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Renewable Energy and Energy Efficiency: European Regional Policy and the Role of Financial Instruments

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Abstract: The study aimed to evaluate whether the regional funds allocated for energy efficiency and renewable energy are related to the quantity of air pollutants discharged and the stage of regional development, and whether the evidence of convergence of regional levels of renewable energy electricity generation can be provided. A comparative analysis of financial instrument implementation within regional programmes was conducted, with a particular focus on instruments dedicated to enhancing energy efficiency and utilising renewable energy. To verify the research hypotheses, statistical coefficients of correlation and concentration, along with trend and econometric models were applied. The findings have confirmed the rise in regional funds for energy efficiency and renewable energy, along with the growing importance of financial instruments in transforming the energy sector. The hypotheses that air pollutant emissions per unit of GDP generated are decreasing, there exists a regional convergence of renewable energy production per capita, and the spatial accumulation of renewable energy production is declining, have been confirmed. No correlation was found between the regional economic development and the level of funds allocated to energy efficiency and renewable energy. The lack of such relationships provides a convincing argument for appropriate state regulation.

Keywords: energy efficiency; renewable energy; financial instruments; regional development; air pollutants

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1. Introduction

Reducing our reliance on fossil fuels is presently the most crucial global task in tackling climate change by adopting a greener lifestyle. One promising approach for achieving these objective and supporting sustainable development goals is the implementation of renewable energy (RE) [1]. Researchers indicate that economic development and technological progress significantly increase energy consumption and environmental degradation, leading to the rapid adoption of RE sources [2,3].

As part of the 'Fit for 55' package, the EU has implemented common post-action regulations to decrease its carbon footprint. The package's objective is to reduce greenhouse gas emissions by at least 55% by 2030, compared to the levels of 1990, and energy consumption by 9%. Additionally, the agreement strives to achieve a level of 42.5% energy production generated from renewable sources, such as solar, wind, sea wave, biomass, hydro, and geothermal [4–6].

Akram et al. stated that investing in the RE production sector leads to a reduction in carbon dioxide emissions in MINT (Mexico, Indonesia, Nigeria, and Turkey) and BRICS (Brazil, Russia, India, China, and South Africa) countries [7,8]. However, it should be acknowledged that some studies show a different impact when developing energy efficiency (EE) and renewable energy sources (RES). Analyses conducted on energy consumption in African countries reveal ambiguous effects on both economic growth and carbon emissions [9].

The significance of renewable energy development for climate protection and achieving climate goals is increasingly viewed in terms of non-essential financial expenses [10]. Low-carbon energy technologies are regarded as a vital component of mitigating climate change [11]. Consequently, developing suitable models for financing green energy infrastructure is crucial [12], especially in the long term [13]. One solution employed in this context involves the participation of governmental institutions [14] and the provision of public funds with an appropriate degree of financial leverage [15–19]. The justification for public intervention in this scenario is to facilitate activities that market participants are either unable or unwilling to undertake themselves, but which are in the public interest to implement [20].

Financial instruments (FIs) are not a new concept in the European Union (the EU) public intervention policy. However, their implementation in the current energy transition and financing period of 2021–2027 is a recent development. This is due to the enhancement of existing debt instruments, in the form of loans and guarantees, with grants resulting in hybrid FIs. The use of hybrid FIs has been rare but is set to increase significantly. It is expected that FIs with a grant component will be widely used in financing EE and RE. The aforementioned topics deserve the research attention for various reasons. Climate change mandates an alteration in attitudes and conducts towards RE, not solely for households, businesses, and public administrations, but, more importantly, as a fundamental policy objective, the establishment of comprehensive and efficient financing of energy transition. FIs can, thus, provide optimal assistance if adopted.

FIs are commercial solutions implemented within financial markets and transferred to the level of public intervention and fund management of operational programmes. They are a measure of financial support from the EU budget aimed at achieving specific policy objectives. Such support may be in the form of equity or quasi-equity investments, loans or guarantees, or other risk-sharing instruments, which can be combined with other forms of financial support [21].

The initial use of FIs occurred during the first half of the 1990s, and from 2007 to 2013 their popularity increased. They were mainly developed on a large scale to tackle market failures following the global financial crisis that occurred between 2008 and 2009 [22]. FIs promote bankable investments that target public objectives in situations where achievable market returns fail to attract private investors [23]. Funding involving FIs is provided for financially viable investments that cannot obtain sufficient funding from market sources [24]. This kind of public intervention fills the financial gap between money demand and supply and offers an alternative to non-refundable grants. It supports not only small and medium enterprises but also other entities to boost regional economic growth. FIs have the potential to facilitate a diverse range of development initiatives that benefit numerous end beneficiaries, by amalgamating public and private funding whilst leveraging a considerable amount of support [25].

During the initial programming period (2014–2020), FIs were used to support enterprise development, particularly investments that generated revenue. The JEREMIE Initiative serves as an early example of this usage. The JESSICA Initiative later employed these instruments to rejuvenate deteriorated urban locales that were unlikely to receive commercial support for modernisation. In the current financial period for 2021–2027, the usage of FIs has become more prevalent, encompassing RES, EE, low-carbon and social support, and microfinance, in addition to the already mentioned areas. This presents both exclusive opportunities to involve private finances in accomplishing environmental objectives and the prospect of executing projects that would not be possible without public support.

Current research on EE and RE primarily focuses on international comparisons at the national level. However, a research gap exists regarding the relationship between the levels of domestic and foreign funds allocated to the development of EE and RE and the underlying economic and environmental factors that may influence the allocation of these funds. Another area which has not received sufficient attention in current research is the assessment of financial instruments as substitutes for traditional subsidies and their efficacy.

The main objective of the article is to assess whether the amount of funds allocated within the regional programmes of Polish voivodships for the development of EE and RE shows a correlation with the level of air pollutant emissions and the level of development of the regions, and whether there appears to be a convergence of the regional levels of electricity production from renewable sources. Long-term trends in energy consumption and production, including renewable sources, and air pollutant emissions from enterprises will also be analysed, taking into account the impact of crisis periods.

The following research hypotheses were verified: higher allocation to EE and RE occurs in regions with higher amounts of air pollutant emissions, higher amounts of air pollutant emissions are found in regions with higher levels of development, a positive relationship between energy consumption and amounts of air pollutant emissions exists, and an increase in the energy efficiency of the GDP generation appears.

