Marcin SALAMAGA • Krzysztof WĄSOWICZ

MODELS OF STIMULATING ENERGY EFFICIENCY OF LOCAL GOVERNMENT UNITS AS AN ELEMENT SHAPING THE SUSTAINABLE DEVELOPMENT OF THE MODERN ECONOMY

Marcin **Salamaga** (ORCID: 0000-0003-0225-6651) – *Cracow University of Economics, Department of Statistics*
Krzysztof **Wąsowicz** (ORCID: 0000-0002-8882-4180) – *Cracow University of Economics, Department of Sustainable Finance*

Correspondence address:
Rakowicka Street 27, 31-510 Cracow, Poland
e-mail: salamaga@uek.krakow.pl, wasowick@uek.krakow.pl

ABSTRACT: The aim of the article is to present the construction of a tool motivating local government units (LGUs) to introduce a policy of saving energy from traditional sources and replacing it with renewable energy sources. The bonus allocation algorithm was built using econometric modelling based on the results of a survey conducted among LGUs. The survey allows for data collection, enabling the creation of energy efficiency indicators, which play a key role in the construction of the LGU bonus mechanism. The strength of the proposed tool lies in its construction based on models calculating the bonuses granted to LGUs depending on, e.g. the reduction of the pollutant emission index, the RES investment expenditure index, or the reduction in the energy consumption rate. This is the first proposal of its kind for a tool improving the energy efficiency of LGUs in Poland that was developed using the scientific method.

KEYWORDS: energy efficiency of municipalities, econometric model of rewarding LGUs, mechanisms supporting energy transition, sustainable development of municipalities

Introduction

Motivation – The role of local authorities in the energy transition for a modern economy

In an urbanised world, sustainable socio-economic development requires policies, measures and instruments to support the creation of energy-saving and low-emission solutions, which are within the local government's sphere of responsibility. The foundation for the implementation of an effective energy transition process lies in the optimal involvement of local authorities by indicating their role and defining the tasks they are supposed to fulfil in such a context. Initiating and implementing changes aimed at climate protection is an opportunity for urban area development in the context of future generations.

The ongoing decentralisation of energy production, transmission, and distribution, as well as the existing possibilities for improving energy efficiencies, have provided increasing opportunities for planning the entire process at a local and regional level. Today, municipalities play an important role in efforts to reduce greenhouse gas emissions by improving energy efficiencies and increasing the use of renewable energy sources. The need to define the socio-economic goals that the municipality should pursue emerges at the forefront, both in relation to its entire economy and its energy management, resulting from the necessity to meet the needs of municipality inhabitants (ensuring energy comfort and a certain standard of living).

It is local governments that have the potential to integrate EU funds for distributed energy generation, energy efficiency, air protection and other elements that are part of a sustainable development strategy.

Improving air quality and using renewable energy sources is important for residents of urban centres. Raising environmental awareness and responsibility for the state of the environment constitute a key challenge in the context of energy transition, the course and nature of which should also encompass the social and economic consequences of this process. Therefore, the proper preparation of local government units (LGUs) and providing them with appropriate legal and financial instruments to respond to these challenges form an important aspect of implementing the assumptions of a low-carbon economy.

In order to meet these expectations, the authors of this article committed to developing a quantification methodology and defining a catalogue of support mechanisms for municipalities setting out to implement an energy-saving policy, climate protection plans, in the context of socio-economic changes and the existing international situation that threatens the availability of specific raw materials, and the global energy crisis. The proposed tool motivates municipalities to embrace the green agenda.

Aim and Originality of the presented research – A proprietary model for rewarding LGUs developing innovative energy strategies

The overarching objective of this research paper was to build a tool motivating municipalities and local government units (LGUs) to introduce policies of saving energy from traditional sources and replacing them with Renewable Energy Sources (RES). The proposed tool, which is an algorithm, also motivated LGUs to take greater care of air quality within their jurisdictions and would, therefore, help to develop the directions of an appropriate pro-ecological policy addressed to municipality inhabitants and business entities within them. The incentive aspect of the motivating tool was based on the development of a system for allocating bonuses paid to municipalities from the state budget, the amount of which depended on the degree of their energy efficiency. The implementation of the tool led to real benefits in terms of reducing energy consumption, increasing the share of RES or reducing CO_2 emissions. This was particularly important in the face of the existing crisis on the energy market, high energy prices, and gradual depletion of non-renewable natural resources, as well as being part of activities aimed at counteracting global warming and meeting the EU's requirements for Member States regarding greenhouse gas reductions. The bonus allocation algorithm was built using econometric modelling based on the results of a survey conducted among local government units. The survey allowed the collection of unique data, enabling the creation of realistic energy efficiency indicators, which play a key role in the construction of the LGU bonus mechanism.

