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DIFFUSION PROCESS OF ECO-INNOVATION IN LOCAL GOVERNMENT

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ABSTRACT: The purpose of this article is to examine the diffusion of eco-innovations in selected local government units. A qualitative approach was applied, using case studies to analyse local revitalisation efforts and pro-environmental initiatives. Findings show that such activities measurably improve residents' quality of life and environmental conditions. Despite these benefits, progress is often hindered by rigid legal frameworks. Practical implications include recommending the enhancement of current strategies by integrating technologies such as solar energy and developing local sustainability indicators. Socially, local initiatives foster community engagement and environmental awareness. The originality of this study lies in its focus on eco-innovation diffusion driven by local governments, rather than the business sector. The article highlights the value of empowering municipalities to act as key agents of sustainable development.

KEYWORDS: eco-innovation, territorial self-government units, diffusion of change

Introduction

As environmental sustainability becomes an urgent global priority, local authorities increasingly recognise the need to implement eco-innovative solutions to address ecological challenges within their jurisdictions. Eco-innovation, defined as the development and application of new products, processes, or business models aimed at reducing environmental impact, has become a key tool to support sustainable growth. Local authorities, at the interface between government and community, play a crucial role in implementing eco-innovations that are tailored to the specific needs and capacities of their regions.

In this context, it becomes evident that eco-innovation in local government should be understood within the broader framework of community-based environmental action. Territorial self-government units in Poland are equipped with a set of legal instruments that enable them to both protect the environment and shape local development policy in line with the principles of sustainable development. These tools include development strategies, environmental protection programs, low-emission economy plans, spatial development studies, and local zoning plans. Implementation of the objectives outlined in these strategic documents has translated into substantial financial commitment: in 2020 alone, Polish local governments allocated PLN 17.8 billion – accounting for 6.9% of their total expenditures – towards environmental protection and municipal management, with municipalities providing the overwhelming majority of this funding (98.8%).

This article aims to analyse how local governments implement eco-innovations and assess their impact on sustainable development, social well-being, and regional resilience. This article examines selected examples of eco-innovation initiatives undertaken by local governments, analysing how such efforts contribute to environmental sustainability, improve quality of life, and support regional economies. The analysis highlights the significant and growing involvement of municipalities in environmental infrastructure projects, often supported by European Union structural funds and guided by EU environmental policies. Moreover, the role of social factors – such as public awareness, cultural attitudes, and social capital – is recognised as a critical component in enhancing the capacity for innovation at the local level. Ultimately, the findings point to a diverse array of strategies that exemplify best practices in eco-innovation diffusion and provide practical insights for broader application across different territorial units.

An overview of the literature

Eco-innovations in local government should be viewed within the broader context of local community engagement in environmental protection. As emphasized by the authors of the article "Selected Economic Aspects of Local Government Involvement in Environmental Protection" (Drewnicka et al., 2020, pp. 187-203), territorial self-government has been equipped with legal instruments that enable environmental protection and the shaping of local policy based on the principle of sustainable development. These instruments include: development strategies, environmental protection programs, low-emission economy plans, spatial development conditions and directions studies, and local zoning plans. In implementing the objectives and directions outlined in these documents, in 2020, local government units allocated a total of PLN 17.8 billion from their budgets to environmental protection and municipal economy – amounting to 6.9% of their total expenditures. A significant observation is that 98.8% of this amount originated from municipal budgets. (PLN 17.6 billion). The remainder was covered by county budgets (0.8%, or PLN 137.2 million), and voivodeship budgets (0.4%, or PLN 72.6 million).

Expenditures on environmental protection and municipal management also had the highest share within overall municipal budgets – 8.2%, compared to 0.5% in counties and 0.4% in voivodeships. This highlights the key role of municipalities in shaping local environmental policy. An analysis of municipal budget spending shows that significant financial resources are primarily allocated to wastewater management, water protection, and, since 2013, also to municipal waste management. In recent years, municipalities have also been increasing their expenditures on air quality and climate protection. (Drewnicka et al., 2020, pp. 187-203).

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In 2020, the contribution of municipal local government units to the financing of gross fixed capital formation in environmental protection in Poland was substantial across several key sectors. Specifically, municipalities accounted for (Drewnicka et al., 2020, pp. 187-203):

- 82.9% of expenditures related to the protection of biodiversity and landscape;
- 56.3% in the area of wastewater management and water protection (including 59.5% for sewage network infrastructure, 69.0% for stormwater drainage, 47.9% for wastewater treatment);
- 16.8% in air protection (detailed allocations of: 44.5% for air pollution prevention measures, 79.9% for investments in non-conventional energy sources);
- 15.7% in waste management (including 26.4% for waste collection and transport, 38.4% for selective waste collection systems);
- 13.3% in the area of protection against ionising radiation;
- 11.9% for the protection of surface and groundwater resources;
- 10.7% in noise and vibration reduction efforts, with 69.7% of this related to source modification;
- 3.2% in environmental research and development activities;

  53.5% in other environmental protection-related activities.

In addition, it is important to highlight that (Drewnicka et al., 2020, pp. 187-203):

- with the deepening of municipal autonomy, there has been a corresponding increase in their involvement in the implementation of pro-environmental investment projects;
- structural funds constitute a significant driving force behind ecological investments these funds are primarily accessed by municipalities and enterprises striving to meet standards imposed by European Union institutions;
- in recent years, particular emphasis has been placed on the execution of water supply and sewage infrastructure projects, as well as on tasks related to waste management;
- despite the substantial material outcomes achieved through investments in environmental protection and municipal services, the scale of unmet needs in various regions of the country remains considerable. It may therefore be concluded that municipal self-government units in Poland are playing an increasingly strategic and quantitatively significant role in the development of environmental protection infrastructure. However, it appears that this process would not have been possible without cooperation and support not only in the form of financial resources provided by the European Union, but also through the broader influence of sustainable development policies aimed at environmental protection and improvement, as promoted by EU institutions. As a result, both local government decision-makers and residents are becoming more aware and sensitive to environmental protection issues. (Drewnicka et al., 2020, pp. 187-203).

An important condition determining the capacity to absorb and implement innovation, particularly eco-innovation alongside capital, is the social factor. This is because economic development is largely shaped by values, cultural patterns, social awareness, and attitudes (Hryniewicz, 2004; Harrison & Huntington, 2003; Porter, 2003). To sustain a high level of development dynamics, it is essential to foster innovation awareness among individuals, enhance their knowledge, qualifications, and openness to change, and to develop networks and relationships based on trust and reciprocity fundamental components of social capital (Tuziak, 2013, p. 10). In a model of development that includes the creation of modern and flexible forms of organisation in the social and economic spheres, the ability of society to accept change and innovation plays a key role. (Tuziak, 2019, pp. 138-140).