The scope of the study is characterised by a certain degree of originality, as it is, to the best of the authors' knowledge, the first example of such a comprehensive regional study of the relationship between funds allocated to EE and RE within regional development programmes and a number of selected environmental and economic variables. This also relates to an assessment of the extent to which FIs are used to support EE and RE. And, although the evaluation of the impact of these instruments requires the collection of data covering several more years, the introduction of the application of FIs in this area should be considered as relatively original, since there are very few studies on this subject. The use of a convergence model to examine whether there is an equalization in regional levels of renewable electricity production, as well as the use of data over a long period, covering three funding periods under the European Regional Development Fund, throughout the study also appear to be novel. The extension of the analysis horizon should make it possible to reduce the bias in the analysis caused by reverse causality and potential omitted variable problems. It also reduces the impact of outliers.

The rest of the paper is organised as follows: Section 2 describes the importance of investing in RE, Sections 3 and 4 present the history and prospects of using FIs for socio-economic development, with a particular focus on increasing investment in EE and RE, Section 5 presents the sources of the statistical data and the research methods used, the results and comparative analysis are presented in Section 6, and, finally, the discussion and conclusions are presented in Section 7.

2. Importance of RE Development

According to economists, rapid economic growth depends, among other things, on an efficient and reliable energy system [26], generates greater demand for electricity [27], and has a greater impact on environmental degradation [28] through increased greenhouse gas emissions [29]. To promote environmental sustainability, it is essential to alter the energy model by shifting the focus from fossil fuel-based energy production to energy production from renewable sources [30]. To achieve this, prioritising investments in EE and RE is crucial. On the one hand, they facilitate the achievement of the objectives outlined in the European Green Deal, while on the other, they enable the decrease in production costs and the extent of energy exclusion. Greater investment in EE and RE will also translate into better health and longer life expectancy for European citizens [31]. The quality of the environment is also influenced by globalisation, which also supports the growth of RE. As globalization intensifies, renewable energy (RE) has a greater effect on reducing CO2 emissions. This reduction is particularly pronounced in developed countries that generate less fossil fuel energy and employ more advanced technologies [32,33]. However, some authors have reported the existence of an inverse relationship [34].

Many countries endorse the growth of RE by setting up a legal system that assists in achieving sustainable development. The vast majority of countries have established objectives and implemented policies oriented towards increasing energy from renewable sources [35]. Additionally, they have implemented acceptable legal frameworks, as the inconsistent regulatory setting causes investor uncertainty and limits the use of contempo-

rary RE technologies [36]. The implementation of RE- and EE-oriented policies requires significant participation from central and local authorities [14]. Clear and stable governmental policies on climate change alleviate the concerns of potential investors and impact the financing decisions of banks and other institutions [37]. If an increase in the financing of investments in RE production is observed along with a clear message of emphasising policies to support environmentally friendly investments, this will efficiently contribute to improving environmental quality [38]. Analysis of data from 119 non-OECD countries between 1980 and 2006 has shown that the financing of RE sources is closely linked to the development of the financial sector. Financial intermediation, especially commercial banking, has a positive impact on the amount of RE produced, including through the financing of companies and RE projects [39]. Research in the United States shows that financial development promotes RE consumption in the medium and long term, and that financial markets are the two most important in that case [31,40].

Previous studies on the relationship between RE consumption, emissions, and economic growth indicate that these relationships depend on the level of economic development of a country, and repeatedly confirm the existence of bidirectional relationships between these phenomena [41–45], especially in the long term [46]. Yang et al. found evidence that investment in RE projects leads to significant economic growth and reduces emissions risks [47]. A positive relationship between these phenomena has also been confirmed for OECD countries [1]. However, some studies suggest that there is no clear evidence that the production and consumption of RE has a positive effect on GDP growth [48] or the variability of this effect is uncertain (positive and negative) in the long term [47]. Bibi and Li found that the impact of RE consumption on economic growth is positive and significant above a certain threshold of consumption [26,49]. If developing countries consume such energy below a certain level, the impact on economic growth is negative. The extent and nature of the impact on economic growth of increasing the share of renewable energy production and consumption varies not only from country to country, but also depends on a number of political and economic factors [50], with only a few cases characterised by long-term equilibrium [51]. However, it is important that the transition from fossil fuels and the change in the structure of energy consumption increases green factor productivity through the use of new green technologies [52]. Such stimulation of low-carbon approaches in economic growth can be achieved through public investment in the research and development of RE technologies that will reduce carbon emissions from the use of natural resources [53] and will also have economic and financial effects [13,54]. However, [54] decisions to invest in energy system transformation, including the necessary infrastructure, depend on many factors, including, most importantly, country and project risk, political and environmental stability, and the cost of capital [55]], as well as household characteristics, including income levels and unobserved characteristics, such as environmental motivations [56].

Acknowledgement of EU programmes under which Poland can finance energy transition has identified its priorities [57,58]. However, their implementation depends on the number and size of projects and the range and design of FIs used. Although the EU has increased public funding for energy, it is not enough to make a full transition to clean energy [59]. One mechanism that will increase the involvement of private capital in this area is the extensive use of FIs.

3. The History and Goals of Financial Instruments in EU Policy

FIs provide support in the form of loans, loan guarantees, and equity participation to projects that would have no chance of being financed by the banking sector. In this way, they help to overcome existing market failures by leveraging public funds [22,23,60] and support cohesion policy by simultaneously implementing risk-sharing and achieving objectives included in EU Member States' development programmes.

The European Commission's shift from grant instruments to repayable instruments in the effective use and management of structural funds was intended to promote better

economic and social impact. The most commonly cited impacts in the literature include the following [20,24,61–64]:

- Revolving, which means that funds can be used more than once, increasing the efficiency with which public funds are used.
- Repayability of funds, which results in financing projects with lower risk.
- The possibility of bridging market failures in access to capital.
- Moving away from a culture of 'grant dependency'.
- Additional leverage through the involvement of private funds.
- Access to a wider range of financial services and increased experience of financial intermediaries.

The growing use of FIs in individual countries has stimulated interest in the subject and research into their strengths and weaknesses. Typically, studies have compared FIs with grants and sought to identify their advantages over non-repayable support. The benefits of using of FIs in the context of the EU Structural Funds have been documented by, among others, Wishlade and Michie [65], Núñez-Ferrer et al. [23], Matshkalyan and Feher [63], Nyikos and Laposa [66], and fi-compass [67].

