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Improving the energy efficiency of buildings: lessons learned from Poland

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Abstract. The aim of the article is to demonstrate the effects of the distribution and application of EU structural funds on improving the energy efficiency of buildings (IEEB) in the regions of Poland. Conducting detailed analyses, based on data from 3,914 projects co-financed with a total of €1.876 billion under 16 Regional Operational Programs (ROPs) 2014–2020, led to the indentification of similarities and differences with regard to the beneficiaries, the implemented investments, and the spatial distribution of funds. In all regions, a huge disparity was observed in the disbursement of funds in favor of self-government units compared to the other categories of beneficiaries. Considering the investments, thermo-modernization and combination measures dominated, and their regional differentiation is mainly due to the nature and age of the buildings. The largest amounts of subsidies were obtained by cities from northern, western and southern Poland, whereas projects were more numerous though individually smaller in rural areas in central and eastern Poland. The spatial distribution of investments still reflects the post-partition division of Poland. The recommendations developed guide policy thinking for better implementation of IEEB actions within the framework of EU Cohesion Policy.

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Contents:

1. Introduction

Relevant energy management is an essential factor in sustainable development efforts, and improving energy efficiency is one of the milestones for achieving carbon neutrality globally (Vera, 2007; Rehman Khan et al., 2023). This is a part of the trend of endeavors to tackle the effects of climate change through the reduction of greenhouse gas emissions, the improvement of energy efficiency and the implementation of sustainable development principles worldwide, initiated by the adoption of the United Nations Framework Convention on Climate Change and the Agenda 21 (1992), the signing of the Kyoto (1997) and Gothenburg (1999 and its revision in 2012) protocols, and cemented in the provisions of the Paris Agreement and the 2030 Agenda for Sustainable Development in 2015 (Birindelli & Chiappini, 2020; Kociuba & Wajs, 2021). To meet these increasingly exigent challenges, countries around the world are revising energy and climate policies, creating new concepts for the development of key economic sectors, modifying approaches to resource distribution and introducing new programs and support tools. This is crucial to develop successful adaptation processes, reduce CO_2 emissions and achieve an effective energy transition by reducing final energy consumption and increasing the share of renewables in the energy mix, which is additionally a key challenge in moving away from a fossil-fuels-based economy.

The European Union (EU) – one of the largest carbon dioxide emitters among the G20 members (along with China and the United States) – has not only the ambition but also the opportunity to complete the transition to a carbon-neutral economy by 2050, due to the advanced implementation of increasingly ambitious energy and climate policies in Member States (MS), which are obliged by law to implement EU level directives and regulations into their legislation (Turner 2013; Kociuba & Wajs, 2021), as well as to support MSs in introducing pro-climate and pro-energy initiatives with funds under national and regional operational programs (Dębkowska et al., 2022). At the institutional and programming level, there is support particularly for initiatives aimed at achieving energy efficiency, which, according to the statutory definition, is understood as the ratio of the achieved magnitude of the utility effect of a given object, technical device or installation, under typical conditions of its use or operation, to the amount of energy consumption by this object, technical device or installation, or as a result of the performed service necessary to achieve this effect (Journal of Laws 2016 item 831 as amended).

In recent decades, the European Union has paid particular attention to the buildings sector, as buildings account for 40% of EU energy consumption and 36% of greenhouse gas emissions (COM/2021/550 final). As many as 85% of EU buildings were built before 2000 and, among those, 75% have poor energy performance. The building renovations, which annually cover about 11% of the EU's building stock, only 0.4–1.2% (depending on the Member State) are aimed at improving energy efficiency, and it is through such measures that total energy consumption can be reduced by 5–6% and CO_2 emissions by 5% (COM/2020/662 final). Hence, improving the energy efficiency of buildings (IEEB) has become one of the key elements of legislative work and the assumptions of strategic-programming documents, which have been translated into programming principles for the distribution of funds under the EU Cohesion Policy to subsidize many types of activities and investments based mainly on the use of active, passive and RES-based technical solutions. Active solutions for space heating and domestic hot water include heat pumps, boilers and district heating or decentralized heating, as well as efficient lighting and appliances. Passive technologies for space heating are based on thermal insulation to store energy. Most used renewable technologies are PV, solar thermal, geothermal and biomass (D'Agostino et al., 2021).

The issue of improving the energy efficiency of buildings, which is important for achieving ambitious climate goals, has received a number of studies. Since the beginning of the 21st century, there has been a noticeable increase in scientific research on energy efficiency in the world, mainly in China (Abdelrahman et al., 2021). Research is conducted in the technological stream – developing the best techniques for measurement and evaluation (Chatterjee & Ürge-Vorsatz, 2021) as well as implementing high-performance technologies in the construction sector (Zhou, et al. 2023). The second strand focuses on the creation of sectoral policies and legislation that support the transition to low-carbon construction and decarburization of buildings (He et al., 2020; Maduta et al., 2022) and the evaluation of their effects (Liu et al., 2019). For example, Li and Bin (2015) conducted an analysis of policies regarding building energy efficiency in terms of improving living standards and climate change mitigation in China, while Kamal et al. (2019) analyzed the impact of energy efficiency policies by assessing the evolution of the building sector in Qatar. D'Agostino et al. (2021) summarized

the development of Nearly Zero Energy Buildings in the EU and its Member States, and De Boeck et al. (2015) examined the topic of improving the energy performance of residential buildings. More broadly, studies also focus on the challenges for selected countries (i.e., the Visegrad Group) of shifting to carbon neutrality (Streimikiene, 2021) or assessing the opportunities in implementing EU green transition policies (Brożyna et al., 2023). The third group concerns financial mechanisms and instruments for energy efficiency (Kochanski, 2014). Studies focus on the distribution of funds in EU Member States under individual operational programs (Serafin, 2019), and their territorial coverage is limited to the entire country (Nigohosyan et al., 2021), regions (Czykier-Wierzba, 2020), or smaller units (Serafin, 2019). Another group in this trend refers to the beneficiaries of the funds. Energy efficiency issues are most often considered in relation to measures and investments implemented by local government units (Piekarska, 2015), or firms (Nigohosyan et al., 2021; Dembicka-Niemiec et al., 2023). Studies focus on, for example, methods of increasing energy efficiency in small and medium-sized enterprises and ways and sources of financing projects (Skoczkowski et al., 2014), or only on methods for improving energy efficiency in households (Mirowski, 2012), or multi-family buildings (*Opracowanie metodologii* …, 2019). Occasionally, works combine these threads, such as Statistics Poland's report on improving the energy efficiency of public administration buildings in 2007–2013 (*Badanie efektywności* …, 2015). Single studies determine the use of EU funds on low-carbon economy in the large companies sector (Dembicka-Niemiec et al., 2023), or assess the effectiveness of EU-supported energy efficiency measures for SMEs (Nigohosyan et al., 2021). In this regard, there is a noticeable lack of research that synthesizes the distribution of funds on IEEB with project beneficiaries and the area of support.

Therefore, the aim of this article is to demonstrate the effects of the distribution and application of structural funds on IEEB in the regions of Poland and to identify similarities and differences in implemented investments, the spatial distribution of funds, and the financing of entities. Analyses were conducted on a regional layout for three main groups of issues: 1) the type of beneficiaries, 2) the investments made; 3) the size of the territorial unit, based on data from 3,914 projects on IEEB co-financed under 16 ROPs 2014–2020 using desk research, purposive sampling and descriptive statistics methods. The comprehensive analysis made it possible to answer the research questions: 1) Who benefited from the funds? 2) What investments were implemented? 3) Where were the funds distributed? The research findings and insights from the discussion formed the basis of recommendations which guide policy thinking and channel legislation for more effective implementation of measures and investments on IEEB under EU Cohesion Policy.

2. EU's energy-climate and cohesion policies related to IEEB

The adoption of the EU Climate and Energy Package (the so-called 3x20% package) (2009/28/EC) had a significant impact on the formulation of energy and climate policies that largely influenced the allocation and disbursement of funds in 2014–2020. Its implementation was to guarantee that by 2020 the EU would reduce greenhouse gas emissions by 20% compared to 1990, obtain a 20% share of energy from renewable sources in the energy mix, and increase energy efficiency by 20%. In the context of construction, of key importance was the entry into force of the recast of the Energy Performance of Buildings Directive (EPBD) (2010/31/EU), which required MSs to make all new buildings near-zero energy buildings (NZEB) (Note 1) by December 31, 2020 (this requirement was to apply to all new buildings occupied and owned by public authorities after December 31, 2018). On the other hand, the Energy Efficiency Directive (EED) (2012/27/EU) aimed to reduce total final energy consumption by 9% by 2016 and required MSs to renovate 3% of government buildings annually as of January 1, 2014.

The findings of these documents were reflected in EC Europe 2020: A Strategy for Smart, Sustainable and Inclusive Growth (COM/2010/2020), which was the main strategic document for EU development and outlined the framework of the Cohesion Policy 2014–2020. One of the strategic objectives was climate and energy action, promoting a low-carbon economy. Measures and investments were mainly implemented under Thematic Objective (TO) 4 "Supporting the shift towards a low-carbon economy in all sectors" under the European Regional Development Fund (ERDF). The allocation for TO4 was €40 billion, of which 65.9% were ERDF funds (cohesiondata.ec.europa.eu).