The first aspect of networked connections relevant to the creation and diffusion of innovation is interaction. In the interactive model of the innovation process, both business and academia can exert bidirectional influence through "push" and "pull" mechanisms. Active partners in these interactions may include small regional enterprises and, increasingly, end users of products, processes, and services. The second, structural-functional aspect of innovation networks involves the clustering of actors. Experience shows that the regions experiencing the highest levels of economic growth tend to form dense networks of enterprises that collaborate closely with each other and with public business support agencies. A third important element of innovation particularly in its spatial (regional) dimension is the creation of networks that enable economic coordination. These are neither strictly hierarchical nor fully market-based structures. Instead, they encourage reciprocity, exchange, and trust-building. Such networked linkages are frequently leveraged by companies operating in innovative environments. Fourth, all elements of an innovative economy are important – from fundamental

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research to the collection, targeted processing, and business use of market-related information. (Tuziak, 2019, pp. 140-141).

The concept of eco-innovation has evolved gradually, expanding and deepening its original definitions while incorporating new dimensions in response to changing environmental and social challenges. Although numerous definitions of innovation exist in the literature, this article presents the most relevant ones for the purposes of the present analysis.

Originally, the concept of eco-innovation was narrowly focused on measuring and minimising negative environmental impacts, particularly through the reduction of greenhouse gas emissions, the improvement of energy efficiency, and the development of renewable energy sources. Fussler and James (1999) emphasise that eco-innovation encompasses various aspects of the natural environment, including water, air, soil, and natural resources (Fussler & James, 1999). Carley and Spapens (2000) broaden this definition by incorporating product design and life cycle management as key components in the implementation of eco-innovation. They also highlight its role in the ecological modernisation of industrial societies by integrating environmental concerns at the earliest stages of product and process design (Carley & Spapens, 2000). P. James (2001, pp. 77-97) introduces a customer- and business-oriented perspective, defining eco-innovation as a product that not only delivers value to both customers and businesses but also significantly reduces its environmental impact. His approach emphasises the balance between environmental and business benefits (Charter & Clark, 2001).

In general, eco-innovation refers to a new or significantly improved product, process, organisational method, or marketing approach that results in environmental benefits when compared to conventional alternatives (GUS, 2009). This definition emphasises the crucial role of eco-innovation across all areas of organisational activity, extending beyond the traditional focus on products and services. According to Kanerva et al. (2009), eco-innovation encompasses any innovation that reduces the negative environmental impact of economic processes, with an emphasis on the overall reduction of environmental harm. The European Commission (European Commission, 2012) defines eco-innovation as any innovation that delivers environmental benefits and business value by reducing negative environmental impacts or improving the efficient use of resources. This definition highlights the broad applicability of eco-innovation, encompassing both technological and non-technological innovations. According to Szpor and Śniegocki, "eco-innovation refers to activity aimed not only at reducing the harmful impact of economic processes on the environment, but also at the productive use of natural resources. Therefore, in addition to the ecological dimension, the economic dimension (cost reduction) and security concerns (reducing dependency on raw material supplies) are equally important. Innovations also play a crucial role in mitigating the effects of environmental change caused by human activity -both in terms of impacts on nature and on the economic system itself. The increasing destabilisation of ecosystems by anthropogenic factors will inevitably translate into mounting pressure from the changing environment on economic systems – the most prominent example being the consequences of climate change and the need to reduce their costs through adaptive measures." (Szpor & Śniegocki, 2012).

The above definitions reflect the evolution of thinking about eco-innovation – from early pro-environmental actions focused primarily on environmental protection (Fussler & James, 1999), through an emphasis on integrated product life cycle management (Carley & Spapens, 2000), to more recent concepts that incorporate sustainable development strategies, resource efficiency, and economic added value (European Commission, 2012).

The authors of this article argue that eco-innovation should be understood as any form of innovation that brings environmental benefits while simultaneously incorporating a social dimension. These are solutions that not only minimise the impact on nature by reducing emissions and their environmental consequences but also respond to the social effects of such emissions. Eco-innovations support social tools by creating new jobs, improving quality of life, and promoting equitable access to resources and technologies sustainably.

The core objective of ecological innovation is therefore to reduce the negative impact of human activity on the environment (anthropopression), enhance the efficiency of natural resource use, and align economic activity with environmental requirements. Eco-innovation encompasses a wide array of elements: products, processes, production technologies, ideas, management methods, legal and institutional regulations, as well as social attitudes and concepts that support innovative pathways for the sustainable development of cities and regions.

The term "diffusion," as Tuziak emphasises, originates in ethnology when used in the context of social phenomena. In that field, it referred to the process of transferring cultural products from highly developed centres and groups to less developed ones, and to the analysis of how entire cultures spread (Makarczyk, 1971, p. 107; Gałęski, 1971, p.16)[1].-

Tarde G. (1895) is considered a precursor of the modern theory of innovation diffusion. He analysed and explained social life and its processes through the lens of simple and universal psychological mechanisms, the most important of which is imitation (Gałęski, 1971, p. 15). Tarde's greatest contribution lies in highlighting the role of opinion leaders – individuals whose behaviours are imitated by other members of a group – and in developing a model of innovation absorption (Gałęski, 1971, p. 16). A crucial factor in the innovation diffusion process is the social environment. Scholars distinguish two categories of social environmental factors that influence the pace, and nature of innovation adoption: (1) the structural characteristics of a given community, which shape the interactions within it, and (2) the behavioral patterns that guide the actions of its members (Makarczyk, 1971, p. 107).

The values and norms accepted within a society can either hinder or accelerate the diffusion of innovation. Acknowledging this, M.E. Rogers (1962, pp. 57-62) developed a dichotomous typology of norms, distinguishing between two ideal types: modern and traditional norms. The characteristics of societies governed by modern norms – as defined in Rogers' model – can be relatively easily identified. These include, for instance, a higher level of technological advancement and a greater appreciation of science compared to traditional societies.