The history of repayable aid in the form of financial engineering instruments in EU policy dates back to the 1990s. They were first used in Belgium, Germany, and the UK during the 1994–1999 programming period, with EUR 0.57 billion [68]. Other Member States followed suit in the 2000–2006 period (EUR 1.2 billion), allocating funds for business development. However, these instruments gained widespread popularity between 2007 and 2013 (EUR 16.45 billion), when they were used in 25 of the 28 Member States. In all of them, instruments open to enterprises were established, in 11 countries they financed urban development, and in 9 countries the FIs were used in the fields of EE and production of energy from renewable sources [68], in accordance with Article 44 of EC Regulation 1083/2006 [69]. By the end of 2015, a total of 1 055 FIs had been created. The vast majority of these, both in terms of quantity and value, were aimed at developing the SME sector (89% in volume, 86% in value terms). Urban development projects accounted for 6.7% of the total number of FIs (9.8% in value terms) and EE for 4.2% of FIs (4.2% in value terms) [23]. The vast majority of FIs were introduced in the form of loans, credits, and guarantees.

The next programming period (2014–2020) introduced some changes in the way FIs operate. One of these was the need for an ex ante analysis to determine the real need for this form of support and to identify the funding gap. At the same time, the scope of the FIs was extended to all programme objectives, and the possibility of creating cross-border instruments was introduced [70]. During this period, there was a significant increase in the amounts allocated to FIs, which was also due to an increase in allocations to combat the effects of the COVID-19 pandemic. In particular, measures were taken to increase the liquidity of enterprises and to finance their day-to-day operations. The available data show that the popularity of FIs is increasing both in the EU and in Poland. There is also a significant increase in allocations to finance RE and EE improvements.

By the end of 2021, FIs will have been implemented in 25 Member States. The programme contribution committed to FIs amounted to almost EUR 29 billion by the end of 2020, including EUR 2.51 billion in EE and RE. Over the period 2014–2020, more than EUR 23 billion has been disbursed to FIs, of which around EUR 19 billion has been invested in or committed to final beneficiaries, leveraging EUR 49.3 billion of investment (+29% year-on-year change) at the level of final beneficiaries [71].

At the end of 2021, the allocation for FIs in the submitted programmes was around 8% of the total ERDF and Cohesion Fund allocation for 2014–2020. The share of FIs varies, with the highest allocation planned in the United Kingdom (22%), Italy and Greece (both 18%), and no allocation in Denmark, Ireland, and Luxembourg [71]. In Poland, 5% of the ERDF and Cohesion Fund was allocated to FIs, one of the lowest shares in the EU.

Among the Polish regions, the largest nominal amount of support through FIs was allocated by the śląskie and wielkopolskie voivodships, and the smallest by the lubuskie, podlaskie, opolskie, and warmińsko-mazurskie voivodships, which clearly stand out in terms

of the amount allocated to this form of support. All voivodships programmed FIs for enterprises in the 2014–2020 period, and only some used them to support EE and RE (dolnośląskie, lubuskie, łódzkie, małopolskie, opolskie, podlaskie, and wielkopolskie). However, these were not significant amounts compared to the FIs dedicated to SMEs. They represented 10.5% of the total allocation in the FIs and were treated more as pilot expenditure.

4. Implementation of Fis in 2021–2027

For the 2021–2027 programming period, the European Common Provisions Regulation provides for the possibility of using a mechanism combining an FI with a donation [72]. The new rules go even further. They allow, under certain conditions, the provision of capital rebates and capital grants in addition to interest subsidies and technical assistance in a single operation, in accordance with the FI's rules. It is generally considered that the use of capital rebates can be particularly effective in financing efficiency investments, as the subsidy and its amount are linked to the achievement of a certain target and threshold of energy savings.

Almost half of the EU's FIs in 2021–2027 will support investment in SMEs. Nearly EUR 8.5 billion will be invested in SMEs in the form of loans (49%) or equity (20%) to improve access to finance, which is still a barrier for many startups and growing companies. Support through FIs for investment in research and innovation (EUR 1.7 billion) and digitalization (EUR 417 million) also contributes to the Smarter Europe priority. Almost a quarter (24%) of the planned allocations to FIs are earmarked for investments in EE (EUR 4.3 billion) and 8% for RE (EUR 1.5 billion). EUR 6.0 billion, double the amount invested in 2014–2020, will be allocated to cover the investment gaps in the energy transition and the low-carbon economy in sectors crucial to the success of the European Green Deal. There are also significant commitments to support urban and territorial development through FIs (EUR 633 million). This can be achieved through the New European Bauhaus model for FIs. An analysis of the amounts allocated to FIs shows two clear leaders—Poland and Italy. Most Member States plan to focus on loans and grants. Other products, such as equity or guarantees, play a lesser role.

The allocation of repayable support in relation to the total allocation under the regional programmes of the Polish voivodships is characterised by strong heterogeneity. The lubelskie voivodship allocated the largest amount of funds under the FIs (31% of the total allocation) and the mazowieckie voivodship the smallest (6%) (Figure 1).

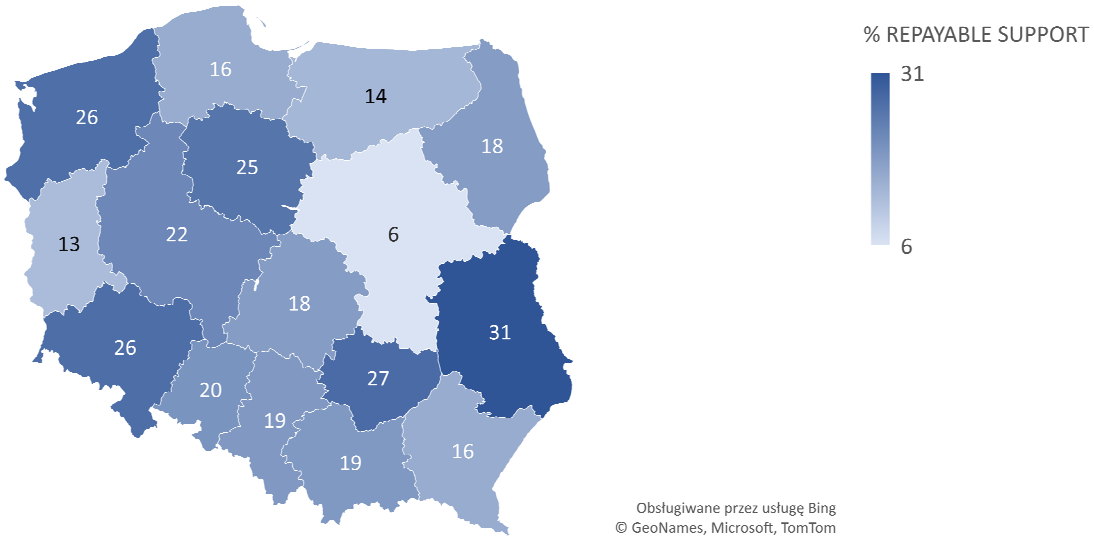


Figure 1. Share of FIs in total allocation in the regional programs in 2021–2027 (%). Source: own calculations based on fi-compass.

