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Instruments for Supporting Implementation of Sustainable Development Goals for Construction Sector – Case of Poland

Abstract: Currently, three billion people face dangerous levels of air pollution and rely on non-renewable energy sources for cooking and heating. Due to its environmental impact, the construction sector is a particularly important area for implementing sustainable development policies. On July 10, 2023, the UN published *The Sustainable Development Goals Report 2023* (SDGs). In accordance with the provisions of Goal 7 (which was discussed in the above document), the international community should increase its share of renewable energy sources in the global energy mix and promote investment in clean energy technologies by 2030. Achieving this goal necessitates the introduction of support mechanisms to enhance the energy efficiency of residential buildings. Hence, this study aims to showcase the legal and financial tools that aid the growth of energy-efficient construction in Poland, to compare the renovation costs of an existing residential building in order to meet energy-efficiency standards, and to detail the financial support that is available for planned thermal-modernization efforts.

Keywords: sustainable development, legal instruments, financial instruments, low-energy construction, residential building, Poland

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1. Introduction

According to the UN, pollution that was emitted during the combustion of heating fuels contributed to the deaths of 4.3 million people in 2012; in 2016, 90% of the population of major cities breathed polluted air, leading to the deaths of 4.2 million people [1]. In 2021, air quality had improved globally thanks to a number of protective measures [2]; however, this was still a problem in large cities, where the number and types of pollution sources caused significant local exceedances of limit levels [3].

Although significant progress has been made in the use of renewable energy sources over the past decade, there is still a need to increase access to clean fuels and technologies and increase the use of renewable energy sources in buildings according to *The Sustainable Development Goals Report 2023* [1]. In accordance with the tasks for implementing Sustainable Development Goal 7 (Ensure access to affordable, reliable, sustainable and modern energy by 2030), the international community should ensure universal access to affordable, reliable, and modern energy services (Task 7.1), significantly increase the share of renewable energy sources in the global energy mix (Task 7.2), double the rate of increase in global energy consumption efficiency (Task 7.3), promote investments in energy infrastructure and clean-energy technologies (Task 7.A), and expand infrastructure and modernize technologies to enable access to modern and sustainable energy services for all residents (Task 7.B). Implementing the tasks of Goal 7 will improve the quality of people's lives, which will contribute to a significant reduction in the number of deaths and diseases that are caused by air pollution (Goal 3: Ensure healthy lives and promote well-being for all at all ages – Task 3.9) [1].

When implementing the above tasks, the construction sector should be taken into account, which is a particularly important area for implementing sustainable development policies [4, 5]. Significant energy savings can be made here, and greenhouse gas emissions can be minimized; these are important in shaping a low-carbon economy [6]. As Carlander and Thollander [7] pointed out, both reductions in emissions during the construction phases and reductions in energy consumption during the operation phases are needed in order to reduce the emissions from buildings. In addition, low-energy building materials and energy-efficient equipment with low operating energy requirements should be used for their construction [5]. The basic criterion for the energy efficiency of a building is the achievement of an adequate indicator of annual specific energy demand for heating and ventilation (EUco). In Poland, an energy-efficient building is considered a building for which the EUco is no more than 40 kWh/m^2/year, while a passive building is one for which the EUco is no more than 15 kWh/m^2/year [8]. These buildings provide high thermal comfort through the use of passive heat sources and dramatic reductions in heat loss through the use of specific technologies and materials in the thickness of the insulation layer of the building envelope, the use of renewable heat sources, and the use of energy-efficient window and door frames [9]. Meeting these criteria in new buildings is not difficult, since

solutions that will increase the level of energy efficiency can already be applied at the design stage. The problem arises in existing buildings, which were constructed at a time when energy efficiency was not commonly discussed by politicians, scientists, designers, or building contractors. The thermal upgrading/renovation of an existing building to energy-efficiency requirements is a time-consuming and costly process.