However, Rogers also identified an additional, less frequently analysed yet equally important trait: empathy, or the ability to take on others' perspectives. This capacity is generally more pronounced in modern societies than in traditional ones. In contrast, societies shaped by traditional norms tend to resist innovation more strongly. The extreme form of this conservatism is neophobia – a fear of novelty and any innovation that might disrupt the existing social order (Rogers, 1962, pp. 57-62; as cited in Makarczyk, 1971, p. 111). E.M. Rogers (1983) defined the diffusion of innovations as a process by which an innovation is communicated through specific channels over time among members of a social system. This constitutes a particular form of communication wherein the message pertains to novel ideas. Communication itself is understood as a process in which participants create and exchange information with one another in order to achieve mutual understanding (Rogers, 1983, p. 91).

Rogers further distinguished a set of attributes that constitute the core components of an innovation: Relative advantage refers to the degree to which an innovation is perceived as superior to previous solutions. This attribute – measured through economic performance, prestige, popularity, or user satisfaction – increases the likelihood that the innovation will be rapidly accepted by its target environment.

Compatibility refers to the degree to which an innovation is consistent with existing technologies, solutions, or practices. Innovations that build upon prior experiences or are aligned with previously adopted systems tend to be more readily accepted by their intended users or communities. When an innovation fits well within the existing operational or cultural framework, it faces less resistance and benefits from smoother integration into current routines.

Complexity refers to the degree of difficulty associated with understanding and using an innovation after its introduction. The easier the innovation is to use, the more quickly potential adopters and future imitators are likely to master and integrate it. Simplicity facilitates acceptance, especially among broader user groups.

Trialability indicates the degree to which an innovation is made accessible for preliminary use. When new users are given early access by the provider, they are better positioned to assess its relevance and decide more quickly whether implementation is necessary.

Observability describes the extent to which the results of implementing an innovation are visible and noticeable to others. When the outcomes are clearly observable, potential users are more likely to recognise their value and practical benefits, which enhances confidence and encourages broader

[1] G. Tarde'a (1895), E.M. Rogersa (1962), E. Katza, M.L. Levina, H. Hamiltona (1963), T. Hagerstranda (1967), G.E. Jonesa, (1967), R. Linthona (1975).

adoption. In his seminal work „Diffusion of Innovations", E.M. Rogers (1962, pp. 12-13.) outlined a five-stage model through which individuals or organisations progress when deciding whether to adopt an innovation. These stages provide insight into the cognitive and behavioural process behind diffusion:

- Knowledge – The initial stage, in which the individual becomes aware of the existence of an innovation but lacks detailed information and understanding. At this point, there is often no active search for information.
- Persuasion – The individual begins to show interest in the innovation and actively seeks further information. Emotional and attitudinal responses begin to form during this stage.
- Decision – Based on acquired knowledge and evaluation, the individual forms an opinion and decides to either adopt or reject the innovation. This stage is often regarded as the most critical in the process.
- Implementation – Following a decision to adopt, the innovation is put into use. During this stage, the individual or organisation assesses its effectiveness and adapts it as needed.
- Confirmation – After sustained use and positive experience, the innovation is confirmed as useful. The individual or organisation integrates it fully and continues its use, reinforcing the decision.

The adoption of an innovation can generate both positive and negative consequences. By its very nature, innovation tends to be temporary, particularly in the era of rapid technological advancement, where new solutions are frequently replaced by their successors. According to E.M. Rogers, the consequences of innovation adoption can be classified across three dimensions:

Desirable vs. Undesirable – Desirable consequences are functional outcomes of innovation adoption for the individual or social system. Undesirable consequences refer to dysfunctional effects that may occur in either individual or collective contexts.

Direct vs. Indirect – Direct consequences involve immediate changes in individuals or social systems resulting from the adoption of an innovation. Indirect consequences, on the other hand, are secondary effects that arise from contact with the innovation rather than from its adoption per se.

Anticipated vs. Unanticipated – Anticipated consequences are changes foreseen by individuals or social systems as a result of innovation. Unanticipated consequences are unforeseen outcomes that emerge despite the innovation's intended function.

The law of innovation diffusion describes the process through which new products, technologies, or services are gradually adopted by a market. According to Rogers' model, any innovation must pass through specific adopter categories to achieve widespread success (E.M Rogers 1983, p. 91):

- Innovators (2.5%) – Risk-takers and early experimenters who are eager to try new ideas.
- Early adopters (13.5%) – Individuals who quickly embrace innovations after observing their benefits among innovators.
- Early majority (34%) – A large group that adopts innovations once they become mainstream or socially validated.
- Late majority (34%) – Cautious individuals who wait until innovations become the standard market offering.
- Laggards (16%) – The most resistant group, adopting innovations only when they are no longer avoidable.

Additionally, Frank Bass conceptualised innovation diffusion as a social process unfolding over time, where cumulative adoption increases with time (Klincewicz, 2011, p. 155). As the diffusion process progresses, the total number of adopters grows, generating increasing value. The adoption pattern typically follows a bell-shaped curve, with the number of new adopters rising to a peak and then gradually declining. This pattern is often modelled using a differential equation that mathematically captures the dynamics of adoption over time (Philippas, 2011).

$$\frac{dN(t)}{dt} = \left[p + \frac{q}{m}N(t)\right] * [m - N(t)]. \quad (1)$$

In the Bass Diffusion Model, the process of innovation adoption over time is expressed mathematically, typically using a differential equation. The model includes the following variables and parameters:

- **N(t)** – the cumulative number of innovation adopters at time *t*. The derivative of N(t) to time represents the rate of adoption, i.e., the number of new adopters at a given moment.
- **m** – the market potential or the total number of potential adopters, including both current and future users. The expression *(m – N(t))* therefore indicates the remaining market of potential adopters who have not yet adopted the innovation.

The Bass model assumes that the entire market will eventually adopt the innovation, meaning that N(t) will approach *m* over time.

- **p** – the coefficient of innovation, representing the influence of external factors such as advertising, promotional efforts, or mass media. This coefficient reflects the rate at which individuals adopt an innovation independently of others.
- **q** – the coefficient of imitation, representing the effect of social influence, especially the tendency of individuals to adopt an innovation after observing others doing so. This coefficient captures the internal dynamics of diffusion, such as word-of-mouth and peer influence.

This model helps explain the classic bell-shaped adoption curve observed in many innovation diffusion processes: early adoption is driven primarily by innovators influenced by marketing (p), while the acceleration phase is dominated by imitators responding to social influence (q).

The authors understand the diffusion of eco-innovation as the process through which innovations spread and are widely adopted by enterprises and the broader economy. This process occurs when, following the initial successful implementation of a novel technical, organisational, or environmental solution, such innovations are subsequently embraced by other economic actors. The authors introduce a significant addition to the classical concept of innovation diffusion – namely, the ecological dimension, which, in the context of growing climate awareness and the pursuit of sustainable development, is gaining increasing importance.