The structure of the regional shares of allocations for EE and RE in the total allocation is also highly differentiated. The lowest share was in wielkopolskie (8.24%) and the highest

was in podlaskie (19.27%), with an average share of 13.04%. EE investments and RE projects are generally characterised by very low or negative internal rates of return (in the case of EE) or high upfront capital costs and lower operating costs (in the case of RE). In practice, subsidies are often needed to finance parts of energy projects, especially those with low or negative internal rates of return, or when they are needed for social reasons or for deep renovation. Therefore, in 2021–2027 the EE sector grants can be combined with FIs to achieve the following [73]:

- Improve the quality of projects through technical assistance in the preparation phase and throughout the investment cycle.
- Achieve ambitious energy savings targets within a reasonable timeframe, thereby incentivising final beneficiaries to undertake deeper renovation projects with higher energy savings than they would otherwise undertake without such a grant component.
- Reduce the cost and burden of financing through financial instruments.
- Reduce the perceived risk of certain market sub-segments.
- Tackle fuel poverty.

The combination of FIs and grants is justified when revenues cannot cover initial investment costs and the project is too risky to attract financing on acceptable terms without high-risk coverage. Depending on the identified market failure, this hybrid financing can take different forms. The combination can take the form of an FI and a grant for interest rate and guarantee fee subsidies, technical assistance, capital grants, and performance-based grants (capital rebates, repayable, or convertible grants) [74].

Funds received by managing authorities from the ERDF or the Cohesion Fund and earmarked for the promotion and development of EE and RE can finance projects in two ways. The first way is through a holding fund, which in turn will channel funds to final beneficiaries through financial intermediaries. In the second way, funds are transferred directly from the managing authority to the financial intermediaries. The financial intermediaries are responsible for the implementation of the operation (loan and grant components) and will identify clients, verify and evaluate applications, and disburse funds. At each level, additional funding may come in the form of, for example, national and regional funds and contributions from the financial intermediary or external investors, creating a multiplier effect. Final beneficiaries may be individuals, homeowners' associations, housing cooperatives, SMEs, mid-caps, or larger companies that meet the eligibility criteria. FIs supporting EE and RE sources under Article 58(5) of the CPR take the form of a combined product comprising a debt instrument (loan) or a guarantee instrument (guarantee, surety) and a non-repayable instrument [72]. In the case of EE projects, the aim is to reduce primary energy demand by at least 20% compared to the situation before the investment.

5. Materials and Methods

Information and data on financial instruments used at the EU level have been extracted from the fi-compass database provided by the EC in partnership with the EIB. Data on FIs in previous periods were obtained from the European Cohesion Data database and DG Regio reports. Information on FIs in Poland was obtained from the Polish Ministry of Funds and Regional Policy. Data on the state of the environment were obtained from the Local Data Bank of Statistics Poland. Selected statistical and econometric measures and methods were used in the analyses. To study the degree of concentration, the Gini coefficient was used. The measure meets all four criteria for the evaluation of inequality measures, namely transfer principle, scale independence, independence from population size and decomposability, and is determined on the basis of the Lorenz curve, measuring the inequality of the distribution of the variable under study [75] and calculated according to the following formula:

$$G(X) = \frac{1}{n}\left(n + 1 - 2\left(\frac{\sum_{i=1}^{n}(n+1-i)x_i}{\sum_{i=1}^{n} x_i}\right)\right)$$

Points represented by Lorenz curve describe the relationship between the cumulative value of the variable under study and the share of elements in the population. The Gini coefficient takes values in the range <0;1> and measures the deviation of the Lorentz curve from the straight line drawn for such a population, in which all the elements have an equal share in the population. As the value of this coefficient increases, we observe an increase in the inequality of the distribution of the analyzed variable among the units of the population under consideration, i.e., an increase in its differentiation and concentration.

Classical linear regression models [76,77] were used to examine the dynamics of variables based on time series data and the relationships between variables based on cross-sectional data, with structural parameter estimation using ordinary least squares (OLS) [77]. More comprehensive models and estimation methods more advanced than OLS could also be used to assess the trends and dependencies of the variables, but in the current study, the quality of the models considered is high enough that their use was not found to be justified.

The analysis of absolute β-convergence was carried out on the basis of the convergence equation derived from the Solow–Swan growth model [78]:

$$\frac{1}{T} ln\left(\frac{Y_{iT}}{Y_{i0}}\right) = \alpha_0 + \alpha_1 ln Y_{i0} + \varepsilon_{iT}$$

where
$\frac{1}{T} \cdot ln\left(\frac{Y_{iT}}{Y_{i0}}\right)$—annual growth rate of examined variable in region i;
Y_{i0}—initial level of examined variable in region i.

The above equation describes the inverse relationship between the dependent variable representing the average growth rate of the phenomenon under analysis and its initial level represented by the explanatory variable. The levelling phenomenon of a variable occurs when the parameter α_1 is negative and statistically significant [79]. It means that objects (regions) with lower relative values of the examined variable tend to increase its levels faster.

The rate (speed) of equalisation of the levels of a given variable β has been determined on the basis of the following formula:

$$\hat{\beta} = -\frac{1}{T} \cdot ln(1 + \hat{\alpha}_1 \cdot T),$$

where T is the examined period and its higher values corresponds to a greater tendency toward convergence.

The values of the have-steady-state measure $T_{1/2}$, which characterises the length of the convergence half-period and is usually expressed in years were calculated using the following formula:

$$T_{1/2} = \frac{\ln 2}{\hat{\beta}}$$

It should be noted that since the convergence model describes a non-linear relationship, the full period of convergence is expected slightly after $2T_{1/2}$ years.

The proposed approach of verifying the hypothesis of the existence of convergence of the variable under study is widely used in empirical research, mainly to assess income convergence, but also for many other phenomena. One of the many advantages of this approach is its ability to capture non-linearity in the relationship between the variables under study. At the same time, it avoids the often inconclusive results obtained, for example, with a stochastic approach based on cointegration analysis.