A significant beneficiary of these funds was Poland, where energy efficiency improvements were supported with more than €9.8 billion. At the national level, investments were mainly co-financed under the Operational Program Infrastructure and Environment (OPI&E) 2014–2020, with a budget of

€27.4 billion, of which €2.8 billion was earmarked for measures related to the low-carbon economy (www.gov.pl/web/climate/poiis)(Note 2) and the Eastern Poland Operational Program dedicated to the five voivodeships with the lowest GDP and located in eastern Poland (Lubelskie, Podlaskie, Warmińsko-Mazurskie, Podkarpackie and Świętokrzyskie) with an allocation of €441 million. Investments in improving energy efficiency under TO4 implemented in 16 Regional Operational Programs (ROPs) have been subsidized to the tune of €5.24 billion (*Programowanie perspektywy* …, 2014).

The entry into force of the principles of the Paris Agreement and the adoption of ambitious goals for a climate-neutral EU by 2050 triggered a number of legislative initiatives. The regulatory and policy framework supporting the decarburization of building stock was set by the "Clean Energy for All Europeans" package (COM/2016/0860 final), while implementation guidelines included the revised EED (2018/2002/EU), which adopted the reduction of primary and final energy consumption to 32.5% by 2030, and the revised EPBD (2018/844/EU) requiring MSs to develop long-term renovation strategies to decarbonize their national building stock by 2050. Implementation of the "Clean Energy for All Europeans" package has required MSs to prepare new documents at the national level, i.e. integrated National Energy and Climate Plans (NECPs) (under the Regulation (EU) 2018/1999 on the Governance of the Energy Union and Climate Action), which outline how to meet the EU energy and climate targets for 2030.

Improving the energy efficiency of buildings is also one of the crucial priorities of the new initiatives introduced in 2020, i.e., the European Green Deal (COM/2019/640 final) and its part "Renovation Wave Strategy" (COM/2020/662 final) that aims to at least double the annual energy renovation rate of buildings by 2030 and foster deep renovation. Completing the formal adoption process of another revision and strengthening of the EPBD is one of its key building blocks. The recast EPBD states that all new buildings should be zero-emission as of 2030 (new buildings occupied or owned by the public sector as of 2028) and ensures that all buildings (whether new or renovated) should become zero-emission by 2050. In addition, it seeks, for example, to accelerate building renovation rates (MSs are required to renovate the 16% worst-performing non-residential buildings by 2030 and the 26% worst-performing buildings in this category by 2033) and promote the uptake of renewable energy in buildings, as well as to move away from fossil fuels for heating (all new publicly owned buildings must have zero on-site emissions from fossil fuels as of 2028, others as of 2030). This initiative is in line with the energy aspect of the EU's climate transition as part of the implementation of the "Fit for 55" legislative package (COM/2021/550 final), which, along with the REPowerEU plan (COM/2022/230 final), further highlighted the need to address the EU's building stock to reduce Europe's dependence on foreign energy sources and introduces an increase from 9% to 13% of the binding energy efficiency target. This is to be fostered by the implementation of the revised EED (2023/2413/EU), which establishes a new EU target to reduce final energy consumption by 11.7% by 2030 (for EU countries an average of 1.49% between 2024 and 2030), and for the public sector additionally introduces, for example, an obligation to deliver a 1.9% annual reduction in the final energy consumption in buildings, and to renovate annually at least 3% of the floor space of building stock under central administration and local and regional government. These transformative roadmaps also guide the distribution of funds in the 2021–2027 perspective supporting EU Member States to comprehensively renovate their building stock and meet ambitious NZEB standards.

3. Materials and methods

The article focuses on projects, their beneficiaries and investments in IEEB co-financed under Regional Operational Programs 2014–2020 in Poland. Secondary sources from the public domain, that is, databases containing lists of projects provided by the Ministry of Funds and Regional Policy (www.funduszeeuropejskie.gov.pl), as well as implementing documents for Regional Operational Programs (including Detailed Descriptions of Priority Axis), were used for detailed analysis. Finally, a set of 3,914 projects implemented in 16 ROPs, co-financed by ERDF 2014–2020 under TO4 were analyzed. Data from the National Court Register were used to identify the economic sector of the beneficiaries. Data from the Local Data Bank (BDL) of Statistics Poland (https://bdl.stat.gov.pl/bdl/) were used in assigning units to particular categories.

The research was carried out using desk research (Bednarowska-Michaiel, 2015) and purposive sampling (Frankfort-Nachmias et al., 2016) and descriptive statistics (Starzyńska, 2006) methods, using secondary data obtained from the *List of projects implemented under European Funds 2014–2020 in Poland* (*Lista projektów* …;

www.funduszeeuropejskie.gov.pl) for a dataset collected until April 3, 2023. The exchange rate of EUR 1 = PLN 4.5 was adopted.

The work was divided into three stages.

In the first stage, the data were subjected to selection using the desk research method. For further analysis, using the purposive sampling method, only those investments were selected that met the criteria for areas of support for energy efficiency of buildings in accordance with the Annex to the European Commission Implementing Regulation (EU) No 184/2014 of 25 February 2014 on the nomenclature of the categories of intervention for support from the European Regional Development Fund under the European territorial cooperation goal. The following codes for the scope of intervention were adopted for analysis:

- 013 Energy efficiency renovation of public infrastructure, demonstration projects and supporting measures (II. Infrastructure providing basic services and related investment),
- 014 Energy efficiency renovation of existing housing stock, demonstration projects and supporting measures (II. Infrastructure providing basic services and related investments),
- 068 Energy efficiency and demonstration projects in SMEs and supporting measures (IV. Development of endogenous potential),
- 069 Support to environmentally-friendly production processes and resource efficiency in SMEs (IV. Development of endogenous potential).

Using the purposive selection method, investments related to street lighting were rejected due to their insignificant connection to IEEB.

The second stage involved the selection of categories that constituted the subject of analysis. Three groups of issues were distinguished. The first was the type of beneficiary. Each beneficiary was verified in terms of the scope and form of its economic activity (data came from the online system of the National Court Register) and the legal basis of its activity (based on binding statutes). Based on the number of projects implemented and the amount of subsidies obtained, eight leading categories were distinguished. These are: 1) self-government units (SGU); 2) residential and housing communities (R&HC); 3) public health service (PHC); 4) non-governmental organizations (NGO) (associations, foundations, inter-municipal associations and cooperatives established under separate legal acts); 5) the private enterprise sector (PES); 6) financial institutions (FI) such as the Bank of National Economy, the European Investment Bank, the Savings Banks that are distributors of funds on IEEB under separate programs and financial instruments; 7) religious institutions (RI) and 8) other beneficiaries (OB), e.g. public administration, universities, police, fire departments, that implemented individual projects.

The second group of issues was the type of investments made. The basis for the division was again the number of projects and the amount of subsidies. Eight categories were selected for detailed analysis. These are: 1) thermo-modernization (T), including insulation of external walls, ceilings, roof, replacement of windows and external doors, 2) renewable technical solutions (R) (photovoltaic, solar thermal collectors, heat pumps); 3) thermo-modernization combined with installation or replacement of energy and/or heat sources based on RES (T+R), 4) thermo-modernization combined with replacement of lighting to energy efficient solutions (T+L), 5) thermo-modernization combined with investment in RES and energy-efficient lighting (T+R+L); 6) construction of energy-efficient and passive buildings, including demonstration buildings (DB); 7) financial instruments (FI) which is the same as the "finance institution" category where the beneficiary was a financial institution that redistributed funds on IEEB in the region, and 8) other investments (OI), such as replacement of heat sources based on fossil fuels (e.g., gas or coal furnaces), or connection to a district heating network.

The third group of issues was the size of the territorial unit in which investments were implemented. We have distinguished: 1) cities, with a population >50,000; 2) towns, with a population >5,000; 3) rural areas with the administrative status of a rural municipality, 4) N/A – projects were implemented or funds distributed throughout the region. This classification is based on the DEGURBA degree of urbanization. Population data for categories 1 and 2 were obtained from the BDL of Statistics Poland.

In the third stage, the collected data were utilized for statistical analysis, using descriptive statistics methods. Analyses were conducted in three groups, resulting from the purpose of the study, with reference to the regional and national context. For each group, compilations were made in relation to the granted amounts of subsidies and the number of implemented projects, as well as the percentage of total amounts/projects that were disbursed/implemented in the voivodeship. The values of subsidy amounts resulted from the methodology

for calculating the maximum amount of subsidy specified in Regulation (EU) No 1303/2013. Carto-diagrams and charts were developed to graphically present the compiled statistical material; the maps were made using QGIS 3.16 Hannover. In order to keep the message clear, in the figures relating to the amounts of subsidies (Fig. 3, 5, 7), cartograms show the percentage share of subsidies per voivodeship, while pie charts present allocations per region per category (beneficiaries, investments, territorial units). Similarly, cartograms illustrating the numbers of projects (Fig. 4, 6, 8) show the percentage share of projects per voivodeship, while pie charts present the number of projects implementable in each voivodeship by individual categories (beneficiaries, investments, territorial units).

The research findings and insights from the discussion (Section 5) made it possible to answer three research questions: 1) Who benefited from the funds? 2) What investments were implemented? 3) Where were the funds distributed? They also provided the basis for policy recommendations for more effective implementation of measures and investments on IEEB under EU Cohesion Policy (Section 6).