This expanded perspective implies that the diffusion process is no longer confined to innovations aimed solely at improving economic or technological efficiency. Instead, it also encompasses solutions that contribute to environmental protection, emission reduction, resource conservation, and energy efficiency enhancement. Within this framework, the diffusion of eco-innovations plays a pivotal role in the transformation of the economy toward a more sustainable operational model.

Once successfully implemented by pioneering enterprises, eco-innovations can establish new market standards, encouraging other entities to replicate and adapt these practices. This process not only fosters technological advancement but also facilitates the development of competitive advantage grounded in environmental responsibility a value increasingly recognized and appreciated by both consumers and investorsA notable contemporary development is the shift in innovation processes including those related to environmental innovation towards the open innovation paradigm, which is gradually replacing the traditional model of closed innovation. This shift reflects the recognition that valuable ideas may originate both within and outside the boundaries of an organisation and can be brought to market from either source (Chesbrough, 2003). These evolving processes are shaped by broader phenomena such as globalisation and networked structures (Jasiński, 2012), which, in turn, give rise to challenges such as global competition, shortened product life cycles, and rapid technological advancement. Collectively, these factors contribute to making innovation processes increasingly cost-intensive and risky.

Innovation diffusion is conceptualised as a form of communication that involves the dissemination of new ideas and is inherently associated with uncertainty. This uncertainty, however, may be mitigated through enhanced access to information. The fundamental components of the system within which diffusion processes take place include: the innovation itself (including ecological innovations), the population of potential adopters, their decision-making processes, and the flow of information about the innovation between producers and users.

Scholars are particularly interested in the rate of diffusion within social systems and the factors that influence it. The rate of diffusion can be understood as the proportion of potential users who adopt an innovation over time. In general terms, the speed of diffusion is determined by the magnitude of positive change the innovation offers to its users, the cost of adoption, and non-economic factors such as the degree to which the innovation aligns with existing values and prior experiences (Neely & Hii, 1998). Among the characteristics of innovations that influence their diffusion, Rogers (1995) identifies the following (Tidd et al., 2006):

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- Relative advantage – the degree to which an innovation is perceived as superior to the idea it replaces.
- Compatibility – the extent to which an innovation is perceived as consistent with existing values, past experiences, and the needs of potential adopters.
- Complexity – the degree to which an innovation is perceived as difficult to understand and implement.
- Trialability – the extent to which an innovation can be experimented with on a limited basis. Observability – the degree to which the results of the innovation are visible to others.

The suitability of a given innovation adoption model depends on the interplay between demand-side and supply-side factors. Among demand-driven models, typically of a statistical nature, the following can be distinguished (Tidd et al., 2006):

1) The Epidemic Model – This model assumes a homogeneous population of potential adopters and posits that innovations spread through direct, interpersonal communication, often within geographically proximate groups. According to this model, the acceleration of innovation adoption depends heavily on effective communication and the provision of clear technical guidance and economic information. It is particularly useful for describing the diffusion of new processes, techniques, and procedures.
2) The Bass Diffusion Model – This model differentiates between two categories of potential adopters: innovators and imitators. Diffusion occurs in a manner akin to an epidemic, resulting in a skewed S-shaped adoption curve due to early adoption by innovators. The model suggests that different marketing strategies are needed to target these distinct adopter groups. The Bass model is particularly suited to explaining the diffusion of consumer products.
3) The Probit Model – This approach assumes that potential adopters possess varying threshold values for the costs and benefits of adopting an innovation. The model suggests that diffusion occurs more rapidly among populations with similar characteristics. In the Probit model, potential adopters are aware of the innovation's value but may delay adoption until perceived benefits exceed a certain threshold.
4) The Bayesian Model – This model posits that a lack of information is the primary barrier to innovation diffusion. Potential early adopters may hold differing beliefs about the value of an innovation, and these beliefs evolve based on the outcomes of experimental adoption efforts. However, because the results of such experimentation are not broadly disseminated, imitation is significantly constrained. Consequently, other potential adopters cannot benefit from these insights. The model implies that better-informed individuals are not necessarily the first to adopt an innovation, challenging a key assumption of earlier models.

The second category of innovation diffusion models comprises those that focus on the supply-side of the process. These models are predominantly sociological in nature, placing greater emphasis on the interactions between demand and supply factors. The following models can be classified within this category (Tidd et al., 2006):

1) The Appropriability Model – This model emphasises the relative advantage of an innovation, focusing almost exclusively on the supply side. It assumes that innovations with sufficient perceived value will be adopted by the market.
2) The Dissemination Model – This approach highlights the availability of information, positing that the existence and accessibility of communication channels are the most critical factors in the diffusion of innovation.
3) The Utilisation Model – This model underscores the importance of reducing barriers to the use of innovation. It takes demand-side aspects into account, particularly the structural and perceptual barriers associated with the adoption and actual application of innovations.
4) The Communication Model – This model stresses the significance of feedback loops between innovation developers and potential users. It recognises that the continuous exchange of information is vital for the refinement and successful diffusion of innovations.

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Research methods

In this chapter, the authors employed a critical literature review and a case study approach to address the research problem. The observation of the rate of eco-innovation diffusion was based on a local program aimed at reducing the negative impact on the local community and natural environment.

The objective of this article is to analyse the processes associated with the diffusion of ecological innovations within selected local government units. To achieve this aim, the following research questions were formulated:

- How did the process of eco-innovation diffusion unfold?
- What were the effects of implementing ecological innovations on residents and the local government?
- What actions should be continued to further facilitate the diffusion process?

The article adopts a dual-method approach. The literature review enabled the identification of key innovation concepts and provided a critical framework for understanding the diffusion of innovations, including environmental innovations. The empirical component is based on a case study of a selected local government unit, involving document analysis, observation of revitalisation activities, and assessment of the environmental outcomes of eco-oriented investments.

The findings highlight the importance of initiatives undertaken to revitalise degraded areas and restore social, economic, and environmental functions at the local level. The data presented indicate the ongoing development of the analysed local authority in implementing new ecological and socially responsible solutions, which may serve as a model and source of inspiration for other municipalities.

Based on the analysis, it was concluded that the examined local government unit, by pursuing defined environmental objectives, has the potential to improve environmental conditions through the use of innovative solutions. However, the legal time constraints imposed on the implementation of these measures reveal a lack of sufficient implementation momentum. Moreover, the analysis of innovation diffusion related to a specific pro-environmental initiative indicates that the social benefits are materialising too slowly in relation to the requirements of existing environmental legislation.

