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Urban Bioeconomy in Poland: Experience and Potential

Miejska biogospodarka w Polsce: doświadczenia i potencjał rozwoju

Abstract

The challenges of climate change require decision makers to put the emphasis on a resource-efficient and low-carbon urban economy. This course of action is promoted in the European Union's "Green Deal" strategy. The policy includes a push for a circular economy, including bioeconomy. Urban areas are classified as centres of change: bioeconomy hubs. The aim of the paper is to present prevailing outcomes in the field of urban bioeconomy and to determine the potential of cities in Poland in this area. The potential to develop the urban bioeconomy in Polish cities is significant. In most Polish cities, there is still a significant share of biologically active areas, agricultural land and forests. The potential of biologically active spaces in most Polish cities is underestimated. To this end, the analysis undertaken in this article is based on an investigation of scientific studies, internet sources and other data, including public statistics.

Keywords:
urban agriculture, bioeconomy, circular economy, local development

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Streszczenie

Miasta oraz samorządy lokalne odgrywają kluczową rolę w procesie transformacji w stronę zrównoważonego rozwoju. Współcześnie w związku ze skutkami zmian klimatu nacisk kładzie się na zasobooszczędną i niskoemisyjną gospodarkę miejską. Kierunek ten jest promowany w polityce „Zielonego Ładu" Unii Europejskiej. W politykę tę wpisana jest gospodarka o obiegu zamkniętym, której część stanowi biogospodarka. Obszary miejskie wskazywane są jako kluczowe centra przemian w tym obszarze – tzw. bioeconomy hubs. W artykule zaprezentowano dotychczasowe doświadczenia związane z rozwojem biogospodarki miejskiej oraz określono potencjał polskich miast w tym zakresie. Dokonano tego na podstawie kwerendy opracowań naukowych, źródeł internetowych i innych zebranych danych oraz analizy statystyki publicznej.

Słowa kluczowe:
rolnictwo miejskie, biogospodarka, gospodarka o obiegu zamkniętym, rozwój lokalny

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Introduction

For several decades, sustainable development has been identified as the optimal direction of development on both a macro and micro scale. However, theoretical recognition and political declarations have yet to be clearly translated into practice. We are still much more likely to speak of unsustainable rather than sustainable development both globally and locally. The circular economy (CE), and within it the bioeconomy, is a key element of the sustainable development strategy. Time will tell if it turns out to be a driving force.

The circular economy is one of the policy priorities of the European Union (EU) and an important element of its "Green Deal" strategy. Alongside the circular economy, the concept of bioeconomy is also emerging. In its broadest sense, it is defined as the renewable, sustainable production of goods and services using bioprocesses, biotechnology and biomaterials [**OECD, 2009**; **European Commission, 2012**]. The key aspect of the bioeconomy is eco-innovation, stimulated by a development model that integrates business and environmental objectives. The foundation of biological processes and the basing of bioeconomy on processes and phenomena occurring in nature can be seen in concepts such as circular bioeconomy, bio CE and bio-based CE [**Vanhamäki et al., 2020**]. The bioeconomy consists of many activities that use biological processes and organic matter. It maximises the closed cycle circulation of water, organic matter and energy. Such an economic transformation is resource-efficient and makes a positive contribution to offsetting the greenhouse effect [**Gomez San Juan et al., 2019**]. At the same time, few cities in the world have integrated CE into their daily operations. "In cities, less than 2% of nutrients in food and organic waste (excluding manure) are re-inserted back into nutrient cycles, losing potential value, and adding to future environmental cost" [**Lacy et al., 2020**].

The direction of the bioeconomy as a segment of the circular economy is promoted by the European Union [**European Commission, 2012**; **European Commission, 2018**]. A 2018 renewed EU strategy identifies cities as key hubs of change in this area (bioeconomy hubs). The action plan emphasises the importance of urban organic waste for the production of biodegradable materials and its use for the restoration of degraded land. The intention of regulations concerning biodegradable waste introduced in the European Union is the possibility to use the fertilising properties of bio-fraction for energy purposes, to manage increasing amounts of waste, and at the same time to reduce the emission of greenhouse gases, especially methane. The development of biogas technology as part of the future energy mix of the EU was included in the Smart Sector Integration strategy published in 2020, in which the European Commission presented guidelines for transformation in achieving climate neutrality. The potential for biogas production from waste has been estimated at 2.7% – 3.7% of total EU energy consumption. Another direction of bioeconomy is a food-to-food approach. It is understood as the use of food waste in the process of fertilising crops [**European Commission, 2015**].