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The implementation of the main objective required clarifying the role of the municipality, the basic local government unit shaping sustainable growth, a part of which is the net-zero economy. The main objective corresponded to the following research question constituting the basis of the issues undertaken in the research paper: How important is the role municipalities play in international, national, regional, and local efforts to reduce greenhouse gas emissions? Do they protect the environment, reduce the use of raw materials through improved energy efficiencies and an increased use of renewable energy sources? In reference to the research problem defined in such a manner, the following main research hypothesis was formulated and verified in the research:

- H0: An appropriate financial programme supporting energy management carried out by municipalities can effectively motivate the municipality to implement the tasks of a sustainable development policy, the axis of which is low emissions.

  Verification of the above hypothesis requires verification of the following auxiliary hypotheses:
- H1: The distribution of bonus amounts that local government units would expect in exchange for greater involvement in activities supporting sustainable development is limited in shape from above and is well amenable to S-shaped curve modelling.
- H2: Municipalities have the greatest expectations regarding bonuses granted for improving energy efficiency in the area of reducing energy consumption from fossil fuels.
- H3: The distribution of the amounts of bonuses expected by local government units for energy efficiency shows a right-sided asymmetry (most local government units count on lower bonuses compared to the percentage of cities expecting high bonuses).

The adopted research methodology allowed the building and testing of different variants of the algorithm for stimulating the energy efficiency of local government units. Validation of the obtained models and simulation studies with LGU participation allowed us to assess the scale of benefits for the economy and environmental protection that were delivered through the implementation of an algorithm. The implementation of the project may become a reference point for building similar solutions in other EU countries that are assuming zero-emission growth and for international scientific discourse in the area of solutions to improve energy efficiency implemented at the level of local government authorities.

Overview of literature

Rewarding entities pursuing an active policy of reducing conventional energy consumption

The concept of a sustainable city is founded on an orientation towards environmental issues and an identification of the primacy of the quality of life assessment in urban areas (Preeth et al., 2018). The modern municipality, alongside intelligent solutions, based on innovative technologies, emphasises sustainable development and protection of the urban fabric (Amudha, 2021). It is essential to use environmentally friendly energy technologies integrated into the urban environment to minimise pollution, consumption of limited natural resources and carbon intensity (Li et al., 2020). Sustainable development is a concept of stimulating socio-economic processes in such a way that economic growth takes place through a more efficient and rational use of all resources. Its essence is to link rapid economic development and an increase in the quality of life of the population with an improved natural environment and the drive to preserve it for future generations.

Creating a model for rewarding and supporting municipalities that pursue an economical energy policy in order to mitigate the negative effects and obtain funds from local government units for further investments in improving their energy efficiency is an innovative intention, both in its theoretical and practical aspects. Therefore, the attempt to situate the proposed considerations in the context of current scientific analyses is a complicated task. Current research is aimed at assessing the impact of selected factors (mainly RES), usually in the smart city concept, on the amount of energy consumption (Ismagiloiva et al., 2019; Gao et al., 2020; Li, 2022). Often presented is the development of energy efficiency meters, which are a response to the requirements related to a) monitoring and planning in the field of energy management and b) controlling its management towards sustainable development, which is required, for example, at the level of the European Union (Melica et al., 2018; Palermo et al., 2020).

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Martinez et al. (2018) and Adesanya et al. (2020) analysed 5 urban centres in the United States of America, in which attempts were made at a full-scale use of renewable sources of electricity. The authors describe and compare the social, political and economic similarities and differences between these communities to better understand the factors that support a successful renewable energy transition. The analysis is based on Geels' multi-level perspective theory in assessing the sustainable energy transition and the energy transition process (Banerjee et al., 2017; Prehoda et al., 2019). Similar research by Li et al. (2020) found that actions taken at the local level contributed significantly to the transformation in Hawaii. Other writers (Hess & Gentry, 2019; Zhu & Wang, 2020) point out that social involvement through local government organisations in the planning and implementation process is crucial for establishing documented energy transition goals.

During the last decade, there has been a lot of research into the promotion of renewable energy. Shi (2014) and Kilinc-Ata (2016) analyse factors influencing the share of renewable energy in total energy supply. The analysis was carried out on panel data covering 26 OECD countries between 1990 and 2010. The results of a bidirectional model with fixed effects indicate that policy measures play an important role in increasing the share of renewable energy (Proença & Fortes, 2020). The analysis found a positive impact of research and development (R&D) on the share of renewable energy because R&D activities have reduced the cost of renewable energy generation. The results indicate that having a market-based policy instrument (e.g. feed-in tariffs or quota commitments) increases the country's share of renewable energy. The same research also demonstrates that a large increase in energy consumption reduces the share of renewable energy in the total energy supply.

A review of the selected literature points to an overarching motive – an attempt to determine the cost-effectiveness of government support for the research, development and implementation of technologies generating renewable electricity (Song et al., 2022). Even though a wide range of information on subsidy mechanisms is available (Mazurek-Czarnecka et al., 2022), there is a lack of consistent and useful data on subsidy expenditure or recipients.