The purpose of this paper is to present the legal and financial instruments that support the development of energy-efficient construction in Poland, to compare the costs of renovating an existing residential building to meet energy-efficiency criteria, and to present the available level of financial support for measures to increase the energy efficiency of the residential building in question (focusing on the Clean Air Program). The presented case study constitutes the detailed aim of this study. The realization of the set research goal required an in-depth analysis of the subject literature and source documentation, the provisions of European and Polish laws, and the guidelines of Polish financial support programs for improving the energy efficiency of buildings. The paper also performed construction costing.

2. Evolution of EU Legal Instruments for Energy-efficient Construction

In the European Union, the construction sector covers more than 40% of total energy consumption [9]. The upward trend in energy consumption has led to an increase in the sector's carbon emissions. As Sachanbińska-Dobrzyńska [10] pointed out, climate protection and energy efficiency can be achieved through a variety of programmatic and legal instruments. Hence, the Council of the European Union approved an action plan on energy efficiency and demanded specific legal instruments for the construction sector in 2000. As a result, Directive 2002/91/EU [11] was adopted, with the goal of establishing specific measures to ensure that the large unrealized potential for energy savings in the construction sector was realized.

In 2006, Directive 2006/32/EU [12] was adopted to improve end-user energy efficiency, manage energy demand, and promote renewable energy production. The act required EU member states to implement energy-saving methods and use energy-efficient appliances to achieve a 9% energy-saving target. Directive 2009/28/EU [13] created conditions for promoting energy efficiency in renewable energy, the share of which was to account for 20% of the total energy consumption in the European Union by 2020 (the overall national target for Poland was 15%). Such legal regulations created opportunities for developing energy-efficient construction through the implementations of renewable energy installations. These opportunities were strongly supported by the requirements of Directive 2010/31/EU [14], which mandated that newly constructed buildings met higher energy standards (including all new buildings to become near-zero energy buildings by December 31, 2020). In addition, the member states were required to develop national plans to increase the

number of near-zero energy buildings and publish a progress report [14]. Another update to the directive (this time, in 2012 [15]) recommended spreading the use of the smart metering of energy consumption, the installation of renewable energy sources, and energy-saving technologies. Directive 2018/844 [16] additionally required the development and implementation of long-term renovation strategies, emphasized the development of electromobility, introduced the Smart Readiness Indicator (an indicator of a building's readiness to serve the smart grid), and sanctioned changes and simplified the process of creating energy-performance certificates. According to the directive's provisions [16], energy efficiency was to additionally increase by at least 32.5% by 2030, and the member states were to achieve new energy savings each year during the period of January 1, 2021, through December 31, 2030.

The most recent piece of legislation in this area was Directive 2023/1791/EU [17]; according to this, the EU planned to achieve energy neutrality by 2050. The new target called for an 11.7% reduction in final energy consumption, with all member countries achieving an average annual energy savings rates of 1.3% between 2024 and 2025, 1.5% between 2026 and 2027, and 1.9% in 2028; this places the average annual volume at 1.49% (the existing requirement is set at 0.8%). The regulation also stipulated that EU countries should prioritize energy-efficiency improvements for vulnerable consumers, low-income households, and people who live in social housing. And in the public sector, the annual reduction in energy consumption was set at 1.9% (excluding public transportation and the armed forces). In addition, the member states were required to renovate at least 3% of the surface areas of those buildings that belong to public institutions each year [17].

3. Polish Implementation of Legal Instruments for Energy-efficient Construction

In Polish legislation, the provisions of the EU directives on energy-efficient construction appeared in the Law on Energy Performance of Buildings of August 29, 2014 [18]. The provisions of this law also amended the provisions of other laws, including the Construction Law [19], the Environmental Protection Law [20], and the Real Estate Management Law [21]. The introduced regulations meant that achieving the goal of near-zero-energy construction forced the introduction of new design standards and technical and construction requirements for buildings as well as the creation of instruments for supporting investors who are planning to build or buy energy-efficient houses [10].