Finally, the following future recommendations were proposed: continued implementation of adopted strategies, including eco-innovations within the studied municipality; consideration of alternative innovation types not previously prioritized – such as solar energy or geothermal sources – which could reduce greenhouse gas emissions while supporting compliance with legal requirements; the need to define sustainable development indicators at the local government level; and the intensification of efforts to accelerate the diffusion of sustainable innovations. Activities related to ecological innovations within the selected local government unit are based on the revitalisation of degraded areas and the restoration of lost social, economic, and environmental components of the local system.

The stimulation of innovation emergence and diffusion – including eco-innovation – plays a significant role in local development policy. Identifying the key determinants that influence innovation processes and proposing effective instruments for their stimulation is essential from the perspective of enhancing the competitiveness of local systems.

Innovativeness constitutes a fundamental pillar of local development, understood as a set of activities aimed at the creative, efficient, and rational use of the material and immaterial resources of a given area, in both economic and social terms. These activities are designed to create conditions for overcoming existing barriers and preventing the emergence of new ones in the medium- and long-term perspective (Kot, 2003).

The demand for innovative actions in local and regional development is growing, particularly in light of the unique developmental conditions that characterise individual territorial units. These conditions call for tailored and context-specific measures, which in turn significantly affect the effectiveness of undertaken initiatives.

Innovation is one of the primary driving forces of economic development and, consequently, one of the key factors contributing to positive economic transformation and the improvement of social well-being.

Innovations, and particularly eco-innovations emerging at the local level, enable a range of benefits and developmental transformations, including the following (Sztando, 2017):

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- The generation of new products, services, and information, as well as the enhancement in quantity, quality, and diversity of existing ones, along with their local application or commercialisation to entities operating beyond the local environment;
- The more comprehensive, autonomous, and collective satisfaction of residents' needs;
- The resolution of local social, economic, and environmental problems, and the prevention of such issues, even when their origins lie beyond the local scale;
- The revitalisation of degraded areas and the restoration of lost social, economic, and environmental elements of the local system;
- The more efficient use of resources required for the aforementioned activities, whether locally available or sourced from outside the locality.

The adaptation of these activities to the system of values shared by the local community and the broader regional or national collectives to which it belongs. Discussions on innovation within local government units in the scholarly literature often refer to the level of innovativeness, and in particular to eco-innovativeness, which may be understood as the capacity of a local authority to engage in the innovation cycle. Given that regions and municipalities are equipped with administrative, planning, and economic instruments that influence the economy, space, and society – and which may also serve as tools for stimulating innovation – innovativeness is increasingly perceived as an integral element of the intra-regional and local policy toolkit (Brol, 2009).

The innovativeness of a territory can result both from market behaviours of economic actors and from the outcomes of development policies implemented by local government units, as well as other policies that influence territorial systems (Brol, 2013). A local development strategy oriented towards innovation constitutes one of the primary drivers of local growth, and should encompass and integrate key dimensions of this development: social, economic, spatial, ecological, and cultural. It should also ensure the effective coordination of investment processes and financial management at the municipal level (Kożuch, 2012; Makieła, 2013).

Local innovation strategies, as instruments for fostering innovativeness and supporting governance transformation, influence the allocation of goods and services intended to meet societal needs. This transformation gives rise to new structures and forms of governance, such as deliberative forums or decision-making systems for political processes. These processes are place-based, inherently tied to specific locations and spatial scales (Moulaert, 2009). They are characterised by territorial embeddedness and contribute to social cohesion (Van Dyck & Van den Broeck, 2013; MacCallum, 2009).

Local communities demonstrate a propensity for innovation, particularly in the spheres of cultural, organisational, and educational innovation, which often require the application of codified and embedded knowledge (Łuczyszyn, 2012).

An important domain in which local innovativeness should be manifested – particularly in the form of eco-innovation – is the management of natural resources. The processes involved in natural resource management include use, protection, and shaping. Use refers to the utilisation of resources within economic activities. Protection involves the undertaking – or avoidance – of actions that enable the preservation or restoration of ecological balance. Shaping refers to the intentional modification of ecosystems and the strategic guidance of their development in such a way that prevents degradation while allowing for the attainment of maximum long-term economic and social benefits (Karpa et al., 2010). Eco-innovations are defined as "new or significantly improved solutions (products, processes, organisational or marketing methods) whose objective is the alternative management of natural resources by the principles of sustainable development ('sustainable development innovations')" (Woźniak, 2021). The primary aim of eco-innovations is to reduce the negative environmental impact of economic activities. However, their implementation also contributes to enhanced competitiveness, innovativeness, and economic growth (Foltynowicz, 2015). In the long term, eco-innovations result in an improved quality of life (Dziedzic & Woźniak, 2013). From the perspective of the entire local system and all dimensions of its development processes, the following preconditions for endogenous innovation can be identified (Stöhr, 1990):

- Social incentives and rewards for individual initiatives and entrepreneurs, particularly those oriented toward generating broader benefits for the local community;
- Institutionalised transfer of information, innovation, and entrepreneurial initiatives from external sources into the community and within it. This may be implemented, for example, through the

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promotion of joint research projects among businesses or the development of a local innovation network for the exchange of knowledge, goods, and services;

- The promotion of cooperation among local entrepreneurs;
- A broader democratisation of decision-making processes.

Among the external conditions that enhance the innovativeness of local systems are the following (Stöhr, 1990):

- Facilitated access to market information, new technologies, innovative forms of organisation and management, and the experiences of other local initiatives;
- Co-financing of regional and local institutions;
- Promotion of individuals and groups with innovation potential at the local level;
- Allocation of key activities, financial resources, and decision-making authority to local agencies;
- Evaluation of the outcomes of implemented actions;
- Promotion of flexible institutional structures at both local and supra-local levels.