Material and research methods

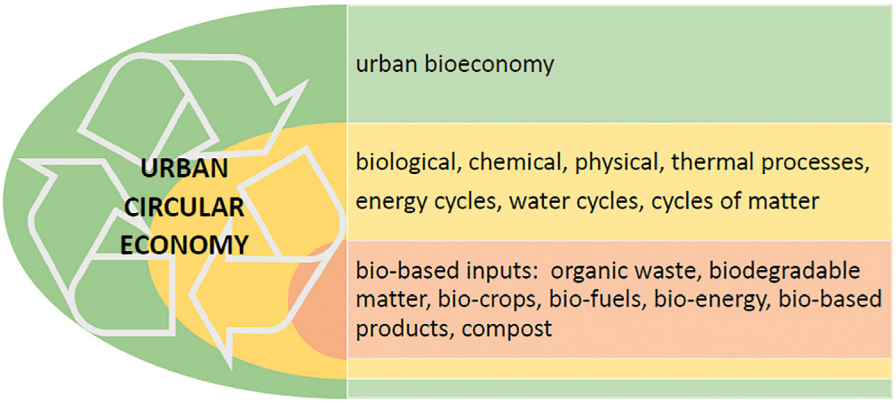
The aim of the paper is to present prevailing outcomes in the field of urban bioeconomy and to determine the potential of cities in Poland in this area. To this end, the analysis undertaken herein is based on an investigation of scientific studies, internet sources and other collected data, including public statistics. The data for cities is divided into large cities (38) with more than 100,000 inhabitants, medium-sized cities (180) with over 20,000 to 100,000 inhabitants, and towns (367) with 5,000 to 20,000 inhabitants in the 2018–2019 period.

The bioeconomy takes advantage of naturally occurring phenomena in nature, or nature-based solutions (NBS). The methods used can be divided into mechanical, biological, chemical, thermal and combined. The production of biogas, mainly biomethane, can be maximised by improving natural conversion processes. Figure 1 provides a schematic view of the urban bioeconomy.

The bioeconomy is combined with so-called blue-green infrastructure (BGI). It affects many natural, social and economic processes. The circulation of water and organic matter allows BGI to be supplied with necessary growth substances. An important direction is to retain water in cities through so-called small retention to optimise water management. Capturing rainwater and managing it onsite in most of these types of treat-

ments is uncomplicated and produces rapid results. BGI includes a system of natural and technical solutions for the management of greenery and water resources. The development of BGI is directly linked to spatial management, which emphasises the need to optimise the share of permeable surfaces in cities, preferably biologically active ones that allow for water infiltration in the ground. Dispersed urban land ownership is an impediment to the introduction of blue-green infrastructure and small-scale retention solutions. What is important is their universality, thanks to which adequate economies of scale can be achieved in an urban setting. The inclusion of residents who implement BGI and small retention elements on their properties is key to the "acupuncture" mechanism. A system dispersed throughout urban space enables the implementation of the sponge city strategy [**Massini, Smith, 2018**; **O'Sullivan, Mell, Clement, 2020**].

Figure 1. Urban bioeconomy



Source: Own study.

An emerging direction in the bioeconomy that is related to urban forests is agroforestry. Agroforestry is land use that combines agricultural activities with the cultivation and care of trees. It is the practice of deliberately integrating tree plantings with cropping systems, as well as with animal husbandry to optimise the results of ecological and economic impacts. Agroforestry is closely related to organic farming. The resulting biodiversity in combination with animal husbandry provides extremely good environmental and economic results.

The renaissance of urban agriculture (city/urban farming) is also part of the bioeconomy. Urban agriculture has many varieties and a diverse scale. From single beehives to large farms that have been absorbed by urbanisation processes into the administrative borders of cities. Forms of urban agriculture include horticulture, forestry, animal husbandry, greenhouse crops, plantations, vineyards, hydroponic crops, orchards, aquaculture, apiculture, edible parks, allotments, container herb and vegetable gardens. There is therefore a great wealth of activities linking the city to agriculture.