6. Results

The empirical part of the article includes an analysis of the level and spatial structure of the allocation of funds for EE and RE within the Polish regional programmes. It also examines trends in energy consumption and production, including energy from renewable sources, as well as trends in pollutant emissions per unit of gross domestic product.

A positive development observed in Poland between 2000 and 2021 is the reduction in emissions of air pollutants from installations measured in tonnes per million of GDP. Over the whole period, the average annual rate of decrease was 9.66 tonnes, and between 2000–2009 and 2010–2021 it was 14.08 and 6.61 tonnes, respectively. At the same time, there was a decrease in this trend in the two most recent crisis periods, namely 2008–2009 and 2020.

Under the EU's regional policy, each voivodship receives funds that it can use for regional development policy, including measures to mitigate adverse climate change. These funds have increased significantly in successive programming periods (see Table A1 in Appendix A). In the 2014–2020 period, only nine voivodships decided to support the energy transition through FIs. Between 2021 and 2027, more than EUR 4 billion will be allocated to EE and RE priorities. Almost half of this amount (44%) will be provided in the form of FIs. However, there is considerable variation both in the size of the EE and RE allocations and in their share of the total FI allocation (Figure 2).

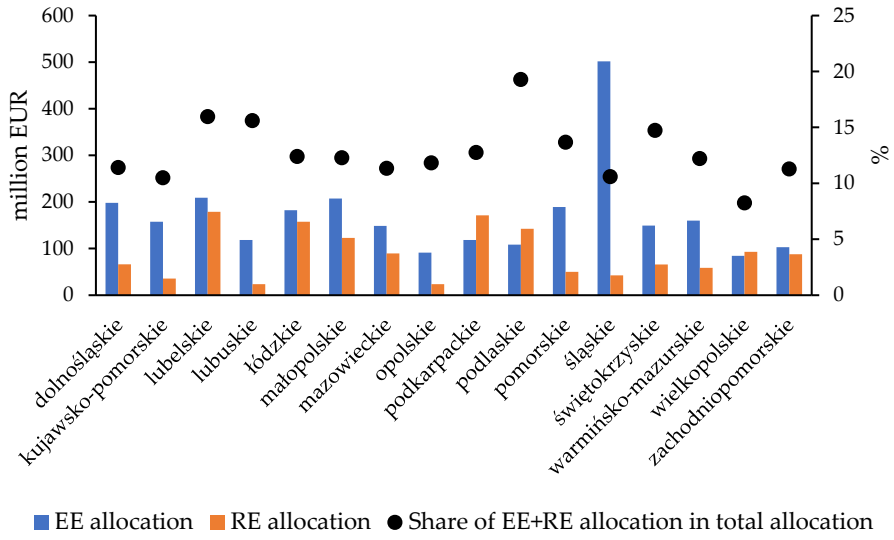


Figure 2. Allocations in energy efficiency (EE, millions EUR) and renewable energy (RE, millions EUR), and share of allocation in EE and RE in total allocation (%) by voivodships in 2021–2027. Source: own study based on fi-compass and the Ministry of Funds and Regional Policy.

An analysis of the structure of repayable support by type of FI shows the dominance of loans and FIs with a grant element, a new product in the EU support system. Loans account for 29.14% of the allocation planned for these priorities and grants in the form of FIs account for 14.54%. Equity and guarantees are much less popular (Figure 3). However, non-repayable grants will continue to dominate (56.32%) the total allocation in regional programmes. In the period 2021–2027, the use of repayable instruments is significantly higher than in previous years. For example, under the objective 'Promotion of EE and GHG emission reductions', FIs account for 35% of the total allocation, while under the objective 'Promotion of RE', this share is 60% at national level.

Electricity demand per capita in Poland grew steadily between 2001 and 2021, except for periods of economic downturn caused by the economic crisis in 2008–2009 and the COVID-19 pandemic in 2020 (Figure 4), reaching an average annual increase of 59.81 kWh.

At the same time, energy consumption per unit of GDP generated has been decreased from 0.16 GWh per 1 million PLN of GDP in 2001 to 0.06 in 2021. Between 2005 and 2021, the production of energy from renewable sources in Poland also increased, but the increase was not uniform (Figure 5). It was characterised by periods of slower growth or even decline, mainly due to economic and regulatory factors. The period of decline in RE production was due to changes in Polish regulations, which reduced the attractiveness of RE production and limited its supply. In contrast, the above-average growth from 2018

onwards was due to the increasing popularity of photovoltaic installations, resulting from the introduction of favourable tax.

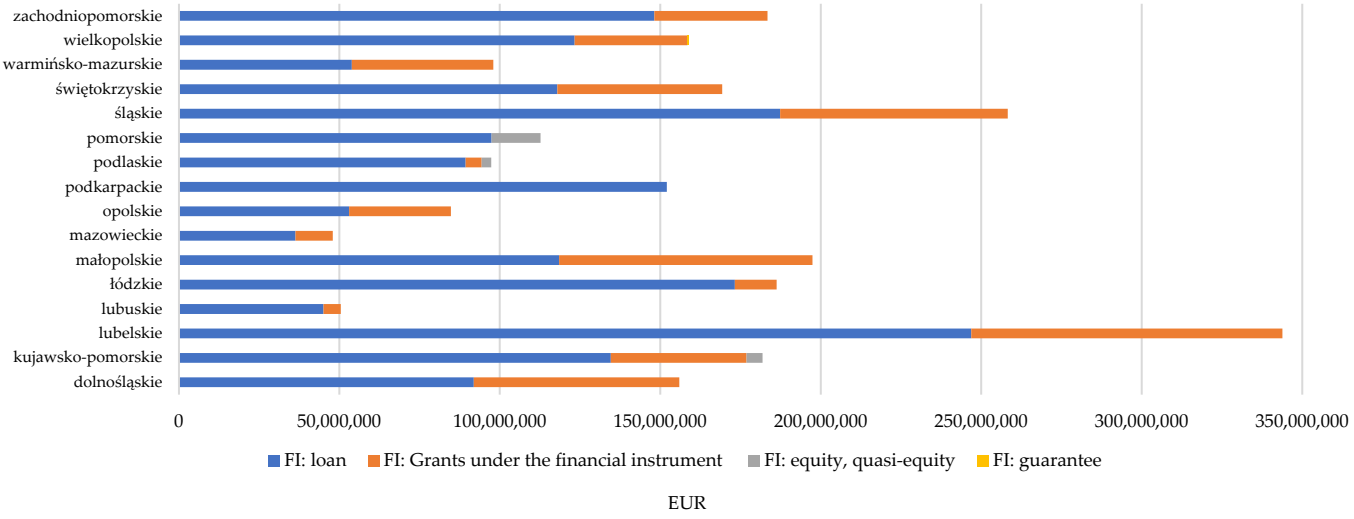


Figure 3. The types and allocation of FIs in the voivodeships in 2021–2027 (EUR). Source: own calculations based on fi-compass and the Ministry of Funds and Regional Policy.