Poland's implementation of these acts also addressed the issue of improving the energy efficiency of buildings in many places. An ordinance on the detailed scope and form of a construction project is worth mentioning [22]; this introduced the obligation to use highly efficient alternative systems of energy and heat supplies for buildings (as long as they were technically available and environmentally and

economically feasible). This provision was applied to all buildings regardless of the sizes of their floor spaces. "Highly efficient alternative energy and heat-supply systems" should be understood as decentralized energy supply systems that are based on renewable energy, cogeneration, district or block heating/cooling (particularly when based entirely or partially on renewable energy), and heat pumps. In contrast, the ordinance on the technical conditions to be met by buildings and their locations [23] starting on January 1, 2014, introduced the obligation that buildings must simultaneously meet the requirements of the permissible value of the EP index (annual demand for non-renewable primary energy) and the requirements of the minimum thermal insulation of the building envelope (walls, floors, roofs, ceilings, windows, and doors) as well as ducts (central heating and hot water systems). In Poland, it was enough to meet one of these two conditions by the end of December 2013. This has become a major challenge for designers, since the EP value for a particular building is determined by a combination of factors (such as thermal insulation, the method of ventilation, the type of fuel that is used to heat the building, and even its location). EU regulations from 2012 [15] and 2018 [16] have also been implemented in Poland with the Law on Energy Efficiency [24].

In connection with the obligation to report to the European Commission, four national energy-efficiency action plans have already been developed in Poland; these documents include descriptions of the planned energy-efficiency measures in the various sectors of the economy that are necessary for achieving the national goal of energy efficiency. The next report will form part of the National Energy and Climate Plan for the years of 2021–2030 (submitted in 2019) [25]. Poland has seen a steady decline in energy intensity; such a trend is the result of the measures that are aimed at improving energy efficiency and the effect of rapid GDP growth against the rate of energy consumption. Further action on energy management in Poland is to be based on the continued implementation of those policies that are aimed at increasing the energy efficiency of the economy and the implementation of the goals in accordance with the principle of cost minimization [26].

The most recent revision of EU energy-efficiency legislation was in 2023 [17], but Poland has not yet implemented this new directive. EU member states are required to implement the new regulations within two years.

4. Materials and Methods

The legal and administrative instruments that regulate energy efficiency in the construction sector have been strengthened over the years by public financial support, which helps overcome economic [27], financial [28, 29], or demographic [30] barriers to the large-scale implementation of clean technologies. Several programs are currently in place to support the development of energy-efficient buildings; these are shown in Table 1.

Table 1. Breakdown of financial instruments supporting energy-efficient construction in Poland

National Reconstruction Plan	European funds	Priority Program of National Fund for Environmental Protection and Water Management	Thermo-modernization and Renovation Fund	Other forms of support
1. Measure B3.5.1 – Investments in energy-efficient housing for low- and middle-income households **2.** Measure B1.1.2 – Replacement of heat sources and improvement of energy efficiency in residential buildings in part concerning multi-family buildings **3.** Measure B3.4.1 – Investments for comprehensive green transformation of cities	**1.** European Funds for Infrastructure, Climate, Environment. Measure 1.1 – Energy efficiency **2.** European Funds for Lodz Voivodeship. Measure 2.4 – Passive buildings **3.** European Funds for Western Pomerania. Measure 2.7 – Increasing energy efficiency of public buildings (ZIT) **4.** European Funds for Western Pomerania. Measure 2.8 – Increasing energy efficiency of public buildings (IIT) **5.** European Funds for Kuyavia and Pomerania. Measure 2.3 – District heating plants, district heating networks, and energy efficiency of municipal buildings – regional ZIT **6.** European Funds for Kuyavia and Pomerania. Measure 2.18 – District heating plants, district heating networks, and energy efficiency of municipal buildings OPPT **7.** European Funds for Greater Poland. Measure 10.6 – Bringing Eastern Greater Poland closer to achieving climate neutrality **8.** European Funds for Silesia. Measure 2.6 – Renewable energy sources **9.** European Funds for Silesia. Measure 10.6 – Development of distributed energy based on renewable energy sources	**1.** Measure 4.2 – Zero-carbon energy system. Agroenergy. Part 1) Microinstallations, Heat Pumps, and Associated Energy Storage **2.** Measure 4.12 – Zero-carbon energy system. RES – source of heat for heating industry **3.** Measure 4.15 – Zero-carbon energy system. Energy-intensive industries – improving energy efficiency **4.** Measure 4.16 – Zero-carbon energy system. Energy for countryside **5.** Measure 5.1 – Good air quality. Clean air **6.** Measure 5.2 – Good air quality. Clean housing **7.** Measure 5.4 – Good air quality. Energy-efficient construction **8.** Measure 5.6 – Good air quality. Renovation with EPC (energy performance contract) plus guarantee **9.** Measure 5.8 – Good air quality. My warmth **10.** Measure 8.2 – Stop smog **11.** Measure 8.8 – Climate spas **12.** Measure 2.1 – Support for energy and environment sectors from European Regional Development Fund. District heating infrastructure **13.** Priority Programs of Provincial Funds for Environmental Protection and Water Management	**1.** Thermomodernization bonus with option of thermomodernization grant (owners or managers of residential buildings, collective housing, public utilities, and others) **2.** Bonus for municipal housing stock with option of grant for thermal modernization or renovation projects of residential building **3.** RES grant for owners or managers of multi-family residential buildings for purchase and installation of renewable energy source (RES) installations	**1.** Public-private partnership (PPP) is based on multi-year agreement specifying division of tasks and risks between public entity and private partner **2.** Commercial bank financing programs