4. Research results

4.1. Subsidized investments to improve energy efficiency of buildings in the regions

Investments in energy efficiency improvements from the ERDF 2014–2020 under TO4 implemented under 16 Regional Operational Programs were subsidized to a total amount of €5.243 billion, of which a total amount of €1.876 billion was spent on IEEB. A comparison of the amount of funding in each region to the total amount spent under TO4 from the ERDF 2014–2020 in the 16 ROPs (Fig. 1) shows that the largest support was allocated in the Śląskie Voivodeship (€285.7M) and the lowest in the Opolskie Voivodeship (€37M). Most funds, in relation to the total amount of subsidies, were allocated in the Dolnośląskie Voivodeship (14.5%) and the least in the Podkarpackie Voivodeship (5.2%). Nationally, subsidies for energy efficiency of buildings averaged 8.3% in the regions. Under the ERDF 2014–2020, 3,914 projects were implemented. Their number ranged from 75 in Pomorskie to 568 in Lubelskie (Fig. 2). The average amount per project oscillated around €480K, reaching a maximum in the Pomorskie (€1,750M) and a minimum in the Lubelskie (€257K) and Warmińsko-Mazurskie (€283K) voivodeships.

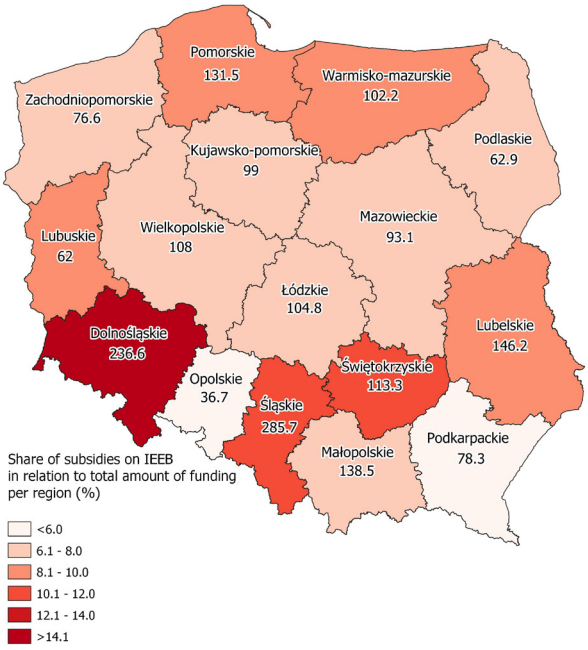

Fig. 1. Comparison of the subsidies on IEEB (in M) to the share of allocation on IEEB in the total amount of ERDF 2014–2020 subsidies per region
Source: authors' work

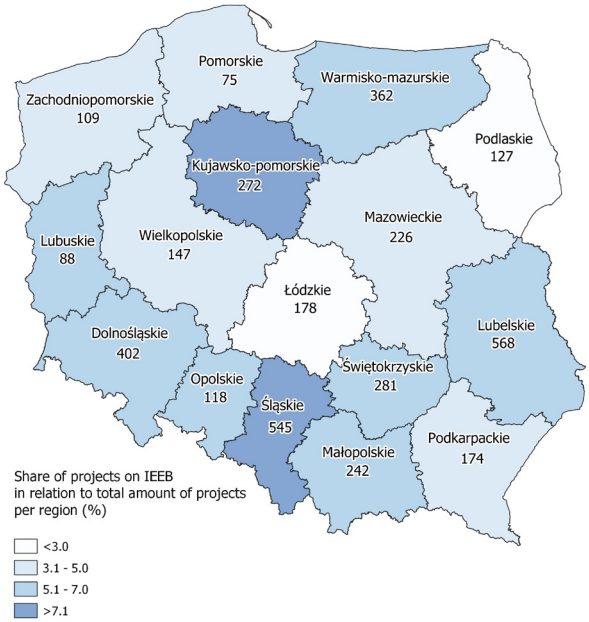

Fig. 2. Comparison of the number of projects on IEEB in the regions to the share of projects on IEEB in the total number of projects per region
Source: authors' work

4.2. Type of beneficiaries

The results of the analysis of the distribution of funds on IEEB for each category of beneficiary are presented in Figure 3, and a compilation of the number of projects implemented by them is given in Figure 4.

The analysis shows that the beneficiaries who obtained the most subsidies were self-government units (€1.3B). This rule applied to all voivodeships, with the amount of funds unitary SGUs received being largest in Śląskie (€222.3M), and funds as a proportion of the total allocation per region being largest in Zachodniopomorskie (93.6%) and Łódzkie (84.6%). In addition, SGUs implemented the largest number of projects (2,553). The leader was Śląskie Voivodeship (484). SGUs' projects prevailed in the Łódzkie (94%) and Lubuskie (92%) voivodeships.

In terms of allocation raised, financial institutions (FI) ranked second (€189.5M). They handled the redistribution of funds for IEEB in ten regions. The largest pools in absolute terms were provided by Śląskie (€31.8M) and Wielkopolskie (€28.9M), but the share in total allocation per region was largest in Podlaskie Voivodeship (35.1%).

Public health care (PHC) obtained a total of €112.5M and implemented 139 projects in all regions of Poland. Śląskie Voivodeship was in the lead (21 projects amounting to €14.7M) and, in terms of share in the total amount of subsidies per region, Lubuskie Voivodeship (21%). Enterprises (PES) nationwide were beneficiaries of €106.3M and implemented a total of 684 projects. Leaders among the voivodeships were Lubelskie (€31.4M, 250 projects), Małopolskie (€18.5M; 104 respectively) and Świętokrzyskie (€13.M; 113 respectively). Residential and housing communities (R&HC) obtained a total of €65.1M and implemented 322 projects in eight voivodeships. They were most active in raising funds in the Warmińsko-Mazurskie (113 projects for €17.2M) and Dolnośląskie (105; €16.7M, respectively).

The share of other groups of beneficiaries, although they joined in raising and disbursing EU funds in almost all voivodeships, was low (nationally, 1.2–3.5%; regionally, 1–2% on average). In the context of religious institutions (RI), it is important to note the beneficiaries from Pomorskie Voivodeship, which raised a total of €15.5M, which accounted for about 12% of the amounts distributed in the region. NGOs obtained the largest funding

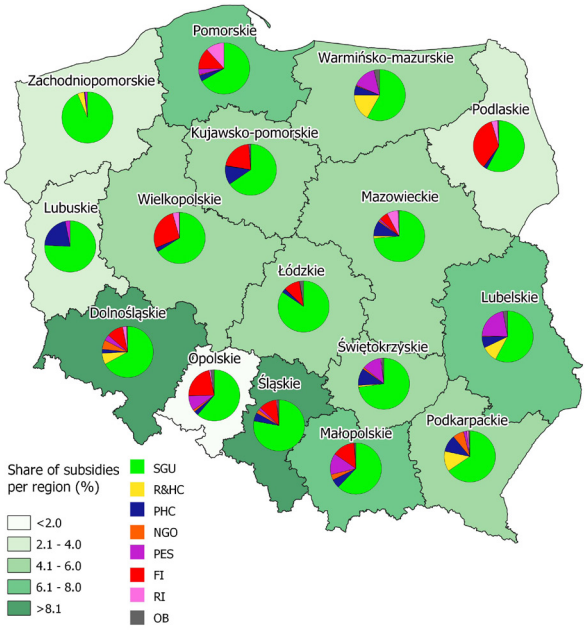

Fig. 3. Allocation of funds in the regions by type of beneficiary
Source: authors' work

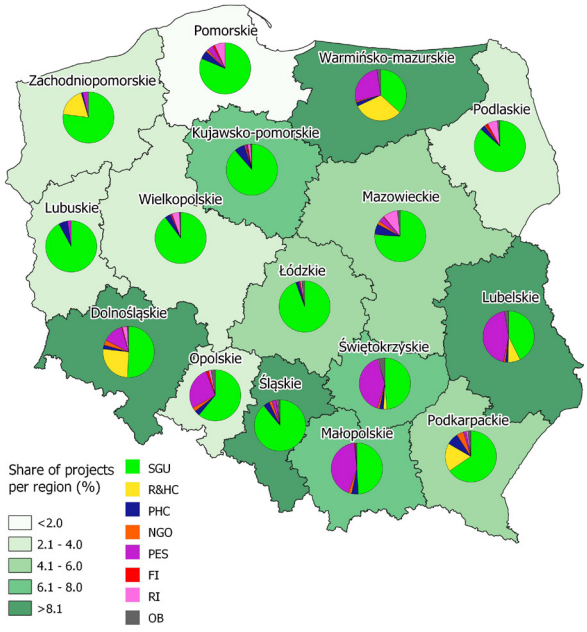

Fig. 4. Number of projects in the regions by type of beneficiary
Source: authors' work

Abbreviations: SGU – self-government unit; R&HC – residential and housing community; PHC – public health service; NGO – non-governmental organization; PES – private enterprise sector; FI – financial institution; RI – religious institution; OB – other beneficiaries

in Dolnośląskie Voivodeship (€14M, 6% of the total amount), and in the OB category in Lubelskie Voivodeship (€4.3M; 3% of the total amount).

4.3. Types of investments

The results of the analysis of the distribution of funds for IEEB in regions for each category of investment are presented in Figure 5, and a compilation of the number of projects implemented is shown in Figure 6.

Investments in thermal modernization (T) were subsidized in all regions. They absorbed the largest amounts of subsidies nationwide (€765.8M), but only in five voivodeships did they account for more than 50% of the total allocation per region. Among the regions, Śląskie (€175M; 397 projects) and Dolnośląskie (€93.3M; 246) dominated. Thermo-modernization projects prevailed in Zachodniopomorskie (76.1% in total).