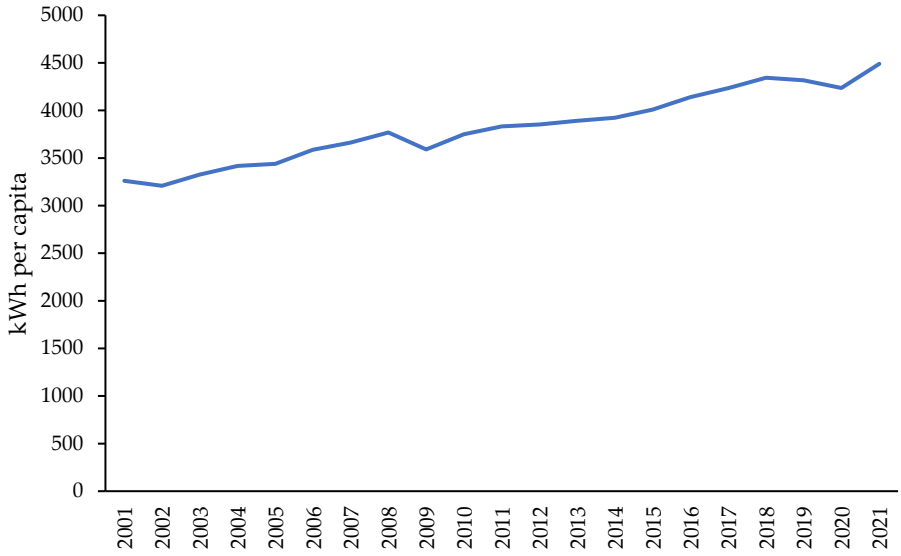


Figure 4. Consumption of electricity (kWh per capita) in Poland in 2001–2021. Source: own study based on Statistics Poland.

The results of the estimation of the parameters of the linear trend model describing the dynamics of energy production from renewable sources in Poland in the period 2005–2021 are presented in Table 1.

The model fits the empirical data very well, the parameter at the time variable is statistically significant, but for data covering the whole period the RESET test suggests a non-linear functional form of the model other than linear and there is autocorrelation of the random error. The average annual increase in energy production from renewable sources was equal to 1702.56 GWh.

Polish RE production per 100,000 inhabitants also increased over the same period. The results of the estimation of the dynamic model describing the changes in this variable over time are shown in Table 2.

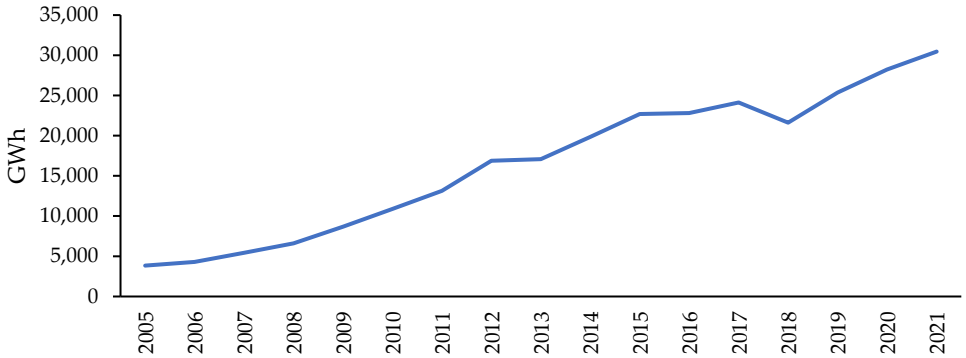


Figure 5. Production of electricity from renewable energy sources (GWh) in Poland in 2005–2021. Source: own study based on Statistics Poland.

Table 1. Estimation results of trend model for the production of electricity from renewable energy sources (GWh) in Poland 2005–2021. Source: own study.

	(1)
Variables	**2005–2021**
Constant	1261.47 (1.62)
Production	1702.56 *** (22.35)
Observations	17
R-squared	0.97
Shapiro–Wilk (p)	0.997
RESET (p)	0.403
White (p)	0.295
Durbin–Watson	1.068

Notes: *** indicate statistical significance at the 1% level. The figures in () are *t* statistics.

Table 2. Estimation results of trend model of production of electricity from renewable energy sources (GWh per 100,000 inhabitants) in Poland in 2005–2021. Source: own study.

	(1)
Variables	**2005–2021**
Constant	3.15 (1.56)
Production per 100,000 inhabitants	4.46 *** (22.66)
Observations	17
R-squared	0.97
Shapiro–Wilk (p)	0.928
RESET (p)	0.432
White (p)	0.419
Durbin–Watson	1.101

Notes: *** indicate statistical significance at the 1% level. The figures in () are *t* statistics.

Again, the model fits the empirical data very well, and the parameter on the explanatory variable is statistically significant, but for data covering the whole period, the RESET test suggests a functional form of the model other than linear, and autocorrelation of the

random error also occurs. The average annual increase in renewable energy production per 100,000 inhabitants was 4.46 GWh.

An analysis of RE production on a regional basis reveals significant variations in this variable (Figure 6). In the period 2005–2021, some voivodships, namely warmińsko-mazurskie, podlaskie, pomorskie and zachodniopomorskie, experienced a strong increase as a result of a strong emphasis on RE and EE policies.