Source: own work based on [31, 33]

One of the main financial instruments is the National Fund for Environmental Protection and Water Management's Priority Program 5.1. "Good air quality. Clean air" (hereinafter referred to as the Clean Air Program), with a budget of 83.3 billion PLN[3] (the program's implementation period covers 2018–2029). The funds are intended to implement projects that are aimed at improving air quality and reducing greenhouse gas emissions by replacing heat sources and improving the energy efficiency of single-family buildings. Since the beginning of the program (i.e., from September 19, 2018, through January 26, 2024, 770,235 applications were submitted (for an amount of 22,394,463,718 PLN); of these, 655,631 contracts were signed (for a total value of 17,572,587,850 PLN) [31]. The subsequent update of the program went into effect on April 22, 2024, and the beneficiaries of the program are individuals – owners and co-owners of buildings and dwellings. In order to receive the subsidy, one must choose equipment (heat pumps with the minimum-indicated energy-efficiency class or boilers with improved standards) that is included in the list of green equipment and materials [32]. Subsidies for individual works are based on a beneficiary's assignment to one of three support groups, where income criteria are the determining factors [31]:

- basic level of funding (beneficiary's annual income must not exceed amount of 135,000 PLN);
- increased level of subsidy (average monthly incomes per household member must not exceed amounts of 1,894 PLN for multi-person household and 2,651 PLN for single-person household);
- highest level of subsidy (average monthly incomes per household member must not exceed amounts of 1,090 PLN for multi-person household and 1,526 PLN for single-person household).

In financing, the rule is that the lower the income of the beneficiary, the higher the subsidy. In addition to replacing the heat source, the subsidy may cover the replacement and installation of new central heating and hot water systems, photovoltaic micro-installations, mechanical ventilation with heat recovery, insulation of building partitions, replacements of window and door frames, and preparations of required project documentation. Aside from the indicated maximum subsidy, one can additionally receive 1,200 PLN for the performance of an energy audit [33]. The types of projects that are supported and the amounts of the respective maximum funding are shown in Table 2.

Also worth noting is the National Fund for Environmental Protection and Water Management's Priority Program 5.4. "Good air quality. Energy efficient construction." This program aims to improve air quality by reducing the energy consumption in buildings (including that which results from increased renewable energy production) and reducing or avoiding carbon dioxide emissions. The budget for

[3] The zloty (PLN) is the currency that is used in Poland. According to the exchange rate on June 11, 2024, 1.00 PLN = 0.22 EUR; 1.00 PLN = 0.24 USD.

implementing the program is up to 5,455 million PLN, including 2.825 billion PLN for non-refundable forms of financing and 2.630 billion2PLN for repayable forms of support. Energy retrofits are subsidized for those buildings that are intended for culture, worship, education, care, upbringing, and science. The intensity of the grant funding ranges from 85 to 95% depending on the number of improvements that are applied [33].