Many researchers point to the benefits of incorporating agricultural activities into the city structure. These include **Smit, Nasr, and Ratta** [**2001**]; **De Zeeuw** [**2011**]; **Palej** [**2011**]; **Giecewicz** [**2005**]; and **Szulczewska** [**2012**]. In particular, these voices highlight environmental benefits, which include: increased biodiversity, reduction of urban heat islands, air purification, soil protection and noise reduction. In addition, they singled out social benefits, including healthy local food supplies, recreational areas, and environmental education opportunities. Meanwhile, among the economic benefits they noted the development of jobs and energy resources developed locally.

Among the controversial issues of urban agriculture development, the aspect of urban environmental cleanliness is raised, especially in terms of air and soil pollution, as well water contamination. There are also concerns about the threat to biodiversity from the introduction of alien (introduced) species. The argument for the development of the urban bioeconomy is its complementary nature in opposition to the scepticism surrounding the issue of biocrop competition for industrial food crops. In this case, there is no question of converting arable land into land for biocrops. However, the proliferation of agriculture, especially urban

horticulture as a complement to urban space, can perform a variety of functions, from ecological to social and economic to aesthetic. Urban agriculture in the sense of the integration of agrarian structures within the city can be carried out on "reclaimed" areas in urban spaces, on wastelands, as well as on a micro scale as part of parks or playgrounds. In this last case, it can also perform educational functions.

As a result of production and consumption in situ, urban agriculture also fosters prosumer attitudes. The role of the consumer in this case is more active in relation to the conventional food supply system. In the case of small towns, it can also affect food self-sufficiency, and in the case of larger ones, reduce dependence on external supplies [**European Commission, 2020**; **Cities and Circular Economy for Food, 2019**].

Results

Land and zoning potential for bioeconomy in Polish cities

Bioeconomy initiatives are increasingly appearing in Polish cities. The potential for urban bioeconomy development is closely related to the type of land available. The area of biologically active land in cities is gradually decreasing. Considering the ratio of the share of built-up and urbanised land in the total urban area, the trend in recent years (2010–2018) has shown an average loss of 1.2%. The changes are greatest in large cities, where they amount to 1.8%, and in medium-sized cities and small towns they amount to 1.1% and 0.8% respectively (Main Office of Geodesy and Cartography (GUGiK) data)[1].

An important element of urban spatial policy should be the monitoring of changes in available space, whose permanent element is the analysis and evaluation of the effects of soil sealing and changes in the share of biologically active areas. In the context of urban bioeconomy development, the share of agricultural and forest land and land use is also important.

A conspicuous transformation of urban agricultural areas occurred after the amendment of the Act on Protection of Agricultural and Forest Land in 2008 (Journal of Laws 2004 No. 121 item 1266 as amended). The new regulations removed protection for agricultural land in urban areas and attracted a large wave of farmland purchases and decisions to reclassify such land as building plots. Allotment gardens, which were not in the form of agricultural land, were excluded from the new law. In the following years, urbanisation pressure reduced the area of agricultural land in the spatial structure of cities. However, despite urbanisation processes, Polish cities still have the potential to develop urban agriculture [**Szulczewska, 2012**; **Szymańska et al., 2017**]. There are approximately 176,000 farms within the boundaries of Polish cities. In addition, allotment gardens are popular with residents.

Table 1 presents data on land covered with grass vegetation and agricultural crops within the administrative boundaries of the analysed towns.

Table 1. Land covered with grass vegetation and agricultural crops within the administrative boundaries of cities with more than 5,000 residents in Poland in 2018

Land covered with grass vegetation and agricultural (ha)	Large cities (over 100,000 pop.)	Medium-sized cities (over 20,000–100,000 pop.)	Towns (5,000–20,000 pop.)
Total area (ha)	2114204662	5435830332	28522500744
Average area (ha)	55636965	30199057	77506796
Share of total area (min-max %)	13.43%–61.24%	9.11%–84.69%	5.01%–92.48%
Average share of total area (%)	36.65%	45.29%	53.77%

Source: Own study based on Main Office of Geodesy and Cartography (GUGiK) data.

[1] Built-up and urbanised land includes residential areas, industrial areas, other built-up areas, undeveloped or under-development urbanised areas, recreational and leisure areas, roads, railway areas, other areas for transportation, and fossil land.