Investments in thermal modernization combined with the installation of PV, thermal solar collectors or heat pumps (T+R) were co-financed in all regions for a total of €406.2M. Świętokrzyskie (€75.1M, 197 projects, as much as 70.1% per region) and Lubelskie (€67.8M; 214 projects) stood out among the regions. Investments in thermal modernization combined with lighting replacement (T+L) were subsidized in 15 voivodeships (Pomorskie being the exception) to the tune of €146.9M. The largest amounts per region were allocated in Śląskie Voivodeship (€31.5M). T+L investments were particularly popular in Warmińsko-Mazurskie Voivodeship (19.1% of the allocation, 19.6% of projects in the region). 271 projects in the T+R+L category received funding of €98.3M. Lubelskie Voivodeship prevailed (€24.6M; 94 projects) and, in terms of share, Opolskie Voivodeship (34%; 24.6%, respectively).

A total of 108 projects related to the installation of RES equipment (R) were implemented in 14 voivodeships (excluding Wielkopolskie and Zachodniopomorskie) and were subsidized to the tune of €56.08M. The largest amounts were allocated in Dolnośląskie Voivodeship (€16.9M, 7% of the total amount), whereas Małopolskie Voivodeship dominated in terms of the number of projects (17; 7% in total).

Energy-efficient buildings (DB) were constructed under 38 projects in six voivodeships (Śląskie, Lubelskie, Lubuskie, Łódzkie, Małopolskie and

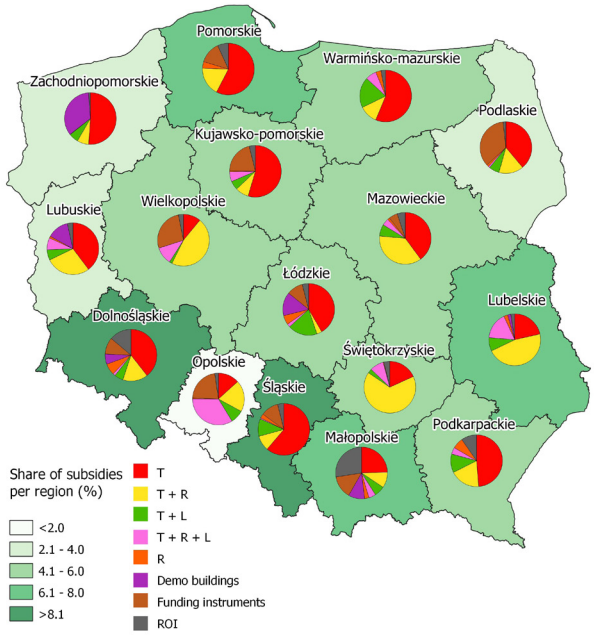

Fig. 5. Allocation of funds in the regions by type of investment
Source: authors' work

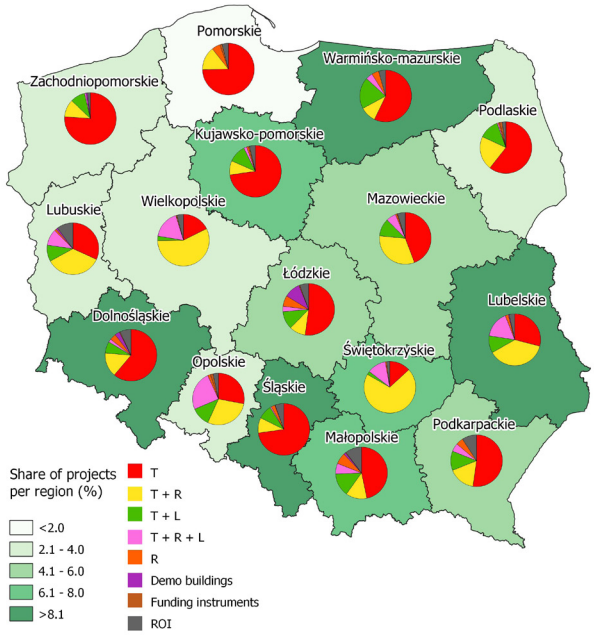

Fig. 6. Number of projects in the regions by type of investment
Source: authors' work

Abrevitaions: T – thermo-modernization; T+R – thermo-modernization combined with investment in RES; T+L – thermo-modernization combined with energy-efficient lighting; T+R+L – thermo-modernization combined with investment in RES and energy-efficient lighting; R – investment in RES; DB – energy efficient and passive buildings, including demonstration buildings; FI – financial instruments, OI – other investments

Zachodniopomorskie) to the tune of €82.4M, of which €79.9M was spent on the construction of demonstration buildings. In this category, in terms of amounts spent, the Zachodniopomorskie Voivodeship stood out in particular (€26.3M, 34% of the total amount), and in terms of projects implemented, the Łódzkie Voivodeship (18; 10.1% in total).

In the "other investments" (OI) category, €130.4M was spent. The largest amounts of subsidies were granted in Małopolskie (38.1M; 27% of the total amount) and Dolnośląskie (€32.7M; 14%). In terms of the number of projects, the leaders were Pomorskie (30), Dolnośląskie (28) and Wielkopolskie (25) and, in terms of share in the region, Małopolskie (10.3%).

4.4. Size of the territorial units

The results of the analysis of the distribution of funds by region for IEEB for each territorial unit size category are shown in Figure 7, and a compilation of the number of projects implemented is presented in Figure 8.

On a national scale, the largest amount of funds was spent in cities (€761.6 M) and, in terms of regions, in Śląskie (€184.2M; 64.5% in the region), Małopolskie (€85.1M; 61.5%) and Pomorskie (€76.3M; 58.1%). At the opposite pole were Opolskie (€10M) and, in terms of the share in the region, Mazowieckie (13.9%). Measures in IEEB in towns totaled €572.7M, and investments in this category were subsidized mainly in Dolnośląskie (€91.8M), Śląskie (€63.2M) and Warmińsko-Mazurskie (€53.3M). In terms of share of allocation per region, Warmińsko-Mazurskie (52.2%), Podkarpackie (48.3%) and Opolskie (47.7%) led the way. The least funds were disbursed in Podlaskie Voivodeship (€12.1M; 19.2% of the total amount). Investments in rural areas were subsidized with €514.8M. The amounts of allocations were largest in Dolnośląskie (€72.1 M), Lubelskie (€61.4M) and Świętokrzyskie (€57.5M) and smallest in Zachodniopomorskie (€8.7M; 11.4% of the total amount). Rural units were the leaders in raising funds in Świętokrzyskie (50.8% of the total amount), Mazowieckie (50%) and Lubelskie (42%).

In regard to the number of projects, rural areas dominated (1,725 projects). The voivodeships of Lubelskie (293) and Kujawsko-Pomorskie (61.4% in total) stood out in particular. In towns, a total of 1,308 projects were implemented; the most in the Warmińsko-Mazurskie (197; 54.4% in total) and Dolnośląskie (171) voivodeships. In the case of cities (782 projects in total), the largest disparities between the voivodeships were 248 projects in Śląskie (45.5% in total per region) compared to 9 in Opolskie (7.6%).

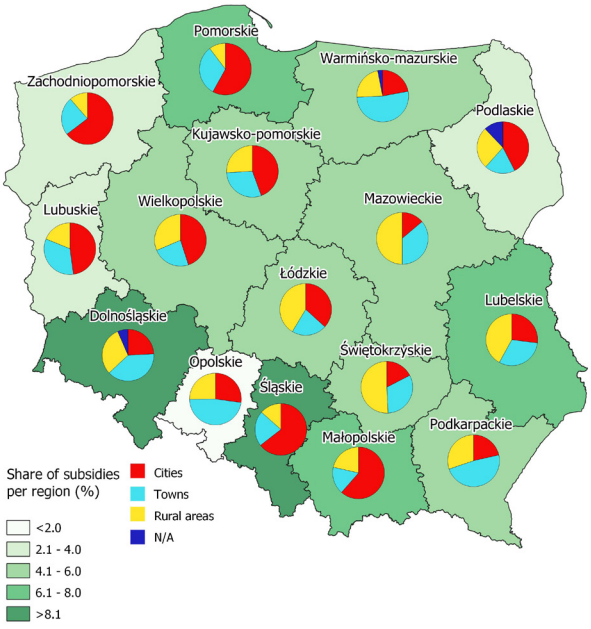

Fig. 7. Allocation of funds in the regions by type of territorial unit
Source: authors' work

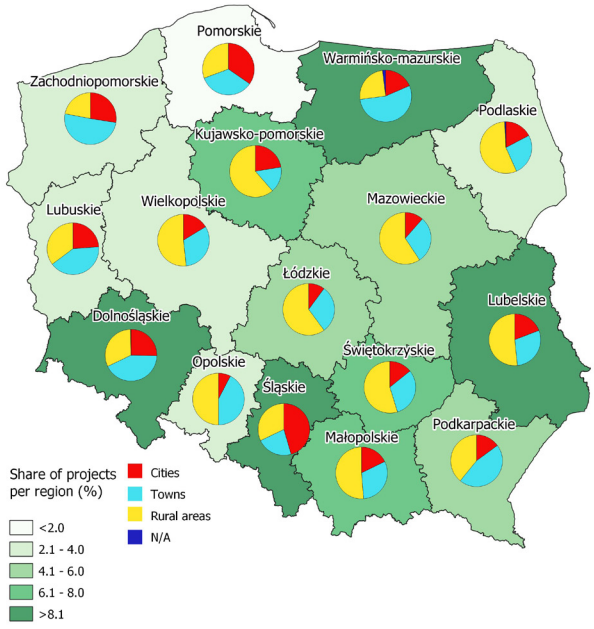

Fig. 8. Number of projects in the regions by type of territorial unit
Source: authors' work

Investments with a regional scope were implemented in three voivodeships, i.e. Dolnośląskie, Warmińsko-Mazurskie and Podlaskie, with only the last having a significant (12%) share of the ROP allocation.