Table 2. Types of projects supported under Clean Air Program

Type of project	Basic funding level	Increased subsidy level	Highest subsidy level
Replacement of inefficient heat source (solid fuel) with air-to-water or ground-source heat pump, along with replacements and installations of other components	**Without photovoltaics** – without comprehensive thermal modernization: 35,000 PLN – with comprehensive thermal modernization: 60,000 PLN **With photovoltaics** – without comprehensive thermal modernization: 41,000 PLN – with comprehensive thermal modernization: 66,000 PLN	**Without photovoltaics** – without comprehensive thermal modernization: 50,000 PLN – with comprehensive thermal modernization: 90,000 PLN **With photovoltaics** – without comprehensive thermal modernization: 59,000 PLN – with comprehensive thermal modernization: 99,000 PLN	**Without photovoltaics** – without comprehensive thermal modernization: 70,000 PLN – with comprehensive thermal modernization: 120,000 PLN **With photovoltaics** – without comprehensive thermal modernization: 79,000 PLN – with comprehensive thermal modernization: 135,000 PLN
Replacement of inefficient heat source (solid fuel) with efficient boiler or gas-fired boiler plant, along with replacements and installations of other building components	**Without photovoltaics** – without comprehensive thermal modernization: 25,000 PLN – with comprehensive thermal modernization: 50,000 PLN **With photovoltaics** – without comprehensive thermal modernization: 31,000 PLN – with comprehensive thermal modernization: 56,000 PLN	**Without photovoltaics** – without comprehensive thermal modernization: 32,000 PLN – with comprehensive thermal modernization: 72,000 PLN **With photovoltaics** – without comprehensive thermal modernization: 41,000 PLN – with comprehensive thermal modernization: 81,000 PLN	**Without photovoltaics** – without comprehensive thermal modernization: 50,000 PLN – with comprehensive thermal modernization: 100,000 PLN **With photovoltaics** – without comprehensive thermal modernization: 59,000 PLN – with comprehensive thermal modernization: 115,000 PLN
No heat source replacement, replacements and installations of other building components	**Without photovoltaics** – without comprehensive thermal modernization: 13,000 PLN – with comprehensive thermal modernization: 33,000 PLN **With photovoltaics** – not applicable	**Without photovoltaics** – without comprehensive thermal modernization: 25,000 PLN – with comprehensive thermal modernization: 48,000 PLN **With photovoltaics** – not applicable	**Without photovoltaics** – without comprehensive thermal modernization: 40,000 PLN – with comprehensive thermal modernization: 70,000 PLN **With photovoltaics** – not applicable

Source: own work based on [31]

Another form of support is offered by the Thermomodernization and Renovation Fund, which was introduced by the provisions of the Act on Support for Thermomodernization and Renovation and the Central Record of Emission of Buildings of November 21, 2008 [34]; along with implementing the acts, this makes it possible to increase the energy efficiency of already existing buildings. It is one of the best-performing pieces of legislation in the construction sector.

5. Results and Discussion

5.1. Renovation of Existing Residential Building to Meet Energy-efficiency Criteria in Poland – Technological Solutions That Are Used

The subject of the study was an existing single-family residential building that was located in the village of Prądocin (a municipality of Nowa Wieś Wielka, Poland); it had a usable area of 103.19 m^2 (with garage – 129.80 m^2). It was a two-story non-basement building with a usable attic that was made with the use of traditional technology (brick): it featured three-layered walls that were made of aerated concrete (with a thickness of 24 cm) with polystyrene insulation (with a thickness of 5 cm) and another layer of aerated concrete (with a thickness of 12 cm), a wooden ceiling, a gable roof covered with ceramic tiles (with 15 cm mineral wool insulation), double-glazed windows, and wooden external doors. The building used gravity ventilation and a fuel oil water boiler [35].

The analyzed house was in good technical condition. During the course of analyzing the thermal resistance of the selected building partitions and installation solutions, it was found that they did not meet energy-efficiency standards and the requirements of Regulation [23], which read that the building must have an EP ratio that was below 70 kW/m^2/year. The window and door woodwork was characterized by poor thermal-insulation performance. The gravity ventilation in the building did not deviate from the technical requirements, but its replacement with mechanical ventilation with heat recovery was required in order to meet energy standards. The central heating system was characterized by the low efficiency of the heating boiler.