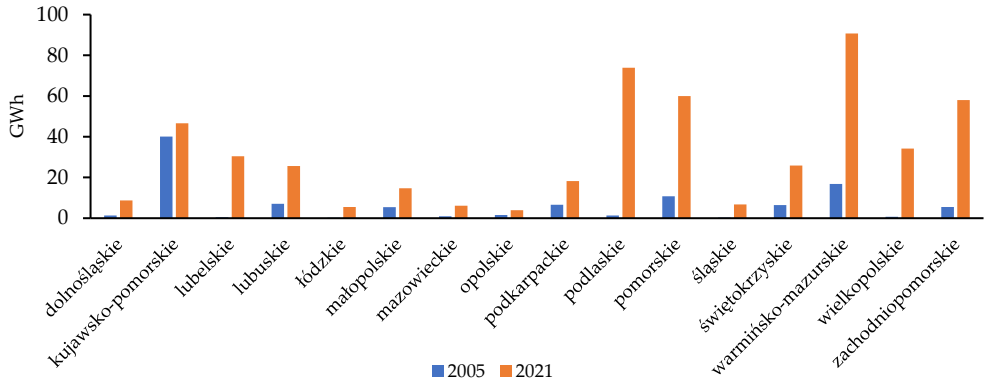


Figure 6. Share of renewable energy sources in total production of electricity (%) by voivodship in 2005–2021. Source: own study based on fi-compass and the Ministry of Funds and Regional Policy.

The verification of the hypothesis of equalisation of regional production levels of electricity from renewable sources was carried out using models (1) and (2), presented in Table 3.

Table 3. Estimation results of convergence equation for the production of electricity from renewable sources (GWh per 1,000,000 inhabitants) in voivodeships in 2005–2021. Source: own study.

	(1)	**(2)**
Variables	**2005–2021 Full Sample**	**2005–2021 Without Outliers [1]**
Constant	0.351 *** (10.04)	0.344 *** (11.54)
Production per 1,000,000 inhabitants	−0.047 *** (−5.81)	−0.044 *** (−6.29)
Observations	16	15
R-squared	0.71	0.75
Shapiro–Wilk (p)	0.835	0.648
RESET (p)	0.433	0.510
White (p)	0.493	0.433
Durbin–Watson	1.506	1.561
B	0.0876	0.0761
$T_{1/2}$	7.92	9.11

Notes: *** indicate statistical significance at the 1% level. The figures in () are *t* statistics. [1] małopolskie voivodship was identified as an outlier.

The goodness of fit of both models to the empirical data is satisfactory and their parameters are statistically significant. The rate of convergence (average annual rate of levelling) of RE production per 1,000,000 inhabitants for the voivodeships) is 8.76% for model (1) including the full sample and 7.61% for model (2) with the outlier observation removed. The half-time convergence is 7.92 and 9.11 years, respectively (Table 3). This means that if the current trends are maintained, the same level of RE production per capita will be observed in the Polish voivodships in about 19–20 years.

The above analyses were complemented by the verification of research hypotheses formulated in general terms in the introduction (see Table 4).

Table 4. Research hypotheses. Source: own study.

Research Hypotheses	Pearson's Linear Correlation Coefficient	Decision
	National level	
H1: There is no correlation between the level of development (GDP per capita) and the amount of air pollutants emitted by industrial plants	$r_{xy} = -0.39$	We cannot reject the null hypothesis at significance level $\alpha = 0.05$
H2: There is no correlation between energy consumption and the amount of air pollutants emitted by industrial plants	$r_{xy} = -0.34$	We cannot reject the null hypothesis at significance level $\alpha = 0.05$
H3: There is no correlation between energy production and the amount of air pollutants emitted by industrial plants	$r_{xy} = 0.07$	We cannot reject the null hypothesis at significance level $\alpha = 0.05$
H4: There is no correlation between the level of development (GDP per capita) and energy consumption	$r_{xy} = 0.99$	We can reject the null hypothesis at significance level $\alpha = 0.05$. There is a statistically significant positive correlation
H5: There is no correlation between energy consumption in GWh per GDP and gas emissions in tonnes per GDP	$r_{xy} = 0.998$	We can reject the null hypothesis at significance level $\alpha = 0.05$. There is a statistically significant positive correlation
H6: There is no correlation between the level of development (GDP per capita) and energy production from RE sources	$r_{xy} = 0.96$	We can reject the null hypothesis at significance level $\alpha = 0.05$. There is a statistically significant positive correlation
	Regional level	
H7: There is no correlation between the level of development (GDP per capita) and the level of allocation in EE and RE	$r_{xy} = 0.09$	We cannot reject the null hypothesis at significance level $\alpha = 0.05$
H8: There is no correlation between the level of development (GDP per capita) and the share of allocation in EE and RE in the total allocation	$r_{xy} = -0.47$	We cannot reject the null hypothesis at significance level $\alpha = 0.05$
H9: There is no correlation between the amount of air pollutants emitted by industrial plants and the level of allocation in EE and RE	$r_{xy} = 0.44$	We cannot reject the null hypothesis at significance level $\alpha = 0.05$
H10: There is no correlation between the amount of air pollutants emitted by industrial plants and the share of allocation in EE and RE in the total allocation	$r_{xy} = -0.37$	We cannot reject the null hypothesis at significance level $\alpha = 0.05$
H11: There is no correlation between the level of development (GDP per capita) and the level of allocation in EE and RE per capita	$r_{xy} = -0.77$	We can reject the null hypothesis at significance level $\alpha = 0.05$. There is a statistically significant negative correlation
H12: There is a positive correlation between the level of development (GDP per capita) and the amount of air pollutants emitted by industrial plants.	$r_{xy} = 0.63$	We can reject the null hypothesis at significance level $\alpha = 0.05$. There is a statistically significant positive correlation
H13: There is a positive correlation between the share of allocation in EE and RE in total allocation and the share of RE production in total energy production	$r_{xy} = 0.30$	We cannot reject the null hypothesis at significance level $\alpha = 0.05$
H14: There is a positive correlation between the level of development (GDP per capita) and the level of energy production from renewable sources (both in absolute terms and measured per capita)	$r_{xy} = 0.77–0.97$	We can reject the null hypothesis at significance level $\alpha = 0.05$. There is a statistically significant positive correlation (apart from małopolskie and śląskie voivodeships)

The first part concerns the relationships observed at the country level. In the period 2000–2021, a lack of statistically significant correlation was observed between the level of development measured by GDP per capita and air pollutants from plants (Pearson's linear correlation coefficient $r_{xy} = -0.39$). For the period 2001–2021, the null hypothesis of no correlation between air pollutants from plants and energy consumption ($r_{xy} = -0.34$) and energy production ($r_{xy} = 0.07$) cannot be rejected either. However, there was a strong positive correlation between the level of development and energy consumption ($r_{xy} = 0.99$), and between energy consumption in GWh per 1 million GDP and gas emissions in tonnes per 1 million GDP ($r_{xy} = 0.998$). Between 2005 and 2021, a strong positive correlation also occurred between the level of development and energy production from renewable sources ($r_{xy} = 0.96$).