The success of Polish local governments has often been attributed to the leadership of elected officials. However, at a certain point, social innovation can no longer be sustainably or effectively produced based solely on the individual capabilities of even the most enlightened leaders. What becomes essential is the capacity to generate eco-innovations that impact the local community, driven by the collective intelligence and shared wisdom of residents and the institutions they create. Local governments are developing their own repositories and networks of best practices, which increasingly include innovation-oriented components. One particularly significant example is the European URBACT network, which focuses on documenting and disseminating urban best practices across Europe. Similar initiatives have been developed on other continents as well. For instance, in Latin America, a specialised database system has been created to register and share social and democratic innovations. A prominent example of such an innovation is the participatory budget, which, although now widely used in Poland and other European countries, was first introduced not in Europe but in Brazil, following the fall of the military dictatorship. It was implemented as a mechanism to empower citizens by enabling them to co-decide on the allocation of public funds for projects they consider important. In Poland, the participatory budget was first introduced in the Tri-City area, where several pioneering initiatives were undertaken. These included the citizens' budget in Sopot, the Forum of Non-Governmental Initiatives in Gdańsk, and the Municipal Laboratory of Social Innovation in Gdynia. Among the list of innovative cities – admittedly based on a subjective perspective – are also Warsaw, Wrocław, Poznań, as well as smaller urban centres such as Dąbrowa Górnicza, Rybnik, Niepołomice, and Cieszyn. Some cities – although this remains relatively rare have begun establishing dedicated organisational units aimed at stimulating the development of social innovations. One of the better-known examples is the aforementioned Laboratory of Social Innovation in Gdynia. A similar initiative is currently being planned in Warsaw, a city with substantial experience in creating such spaces, though this will be the first time they are specifically focused on social innovation. Previous initiatives in Warsaw were mainly oriented toward creative industries or business incubators.

The process of eco-innovation diffusion in local government is illustrated in Figure 1. Examples of eco-innovations implemented at the local government level include: programs for replacing existing residential heating systems, waste management initiatives, and the monitoring of municipal waste streams.

In analysing the implementation dynamics of the program aimed at replacing existing residential heating systems that rely on solid fuels – such as coal, pellet, or eco-pea coal – the authors conclude that the program contributes to undeniable social benefits, most notably through the elimination of low-stack emissions in areas where such pollution originates. Moreover, this program is of particular importance, as eight Polish voivodeships have already introduced legal bans on heating residential buildings with non-certified (classless) stoves. In the following year, residents in 11 voivodeships will be required to stop using class 3 and class 4 tiled stoves. By 2028, the use of stoves below class 5, as defined by the PN-EN 303-5:2002 standard, will be prohibited throughout almost all of Poland. These requirements stem from the so-called Anti-Smog Act. The pace at which tiled stoves are being replaced with more environmentally friendly heating technologies demonstrates the diffusion dynamics of this specific eco-innovation within society. According to current estimates, over one million tiled stoves powered by solid fuels (1,057,297 units) remain in operation across Poland. In Wrocław alone, it is estimated that 5,117 municipal housing units are still heated using solid fuels. Assuming an aver-

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age of two stoves per unit, this implies that approximately 11,000 solid-fuel stoves are still in use within the city's residential building stock (SmogLab).

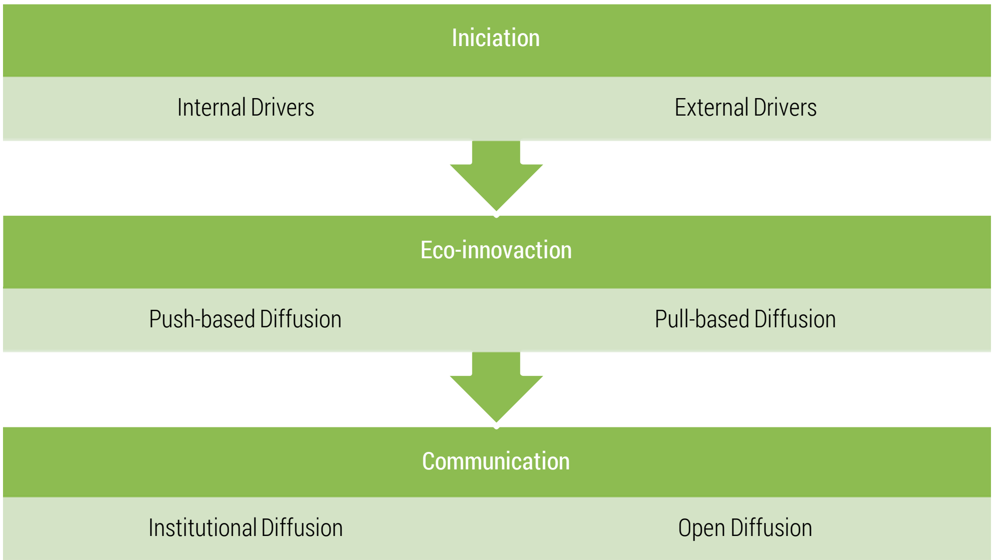

Figure 1. Diffusion process of eco-innovation in local government

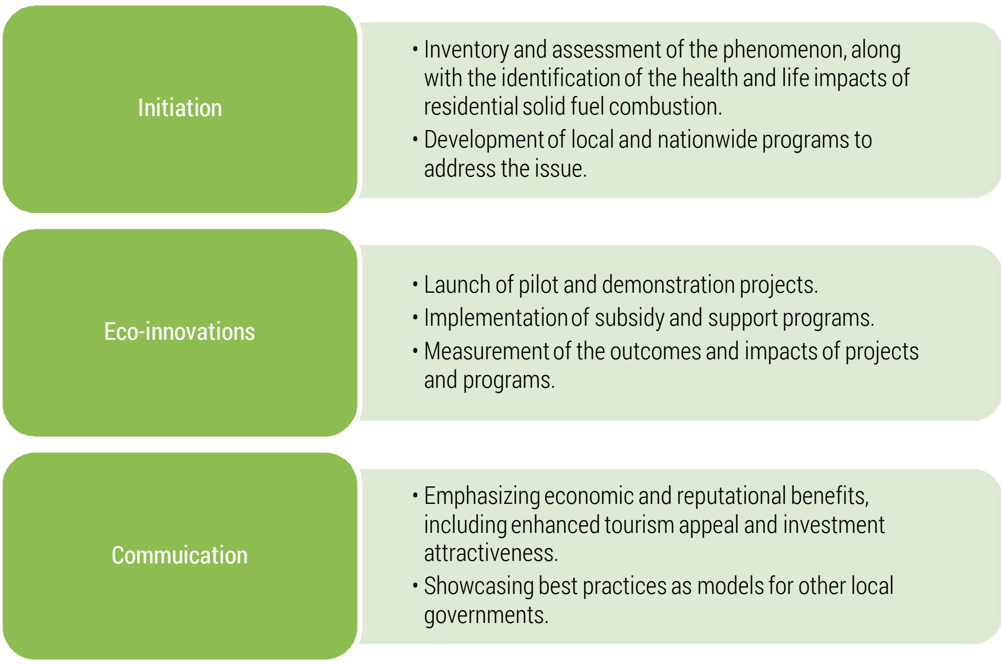

Figure. 2. The Process of Eco-Innovation Diffusion – Replacement of Tiled Stoves: The Case of Wrocław