5.2. Renovation Costs and Level of Financial Support from Clean Air Program

Technological solutions were proposed in two variants that differed in their heat sources, which realized the requirements of the energy-saving standards (Variant 1 – condensing gas boiler; Variant 2 – heat pump). To meet these standards, it was proposed to increase the level of the insulation of the building envelope (walls,

roof, foundation, and ground floor), with the thickness of insulation meeting the requirements of a specific standard. It was also planned to replace the window and door frames as well as the heat source, along with adjusting the entire installation. Variant 1 (condensing gas boiler with a Class A minimum energy efficiency, radiator installation, and gravity ventilation). Variant 2 (an air-to-water heat pump with an improved energy-efficiency class (min. A++), the installation of underfloor heating, and mechanical ventilation with heat recovery). The equipment and installations that were adopted in the technological variants were included in the catalog of eligible costs of the Clean Air Program and were, thus, eligible for financial support for improving the energy efficiency of the building. The levels of the costs along with the maximum level of support for each specific eligible cost from the Clean Air Program are shown in Table 3.

Renovation (also known as the comprehensive thermal modernization of the building) included the thermal upgrading of the building envelope and the replacements of the installations. The total costs of the renovation were as follows: Variant 1 – 238,172.25 PLN (which included the cost of the installation [71,168.70 PLN]); and Variant 2 – 317,444.08 PLN (which included the cost of the installation [129,034.60 PLN]). The levels of the funding vary depending on the type of each eligible cost. For those tasks in the field of the comprehensive thermal rehabilitation of a building envelope, the level ranges from 50% at the basic level of funding to 100% at the highest level (with no threshold for the maximum amount). There are quota thresholds for replacement installations at each funding level, and the percentages of the funding can range from 40 to 100%. The maximum amount of the grant is based on the beneficiary's annual income and the scope of the work. The example did not take the installation of a photovoltaic system into account; hence, the level of the maximum subsidy was assumed according to Table 1 (for projects without photovoltaics). According to the terms of the program, one must conduct an energy audit of a building in order to receive a subsidy (the cost of the audit is also subsidized at an amount of 1,200 PLN). The subsidy levels for the Variants 1 and 2 standards are shown in Tables 4 and 5, respectively.

As can be seen in Tables 4 and 5, financial support could only have applied to selected elements of the renovation; it is the beneficiary who decides for which elements they will receive a grant. Of all of the elements that were indicated in Table 3, replacing the heat source, replacing the woodwork, and insulating the exterior walls were selected for the funding. The other works could not be subsidized due to the restrictions on the maximum funding level. During the course of analyzing Variant 1, it can be seen that, even in the highest subsidy, the beneficiary would have to spend 40,000 PLN from their own resources. With Variant 2, the level would rise to nearly 80,000 PLN. The above-mentioned amounts mostly relate to wall insulation. It follows that, with the highest level of subsidy, 100% reimbursement would be received only for the replacement of the heat source; insulating the roof, foundation, and ground floor was not included in the subsidy.

Table 3. Comparison of costs of renovating existing buildings to energy-efficient standards, along with maximum levels of funding for indicated eligible cost from Clean Air Program

