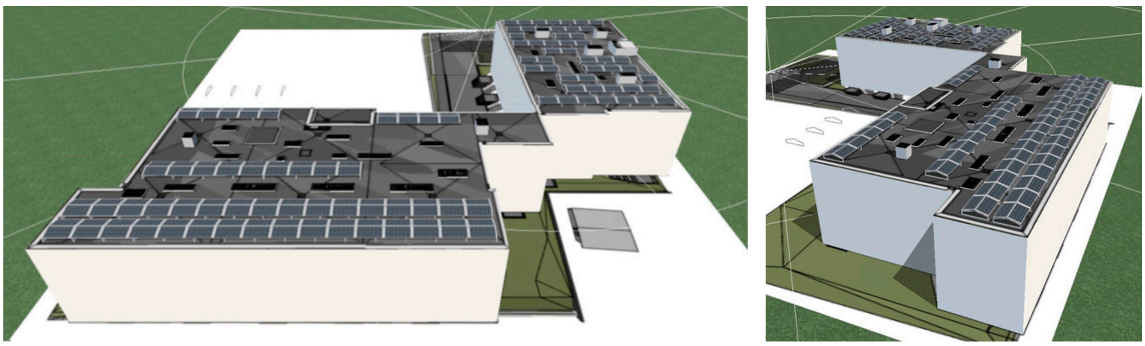

Figure 4. The building at Akacjowa Street in Goleniow, concept of photovoltaic panel arrangement view. Source: Foton OZE sp. z o.o.

After using the standard photovoltaic panels, the roof surface was insufficient to obtain an installation with sufficient power. In order to achieve the required installation power (68 kWp), it was necessary to use panels with higher power. These panels are less cost-effective, with a much higher price per kWp compared with currently standard panels.

On the basis of a detailed analysis of three possible options of an additional heat source, it turned out that for the investor the C option is the most reasonable and economically rational, despite the necessity to use untypical and more expensive panels with higher power, i.e., the solution based on the district heating with additional photovoltaic installation to supply auxiliary equipment and partially for domestic hot water preparation. Practical reasons were determined by the possibility of applying only one solution ensuring compliance with pro-environmental regulations. At the same time, the adopted variant practically did not generate the need to introduce changes to the project in terms of its structure and functions, but only to a small extent in terms of installation projects, which also had a measurable impact on the investor's decision. Moreover, this solution generates practically no additional operating problems, which is extremely important in the case of multi-family residential buildings.

5. Summary and Discussion

This article presents the results of research and analysis of the real-life design and investment processes of multi-family residential buildings. The starting point for the research was the trend observed in the developed countries which resulted from the continuous increase of awareness and the need to implement the principles of sustainable development. Despite the fact that the concept of sustainable development itself is a scientific problem that has been studied and discussed since the seventies of the previous century, it has not been ultimately solved yet, nor implemented into the design process. Sustainable development issues are constantly evolving on the basis of theoretical scientific research and the attempt to introduce the research results in order to confirm validity of the assumptions [40]. In recent years, a broadly understood energy context has become a very important design factor, resulting directly from the paradigm of sustainable development, the integration and correct implementation gives a chance to create a harmonious and sustainable housing environment. As a result of transposition of directives and patterns of conduct from developed European Union countries, and also as a result of increased availability of modern technologies, the issue related to the environmental need to reduce energy consumption has gained a significant importance also in Poland. Since 2009 this has been reflected in the applicable legal regulations, which has begun to evolve greatly toward pro-environmental solutions. This, in turn, had a measurable influence on the design process at virtually every stage.

The building regulations in force in Poland oblige the designer to develop energy performance and rational energy use as an integral part of the construction design. By definition, these regulations are aimed to achieve the maximum reduction of energy demand of the facilities. However, it is connected with the necessity to conduct a thorough analysis of available technological solutions, which due to the fact that they are usually expensive, must be economically justified and finally approved by the Investor. In the case of multi-family housing, the economic calculations and short-term profit are of primary importance. Therefore, the design is generally optimized mainly when it comes to the reduction of current investment costs. Expensive energy-saving solutions, which bring measurable profits only after a long period of time while usage of the building, are marginalized. Coherent and consistent enforcement of formal and legal conditions seem to be the only argument forcing an application of expensive technologies that use renewable energy sources and thus the implementation of sustainable housing investments.