As an illustrative case, Figure 2 presents the diffusion process of the tiled stove replacement program as an eco-innovation, using the example of the city of Wrocław.[2]

2 Subsidy Programs: 1990s and 2000s – Local government initiatives: – Kraków (from approx. 1995): One of the first local programs aimed at reducing low-stack emissions. Subsidies were provided for replacing coal stoves with gas heating or for connecting households to the district heating network. Activities intensified after 2008, culminating in a ban on burning coal and wood from 2019. – Wrocław, Katowice, Poznań, Warsaw (2000–2010): Local stove replacement programs, funded primarily through municipal budgets or provincial environmental protection funds. 2013–2016 – KAWKA Program (nationwide) Initiators: National Fund for Environmental Protection and Water Management (NFOŚiGW) and Regional Funds (WFOŚiGW), Budget: approx. PLN 800 million, Scope: Replacement of solid fuel stoves with gas, electric, renewable energy systems, or connection to district heating; thermal modernization of buildings Outcomes: Over 40,000 low-emission sources eliminated. 2015–2017 – RYŚ Program (not widely implemented) Planned as

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Table 1 presents the number of tiled stoves replaced in Wrocław between 2013 and 2023. A total of 3,921 tiled stoves have been replaced across the city. This represents a tangible social benefit, primarily contributing to the improvement of air quality in areas where low-stack emissions are no longer generated. However, the rate of diffusion – understood as the proportion of users adopting the innovation over time – remains insufficient, particularly when considered from a non-economic (social) perspective. Despite measurable progress, the pace of adoption does not yet meet the urgency or scale required to address broader environmental and public health challenges.

Table 1. Number of Tiled Stoves Decommissioned in Wrocław, 2014–2023

year	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
number	160	297	397	444	461	441	505	130	693	393

Source: authors' work based on https://zmienpiec.pl/mapa-zlikwidowanych-piecow-wroclaw [28-10-2024].

Another example of the eco-innovation diffusion process is waste management. Regulations adopted in Poland, based on the EU Waste Framework Directive, required municipalities to achieve a 35% rate of preparation for reuse and recycling of municipal waste by the year 2023. According to a study by Paweł Głuszyński, only seven out of the 16 regional capital cities managed to meet this target by less than half. The best performance was recorded in Kielce, where the preparation for reuse and recycling rate reached 48.47% of the total mass of collected waste. In Poznań, the rate was 38.06%, and in Gdańsk, 37.18%. (Głuszczyński, 2023). In 2023, due to a statutory requirement, municipalities in Lower Silesia were obligated to achieve at least a 35% recycling rate for municipal waste. Many municipalities failed to meet this target and were at risk of penalties. Specific examples include: Ziębice Municipality: achieved a recycling rate of 53.53%, exceeding the legal requirement. Stronie Śląskie Municipality: achieved a 29.31% recovery and recycling rate, falling short of the 35% threshold. Among the 16 regional capital cities, only seven met the 35% recycling target. Wrocław Municipality: likely did not meet the required level and may face sanctions; however, detailed data is still being processed:

1) In the field of waste management, three key types of eco-innovation are typically distinguished: Innovations related to waste processing and disposal,
2) Innovations improving the collection of specific waste streams (e.g. product-specific bins, containers, collection vehicles),
3) Organizational innovations.

An innovative urban waste management system should ideally operate within the framework of a circular economy. Such a system is planned for implementation in Wrocław in the near future. The concept was proposed by Fortum, the owner of the city's combined heat and power (CHP) plant, and has also been applied in cities such as Klaipėda (Lithuania) and Brista (Sweden) (Fortum, 2010). The system proposed by Fortum focuses on maximising the utilisation of all raw materials and waste, while minimising energy consumption and greenhouse gas emissions. Efficient waste recovery is aligned with the concept of sustainable waste management and supports increased recycling rates in the city. The system will rely on advanced technological solutions, including the development of a specialised and highly efficient sorting facility, which would ensure the recovery of high-quality secondary raw materials. Another crucial component is a multi-fuel CHP plant, which would use the

a continuation of KAWKA, with a focus on thermal modernization of single-family houses. Ultimately, the program was not launched on a national scale and was replaced by newer solutions, such as "Clean Air". 2018–present – "Clean Air" Program (largest to date), Launched: September 2018 Budget: over PLN 100 billion (multi-year funding plan), Scope: Replacement of outdated heating systems ("kopciuchy") with modern systems (gas, heat pumps, RES), thermal modernization of single-family homes; includes grants and tax incentives Significance: The largest environmental program in Poland's history. 2020–present – "Stop Smog" Program, Objective: Support for low-income households in replacing heating systems and thermal modernization, Implementation: By municipalities, in cooperation with the NFOŚiGW, Budget: approx. PLN 1.2 billion (multi-year plan). 2020–present – Local supplementary and protective programs. Many cities have introduced additional subsidies and support mechanisms, including Warsaw, Łódź, Gliwice, and Gdańsk, offering: Supplementary grants, Tax exemptions, Free removal of outdated stoves, and other forms of assistance.

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residual waste remaining after sorting as fuel, enabling the efficient recovery of embedded Energy (http://portalkomunalny.pl/... (source, accessed: 15.05.2025). A waste management system organised in this way would contribute to minimising the volume of waste sent to landfills. However, the regional leader in this domain is Kudowa-Zdrój, a town in Lower Silesia, which had already introduced conscious waste management practices in the 1990s (Figure 3).