Building element to be renovated (comprehensive thermal modernization of building)	Building renovation cost		Maximum subsidy level for indicated eligible cost								
			Basic funding level			Increased subsidy level			Highest subsidy level		
	Variant 1 [PLN]	Variant 2 [PLN]	Support threshold [%/max PLN]	Variant 1 [PLN]	Variant 2 [PLN]	Support threshold [%/max PLN]	Variant 1 [PLN]	Variant 2 [PLN]	Support threshold [%/max PLN]	Variant 1 [PLN]	Variant 2 [PLN]
Insulation of floor on the ground and foundation	32,837.08	34,682.62	50/lack of	16,418.54	17,341.31	75/lack of	24,627.81	26,011.96	100/lack of	32,837.08	34,682.62
Replacement of window woodwork	17,918.93	22,128.69	40/lack of	7,167.57	8,851.48	70/lack of	12,543.25	15,490.08	100/lack of	17,918.93	22,128.69
Exterior door replacement	6,951.79	9,573.14	40/lack of	2,780.72	3,829.25	70/lack of	4,866.25	6,701.19	100/lack of	6,951.79	9,573.14
Roof thermal insulation	26,823.65	30,509.41	50/lack of	13,411.82	15,254.71	75/lack of	20,117.74	22,882.06	100/lack of	26,823.65	30,509.41
Insulation of external walls	82,472.11	91,515.62	50/lack of	41,236.06	45,757.81	75/lack of	61,854.08	68,636.72	100/lack of	82,472.11	91,515.62
Radiator installation	37,801.09	–	lack of support	–	–	lack of support	–	–	lack of support	–	–
Condensing gas boiler	33,367.61	–	40/6,100.00	6,100.00	–	70/10,700.00	10,700.00	–	100/15,300.00	15,300.00	–
Floor installation	–	55,556.51	lack of support	–	–	lack of support	–	–	lack of support	–	–
Heat pump	–	59,823.57	55/19,400.00	–	19,400.00	80/28,100.00	–	28,100.00	100/35,200.00	–	35,200.00
Mechanical ventilation with heat recovery	–	13,654.52	40/6,700.00	–	5,461.81	70/9,000.00	–	9,000.00	100/16,700.00	–	13,654.52
Total (thermal modernization of building envelope)	167,003.55	188,409.48	–	–	–	–	–	–	–	–	–
Total (installation replacement)	71,168.70	129,034.60	–	–	–	–	–	–	–	–	–
Total (installation replacement)	238,172.25	317,444.08	–	–	–	–	–	–	–	–	–

Source: own work based on [31]

It should be noted that, although the subsidy at the highest level can cover 100% of eligible costs, the maximum subsidy amounts of 100,000 PLN for Variant 1 and 120,000 PLN for Variant 2 significantly limited us from achieving a comprehensive thermal modernization of the building. In order to carry out all of the activities for Variant 1, the beneficiary was required to subsidize nearly 200,000 PLN from their own funds; for Variant 2 this amount was 240,000 PLN. Despite the above limitations, the existing building was to achieve the rate of comprehensive thermal modernization that was required by the Clean Air Program; that is, a reduction to 80 kWh/m^2/year in the demand for usable energy. Unfortunately, the lack of a full thermal modernization of the building envelope (the foundation, ground floor, and roof) could have increased the electricity costs when using the heat pump on a daily basis – especially in Variant 2 (as was pointed out by Krajewska and Szopinska [26]). In addition, the building would not have met the requirements of the regulation for Variant 1 nor Variant 2 [23].

Table 4. Level of support from Clean Air Program for renovations according to technological solutions of Variant 1

Variant 1	Costs of renovations of selected elements [PLN]	Basic subsidy level	Increased subsidy level	Highest subsidy level
		(max. grant amount – 50,000 PLN)	(max. grant amount – 72,000 PLN)	(max. grant amount – 100,000 PLN)
Condensing gas boiler	33,367.61	6,100.00	10,700.00	15,300.00
Replacement of window woodwork	17,918.93	7,167.57	12,543.25	17,918,93
Exterior door replacement	6,951.79	2,780.72	4,866.25	6,951.79
Insulation of external walls	82,472.11	33,951.71	43,890.50	59,829.28
Total cost of renovations of selected elements [PLN]	140,710.44	–	–	–
Grant level [PLN]	–	50,000.00	72,000.00	100,000.00
Own funds [PLN]	–	90,710.44	68,710.44	40,710.44

Source: own work based on [31]

Table 5. Level of support from Clean Air Program for renovations according to technological solutions of Variant 2

Variant 2	Costs of renovations of selected elements [PLN]	Basic subsidy level (max. grant amount – 60,000 PLN)	Increased subsidy level (max. grant amount – 90,000 PLN)	Highest subsidy level (max. grant amount – 120,000 PLN)
Heat pump	59,823.57	19,400.00	28,100.00	35,200.00
Mechanical ventilation with heat recovery	13,654.52	5,461.81	9,000.00	13,654.52
Replacement of window woodwork	22,128.69	8,851.48	15,490.08	22,128.69
Exterior door replacement	9,573.14	3,829.25	6,701.19	9,573.14
Insulation of external walls	91,515.62	22,457.46	30,708.72	39,443.65
Total cost of renovations of selected elements [PLN]	196,695.54	–	–	–
Grant level [PLN]	–	60,000.00	90,000.00	120,000.00
Own funds [PLN]	–	136,695.54	106,695.54	76,695.54