The relevant literature includes a number of studies devoted to the effectiveness of economic policies shaping the energy efficiency of individual consumers and prosumers of energy. These programmes are intended to improve energy efficiency or, more broadly, investment efficiency (especially in the case of the business sector). Undoubtedly, a very important element of this policy is various public support tools that motivate entities to take action in areas such as reducing the consumption of energy from fossil fuels, reducing greenhouse gas emissions, lowering energy costs, and improving the environment. Some authors focus on assessing the effects of government subsidies in reducing the costs of energy-saving technologies, which increases their availability to consumers (Martinot & Borg, 1998; Hua & Wang, 2019). There are also articles that analyse the impact of government subsidies on the energy commodity price market (Hahn & Metcalfe, 2021).

Another research stream analyses the impact of subsidies among companies that invest in pro-environmental energy sources. Government support allows them to reduce their energy costs and improve their competitiveness in the market (Frondel et al., 2010; Blum et al., 2013). The literature also includes studies on the effects of tax credits for the purchase of certain energy-efficient equipment and technologies (Brown et al., 2002; Boyd et al., 2008; Yeatts et al., 2017).

Numerous scientific studies examine the effectiveness of various financial programmes that provide incentives for energy-efficient behaviour and investment. An example is the Australian programme *Renewable Energy Target* (RET) aimed at individuals and companies, under which companies generating renewable energy are compensated for each unit of energy. The programme has been analysed in several papers (Martin & Rice, 2012; Nelson et al., 2013). Nie et al. (2017), with the use of game theory, showed that an increase in total subsidies results in an increase in the number of subsidised companies. What's more, tougher competition results in more companies receiving subsidies. The authors also showed that subsidies per kWh produced have a more beneficial impact on the environment and reach more companies than permanent subsidies and that the environmental effects of subsidies per kWh produced are more effective than permanent subsidies. Some authors confirm that public support is conducive to improving the intensity of R&D (Jiang et al., 2018). Empirical studies also show that public subsidies may contribute to widening disparities in socioeconomic development (Lihtmaa et al., 2018). There are also studies showing that government subsidies for energy efficiency in residential buildings are not effective enough to achieve maximum cost savings (Kaygusuz, 2012).

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One important sector supported by states is the electromobility sector. Based on simulation results, de Santis et al. (2022) proposed an innovative system of financial grants for this sector. By analysing various car segments, they proposed a flexible programme containing incentives for customers in EU countries to use ecological solutions in the field of electromobility. The authors, focusing on the study of the effects of tax incentives on energy efficiency, point out that such incentives provide financial benefits to individuals or organisations that change their patterns of behaviour in the energy market, which consequently contributes to the reduction of greenhouse gas emissions and environmental protection (Stevens, 2010; Kaygusuz, 2012). Markandya et al. (2009) point out that the effectiveness of incentives to purchase energy-saving equipment depends on the wealth and mentality of societies. It has also been shown that tax incentives are a more effective form of promoting energy efficiency than the subsidy system. Villca-Pozo and Gonzales-Bustos (2019) propose a change in the existing regulations governing property tax credits in the Spanish market and demonstrate the effectiveness of linking income tax to the increase in the energy efficiency of homes. Nevertheless, some studies draw attention to the low effectiveness of energy taxes in promoting green activities (Nadel, 2012). Bhandary et al. (2021) point out that tax incentives can be costly to implement and can place a heavy burden on public finances, especially if not properly targeted. It is clear that proposals for government subsidies and tax solutions depend on the specific economy, stem from the strength of its links with fossil fuels, and depend on the availability of renewable energy sources and existing environmental patterns among consumers, companies and organisations.

Materials and Methods

Concept and research plan – Proposed original model of rewarding local government units that shape innovative energy strategies

The result of the research is an algorithm, according to which municipalities that meet the established criteria in terms of:

- effects of saving energy from non-renewable sources,
- effectiveness of replacing non-ecological energy sources by RES,
- concern for the quality of the natural environment, especially air in the area administered by them will receive a financial bonus in the form of partial reimbursement of expenses incurred for the electricity used in the current annual accounting period.

This algorithm, thanks to its motivating financial function, will permit achieving real benefits in the field of broadly understood energy efficiency at the local level and, ultimately, also at the national level. It will also enable a meaningful impact on the energy efficiency of municipalities. Due to the problem of complexity, the most important issue is the development and appropriate selection of a set of monitoring tools, which should synthetically present measurable effects of an energy policy in relation to the entire unit (municipality), which also allows for better identification of significant trends. Despite the presence of many specific conditions in the analysed area, the cognitive values of the proposed measures have a simplified value, purified of some phenomena that may have an impact, because the aim of the undertaken research is to obtain transparent effects conducive to improving energy efficiency. Therefore, one partial objective of the research is also to assess the impact of selected factors on the amount of energy consumption, and the development of energy efficiency meters, which are a response to the requirements related to monitoring energy management and controlling its management towards sustainable development required at the level of the European Union and the International Energy Agency (IEA / OECD). The research is also consistent with the actions of the National Energy and Climate Plan and other public programmes and instruments in this field.