It has been shown that there are legal regulations in Poland that enable the implementation of the requirements related to the concept of sustainable development, particularly concerning the need to reduce energy consumption in multi-family housing. However, they are inconsistent and they need to be specified in terms of introducing clear rules and mechanisms enabling the actual implementation of these requirements at any stage of the design and investment process. This applies in particular to the applicable regulations related to the designer's obligation to apply the system heat, if it is technically possible in a given location. The conducted research allowed to observe that relatively imprecise and old schematic assumptions related to this issue may involve serious, negative design consequences, including the inability to implement the investment in the most extreme cases. This applies in particular to the issue related to the determination of EP value and the need to include the value of w coefficient in this process, specific to a given supplier of system energy. It has been shown that the values of these coefficients in particular cities can vary to a great extent. As a result, the designed building, which uses system heat in one location, meets the legal requirements, whereas a building with the same function and similar size, which uses system heat in another location, does not meet these requirements. The requirement to use such a general and well-worn methodology for determining EP values makes the designer and the investor bear the consequences for reasons beyond their control, resulting solely from the parameters of supplied heat that differ depending on the location where the investment is to be implemented. Special attention should be paid to the fact that the value of w coefficient is given by particular heat suppliers annually, based on historical data. This may lead to a situation, in which a given value of w coefficient is relatively low at the time of the design process, while it is higher at the start of the administrative procedure for obtaining a building permit. As a result, the design becomes inconsistent with the binding regulations and the investment requires a thorough modernization or, in extreme cases, the design process needs to be launched practically from the very beginning, taking into account the altered conditions. It also needs to be recognized that from 2021 onwards, the requirements for EP values in Poland will be tightened again in line to create zero-emission facilities. The situations analyzed and described hereinabove will become even more important. Designing multi-family residential buildings based solely on the system heat in Poland will become even more difficult and complicated. To illustrate the actual situation, Table 27 presents the current w coefficient for heating network system in large agglomerations.

Table 27. w coefficient of non-renewable primary energy in selected large cities in Poland (2019).

No.	Town	w Coefficient
1	Bialystok	0.46
2	Bydgoszcz	1.20
3	Gdansk	0.66
4	Katowice	0.46
5	Kielce	1.35
6	Koszalin	1.30
7	Cracow	1.07
8	Lublin	0.49
9	Olsztyn	0.98
10	Opole	1.19
11	Poznan	1.06
12	Suwalki	1.14
13	Szczecin	0.93
14	Warsaw	0.87
15	Wroclaw	1.09

Looking at w coefficient value, it is easy to see that in about 50% of the cities it will be difficult to design a multi-family residential building supplied with heat from the district network in 2021 and in a few cases it is even impossible. The situation is much worse in small and medium-sized towns where 90% of the heating network systems are based on coal and gas-fired boiler plants, giving a non-renewable primary energy ratio of 1.2 to 1.3 (see Table 1).

Despite this, in the face of global pro-environmental assumptions, it should be recognized that the assumption aiming to maximize the use of available system heat in multi-family residential buildings seems to be correct. However, this requires eliminating the imprecise and old schematic legal regulations discussed hereinabove. The positive effects of applying solutions based on the system heat will be measurable only when the heat is used on the largest possible scale and the system solutions are subject to constant modernization in order to ensure the lowest possible emission of pollutants, including greenhouse gas emissions. Therefore, the regulations regarding use of the system heat should be coherent, precise, and enforced in a consistent way. Only then it will be possible to relieve the designer and investor of the responsibility to solve problems generated by the factors beyond their control, and resulting, for example, from the lack of investments in so-called "clean" system energy, which should be the sole task of the owners of these systems, state, and the European agencies aiming at a coherent environmental policy. A similar situation also applies to network electricity. The value of the w coefficient for this energy is currently 3 in Poland and practically eliminates its use in the service of construction facilities in the field of heat, ventilation, and air conditioning. The value of this coefficient (as in the case of system energy) specified in the Regulation [26] is independent of investors and designers.