Source: own work based on [31]

6. Conclusions

The realization of the Sustainable Development Goals (especially Goal 7 [1]) requires the international community to introduce public support instruments in order to overcome financial barriers (i.e., high investment costs [36], long payback times [37], and high investment risks [38]) for implementing measures to improve the energy efficiency of residential buildings. Increasing the number of such buildings will contribute to increasing the share of renewable energy sources in the global energy mix, which will then reduce air pollution levels and improve the comfort and quality of life of the residents (thus, achieving Sustainable Development Goal 3, Task 3.9) [1].

A content analysis of EU regulations indicates the continued evolution of this topic, which is evident in the ever-increasing number of energy-efficient buildings in Europe. EU regulations have consequences in the legislation of its member states; in Poland, the state of the implementation of EU legislation on energy-efficient construction is still not sufficient, but emerging support instruments on this topic have had their direct effects in the forms of financial support programs. Public support programs are particularly important for the owners of existing buildings, where comprehensive thermal modernization is a very costly measure. The largest supporting program in Poland is the Clean Air Program, which assumes the implementation of indicators that significantly affect the realization of sustainable development goals for energy-efficient construction – especially for implementing the tasks of Goal 7 (Measures 7.1, 7.2, 7.3, 7.A, and 7.B) [1]. This program assumes the realization of the following sustainable development indicators [31]:

- number of buildings/housing units with improved energy efficiency – 3,030,000 units;
- number of inefficient heat sources replaced with low-carbon ones in buildings/residential units – 3,000,000 units;
- additional electricity-generation capacity from installed photovoltaic microinstallations – 750 MWe;
- reducing final energy consumption – 38,100,000 MWh/year;
- PM_{10} emission reduction – 213,000 Mg/year;
- reduction of benzo-α-pyrene emissions – 142 Mg/year;
- reduction of CO_2 emissions – 14,200,000 Mg/year.

This study showed that the financial support of the Polish program would not have covered the construction costs of all of the thermal-modernization measures for the existing (studied) building. The program's assumptions (primarily, the threshold for the maximum amount of funding) did not fully achieve the parameters of an energy-efficient building (much less a passive one). Thus, the Clean Air Program does not provide the opportunity to achieve the requirement that was set forth in the 2023 EU directive under the current assumptions; these read that, starting on January 1, 2030, a thorough renovation should lead to the transformation of a building into an emission-free structure [17] and the guidelines that are set by the Polish legislation [23]. This conclusion should persuade Polish authorities to make such changes in the aid programs where, in the subsequent editions of the program, the beneficiaries with the highest levels of funding would be able to implement thermal-modernization measures for zero-emission structures. This would help Poland meet the 11th Sustainable Development Goal (Make cities inclusive, safe, resilient, and sustainable), whereas Task 11.6 states that, by 2030, the city's unfavorable rate of negative environmental impact per capita should be reduced, paying particular attention to air quality (among other things). This conclusion on a global scale was confirmed by Satola et al. [39], who concluded that there was an urgent need

for a transparent and harmonious standardization of energy-efficiency measures in buildings.

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CRediT Author Contribution

K. S.: conceptualization, methodology, software, validation, formal analysis, investigation, resources, data curation, writing – original draft preparation, writing – review and editing, visualization, supervision, project administration, funding acquisition.

M. R.: conceptualization, writing – original draft preparation, writing – review and editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

Public Data: The data analyzed during the following research are available on Clean Air Program. Can be accessed via the following link: https://czystepowietrze.gov.pl.

Restricted Data: Data will be made available on request (MSc thesis written under the supervision of K. Szopińska).

Use of Generative AI and AI-assisted Technologies

No generative AI or AI-assisted technologies were employed in the preparation of this manuscript.

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