5. Discussion

Despite the rules for the distribution of funds being the same for all regions, which resulted both from the provisions of strategic and programming documents, and despite the criteria adopted by the regional boards also being similar, the results of the analysis identify several interregional similarities and differences.

Beneficiares

Nationally, the largest amounts of subsidies for IEEB were obtained by self-government units (69.5% in total) and financial institutions (10.1%). In regard to the numbers of projects implemented, the largest shares were for SGUs (65.2% in total) and enterprises (17.5%). In both cases, the share of other categories did not exceed 10%. In all regions except Podlaskie, beneficiaries were SGUs, PHC and PES. The diversification of beneficiaries was largest in the Dolnośląskie, Mazowieckie and Śląskie voivodeships and smallest in Lubuskie (SGU, PHC and PES) and Zachodniopomorskie (SGU, R&HC, PHC, PES).

In terms of similarities, the predominance of allocation of funds and the number of projects implemented by SGUs come to the fore. SGUs were beneficiaries of from 58% (Lubelskie and Podlaskie) to more than 94% (Pomorskie) of IEEB funds per region. In only four voivodeships did SGUs' projects account for fewer than 50% of the region's projects, reaching more than 90% in the Lubuskie and Łódzkie voivodeships. The average value of a project's subsidy was also high (€0.5M). In general, this is due both to the high needs in this scope, as most buildings in the SGUs' stock, including municipal buildings, require energy efficiency improvements due to their age and deteriorating technical condition – buildings from the 20th century built in traditional technology prevail, and the southwestern and northern areas of Poland also have many buildings from the 19th century (Walicka-Góral, Rybka, 2010; *Badanie efektywności* …, 2015; Dołęga, 2017), as well as changing regulations and standards in this regard (Sikora, 2021). These include, in particular, the requirement for renovation (EED 2012/27/EU) and the implementation of the NZEB standards in public administration buildings (EPBD 2010/31/EU). These factors have influenced a significant increase in SGUs' commitment to apply for regional funds to co-finance IEEB measures compared to the 2007–2013 period (at that time, only 12.4% of investments were co-financed under ROPs; *Badanie efektywności* …, 2015).

Another issue worth highlighting is the relatively low level of subsidies for R&HC, although most of their stock was built in prefabricated large-panel technology (Abyzov, 2019), which has a much higher level of primary energy demand (*Opracowanie metodologii* …, 2019, Tofiluk et al., 2019). R&HCs were beneficiaries of only 3.5% of the allocation and 8.2% of all projects, which translated into a rather low average value of project subsidy (more than €220K). Investments were implemented in only eight regions. This was mainly because R&HCs have already had the opportunity to finance investments in IEEB since the late 1990s with national funds under the so-called thermo-modernization bonus, renovation bonus, or compensation bonus (since 2016 under the TERMO program with an additional RES grant option) (Note 3) (Włodarski, 2018), and in the analyzed period funds for R&HCs were also allocated under the national program OPI&E 2014–2020 (see Note 2). A survey by Statistics Poland (*Opracowanie metodologii* …, 2019) shows that of the 60% of R&HC stock that required thermal upgrading, about 30% had been renovated by 2016, and interest in national funds for IEEB has been declining since 2017 (*Dane liczbowe* …, 2021). As a side note, it can be emphasized that the extensive thermo-modernization activities in the housing cooperatives stock nevertheless did not bring the expected results – the energy reduction targets included in energy audits achieved only 58% (*Efekty termomodernizacji* …, 2019). This is a pressing problem, especially in the context of achieving the "Fit for 55" goals. Turecki et al. (2022) indicated that, for multi-family buildings, Poland should aim to achieve a higher level of CO_2 reduction than the expected 55% target, since the reduction rate for single-family housing is likely to be much lower.

Interregional variations are particularly noticeable in the disproportion between SGU and other categories of beneficiaries. Particularly worrisome is the relatively low level of co-financing for entrepreneurs, who in as many as seven regions obtained less than 2% of the allocation and implemented only 1–3% of the projects per region. In addition, these projects received the lowest subsidies among all categories analyzed (on average only €155K), and in the Wielkopolskie, Kujawsko-Pomorskie and Łódzkie voivodeships total amounts per region were even lower (about €100K, 0.1%).

An extreme case is Podlaskie, where enterprises were excluded from co-financing, while SGUs implemented as many as 94.3% of projects. The only region where enterprises received significant funding (21.5% per region) and implemented a comparable number of projects (44.2% in region) was Lubelskie. Comparing the results obtained with the conclusions of the report *Wpływ funduszy* … (2016), which indicates that the Lubelskie and Podlaskie voivodeships received the largest subsidies in 2007–2013, it can be noted that Lubelskie has continued to pursue a balanced investment policy and support of both SGUs and enterprises, while Podlaskie has focused on the renovation of SGU buildings and has more financial institutions (FIs) involved in the redistribution of regional funds.

Investments

Nationally, the largest amounts were allocated to thermo-modernization (40.8% of the allocation; 49.8% of the projects) and to thermo-modernization combined with investments in RES (21.7%; 23.9%, respectively). The least popular category was DB, which was co-financed in only six voivodeships. There was a high diversification of investments in each region; the exception was Pomorskie Voivodeship (without T+L and T+R+L and DB).

Thermo-modernization projects dominated in 11 regions in terms of amounts spent and in 12 in terms of the number of projects implemented. In general, this is in line with a trend that emerged in the late 1990s, focusing on IEEB by insulating envelopes – external walls and ceilings (most often with Styrofoam), as well as replacing window and door frames and installing control systems that measure and track energy consumption (Bogacki, Osicki, 2008; *Opracowanie metodologii* …, 2019), and is mainly due to years of experience in obtaining funds for this type of investment (*Badanie efektywności* …, 2015; Musiałkowska, Wiśniewski, 2017; *Opracowanie metodologii* …, 2019). Similar trends have been noted in the distribution of funds for revitalization (Ciesiółka, 2017; Tofiluk et al., 2019), under dedicated grants (Patrzałek, 2017) and funds for functional urban areas (Kociuba, 2018; Kociuba, Szafranek, 2018). The results of the study indicate that the accumulation of funds and activities occurred in the Śląskie and Dolnośląskie voivodeships, while the largest share of projects in this category occurred in the Zachodnopomorskie and Pomorskie voivodeships.

Noteworthy is the popularity of investments combining thermal modernization with other measures in IEEB. Among the combination measures, T+R dominated (21.5% of allocations and 23.9% of projects in total). A lower allocation was provided for T+L investments (7.8%; 10.2%, respectively), and the lowest for projects in the T+R+L category (5.2%; 6.9%, respectively). The leaders were: Lubelskie and Świętokrzyskie in the T+R category; Śląskie, Łódzkie and Warmińsko-Mazurskie in T+L; and Lubelskie, Opolskie, Wielkopolskie and Świętokrzyskie in T+R+L. In this context, there is a noticeable shift away from investments based solely on RES (2.5% of allocations and 3% of projects in total), which were still popular in the regions of southern (Dolnośląskie and Śląskie) and northern Poland (Warmińsko-Mazurskie). For some regions, a further decline in interest in this category is observed, especially on rural areas (Chodkowska-Miszczuk & Szymańska, 2018), such as Podlaskie the former leader in RES investments (*Wpływ funduszy* …, 2015). Compared to the 2007–2013 period, there has been an increase in funding for combined measures, as well as a different focus of investments. Previously what dominated were thermo-modernization, often combined with lighting replacement, and separately implemented investments related to the replacement of coal-based heating and RES, and the decisive motivation was to reduce energy consumption and heating costs (the economic aspect) and improve work comfort (the social aspect) (*Badanie efektywności* ..., 2015). In the analyzed period, there was an additional strong emphasis on the comprehensiveness of investments, including the uptake of renewable energy in buildings (the environmental aspect).

Investments in the OI category were co-financed in all regions and were relatively popular (7% of the total allocation, 5.1% of all projects). This is in line with efforts to decarbonize heating sources, which have been conducted in Poland since the early 2000s, mainly through replacement of coal-based heat sources and connections to district heating networks (Włodarski, 2018). It was noticeable that there was very low subsidy for the installation of gas boilers (0.005% of the total amount), resulting from the rising price of this fuel and temporary restrictions on connection to the gas network. These measures should be viewed positively as a part of the implementation of EU energy policy aimed at shifting away from the use of fossil fuels (2021/0426/COD). In the OI category, the voivodeships of Małopolskie, Dolnośląskie and Śląskie led the way. A special case is the Małopolskie Voivodeship – a national leader in the fight for clean air (Rataj, Holewa-Rataj, 2020; Kociuba, Wajs, 2021), where the regional board has allocated almost one third of the funds to support the replacement of coal furnaces.

These investments are crucial, especially since Poland is lagging behind and performing unsatisfactorily in low-carbon energy transition, e.g., compared to the V4 countries. For example, in Poland, between 2005 and 2018, the overall share of RES increased by more than 60% in final energy consumption, and by 45% in heating and cooling (by comparison, in the Czech Republic, the share of RES more than doubled, and the share of RES in electricity production increased more than three-fold). In addition, compared to 2005, GHG emissions per capita increased by 2.6% and GHG energy intensity by 3%; energy consumption per capita also increased (only in Poland), indicating an alarming trend (Streimikiene, 2021). The backwardness in introducing RES into the energy mix and the poor performance in terms of RES penetration and reduction of GHG emissions and energy consumption (Streimikiene, 2021) with the current slow progress in decarbonization and unambitious plans in this regard, and the indecisive policy to transition away from fossil fuels (especially coal), significantly undermine Poland's chances of achieving the "Fit for 55" targets (Brożyna et al., 2023).