The amount of financial bonus received by local government units will depend on the effects achieved in the above-mentioned areas. The guiding principle is that the greater the savings the municipality made in the previous accounting period in energy consumption and the greater the share of RES in the structure of energy consumed by it, the greater the improvement in the quality of the natural environment of the municipality, and therefore the greater the financial bonus it can expect from the state government.

The strength of models designed to determine savings contributions lies in an eclectic selection of measures because the proposed indicators simultaneously determine positive changes for the

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entire entity and the area it administers. It should be noted that the general acceptance by local government units of a model that brings them measurable benefits will allow them to achieve the intended goal in terms of energy savings, the use of alternative source technologies, and obtaining clean energy without the use of conventional raw material carriers on a national scale.

The crux of the proposed tool is the distribution of a bonus aimed at local authorities as a type of remuneration, a bonus awarded for an effective municipal policy in the field of optimisation of energy use in line with the concept of sustainable development. Three elements are taken into account here:

- assessment of the effectiveness of local authorities' energy-saving measures from traditional sources,
- scale of local government investment in renewable energy sources,
- effectiveness of the municipality's activities in reducing air pollution.

The final amount of the bonus is the result of the municipality's performance in these three areas on the one hand and, on the other, will depend on the amount of the municipality's energy consumption costs and its investment expenditure on RES in the last year. Making the amount of the bonus dependent on the scale of expenditure ensures a fair distribution of bonuses that reflects the municipality's potential and its commitment to sustainable energy optimisation. The amount of the bonus in absolute terms should be an aggregate of the variables listed in Table 1.

Table 1. Operationalisation of explanatory variables

Variable name	Operationalisation of a variable	Variable type
WZ_e – electricity utilisation rate	The indicator is calculated as a relative increase in period t in relation to the next period t+1	Continuous variable expressed in %
WZ_g – utilisation rate of gas energy	The indicator is calculated as a relative increase in period t in relation to the next period t+1	Continuous variable expressed in %
WR_{em} – reduction rate of pollutant emissions	The indicator is calculated as the absolute increase in period t in relation to the next period t+1	A continuous variable expressed as the number of days in a year when permissible air pollution concentrations were exceeded in period t
WW_{oze} – RES utilisation rate	The indicator is calculated as a relative increase in period t in relation to the next period t+1	Continuous variable expressed in %
K_{et} – cost of electricity consumption	Cost calculated as the total sum of paid electricity invoices in period t	Continuous variable expressed in PLN
K_{gt} – cost of gas energy consumption	Cost calculated as the total sum of paid invoices for gas energy in period t	Continuous variable expressed in PLN
$W_{oze\,t}$ – investment expenditure on RES in period t	The sum of total investment expenditure on renewable energy based on invoices in period t	Continuous variable expressed in PLN

The authors therefore propose that the bonus paid to local authorities should be an aggregate calculated according to the following formula:

$$Bonus = f_1(WZ_e) \times K_{e_t} + f_2(WZ_g) \times K_{g_t} + f_3(WW_{oze}) \times W_{oze_t} + f_4(WR_{em}) \times W_{oze_t} \quad (1)$$

where:

$f_1(WZ_e)$ – function assigning a partial bonus for savings in electricity consumption in period t relative to the following period t+1 [%],

$f_2(WZ_g)$ – function assigning a partial bonus for savings in gas energy consumption in period t relative to the following period t+1 [%],

$f_3(WW_{oze})$ – function assigning a partial bonus for RES use in period t relative to the following period t+1 [%],

$f_4(WR_{em})$ – function assigning a partial bonus for pollution reduction in period t relative to the following period t+1 [%].

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This study examines fossil fuel energy saving policies only in respect of two common types of fossil fuel energy: electricity and gas, as these were the predominant forms of energy generation used by the surveyed local authorities. If necessary, formula (1) of the bonus can be extended further to include other types of energy sources (geothermal, etc.). A sigmoid Gompertz curve was proposed for the modelling of the f1-f4 function of granting partial bonuses, whose shape roughly corresponds to the payments curve:

- the bonus increases with the increase in the level of energy consumption savings (functions f1, f2), the degree of RES utilisation (function f3) and the progress in the reduction of pollutant emissions (function f4),
- the bonus is capped by maximum levels expressed either by a certain percentage of energy consumption costs (functions f1, f2) or by a certain percentage of RES investment expenditure (functions f3, f4), which allows better control of bonus payments and protects the budget allocated to the proposed programme from overspending. The Gompertz model used to estimate functions f1-f4 is described by the following formula:

$$f(x) = Aexp\left(-exp\left(-B(x-C)\right)\right) + D \tag{2}$$

where:
A, B, C, D – Gompertz function coefficients, where:
A – phenomenon saturation level,
C – scale coefficient,
D – constant coefficient,
x – unknown value.