As shown in Table 1, the highest average area and average share of grass vegetation and agricultural crops are found in small towns. In this group of cities, the greatest variation is also observed in the value of the average share of such land in relation to city area, ranging from 5.01% to 92.48%. In large cities, the average proportion of this type of land is 56.71%, in medium-sized cities it stands at 79.71%, and in small towns it is 91.32%.

Table 2 presents data on forest and wooded areas within the administrative boundaries of the analysed towns. According to the land classification system, this group includes forest, coppice and woodland.

Table 2. Forest and wooded areas within the administrative boundaries of cities with more than 5,000 residents in Poland in 2018

Forest and wooded areas (ha)	Large cities (over 100,000 pop.)	Medium-sized cities (over 20,000–100,000 pop.)	Towns (5,000–20,000 pop.)
Total area (ha)	1474938440	2960122540	19942153672
Average area (ha)	38814169	16445125	54190635
Share of total area (min-max %)	5.77%–59.84%	1.22%–71.96%	0.62%–85.22%
Average share of total area (%)	25.69%	21.17%	32.05%

Source: Own study based on Main Office of Geodesy and Cartography – GUGiK data.

Small towns have the largest average share of woodland in the total area. Moreover, as in the case of arable crops and grassland, this group shows the greatest variation in the share of such lands, ranging from 0.62% to 85.22%. In large cities, the average share of forest areas is 47.23%, in medium-sized cities it is 62.33%, and in small towns it stands at 82.80%. Moreover, a forest area of less than 10% of total city area was recorded in over 21% of large cities, almost 37% of medium-sized cities, and over 17% of small towns. Table 3 presents data on permanent crops in the analysed cities.

Table 3. Permanent crops within the administrative boundaries of cities with more than 5,000 residents in Poland in 2018

Permanent crops (ha)	Large cities (over 100,000 pop.)	Medium-sized cities (over 20,000–100,000 pop.)	Towns (5,000–20,000 pop.)
Allotment gardens, plantations and orchards			
Total area (ha)	204933474	222864607	676968728
Average area (ha)	5392986	1238137	1839589
Share of total area (min-max %)	0.66%–6.36%	0.02%–17.10%	0.01%–50.11%
Average share of total area (%)	3.63%	3.22%	1.70%
Forest nurseries and ornamental plant nurseries			
Total area (ha)	1704412	3245789	16219213
Average area (ha)	44853	18032	44074
Share of total area (min-max %)	0%–0.22%	0%–0.37%	0%–1.41%
Average share of total area (%)	0.03%	0.03%	0.04%

Source: Own study based on Main Office of Geodesy and Cartography (GUGiK) data.

Permanent crops do not occupy a large area of Polish cities compared with agricultural crops and forest areas. Forest nurseries and ornamental plant nurseries in particular add up to a negligible percentage. At the same time, unlike in the case of agricultural crops and forest areas, the importance of allotment gardens, plantations and orchards is the greatest in regional capitals – NUTS 2 (3.75%). Allotment gardens are sometimes viewed as a kind of compensation for those living in urban areas. For residents, these places constitute enclaves of peace from the hustle and bustle of city life and oases of biodiversity in urban areas. The greatest variation in the share of allotment gardens, plantations and orchards is seen in small towns, where it ranges from 0.01% to 50.11%. In cities at the top of the ranking in terms of the share of forest and ornamental plants nurseries, the average share of allotment gardens, plantations and orchards is as follows: 0.12% in large cities,

0.28% in medium-sized cities, and 0.74% in small towns. For allotment gardens, plantations and orchards, the proportions are 5.78%, 12.7% and 27.21% respectively.

The Act of 13 December 2013 on Family Allotment Gardens (ROD) provides conditions for the development of urban gardening. Article 6 of the law states that "government administration bodies and local government units create conditions for the development of RODs." The vast majority of cities in Poland have family allotment gardens within their borders. All large cities have land classified as allotment gardens. Only two medium-sized cities and 13 small towns do not have such land. Small towns also have the smallest share of RODs, orchards and plantations, at 1.7% on average. However, the proportion varies considerably from one town to another, ranging from 0.01% to 50.11%. The average for the five small towns with the highest proportion of RODs, orchards and plantations is 27.1%. Meanwhile, small towns have the largest share of agricultural cropland, at 53.77% of their total area.