It is necessary to consider changes in the regulations, trying to exclude the value of w coefficient, e.g., by determining the energy class of buildings on the basis of non-renewable final energy presenting directly measurable energy demand of the building. Furthermore, by dividing EK value in the developed reports into energy obtained from external suppliers and energy obtained from own sources (e.g., a photovoltaic installation), the obtained results will be much more readable for future users who could easily (independently) determine the operating costs of the building/apartment.

The conducted research clearly shows that the binding pro-environmental legal conditions in Poland, which as a matter of fact are imprecise and inconsistent, force the designer to use additional technical solutions that have a significant impact on the scope of design works, and consequently on the entire design process and the further usage of the building. In this process, the designer also bears a specific responsibility toward the future users of buildings for whom living in a multi-family building should meet the requirements, especially in terms of functionality, low-cost, and easy maintenance, as well as visual attractiveness. The multitude of applied, complicated technological solutions, incomprehensible and difficult to use for the average user, may contradict these expectations. Unfortunately there are a few multi-family housing where only renewable energy sources have been used. The implementation of such investments is usually caused by lack of possibility to apply other, less expensive heat sources. Paradoxically, in such cases the adopted solution is used as a sales point, justifying a high selling price of so-called high tech apartment.

The provisions related directly to the current design realities should not generate the necessity to apply solutions that are unnatural and complicated in use. The buildings based on the use of system energy are by far the most popular among buyers as well as developers. However, in the light of inconsistent present regulations and in the absence of modernization of "non-ecological" heating systems, the possibility of using their full potential is limited. The binding legal conditions should be clarified so that this type of heat energy supply could be used as much as possible and at the same time appropriate funds should be allocated for their modernization.

The necessity to change the regulations and rules in the field of energy efficiency of buildings has also been recognized by the Polish Ministry of Development. In August 2020, the Team for the efficiency and energy transformation of buildings was appointed. One of its tasks is to analyze and recommend legal changes in the field of energy performance of buildings. It is hoped that the problems described here will be recognized and solved.

The research and analysis presented in the article constitute the basis for further work toward the development of a system related to the selection of optimal design solutions from the point of view of conscious interdisciplinary design of facilities, their energy efficiency, and economic dependencies. It will allow to define, with great accuracy, optimal technological and material solutions as early as at the concept stage. The input quantities shall mainly consist of the investor's requirements, design guidelines, and legal conditions. On the basis of these, it will be possible to determine the goal function, the achievement of which will be the framework to make correct decisions in further stages of the design process.