The Gomertz model is used, among others, for demographic purposes and also in economic sciences, e.g. for modelling the diffusion of innovations, i.e. phenomena occurring over time according to an S-curve pattern (Meade & Islam, 2006; Lei & Zhang, 2004). The Gompertz function is particularly useful when the phenomenon under study is characterised by a slow growth rate at first, then the rate increases rapidly, followed by a decrease and the level of the phenomenon stabilises and its growth dynamics ceases. The upper asymptote of function (1) is given by the formula: y= A+B, while the inflection point – at the coordinates of (C; $A/e + D$). The observed distribution of bonus values that local government units would expect in return for greater involvement in activities supporting sustainable development is close to an S-shaped curve, so the use of a function such as the Gomertz function seems justified. This function reflects the 'motivational' nature of the entire tool only to a certain extent of the municipality's performance in improving the parameters exemplified in the principles of sustainable development, and after exceeding certain thresholds of energy or RES use indicators, it 'freezes' the amount of the partial bonus at a certain near-constant level, which is in line with the expectations of experts and, at the same time, of those responsible for public finances (potential creators of such a project). On the other hand, the Gompertz curve may later generate a 'negative' partial bonus in a situation where the municipality does not show progress in its implementation of a programme based on the principle of sustainable development, which will be expressed in negative values of energy use indicators, RES utilisation or the pollutant emission rate. It can be interpreted as a kind of 'warning signal' for the municipality's lack of positive effects in the area in question.

Results of the Research

The data for constructing the TSU bonus tool were obtained from a questionnaire survey conducted on a sample of the 43 largest municipalities in Poland. Respondents provided information based on the notion of municipality in the sense of municipality/city office–institution (i.e. municipal and social infrastructure facilities over which municipality directly holds authority and covers the costs of, e.g. the office building, buildings owned by the municipality, street lighting, etc.), i.e. it refers to the subject scope – expenditure is directly reflected in the budget of a given territorial self-government unit (municipality/city). At the same time, respondents specified a minimum bonus (%), which would motivate them to undertake activities in the relevant areas of efficiency.

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The estimation of the parameters of the Gompertz function was carried out separately in the 4 aforementioned assessment areas of effectiveness of pro-environmental measures: electricity, gas energy, investments in RES and air quality on the basis of data obtained from a survey conducted among 43 Polish cities.

Table 2. Parameters of the Gompertz function used in the model of bonus distribution

Parameter	A	B	C	D
$f_1(WZ_e)$				
Coefficient	6.128	0.436	3.282	-0.067
Standard error	0.031	0.007	0.030	0.024
t-Stat	198.055	62.475	111.193	-2.832
p-value	0.000	0.000	0.000	0.007
R^2	0.967			
$f_2(WZ_g)$				
Coefficient	6.233	0.430	3.333	-0.085
Standard error	0.035	0.007	0.033	0.027
t-Stat	178.005	57.617	99.628	-3.181
p-value	0.000	0.000	0.000	0.003
R^2	0.971			
$f_3(WW_{oze})$				
Coefficient	5.248	0.236	7.257	-0.180
Standard error	0.027	0.002	0.041	0.023
t-Stat	196.626	101.063	178.786	-7.806
p-value	0.000	0.000	0.000	0.000
R^2	0.982			
$f_4(WR_{em})$				
Coefficient	3.122	0.270	7.455	-0.114
Standard error	0.021	0.005	0.038	0.016
t-Stat	145.873	53.873	195.152	-7.178
p-value	0.000	0.000	0.000	0.000
R^2	0.913			

All parameters appear in functions f_1-f_4 are statistically significant at a significance level of 0.01, and the levels of the coefficients of determination in all cases exceed 95%, which proves that the observed outcomes are at least well replicated by the model. The highest value of the horizontal asymptote is for functions modelling indicators WZ_e and WZ_g (around 0.06 = 6%), while, in the case of the function modelling the indicator , that totals about 5%, or 3% respectively for the function modelling the indicator WR_{em}. It follows that local government units see the greatest potential for short-term action towards implementing the principles of sustainable development in the area of improving energy efficiency in non-renewable energy. Municipalities expect the largest bonuses from that source. They least expect the possibility of rapid improvement in air quality (the level of the upper horizontal asymptote 0.03). These are reasonable expectations because measures and investments to improve air quality usually have long-term effects and usually take years to yield results, while the proposed tool distributing bonuses for effective implementation of sustainable development principles has an ad hoc, short-term focus. The estimated models f_1-f_4 were then used to