In the context of the requirement to develop more NZEB buildings, in accordance with EU standards and regulations, the involvement of regional authorities in the application of NZEB solutions is not encouraging. Investments were implemented in only six voivodeships (4.4% of the allocation; 1% of the projects in total), but funds were obtained by almost all categories of beneficiaries. Noteworthy are Łódzkie (18 demo buildings) and Dolnośląskie (12 demo buildings). The largest amount of subsidy (€26.3M) was spent in the Zachodniopomorskie Voivodeship on the construction of a new Marshal's office. This situation is alarming because Poland has registered the lowest share of NZEBs within the total construction market among the EU Member States – in 2012-16 only 8% (to compare, Luxembourg 43%, Austria 40%). In 2016 renovations of non-residential buildings to NZEB standard in Poland accounted for 17% of total NZEBs (residential and non-residential), while new non-residential NZEBs accounted for only 2% (D'Agostino et al., 2021). Therefore, the NZEB diffusion in Poland remains a huge challenge. An example of systemic and effective decarburization efforts is China, which programmatically promotes and introduces energy efficiency in the construction sector through the implementation of demonstration projects, green buildings, development of low-carbon cities, or renovation of old buildings (He et al., 2020; Zhou et al., 2023).

Territorial units

Nationwide, 40.6% of funds for IEEB were spent in cities. Towns used 30.5%, and rural areas 27.5%. The allocation of funds showed significant regional variation (Fig. 7).

The prevalence of subsidized investment in IEEB in cities is observed in the regions of western Poland (Zachodniopomorskie, Pomorskie, Lubuskie, Wielkopolskie) and southern Poland (Śląskie, Małopolskie). Towns raised the most funds in the regions of northern Poland (Warmińsko-Mazurskie) and southern Poland (Dolnośląskie and Opolskie). This is mostly due to the nature of settlement and construction in these regions. These are areas of the former Prussian partition, with the highest urbanization rate nationwide. Both cities and towns are distinguished by the accumulation of old brick (including municipal) and post-industrial buildings, accompanied by post-socialist residential districts built with large-panel technology and in poor condition (Walicka-Góral, Rybka, 2010; Abyzov, 2019). The accumulation of these phenomena occurs especially in the cities of the Silesian conurbation, which received 10% of the RPOs' total allocation for IEEB. Funding for rural areas, on the other hand, was dominant in the regions of eastern and central Poland (Lubelskie, Świętokrzyskie, Mazowieckie and Łódzkie). This is mainly due to the settlement structure and specialization of the economy in this area. These are poorly urbanized areas of the former Russian partition and are predominantly agricultural (Popławski, 2009).

A comparison of the amount of subsidies for urban (generally, cities and towns) and rural municipalities indicates that, in eight regions, funding for urban amounted to three quarters of the allocation and in the Pomorskie and Zachodniopomorskie voivodeships reached 90%. In contrast, only in one region (Świętokrzyskie) was funding for rural municipalities slightly higher than for urban areas. An interesting case is the Mazowieckie Voivodeship (whose capital has a population of 1.8M) where the amounts of subsidies for urban and rural municipalities were evenly distributed (50% each). In a broader context, it is advisable to distinguish Warsaw as a separate sub-region and include the remaining part of the Mazowieckie Voivodeship in the Operational Program European Funds for Eastern Poland 2021–2027.

The situation looks dramatically different for the number of projects. Rural municipalities dominate (44.1% in total), with more than 50% in nine voivodeships (the highest in the Kujawsko-Pomorskie Voivodeship, at 61.4%). Towns

predominated only in the Warmińsko-Mazurskie and Zachodniopomorskie voivodeships (more than 50% in total), and cities only in the Śląskie Voivodeship (45.5% in total). The situation is similar if we compare urban and rural municipalities – in eight regions rural municipalities dominate and in one there is a balance (Opolskie Voivodeship with 59 projects each). Rural municipalities implemented more projects, but for lower amounts. This is mainly due to the smaller cubic volume of buildings under renovation. In addition, rural SGUs tend to have shrinking budgets, which is a constraint in providing their own contribution (Czudec, 2017).

6. Conclusions

Improving the energy efficiency of buildings is one of the critical priorities for the EU on the road to decarbonizing building stock by 2050. Legislative initiatives, the implementation of which is expected to ensure the achievement of increasingly ambitious targets for reducing CO_2 emissions and energy consumption, and the uptake of RES, translate into the distribution of funds under the Cohesion Policy 2014–2020. Poland is in the mainstream of these activities. The allocation for investments and measures on IEEB accounted for as much as 35.7% of funds for TO4 distributed under the 16 ROPs 2014–2020. The analyses carried out in this study allowed the identification of the effects of the distribution and use of structural funds for IEEB in the regions of Poland in relation to three main issues, which was the basis for formulating answers to the research questions.

Answering question 1: "*Who benefited from the funds?*", it should be emphasized that the most prominent players for funds on IEEB in all regions were SGUs. On the other hand, it should be noted that there was a disproportionately smaller subsidizing for investments implemented by other categories of beneficiaries. Against the background of local governments, the low allocation for entrepreneurs is particularly noticeable (exceptions are the Lubelskie and Świętokrzyskie voivodeships). Noteworthy, moreover, is the relatively low interest in subsidizing R&HC investments, which manage the largest stock of multi-family buildings in Poland, and the effects of its renovation do not reach the values assumed in energy audits. This poses a huge challenge, especially in achieving the "Fit for 55" and the revised EED and EPBD targets. In addition, the results indicated "privileged" groups of beneficiaries who have been allocated an increased pool of funds. In the voivodeships of Pomorskie and Mazowieckie these were religious institutions, in Podlaskie and Wielkopolskie financial institutions, and in Lubuskie public health services. There was also niche funding for the renovation of buildings owned by NGOs and the government administration and its subordinate institutions.

Referring to the answer to question 2: "*What investments were implemented?*", the study indicated that the dominant type of investment was thermo-modernization, which in Poland has been treated for years as the simplest way towards IEEB. It should be noted that thermal insulation investments, which have been dominant since the 1990s, were complemented in the analyzed period by active and renewable technical solutions (PV, solar thermal collectors, heat pumps in combination with district heating or efficient lighting and appliances). Therefore, the type of investment and scope of work carried out largely depended on the age and nature of the building stocks. Thermo-modernization (less often realized as a combined action) and replacement of heat sources prevailed in the regions of northern, western and southern Poland (the territory of the former Prussian partition), where a large proportion of buildings still in use date from the 19th century and first half of the 20th, and some of them are listed in the register of monuments, which significantly limits the scope of refurbishment. In contrast, in the regions of eastern and central Poland (the former Russian partition), where post-socialist buildings predominate, renovations are more comprehensive. In addition, it was noted that more and more investments bring not only economic and social benefits, but also have a strong pro-environmental nature. Achieving carbon neutrality requires the transition to NZEB by 2050 but, as the results show, regional boards' interest in subsidizing the development of new energy-efficient and demonstration buildings was negligible, which is worrisome in the context of Poland's weak position in the EU in terms of NZEB diffusion.

In answer to research question 3: "*Where were the funds distributed?*", a comparison of allocations for urban and rural units demonstrates that cities and towns have definitely won the race for IEEB funding. This is especially true for cities in the Silesian conurbation and northern and western Poland. In contrast, the regions of eastern and central Poland recorded greater support for rural municipalities. As in the case of investments, the spatial distribution of funds for individual categories of territorial units still reflects the post-partition division of Poland.

In summary, the co-financing of investments in IEEPs in the regions of Poland under 2014–2020 RPOs indicated a large imbalance in the allocation and distribution of funds, both in terms of the type of beneficiary (here the discrepancies were strongest, and the dominance of SGUs was undisputed), the type of investment (the period was characterized by a shift from passive to active and green technical solutions, with regional specificities arising from the construction and age of buildings) and the size of the territorial unit (urban areas dominate, and the distribution of funds reflects post-partition differences in urbanization and the nature of the development).

The results of the research and the conclusions of the discussions formed the basis for recommendations for more effective implementation of IEEB measures under the EU Cohesion Policy. In the context of boosting the decarburization of the building stock in the near future, in order to meet the new EPBD's targets of doubling the renovation rate, increasing the use of RES and achieving the zero-emission building standard by 2050, at the regional level, seem to be crucial:

1. intensifying efforts and measures to coordinate the distribution of funds for investments combining energy efficiency and renewable energy by introduction of conditionality of investment financing, e.g. conditioning the subsidy of retrofit financing on the requirement of changing the heat source to a low-emission one and/or applying other active and RES-based technical solutions. This seems necessary to support Poland's efforts to transition to carbon-free heat sources, as coal is still the main energy carrier, especially in old buildings;
2. intensifying the subsidization of R&HC investments, which manage the largest stock of multi-family buildings in Poland, and the unsatisfactory results of their (thermal) modernization pose a huge challenge, especially in the context of achieving the "Fit for 55" goals and the revised EED and EPBD targets. Therefore, the following should be pointed out as positive and recommendable: a) diversification of sources of financing for IEEB of multi-family buildings, both under national and EU funds; b) implementation of new financial instruments to facilitate IEEB financing (bonuses, grants, non-refundable subsidies), which additionally allow for flexible disbursement of CP funds and territorial orientation of investments; c) expanding the list of investments to include historic monuments and historic buildings as well as new municipal buildings with improved energy efficiency standards; d) expanding the catalog of beneficiaries, not only to SGUs, but also to other owners of multi-family buildings;
3. greater involvement in stimulating the diffusion of NZEBs (new and retrofitted), and leveling the beneficiary's opportunities in obtaining funds, which should result in the introduction of new legal solutions, mechanisms and financial instruments to promote NZEBs investments, including facilitating the implementation of energy-saving techniques and storage systems, together with renewable energies. In this context, leveraging CP funds to support additional activities in the private sector, including preference for NZEB investments by entrepreneurs and R&HCs, becomes essential;
4. in order for measures in the IEEB to yield tangible results, it is necessary to implement a post-investment control mechanism that will verify whether the recommendations from the energy audits have been implemented in practice.