At the regional level in 2021, there was no statistically significant correlation between the level of development of the region and the level of allocation in EE and RE ($r_{xy} = 0.09$), nor with the share of allocation in EE and RE in the total allocation ($r_{xy} = -0.47$). There was also no correlation between the amount of air pollutants from plants and the level of allocation in EE and RE ($r_{xy} = 0.44$), and the share of allocation in EE and RE in the total allocation ($r_{xy} = -0.37$). Unexpectedly, a statistically significant negative correlation was found between the level of development of the region and the amount of EE and RE allocated per capita ($r_{xy} = -0.77$), as well as the more expected positive correlation between the level of development and air pollutants from plants ($r_{xy} = 0.63$). The analysis of the latter relationship considered over a longer period (2000–2021) leads to very different results. Some of the voivodeships are characterised by positive and some by negative correlations, with significant differences in their magnitude. Moreover, there is no correlation between the share of allocation in EE and RE in total allocation, and the share of RE production in total energy production ($r_{xy} = 0.30$) at the regional level.

Between 2000 and 2021, however, there was a statistically significant positive correlation between the level of development of a region and the level of energy production from renewable sources, both in absolute terms and measured per capita ($r_{xy} = 0.77$–0.97). The exceptions were two voivodeships, małopolskie and śląskie, for which this relationship was not visible.

In addition to examining the direction and strength of the relationship between the variables considered, an analysis of their concentration was also carried out. It was found that there is a relatively strong regional concentration of air pollutants from plants (Gini coefficient = 0.603) and energy production levels (0.592). The initial strong regional concentration of the share of RE production in total energy production decreased significantly from 0.758 in 2005 to a level of 0.573 in 2021. This means that the regions lagging behind in this area have caught up by starting to produce energy from their own RES.

7. Discussion and Conclusions

The results of the study confirmed the conclusions of other studies presented in the theoretical part, which showed a strong relationship between the level of development of the country (region) and energy consumption, which will result in a growing demand for energy. However, meeting the demand for energy from renewable sources, i.e., climate-neutral energy, will require a change in thinking and existing development policy paradigms and, above all, a significant increase in investment in EE and RE.

The EC estimates an annual investment gap in this area of around EUR 185 billion over the next decade, particularly in the residential sector. This sector requires increased EE in buildings and the use of energy from renewable sources, subject to the provision of adequate financing and a stable regulatory and legal environment.

In this context, current trends, such as the increase in allocations in EE and RE, the growing importance of FIs in their transmission to final beneficiaries, as well as the decrease in gaseous pollutant emissions per unit of GDP generated, should be assessed positively, as they indicate the positive direction of technological change in the economy with regard to the climate change objective.

The renewable nature of EE and RE projects and the ability to attract private investors and financial service providers favours their large-scale implementation [80]. Although the use of FIs in the EE and RE priorities for the period 2004–2020 was limited, the advantages of FIs over grants and their growing popularity have been noted by, among others, Wishlade and Michie [65], Nunez-Ferrer et al. [23], Matshkalyan and Feher [63], Nyikos and Laposa [66]. It is also clear that this should mainly be carried out through public initiatives and that local authorities should play an important role, as mentioned by Vatamanu and Cigu [14]. The funds allocated by FIs for EE and RE in 2021–2027 are around 30% in the EU and 60% in Poland, which shows a growing awareness of environmental protection and the importance of energy production from renewable sources [37].

A positive trend can be observed in terms of a more even distribution of the share of RES in total energy production among Polish regions and regional convergence of RE production per 1,000,000 inhabitants. This means that each region tries to use RES specific to its geographical location, e.g., the initial spatial accumulation of RE production volumes due to the dominance of wind farms in the northern provinces is reduced by the increased use of other sources, especially solar energy. However, it is worrying that there is no correlation between the level of development of a region and the amount of air pollutants emitted, and the level of allocation and, consequently, expenditure on EE and RE. The absence of such relationships seems to provide a compelling rationale for appropriate government regulatory intervention, including fiscal incentives, to increase the attractiveness of EE and RE investments through wider use of FIs. FIs can play a crucial role in decarbonisation and RES support programmes [31,32], especially as they will be used extensively in combination with grants in the 2021–2027 programming period.

The financial sector and its development are conducive to the energy transition, and access to markets and FIs are important factors in promoting RE consumption [15]. The use of FIs in the energy transition will influence the formation of regional financial markets and the financial and competence strengthening of regional financial institutions, which will manage not only the funds invested in EE and RE, but also those that finance development in other socio-economic dimensions.

The funds allocated to the FIS for 2021–2027, in particular for energy efficiency and production, are currently very regionally differentiated but will bring benefits in the medium and long term, so further research is needed to systematically assess the impact of EE and RE development on the economy and the synergy of this development with sustainable development [54,81,82]. Carrying out similar studies at mid-term and at the end of the programming period will provide an answer to the question of the cumulative impact and effectiveness of the implementation of the FIs and will make it possible to draw up guidelines and recommendations for decisionmakers in this respect. It may also be useful to carry out international comparative analyses to identify the specificities of individual countries (regions) or homogeneous groups of countries (regions).

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Appendix A

Table A1. Allocations of the European funds by voivodships in chosen programming periods. Source: own study based on fi-compass and the Ministry of Funds and Regional Policy.

	(1)	(2)	(3)	(4)
	2007–2013	**2014–2020**	**2021–2027**	**2021–2027/2007–2013**
Voivodship	**(Million EUR)**	**(Million EUR)**	**(Million EUR)**	**(%)**
lubuskie	439	906	910	107.2
opolskie	427	944	970	127.1
podlaskie	636	1212	1300	104.3
świętokrzyskie	726	1363	1460	101.2
zachodniopomorskie	835	1600	1690	102.3
pomorskie	885	1863	1750	97.7
warmińsko-mazurskie	1037	1727	1790	72.7
kujawsko-pomorskie	951	1902	1840	93.5
mazowieckie [1]	1831	2088	2100	14.7
wielkopolskie	1273	2448	2150	68.9
podkarpackie	1136	2112	2270	99.8
dolnośląskie	1213	2250	2315	90.8
lubelskie	1156	2229	2430	110.2
małopolskie	1290	2876	2690	108.5
łódzkie	1006	2254	2740	172.3
śląskie	1747	3474	5140	194.2
Poland	16,590	31,247	33,545	102.2

[1] mazowieckie including the capital region.

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