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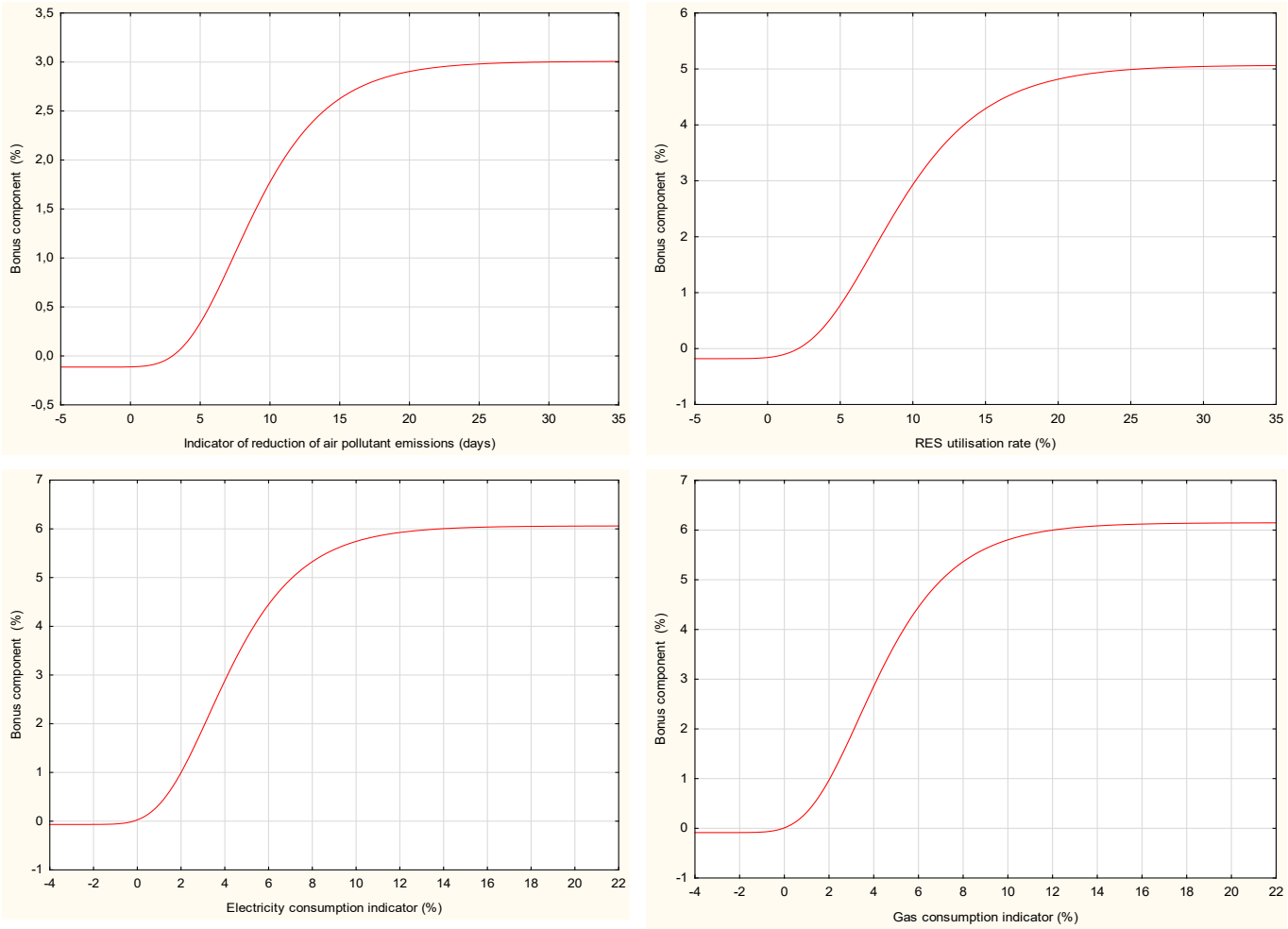

Figure 1. Gompertza function graphs used in the bonus distribution model

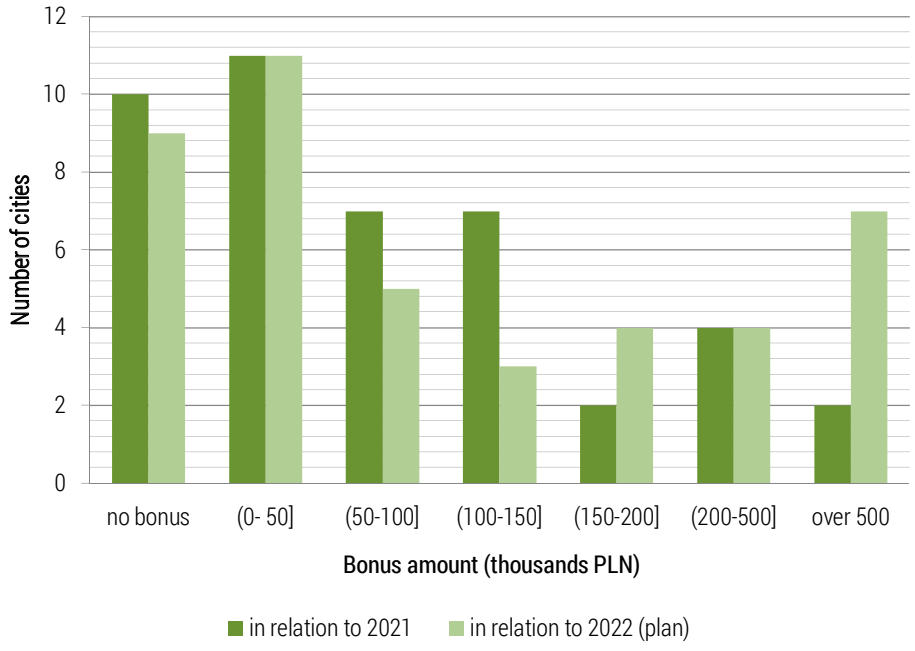

Figure 2. Observed distribution of energy efficiency bonuses in 2021 and 2022 (plan)