The results of the research can be used in comparative studies of the regions of EU Member States on the disbursement of CP funds for improving the energy efficiency of buildings with regard to beneficiaries, investments and territorial units.

Notes

1. According to definition, a nearly zero-energy building (NZEB) means a building that has a very high energy performance, while the nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby (2010/21/EU).
2. Under OPI&E 2014–2020, funding was targeted at renovation of residential buildings in the resources of residential and housing communities from the areas identified in the Strategies of Integrated Territorial Investments (Measure 1.3, sub-measure 1.3.2), with a special envelope earmarked for projects from the Śląskie Voivodeship

for thermal modernization of multi-family buildings, which could additionally be used by SGUs (municipal buildings) and state-owned companies (Measure 1.7; Sub-measure 1.7.1). Also co-financed was the thermal modernization of public buildings (measure 1.3.1) to the tune of €431.5M.

3. Since 2016, the TERMO program has also been able to support SGUs, and since 2022, it has been additionally dedicated to the bonus and MZG (municipal housing stock) grant for the renovation of municipal buildings.

References

Abdelrahman, M.M., Zhan, S., Miller, C. & Chong, A. (2021). Data science for building energy efficiency: A comprehensive text-mining driven review of scientific literature. *Energy and Buildings*, 242: 110885. DOI: https://doi.org/10.1016/j.enbuild.2021.110885.

Abyzov, V. (2019) The main directions of prefabricated large-panel systems' improving. *Structure and Environment*, 11(2): 110–118. DOI: https://10.30540/sae-2019-008.

Act of May 20, 2016 on energy efficiency (Journal of Laws 2016 item 831 as amended).

Adamowicz, M. (2011). Wsparcie rozwoju regionalnego w warunkach uczestnictwa Polski w Unii Europejskiej (Support for regional development under conditions of Polish participation in the European Union – in Polish). *Rocznik Nauk Rolniczych. Seria G: Ekonomika Rolnictwa*, 98(1): 60-74.

Badanie efektywności energetycznej budynków administracji publicznej (rządowej i samorządowej) za lata 2007-2013 (Survey of Energy Efficiency of Public Administration (Government and Local Government) Buildings for the Years 2007-2013 – in Polish) (2015). Statistics Poland, Warsaw.

Bednarowska-Michaiel, Z. (2015). Desk research - wykorzystanie potencjału danych zastanych w prowadzeniu badań marketingowych i badań społecznych (Desk research: harnessing the potential of foundational data in conducting marketing and social research – in Polish). *Marketing i Rynek*, 7: 18-26.

Birindelli, G. & Chiappini, H. (2020). Climate change policies: Good news or bad news for firms in the European Union? *Corporate Social Responsibility and Environmental Management*, 28(2): 831-848. DOI: https://doi.org/10.1002/csr.2093.

Bogacki, M. & Osicki, A. (2008). Termomodernizacja w świetle dyrektywy o charakterystyce energetycznej budynku (Thermomodernization in light of the directive on the energy performance of a building – in Polish), Foundation for Efficient Energy Use.

Brożyna, J., Strielkowski, W. & Zpěvák, A. (2023). Evaluating the Chances of Implementing the "Fit for 55" Green Transition Package in the V4 Countries. *Energies*, 16(6): 2764–2764. DOI: https://doi.org/10.3390/en16062764.

Chatterjee, S. & Ürge-Vorsatz, D. (2021). Measuring the productivity impacts of energy-efficiency: The case of high-efficiency buildings. *Journal of Cleaner Production*, 318: 128535. DOI: https://doi.org/10.1016/j.jclepro.2021.128535.

Chodkowska-Miszczuk, J. & Szymańska, D. (2018). Wybrane zagadnienia związane z rozwojem energetyki odnawialnej na obszarach wiejskich w Polsce (Selected issues related to the development of renewable energy in rural areas in Poland – in Polish). *Rozwój Regionalny i Polityka Regionalna*, (14): 105–116. Available at: https://pressto.amu.edu.pl/index.php/rrpr/article/view/14398.

Ciesiółka, P. (2018). Rewitalizacja w polityce rozwoju kraju (Revitalization in national development Policy – in Polish). *Rozwój Regionalny i Polityka Regionalna*, (39): 9-28.

Czudec, A. (2017). European funds and local economic development. *Social Inequality and Economic Growth*, 49(1): 35-47. DOI: https://doi.org/10.15584/nsawg.2017.1.3.

Czykier-Wierzba, D. (2020). Pomoc z unijnych funduszy polityki spójności dla polskich regionów w latach 2004 – 2020 (Assistance from EU cohesion policy funds for Polish regions in 2004-2020 – in Polish). In: Ambroziak A.A. & Szypulewska-Porczyńska A.D. (eds.), Poland in the European Union - from association to fifteen years of membership: a jubilee monograph dedicated to Professor Elżbieta Kawecka-Wyrzykowska, 123-143, Warszawa, Oficyna Wydawnicza SGH.

D'Agostino, D., Tsemekidi Tzeiranaki, S., Zangheri, P. & Bertoldi, P. (2021). Assessing Nearly Zero Energy Buildings (NZEBs) development in Europe. *Energy Strategy Reviews*, 36: 100680. DOI: https://doi.org/10.1016/j.esr.2021.100680.

Dane liczbowe Funduszu Termomodernizacji i Remontów (Figures of the Thermo-modernization and Renovation Fund – in Polish) (2021). BGK.

De Boeck, L., Verbeke, S., Audenaert, A. & De Mesmaeker, L. (2015). Improving the energy performance of residential buildings: A literature review. Renewable and Sustainable *Energy Reviews*, 52: 960–975. DOI: https://doi.org/10.1016/j.rser.2015.07.037.

Dembicka-Niemiec, A., Szafranek-Stefaniuk, E. & Kalinichenko, A. (2023). Structural and Investment Funds of the European Union as an Instrument for Creating a Low-Carbon Economy by Selected Companies of the Energy Sector in Poland. *Energies*, 16(4): 2031. DOI: https://doi.org/10.3390/en16042031.

Dębkowska, K., Dymek, Ł., Kutwa, K., Perlo, D., Perlo, D., Rogala, W., Ryciuk, U. & Szewczuk-Stępień, M. (2022). The Analysis of Public Funds Utilization Efficiency for Climate Neutrality in the European Union Countries. *Energies*, 15(2): 581. DOI: https://doi.org/10.3390/en15020581.

Dołęga, W. (2017). Wybrane aspekty efektywności energetycznej (Selectedaspects of energyefficiency – in Polish). *Polityka Energetyczna*, 20: 67-78.

Efekty termomodernizacji wielorodzinnych budynków mieszkalnych będących w zasobach spółdzielni mieszkaniowych, realizowanej z udziałem środków publicznych (Effects of thermomodernization of multi-family residential buildings owned by housing cooperatives, implemented with public funds – in Polish). (2019). Supreme Audit Office, Warsaw.

EUROPE 2020: A strategy for Smart, Sustainable and Inclusive Growth. (2010). COM/2010/2020 final.

Frankfort-Nachmias, C., Leon-Guerrero, A. & Davis G., (2016). *Social Statistics for a Diverse Society*. SAGE Publications.

González-Torres, M., Paolo, B., Luca, C. & Pérez-Lombard, L. (2023). Review of EU product energy efficiency policies: What have we achieved in 40 years? *Journal of Cleaner Production*, 421: 138442-138442. DOI: https://doi.org/10.1016/j.jclepro.2023.138442.

González-Torres, M., Pérez-Lombard, L., Coronel, J.F. & Maestre, I.R. (2021). A cross-country review on energy efficiency drivers. *Applied Energy*, 289: 116681. DOI: https://doi.org/10.1016/j.apenergy.2021.116681.

Graczyk, A. (2017). Wskaźniki zrównoważonego rozwoju energetyki (Indicators of sustainable energy development – in Polish). *Optimum. Studia Ekonomiczne*, 4(288): 53-68. DOI: https://doi.org/10.15290/ose.2017.04.88.05.

He, B.J., Zhao, D.X. & Gou, Z. (2020). Integration of Low-Carbon Eco-City, Green Campus and Green Building in China. In: Gou, Z. (eds.). *Green Building in Developing Countries. Green Energy and Technology*. Springer, Cham. DOI: https://doi.org/10.1007/978-3-030-24650-1_4.

Kamal, A., Al-Ghamdi, S.G. & Koç, M. (2019). Role of energy efficiency policies on energy consumption and CO_2 emissions for building stock in Qatar. *Journal of Cleaner Production*, 235: 1409–1424. DOI: https://doi.org/10.1016/j.jclepro.2019.06.296.