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References

1. Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on Energy Efficiency, Amending Directives 2009/125/EC and 2010/30/EU and Repealing Directives 2004/8/EC and 2006/32/EC (Dz.Urz. UE L 315/1). Available online: http://data.europa.eu/eli/dir/2012/27/oj (accessed on 15 June 2020).
2. Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the Energy Performance of Buildings OJ L 153, 18.6.2010. pp. 13–35. Available online: http://data.europa.eu/eli/dir/2010/31/oj (accessed on 15 June 2020).
3. Directive (EU) 2018/844 of the European Parliament and of the Council of 30 May 2018 Amending Directive 2010/31/EU on the Energy Performance of Buildings and Directive 2012/27/EU on Energy Efficiency (Text with EEA Relevance) PE/4/2018/REV/1. Available online: http://data.europa.eu/eli/dir/2018/844/oj (accessed on 15 June 2020).
4. Regulation of the Minister of Infrastructure of 6 November 2008 Amending the Regulation on the Technical Conditions to Be Met by Buildings and Their Location. Available online: http://isap.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=WDU20082011238 (accessed on 15 June 2020).
5. Regulation of the Polish Minister of Infrastructure of 27 February 2015 Concerning the Methodology for Calculating the Energy Performance of the Building or Part of a Building and the Preparation of Certificates of Energy Performance. Available online: http://isap.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=WDU20150000376 (accessed on 15 June 2020).
6. Regulation of the Polish Minister of Infrastructure of 6 November 2008 Concerning the Methodology for Calculating the Energy Performance of the Building and a Residential Unit or Part of a Building Which Is the Whole Technical-Independent Utility and the Preparation and Presentation of Certificates of Energy Performance. Available online: http://isap.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=WDU20082011240 (accessed on 15 June 2020).
7. Ordinance of the Minister of Infrastructure of 6 November 2008 Amending the Ordinance on the Detailed Scope and Form of a Construction Project (Journal of Laws of 2008 No. 201, item 1239 as amended). Available online: https://isap.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=WDU20190001065 (accessed on 15 June 2020).
8. Act of 7 July 1994—Construction Law (i.e., Journal of Laws of 2006 No 156, Item 1118). Available online: http://isap.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=WDU20061561118 (accessed on 15 June 2020).
9. Buratti, C.; Asdrubali, F.; Palladino, D.; Rotili, A. Energy Performance Database of Building Heritage in the Region of Umbria, Central Italy. *Energies* **2015**, *8*, 7261–7278. [CrossRef]
10. Jurelionis, A.; Bouris, D.G. Impact of Urban Morphology on Infiltration-Induced Building Energy Consumption. *Energies* **2016**, *9*, 177. [CrossRef]
11. Tsikaloudaki, K.; Laskos, K.; Bikas, D. On the Establishment of Climatic Zones in Europe with Regard to the Energy Performance of Buildings. *Energies* **2012**, *5*, 32–44. [CrossRef]
12. Adamczyk, J.; Dylewski, R. Changes in heat transfer coefficients in Poland and their impact on energy demand—An environmental and economic assessment. *Renew. Sustain. Energy Rev.* **2017**, *78*, 530–538. [CrossRef]
13. Dall'O', G.; Sarto, L.; Panza, A. Infrared Screening of Residential Buildings for Energy Audit Purposes: Results of a Field Test. *Energies* **2013**, *6*, 3859–3878. [CrossRef]
14. Ferdyn-Grygierek, J.; Grygierek, K. Multi-Variable Optimization of Building Thermal Design Using Genetic Algorithms. *Energies* **2017**, *10*, 1570. [CrossRef]
15. Touloupaki, E.; Theodosiou, T. Optimization of External Envelope Insulation Thickness: A Parametric Study. *Energies* **2017**, *10*, 270. [CrossRef]