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calculate efficiency bonuses for municipalities in the field of sustainable development. The results of a survey were used here, in which the respondent-STUs provided, among other things, the costs of energy consumption (electricity and gas) and their expenditure on RES in 2020-2022. These figures are necessary to make an appropriate simulation of the number of bonuses in absolute terms that the surveyed STUs could rely on. The distribution of bonus sums in millions of zlotys for energy efficiency in 2021 and 2022 is charted in Figure 2.

The distribution of the projected premiums paid to the individual LGUs that took part in the survey shows a clear right-handed asymmetry. The simulations conducted for both years are dominated by cities that would receive a bonus of up to PLN 50,000. Statistically, one in four cities would receive a bonus of this amount. The second largest group are cities that would not receive a bonus (more precisely, had a negative bonus result). Their share among all surveyed LGUs was 23% for efficiency in 2021 and about 21% for energy efficiency in 2022, respectively. Statistically, therefore, more than one in 5 cities did not show adequate overall progress in the relevant efficiency areas that would guarantee the payment of any bonus in accordance with the proposed algorithm. The next largest group was made up of cities that would receive a bonus for efficiency in 2021 of between PLN 50,000 and 100,000 or between PLN 100,000 and 150,000. The share of such cities was about 16% in each group. The same share was also held by cities that would receive a bonus of more than PLN 0.5 million for energy efficiency in 2022. Descriptive statistics of the distribution of simulated bonus amounts are presented in Table 3. It shows that the average bonus amount that an LGU could receive for energy efficiency in 2022 would be about PLN 345.3 thousand, and would be almost twice as high as the year before.

Table 3. Descriptive statistics in the distribution of bonus amounts

Descriptive statistics	Bonus for energy efficiency	
	Relative to 2021	Relative to 2022
Mean (thousands PLN)	153,966	345,327
Standard error (thousands PLN)	38,705	99,735
Median (thousands PLN)	74,267	118,125
Standard Deviation (thousands PLN)	222,346	581,550
Kurtosis	8,084	5,755
Skewness	2,618	2,486

This means that municipalities are planning to improve their efficiency in implementing sustainable development principles. This is also indicated by the value of the median bonuses: considering 2022, half of the municipalities could count on a bonus of at least PLN 118.1 thousand, while according to the efficiency calculated a year earlier, this threshold for half of the municipalities would be only about PLN 74.3 thousand. A comparison of standard deviations and average bonus amounts indicates that bonuses paid for efficiency in 2022 would be significantly more varied in amount than a year earlier. While performing simulations on the basis of average values of the projected amount of bonuses relative to 2022, it should be expected that for the central budget the cost of the project, taking into account all the LGUs in Poland (a total of 2477 municipalities), should not exceed PLN 1 billion. However, the real benefits resulting from reducing energy consumption, increasing the share of RES, and reducing CO_2 emissions, according to estimates, would be much higher than the expenditures incurred. It should be emphasised that the implementation of the project will also bring real benefits to local government units and, according to assessments, it will properly fulfil the motivational function for LGUs. To sum up, the implementation of the project based on the described algorithm will launch a system of positive feedback loops leading to the transformation of sustainable economic development based on modern, highly efficient investments in the energy system at the level of local governments using high-efficiency incentive mechanisms.

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Conclusion and Discussion

Novelty of the research and relevance of project results for the development of the scientific discipline

The research hypotheses were confirmed in light of the research results. The Gompertz curve describes very well the empirical S-shaped distribution of bonus amounts, and the upper partial levels of bonus expectations do not exceed 7% of the costs incurred in relation to the reference period in the considered areas of the effectiveness of pro-environmental activities. Hypothesis H2 was also positively verified: modelling using the Gompertz curve shows local government units' expectations regarding the partial bonus in the area of reducing energy consumption from fossil fuels. Hypothesis H3 was also empirically confirmed: the percentage of local government units with high expectations regarding the amount of the bonus is lower compared to the percentage of cities with lower expectations regarding the amount of the bonus. This means that the amount of the bonus in absolute terms will not be too much of a burden on the state budget.