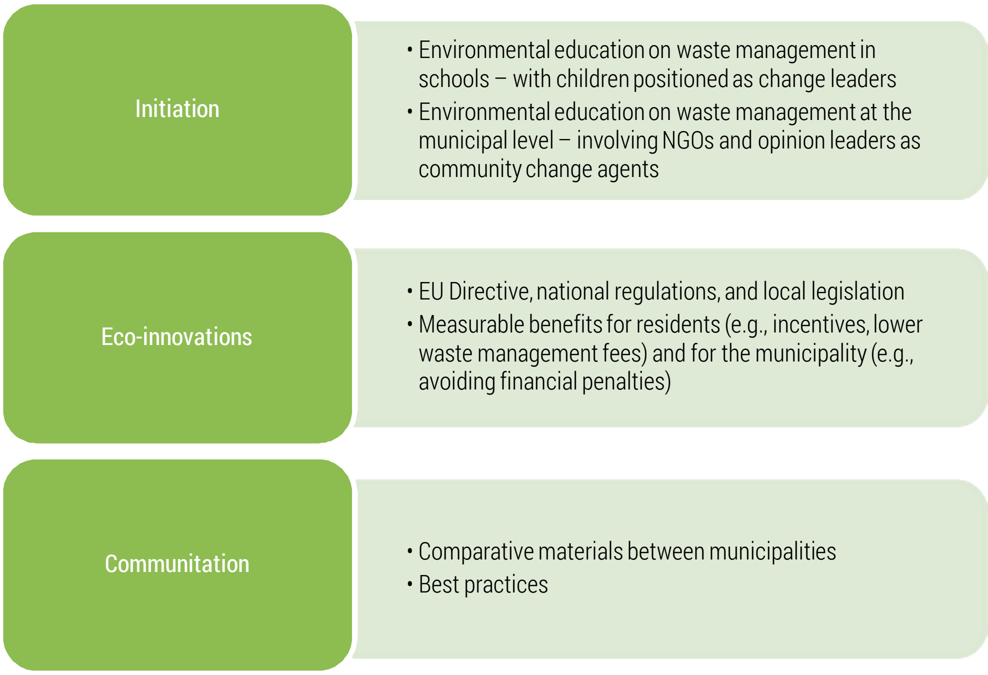

Figure 3. The Process of Eco-Innovation Diffusion: The Case of Waste Management

In the area of municipal waste stream monitoring, special attention should be given to the system implemented by the city of Kielce, which enables precise control of waste mass by fraction. This level of monitoring makes illegal waste handling virtually impossible. By weighing each collected container, the system also allows for the implementation of the "pay-as-you-throw" principle. Although similar technological solutions are applied in many other cities, Kielce's system stands out due to its highly effective integration and data processing capabilities. The system exhibits the key features of a smart city solution. The only element missing for it to be considered a comprehensive model is a feature used in the municipality of Podkowa Leśna, where the local government employs an SMS notification tool to inform property owners, for example, of the need to place out the appropriate waste container in accordance with the waste collection schedule (Drewnicka et al., 2020, p.167.)

Conclusions

Highlighting the importance of eco-innovation in a specific sector within the article can assist in evaluating the effectiveness of actions taken to date and in identifying a strategic direction for future efforts. The data presented point to the continuous development of the examined local government unit in the area of implementing new environmentally and socially oriented solutions, which may serve as an inspiration and example for other municipalities.

Based on the conducted analysis, the authors conclude that the local government unit is pursuing the goals of sustainable development in line with its stated assumptions and has the potential to improve environmental conditions through the adoption of modern solutions. However, legal time constraints on implementation demonstrate that the pace of execution remains insufficient. The diffusion of change for a specific environmental task reveals that the social benefits are being realised too slowly in light of current environmental legislation.

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The research questions posed at the outset of this study have been effectively addressed. The analysis of eco-innovation diffusion processes – particularly in the areas of residential heating system replacement and municipal waste management – provided clear insights into both positive outcomes and existing barriers. The case study findings confirm that eco-innovations can produce tangible environmental and social effects, while also revealing the need for greater institutional support and policy alignment to ensure faster and broader adoption. These results validate the relevance of the research objective and underscore the importance of local innovation capacity in achieving long-term sustainability goals.

In light of the findings presented in this article and the literature review, the following recommendations for future actions are proposed:

- Continuation of adopted sustainable development strategies, including eco-innovation efforts within the examined municipality;
- Consideration of alternative innovations not previously planned, such as solar energy, which could reduce greenhouse gas emissions and facilitate compliance with environmental regulations;
- Establishing measurable indicators for sustainable development at the level of local government units;
- Intensification of efforts to accelerate the diffusion of change;
- Strengthen multi-level cooperation between local governments, regional authorities, NGOs, and private sector actors to improve resource sharing and foster innovation ecosystems;
- Increase public awareness and education on the benefits of eco-innovation through targeted campaigns, community engagement initiatives, and environmental education programs, particularly in schools;
- Introduce incentive mechanisms (e.g. tax reliefs, grants, co-financing) for early adopters of eco-innovations, both individual residents and local businesses;
- Develop digital monitoring and reporting tools (e.g. smart sensors, real-time dashboards) to track the progress of eco-innovation implementation and increase transparency;
- Create a centralised repository of best practices and case studies from across municipalities to facilitate knowledge transfer and replication of effective solutions;
- Establish long-term investment frameworks aligned with sustainability goals, ensuring continuity beyond the short-term political or funding cycles.

The contribution of the authors

Conceptualization, M.P., M.R. and J.T.; literature review, M.P., M.R. and J.T.; methodology, M.P., M.R. and J.T.; formal analysis, M.P., M.R. and J.T.; writing, M.P., M.R. and J.T.; conclusions and discussion, M.P., M.R. and J.T.

The authors have read and agreed to the published version of the manuscript.

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PROCES DYFUZJI EKO-INNOWACJI W SAMORZĄDZIE LOKALNYM

STRESZCZENIE: Zrównoważony rozwój gospodarczy opiera się na ciągłym i efektywnym przepływie zasobów, jednak współczesna działalność człowieka prowadzi do narastających wyzwań środowiskowych i społecznych. Eko-innowacje stanowią kluczowy element transformacji w kierunku zielonej, zasobooszczędnej gospodarki. Celem artykułu jest zbadanie, w jaki sposób wybrane jednostki samorządu terytorialnego wdrażają eko-innowacje oraz jaka jest skuteczność tych działań w kontekście dyfuzji zmian i osiągania celów środowiskowych. Przyjęto podejście jakościowe, łącząc krytyczny przegląd literatury z analizą studium przypadku jednostki samorządu terytorialnego we Wrocławiu. Badanie koncentruje się na lokalnych działaniach rewitalizacyjnych oraz wykorzystaniu technologii sprzyjających zrównoważonemu rozwojowi. Wyniki wskazują, że wdrażanie eko-innowacji sprzyja poprawie jakości życia mieszkańców i wzmacnia lokalną odporność społeczną i środowiskową, choć bywa ograniczane przez sztywne ramy prawne. Wartością dodaną artykułu jest analiza roli samorządów jako aktywnych promotorów zielonej transformacji.

SŁOWA KLUCZOWE: zielona ekonomia, ekoinnowacje, jednostki samorządu terytorialnego, proces dyfuzji