The synergistic effects of urban horticulture development accompany the development of apiculture, which plays an important role in the development of urban biodiversity. The priceless value of bees is related to their ability to pollinate plants. Apiculture is finding adherents in a growing number of Polish cities. The dissemination of apicultural practices is facilitated by emerging social campaigns. Awareness campaigns work best when combined with educational workshops and specific local measures. The increase in the chemicalisation of agriculture means that bee colonies often have better conditions for development in cities than in rural areas. At the same time, honey produced by them is characterised by a wealth of taste and health benefits. Urban apiaries have sprung up in many municipalities around Poland. Many of them are located on rooftops. In Warsaw alone, there are more than 1,000 rooftop apiaries.

Potential of bio-waste and sewage sludge utilisation

An important element of the urban bioeconomy is the management of biodegradable waste. EU rules on the reduction of biodegradable municipal landfill waste are steadily getting stricter. In 2015, the permitted level of biodegradable landfill waste was 50%. In 2018, the figure was 40%, and from 2020 it was 35%.

An important stage enabling the reuse of the bio-fraction is selective collection. At the same time, thanks to segregation, the amount of municipal waste sent to landfills has been reduced. The selective collection of bio-waste is of great importance to the efficiency of the entire system. Bio-waste constitutes about 37% of the total waste mass and is a significant ballast in landfills. It is also a source of greenhouse gas emissions. At the same time, bio-waste has significant energy potential. Biodegradable waste, including food waste, has a high biogas yield of 600 to 800 m3 of biogas from 1 Mg of substrate, on a dry matter basis [**Municipal Waste Management, 2018**]. Waste treatment by composting/fermentation and thermal treatment with energy recovery are of key importance. In addition to the biogas product, the process yields the so-called post-ferment, which is used as fertiliser.

An important aspect of bio-waste utilisation is its management on site. Under the Act on Maintaining Cleanliness and Order in Municipalities (Article 6k Paragraph 4a), owners of properties with single-family houses who compost bio-waste in their home composters can be partially exempted from fees for municipal waste management. Cities are promoting composting among their residents as a way to manage the bio-fraction through fee exemptions and free composting programmes.

In addition to the bio-waste fraction, sewage sludge plays an important role in the urban bioeconomy. Sewage sludge is a by-product of municipal and also industrial wastewater treatment. The dynamic development, construction and expansion of sewage networks and municipal wastewater treatment plants in Polish cities has led to the generation of large amounts of sewage sludge. Based on data from the National Urban Wastewater Treatment Programme, 583,000 tonnes of sewage sludge was generated in 2018, which represents an increase of over 23% in the course of 15 years. In 2018, among the analysed cities, the amount of dry mass of sludge generated in treatment plants was 6,037.8 mg/year in large cities on average, 1,117.2 mg/year in medium-sized cities, and 365.4 mg/year in small towns. At the same time, the scale of sludge management

in cities for agricultural use is relatively small. According to declarations submitted by conurbations (territorial units in wastewater management), as many as 57.6% of them do not use sludge, including 89.5% in the case of large cities. Only 26.1% of the total amount of sewage sludge produced in the analysed cities is used, of which 19.9% is utilised for agricultural purposes, 4.2% for compost and 2% for reclamation. The analysis of the reports also revealed a marginal use of sewage sludge in the total amount of dry mass of sludge produced for land reclamation – 5.6% on average overall, and 7.3% on average for growing plants intended for compost production. Only two large cities used sludge for land reclamation purposes.

Sewage sludge, apart from its natural use as fertiliser, has a high calorific value after undergoing thermal processing [**Burzyńska-Kargul, Suchenia, 2008**]. Moreover, both biodegradable waste and sewage sludge can be an energy resource qualified as renewable energy sources (RES). The development of biogas technologies, especially biomethane, indicates the potential for the development of an urban bioeconomy. The relatively low cost of this technology is also significant. Biomethane can be stored and transported using existing gas infrastructure. Moreover, the technology makes it possible to manage locally produced energy and enables the development of a distributed energy system, which in turn reduces energy transmission losses. Energy security and independence are another important argument in favour of biomethane.