Kochański, M. (2014). Finansowanie instrumentów poprawy efektywności energetycznej w Polsce w latach 2014-2020 (Financing of energy efficiency improvement instruments in Poland in 2014-2020 – in Polish). *Acta Innovations*, 10: 59-77.

Kociuba, D. (2018). Implementation of integrated territorial investments in Poland - rationale, results, and recommendations. *Quaestiones Geographicae*, 37(4): 81-98. DOI: https://doi.org/10.2478/quageo-2018-0038.

Kociuba, D. & Szafranek, E. (2018). New tool for measuring sustainable development in functional urban areas. *European Spatial Research and Policy*, 25(2): 61-79. DOI: https://doi.org/10.18778/1231-1952.25.2.04.

Kociuba, D. & Wajs, K. (2021). Impact of the implementation of EU, national and local policies and legislation on the transition towards eco-cities in Poland. *Bulletin of Geography. Socio-Economic Series*, 53(53): 105-130. DOI: https://doi.org/10.2478/bog-2021-0026.

Li, J. & Shui, B. (2015). A comprehensive analysis of building energy efficiency policies in China: status quo and development perspective. *Journal of Cleaner Production*, 90: 326-344. DOI: https://doi.org/10.1016/j.jclepro.2014.11.061.

Lista projektów realizowanych z funduszy europejskich w Polsce 2014-2020 (List of projects implemented with European funds in Poland in 2014-2020 – in Polish).

Available at: https://www.funduszeeuropejskie.gov.pl/strony/o-funduszach/projekty/lista-projektow/lista-projektow-realizowanych-z-funduszy-europejskich-w-polsce-w-latach-2014-2020/ (Accessed: 06 April 2023).

Liu, Y., Liu, T., Wang, B. & Xu, M. (2019). Developing a methodology for the ex-post assessment of Building Energy Efficiency Special Planning in Beijing during the 12th Five-Year Plan period. *Journal of Cleaner Production*, 216: 552-569. DOI: https://doi.org/10.1016/j.jclepro.2018.12.086.

Maduta, C., Melica, G., D'Agostino, D. & Bertoldi, P. (2022). Towards a decarbonised building stock by 2050: The meaning and the role of zero emission buildings (ZEBs) in Europe. *Energy Strategy Reviews*, 44: 101009. DOI: https://doi.org/10.1016/j.esr.2022.101009.

Mirowski, T. (2012). Methods to improve energy efficiency in households in Poland. *Polityka Energetyczna – Energy Policy Journal*, 15(2): 41-56.

Musiałkowska, I. & Wiśniewski, M. (2017). Fundusze europejskie w finansowaniu rozwoju regionalnego i lokalnego przez samorząd terytorialny w Polsce (European funds in financing regional and local development by local government in Poland – in Polish). *Studia BAS*, 1(49): 87-107.

Nigohosyan, D., Vutsova, A. & Vassileva, I. (2021). Effectiveness and efficiency of the EU-supported energy efficiency measures for SMEs in Bulgaria in the period 2014-2020: program design implications. *Energy Efficiency*, 14(2): 1-18. DOI: https://doi.org/10.1007/s12053-021-09933-4.

Open Data Portal for the European Structural Investment Funds - European Commission | Data | European Structural and Investment Funds. Tyler Data & Insights. Available at: https://cohesiondata.ec.europa.eu/themes/4/14-20 (Accessed: 22 December 2023).

Opracowanie metodologii i przeprowadzenie badania skali działań termomodernizacyjnych budynków mieszkalnych wielomieszkaniowych w celu poprawy ich energochłonności oraz ocena potrzeb i planowanych działań w tym kierunku (Development of a methodology and survey of the scale of thermal modernization measures in multi-family residential buildings to improve their energy intensity and assessment of the needs and planned measures in this direction – in Polish) (2019). Statistics Poland.

Patrzałek, L. (2017). Funkcje dotacji przekazywanych do budżetów samorządów województw (Functions of subsidies transferred to the budgets of regional governments – in Polish). *Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu*, 485: 350-362. DOI: 10.15611/pn.2017.485.28.

Piekarska, E. (2015). Możliwości inwestycyjne samorządu terytorialnego w nowej perspektywie finansowej Unii Europejskiej 2014-2020 (Investment opportunities of local government in the new financial perspective of the European Union 2014-2020 – in Polish). *Zeszyty Naukowe Wyższej Szkoły Bankowej w Poznaniu*, 62(5): 93-106.

Popławski, Z.F. (2009). Zmiany użytkowania ziemi w Polsce w ostatnich dwóch stuleciach (Land use changes in Poland in the last two centuries – in Polish). *Teledetekcja Środowiska*, 42: 69-82.

Programowanie perspektywy finansowej 2014–2020 - Umowa Partnerstwa (2014). Ministerstwo Infrastruktury i Rozwoju, Warszawa.

Rataj, M. & Holewa-Rataj, J. (2020). Analiza zmian jakości powietrza Małopolski w latach 2012–2020 (Analysis of changes in the air quality of Małopolska in 2012-2020). *Nafta-Gaz*, 76(11): 854-854. DOI: https://doi.org/10.18668/ng.2020.11.11.

Regulation of the European Parliament and of the Council (EU) No. 1303/2013 of 17 December 2013 laying down common provisions on the ERDF, the ESF, the CF, the EAFRD and the EMFF (OJ L 347, 20.12.2013).

Rehman Khan, S.A., Yu, Z., Ridwan, I.L., Irshad, R., Ponce, P. & Tanveer, M. (2023). Energy efficiency, carbon neutrality and technological innovation: a strategic move towards green economy. *Economic Research-Ekonomska Istraživanja*, 1–28. DOI: https://doi.org/10.1080/1331677x.2022.2140306.

Serafin, P. (2019). Realizacja polityki spójności na przykładzie krajowych programów operacyjnych i Regionalnego Programu Operacyjnego Województwa Małopolskiego w bieżącej perspektywie finansowej (Implementation of the cohesion policy on the example of national operational programs and the Regional Operational Program of the Małopolska Region in the current financial perspective –

in Polish). *Studia Ekonomiczne: gospodarka, społeczeństwo, środowisko*, 1(3): 24-37.

Sikora, A. (2020). European Green Deal - legal and financial challenges of the climate change. *ERA Forum*, 21(4). DOI: https://doi.org/10.1007/s12027-020-00637-3.

Skoczkowski, T., Bielecki, S., Szymczyk, J. & Palimąka, T. (2014). Metody wzrostu efektywności energetycznej w małych i średnich przedsiębiorstwach (Methods of increasing energy efficiency in small and medium-sized enterprises – in Polish). *Polityka Energetyczna - Energy Policy Journal*, 17(1): 27-40.

Starzyńska, W. (2006). *Statystyka praktyczna* (Practical statistics– in Polish). Wydawnictwo PWN, Warszawa.

Streimikiene, D. (2021). Challenges of Approaching Climate Neutral Society in V4 Countries. *Montenegrin Journal of Economics*, 17(3): 181–191. DOI: https://doi.org/10.14254/1800-5845/2021.17-3.15.

Szymańska, E.J., Kubacka, M., Woźniak, J. & Polaszczyk, J. (2022). Analysis of Residential Buildings in Poland for Potential Energy Renovation toward Zero-Emission Construction. *Energies*, 15(24): 9327. DOI: https://doi.org/10.3390/en15249327.

Turecki, A., Tur, M., Czarnecki, B., Januszkiewicz, K. & Fiuk, P. (2022). Renovation of Modernist Housing Developments in the Pursuit of Modernity for Well-Being and Clean Energy. *Energies*, 15(10): 3737. DOI: https://doi.org/10.3390/en15103737.

Turner, S. (2013). Obowiązki państw członkowskich zasad prawa Unii Europejskiej (Obligations of member states of the principles of European Union law – in Polish). In: Stoczkiewicz M. (ed.), Implementacja prawa klimatyczno-energetycznego UE w Polsce (Implementation of EU climate and energy law in Poland – in Polish), 7-11, Warsaw: ClientEarth Poland Foundation.

Tofiluk, A., Knyziak, P. & Krentowski, J. (2019). Revitalization of twentieth-century prefabricated housing estates as interdisciplinary issue. *IOP Conference Series: Materials Science and Engineering*, 471(11): 112096. DOI: https://doi.org/10.1088/1757-899x/471/11/112096.

Vera, I. & Langlois, L. (2007). Energy indicators for sustainable development. *Energy*, 32(6): 875-882. DOI: https://doi.org/10.1016/j.energy.2006.08.006.

Walicka-Góral, B. & Rybka, A. (2010). Rewitalizacja komunalnych zasobów mieszkaniowych (Revitalization of municipal housing stock – in Polish). *Czasopismo Techniczne. Architektura*, 107: 6-A/1: 161-168.

Włodarski, M. (2018). Efektywność energetyczna budownictwa w dokumentach europejskich i krajowych (Energy efficiency of construction in European and national documents – in Polish). *Biuletyn KPZK PAN*, 187: 260-270.

Wpływ funduszy europejskich perspektywy finansowej 2007-2013 na rozwój społeczno-gospodarczy Polski Wschodniej (Impact of European funds of the financial perspective 2007-2013 on the socio-economic development of Eastern Poland – in Polish). (2016). Ministry of Infrastructure and Development.

Zhou, A., Wang, S. & Chen, B. (2023). Impact of new energy demonstration city policy on energy efficiency: Evidence from China. *Journal of Cleaner Production*, 422: 138560-138560. DOI: https://doi.org/10.1016/j.jclepro.2023.138560.