16. Congedo, P.M.; Lorusso, C.; De Giorgi, M.G.; Marti, R.; D'Agostino, D. Horizontal Air-Ground Heat Exchanger Performance and Humidity Simulation by Computational Fluid Dynamic Analysis. *Energies* **2016**, *9*, 930. [CrossRef]
17. Hassine, I.; Eicker, U. Impact of load structure variation and solar thermal energy integration on an existing district heating network. *Appl. Therm. Eng.* **2013**, *50*, 1437–1446. [CrossRef]
18. Šadauskienė, J.; Paukštys, V.; Šeduikytė, L.; Banionis, K. Impact of Air Tightness on the Evaluation of Building Energy Performance in Lithuania. *Energies* **2014**, *7*, 4972–4987. [CrossRef]
19. Dall'O', G.; Belli, V.; Brolis, M.; Mozzi, I.; Fasano, M. Nearly Zero-Energy Buildings of the Lombardy Region (Italy), a Case Study of High-Energy Performance Buildings. *Energies* **2013**, *6*, 3506–3527. [CrossRef]
20. Gustafsson, M.; Thygesen, R.; Karlsson, B.; Ödlund, L. Rev-Changes in Primary Energy Use and CO_2 Emissions—An Impact Assessment for a Building with Focus on the Swedish Proposal for Nearly Zero Energy Buildings. *Energies* **2017**, *10*, 978. [CrossRef]
21. Sadeghi, A.; Younes Sinaki, R.; Young, W.A., II; Weckman, G.R. An Intelligent Model to Predict Energy Performances of Residential Buildings Based on Deep Neural Networks. *Energies* **2020**, *13*, 571. [CrossRef]
22. Thygesen, R. An Analysis of Different Solar-Assisted Heating Systems and Their Effect on the Energy Performance of Multifamily Buildings—A Swedish Case. *Energies* **2017**, *10*, 88. [CrossRef]
23. Basińska, M.; Kaczorek, D.; Koczyk, H. Building Thermo-Modernisation Solution Based on the Multi-Objective Optimisation Method. *Energies* **2020**, *13*, 1433. [CrossRef]
24. Cho, K.H.; Kim, S.S. Energy Performance Assessment According to Data Acquisition Levels of Existing Buildings. *Energies* **2019**, *12*, 1149. [CrossRef]
25. Congedo, P.M.; D'Agostino, D.; Baglivo, C.; Tornese, G.; Zacà, I. Efficient Solutions and Cost-Optimal Analysis for Existing School Buildings. *Energies* **2016**, *9*, 851. [CrossRef]
26. D'Agostino, D.; Zacà, I.; Baglivo, C.; Congedo, P.M. Economic and Thermal Evaluation of Different Uses of an Existing Structure in a Warm Climate. *Energies* **2017**, *10*, 658. [CrossRef]
27. Życzyńska, A.; Suchorab, Z.; Kočí, J.; Černý, R. Energy Effects of Retrofitting the Educational Facilities Located in South-Eastern Poland. *Energies* **2020**, *13*, 2449. [CrossRef]
28. Geissler, S.; G Charalambides, A.; Hanratty, M. Public Access to Building Related Energy Data for Better Decision Making in Implementing Energy Efficiency Strategies: Legal Barriers and Technical Challenges. *Energies* **2019**, *12*, 2029. [CrossRef]
29. Klaric, S.; Korjenic, A.; Hollands, J.; Subasic, L. Advantages of an Interdisciplinary Approach to the Sustainable Development of Two Scenarios in Bosnia and Herzegovina. *Buildings* **2019**, *9*, 143. [CrossRef]
30. Cursino dos Santos, A.H.; Werneck Fagá, M.T.; Moutinho dos Santos, E. The risks of an energy efficiency policy for buildings based solely on the consumption evaluation of final energy. *Electr. Power Energy Syst.* **2013**, *44*, 70–77. [CrossRef]
31. Howarda, B.; Parshallb, L.; Thompsonc, J.; Hammerb, S.; Dickinsond, J.; Modi, V. Spatial distribution of urban building energy consumption by end use. *Energy Build.* **2012**, *45*, 141–151. [CrossRef]
32. Huang, L.; Zheng, R. Energy and Economic Performance of Solar Cooling Systems in the Hot-Summer and Cold-Winter Zone. *Buildings* **2018**, *8*, 37. [CrossRef]
33. Act of 27 March 2003 on Spatial Planning and Management, Journal of Laws No. 2003 No. 80 Item 717. Available online: https://isap.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=WDU20030800717 (accessed on 15 June 2020).
34. Ordinance of the Minister of Infrastructure of 26 August 2003 on the Method of Determining the Requirements for New Development and Land Use in the Absence of a Local Spatial Development Plan Dz.U. 2003 No 164 Item 1588. Available online: http://isap.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=WDU20031641588 (accessed on 15 June 2020).
35. Firląg, S.; Górecka, W. Multi-family residential buildings according to the regulations of WT 2021. *Rynek Instal.* **2019**, 7–8. Available online: https://www.researchgate.net/publication/335789741 (accessed on 15 June 2020).
36. Wojdyga, K.; Chorzelski, M. Chances for Polish district heating systems. *Energy Procedia* **2017**, *116*, 106–118. [CrossRef]
37. Życzyńska, A. The primary energy factor for the urban heating system with the heat source working in association. *Eksploat. Niezawodn. Maint. Reliab.* **2013**, *15*, 458–462.
38. Decision on building conditions issued by the Mayor of Goleniow Municipality. Administrative decision, No. 424, WPNS.6730.231.2018.KB, 19 September 2019.

39. Energy Law of 10 April 1997. Available online: http://isap.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=wdu19970540348 (accessed on 15 June 2020).
40. Majerska-Pałubicka, B. Attempts to optimize methods of sustainable architectural design. *Architectus* **2014**, *2*, 15–27.