The proposed tool for distributing bonuses for energy efficiency was built on survey data obtained from LGUs located in large cities, whose potential and priorities for action may differ from those represented by rural municipalities. For this reason, generalising the results of this study to all LGUs should be approached with caution. Nonetheless, the bonus assignment tool may be useful for other LGUs, too, as long as the estimation of function f_1-f_4 takes place on the basis of data obtained from representatives of all types of municipalities in Poland. Thus, the advantage of our tool lies in its flexibility and ease of adaptation to current data. Its implementation will be an important factor in motivating municipalities to be more diligent and effective in implementing the principles of sustainable development, especially in the area of energy use. The design of the tool allows control of the upper limit of expenditures transferred from the central budget to municipalities, which is important in conditions of the need to maintain budgetary discipline. On the other hand, however, it is necessary to bear in mind the redistributive role of the bonus allocation algorithm. By improving their energy efficiency, municipalities aim to reduce the consumption of energy from non-renewable sources, and the funds saved as a result can be used to implement other activities important to residents. It is also important to bear in mind the less tangible effects of the motivating role of the proposed tool: by trying to improve the pollution index, municipalities improve the quality of life of their residents, increase their well-being and improve the health of the municipal population.

Based on the above literature review, it can be concluded that researchers usually limit themselves to analysing the effects of government programmes on energy efficiency in relation to companies, organisations and consumers. On the other hand, there are few effective programmes to support local government units in activating their zero-emission policies, and there is a lack of comprehensive and reliable analyses of the benefits of such programmes in the short- and medium-term. This is not only about short-term benefits for the recipients of support programmes but also benefits for the economy, the energy sector, the central budget and the environment. Therefore, there exists a serious research gap, which the authors of this article try to fill.

The proposal centres on a flexible financial support tool dedicated to local government units (LGUs), which will take into account their capabilities of achieving a net-zero economy while motivating them to take pro-ecological actions. This is possible owing to the design of the algorithm that will allocate support according to the degree of energy efficiency, an algorithm built on the basis of the results of surveys conducted directly among local government units. The strength of the proposed tool lies in its design based on econometric models calculating the bonus granted to LGUs depending on, e.g. reduction in the pollutant emission index, the RES investment expenditure index, and reduction in the energy consumption rate. Detailed simulation analyses make it possible to assess the potential benefits of implementing this tool. Studies show that economic and climate benefits will be very significant and will far outweigh the costs incurred in implementing the programme. This is the first proposal of its kind for a tool improving the energy efficiency of LGUs in Poland that was developed using the scientific method (econometric modelling based on efficiency indicators calculated from survey data), which meets the objective problems currently occurring in the EU energy market.

The proposed concept may be an inspiration to build similar solutions in other EU countries, supporting their aspirations to achieve zero-emission growth, improve the energy balance, reduce

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the share of non-renewable energy sources, reduce CO_2 emissions and thus implement EU directives requiring that member states meet their obligation to achieve certain energy efficiency parameters. It will also provide an open forum for international scientific discourse and the exchange of experience of both scientists and energy experts on possible solutions to improve the structure of energy sources used in different countries. It should be borne in mind that the need to adapt to the relevant EU directives concerns not only Poland, but also other EU Member States, and the energy crisis exacerbated by the current armed conflict in Europe has only confirmed the need to develop ways of immediate and long-term policy that will improve the situation. The scientific research proposed here can be treated as one of the elements serving such solutions.

The contribution of the authors

Conception, M.S. and K.W.; literature review, M.S. and K.W.; acquisition of data, M.S. and K.W.; analysis and interpretation of data, M.S. and K.W.; research, M.S. and K.W.

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Marcin SALAMAGA • Krzysztof WĄSOWICZ

MODELE STYMULOWANIA EFEKTYWNOŚCI ENERGETYCZNEJ JST JAKO ELEMENTU KSZTAŁTUJĄCEGO ZRÓWNOWAŻONY ROZWÓJ WSPÓŁCZESNEJ GOSPODARKI

STRESZCZENIE: Celem artykułu jest przedstawienie konstrukcji narzędzia motywującego jednostki samorządu terytorialnego (JST) do wprowadzenia polityki oszczędzania energii ze źródeł tradycyjnych i zastępowania jej źródłami odnawialnymi. Algorytm alokacji premii zbudowano w oparciu o modelowanie ekonometryczne na podstawie wyników ankiety przeprowadzonej wśród JST. Badanie pozwala na zebranie danych umożliwiających tworzenie wskaźników efektywności energetycznej, które odgrywają kluczową rolę w konstrukcji mechanizmu premiowego JST. Mocną stroną proponowanego narzędzia jest jego konstrukcja oparta na modelach obliczających wysokość premii przyznawanej JST w zależności m.in. zmniejszenie wskaźnika emisji zanieczyszczeń, wskaźnika wydatków inwestycyjnych w OZE, zmniejszenie wskaźnika zużycia energii. To pierwsza tego typu propozycja narzędzia poprawy efektywności energetycznej JST w Polsce, uzyskiwana metodą naukową.

SŁOWA KLUCZOWE: efektywność energetyczna gmin, ekonometryczny model premiowania JST, mechanizmy wsparcia transformacji energetycznej, rozwój zrównoważony w gminie

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