Of the approximately 12.5 million tonnes of municipal waste generated in Poland, about 37% is biodegradable waste. This waste, along with biomass, can be used for energy purposes in renewable energy biogas installations. The same is true of sewage sludge, which has a high calorific value due to the nitrogen and phosphorus compounds it contains. Sludge can be used to produce electricity and heat in processes such as thermal recycling, and organic compounds can be used to enable its fermentation to produce biogas.

Table 4. Municipal biogas and biomass plants within the administrative boundaries of cities with more than 5,000 residents in Poland in 2019

Municipal biogas and biomass plants	
Biogas plants	57
Total capacity of biogas plants (MWh)	52.07
Biomass plants	15
Total capacity of biomass plants (MWh)	598.69

Source: Own study based on Energy Regulatory Office data – URE.

Based on data from the Energy Regulatory Office (URE), 317 RES installations were using biogas nationwide, with a total capacity of 245.4 MWh. In the analysed cities, there were 57 such installations with a total capacity of more than 52 MWh (Table 4). The largest number of installations and the highest power capacity were reported in Poland's central Mazowieckie region: 39 installations with a total capacity of 29 MW. Warsaw and Konin were the leading cities in terms of biogas installation capacity, each with two installations, followed by Gdańsk, Łódź and Wrocław. In 2019, there were 52 biomass RES installations in Poland with a total capacity of 1,492.875 MWh. The analysed cities had 15 units with a total capacity of 598.69 MWh. The biomass installation leaders were Warsaw, Szczecin, Konin, each with two installations, followed by Zabrze and Łódź. These five leading cities accounted for more than 76% of the total capacity produced in municipal biogas plants nationwide.

Conclusions

Modern cities are moving away from the traditional industrial-era division into urban and non-urban functions. There is a visible retreat from the previous exclusion of natural and biological processes in urban areas. One symptom of change is the increasingly visible development of the urban bioeconomy. Although this is expressed in terms of local development innovation, it has multiple roots in both the theory and practice of urban development [**Kleszcz, 2016**]. The attribution of novelty to the bioeconomy is due to the reactivation

of many concepts, followed by activities that weave the natural environment into the urban fabric. This new approach is certainly marked by mobilisation around climate change adaptation issues.

The bioeconomy fits into the growing trend of cities evolving towards a circular economy model of operation. The opportunities for using natural raw materials and processes are comprehensive, and the benefits are economic, social and environmental. Success depends on the widespread use of solutions, and these in turn depend on a radical change in the thinking and actions of all urban users. In developing an urban bioeconomy, it is important to break the stereotype of thinking of rural areas as the sole source of food production. Urban areas can and should complement the food supply function. The urban bioeconomy enables local food production, as well as reduces food losses in the transportation process. Reducing waste is an important though often overlooked argument for developing the urban bioeconomy. The use of local bio-material, instead of artificial fertilisation and spraying with pesticides and herbicides in industrial agriculture, can result in healthier food supplied for cities. A further indirect benefit of local food production at the expense of highly processed imported food is an improvement in public health indicators.

The potential for developing the urban bioeconomy in Polish cities is significant. The strategy for creating urban closed loops should be to link urban agricultural and forestry development with food production, waste and energy management. The urban circular economy requires the transformation of production chains. This to a large extent applies to the hitherto neglected issue of the water cycle in cities and the management of biodegradable waste and sewage sludge.

In most Polish cities, there is still a significant share of biologically active areas, agricultural land and forests. And although such areas are less visible in cities than built-up land, their importance is high. The potential of biologically active spaces in most Polish cities is underestimated even though they occupy a substantial area. Cities do not carry out analyses of the effects of changes in the dynamics of urban land type and assessment of the effects of soil sealing. Also, they do not pursue a viable policy of protecting biologically active land, let alone using its potential in urban development policy making. Likewise, few Polish cities use biomass, biodegradable waste and sewage sludge for local energy management. Cities make little use of sewage sludge for land reclamation and compost production.

The changes taking place in the urban bioeconomy indicate that a number of mechanisms and incentives, as well as the dissemination of good practices, will help build an approach that will steadily gain followers in many Polish cities. Much depends on the political will and the involvement of a range of partners, including in particular local authorities and residents. Time will tell if the circular economy, and within it the bioeconomy, will be an accelerator of sustainable urban development in Poland.

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