International Scientific-Methodical Conference

BALTIC SURVEYING'25

Agricultural Biogas in Poland: A Structural and Spatial Analysis in Comparison with Selected EU Countries

Kurowska Krystyna, Kukolska Małgorzata

University of Warmia and Mazury in Olsztyn Faculty of Geoengineering
Department of Land Management

INTRODUCTION Agricultural biogas plays an increasingly important role in the European Union's energy transition towards decentralized and low-emission energy systems. As a local renewable energy source based on the use of organic waste, it supports the development of circular agriculture and strengthens energy autonomy in rural areas. Despite its potential, the biogas sector in Poland is still underdeveloped compared to countries such as Germany, Denmark or France. The development of agricultural biogas is determined not only by technological and financial factors, but also by spatial and institutional conditions. Spatial planning, infrastructure availability, and the involvement of local stakeholders are key to the successful implementation of biogas projects. In Poland, the sector is hindered by fragmented regulations, weak integration with planning documents and limited administrative capacity at the local level. This study presents a comparative analysis of support mechanisms and spatial conditions for biogas development in Poland and selected EU countries. Based on interdisciplinary methods (policy benchmarking, stakeholder analysis, GIS and PCA), the paper evaluates the effectiveness of national support systems using three synthetic indicators: WEF (financial efficiency), WGT (territorial density), and WES (substrate efficiency).

MATERIALS AND METHODS This study employs an interdisciplinary and territorial research approach, combining tools from spatial planning, socio-economic geography, environmental economics, and public policy analysis. The methodological design is based on comparative case study logic and spatial diagnostics, aimed at evaluating institutional effectiveness and spatial patterns of agricultural biogas development.
Five countries were included in the analysis: Poland, Germany, Denmark, France, and the Czech Republic. These countries represent different stages of biogas sector maturity and policy models. The comparison allows for benchmarking Poland's system against varied institutional and spatial governance structures, including feed-in tariffs, auction systems, contracts for difference, and investment-based support schemes.

Country	Number of Installations (2023)	Dominant Support Scheme	Share of Biogas in RES [%]	Source
Germany	~9,400	Feed-in tariffs (EEG), balancing markets	12.5%	BNetzA, 2023
Denmark	~200	Guaranteed tariffs, local partnerships	15.2%	Energinet, 2023
France	~1,600	Contracts for difference (Complément de rémunération)	5.9%	ADEME, 2023
Czechia	~580	Investment subsidies and operational grants	3.8%	ERÚ, 2023
Poland	181	RES auctions, Guarantees of Origin, mixed mechanisms	<1.5%	KOWR, 2024

Table 1. Biogas Development in Selected EU Countries (as of 2023)

Germany
Germany is considered a frontrunner in biogas development within the EU. The sector benefits from the highest density of installations per agricultural area and a well-established spatial footprint. Its success stems from early adoption of feed-in tariffs through the Renewable Energy Sources Act (EEG), a high level of institutional stability, and strong integration with regional and local spatial planning frameworks. Local authorities and farming communities play an active role in project development and energy governance. Germany's decentralised system and reliable infrastructure have fostered long-term investments and a diversified network of biogas producers.

Denmark
Denmark's biogas model is grounded in close cooperation between farmers, municipalities, and the energy sector. The country supports biogas through guaranteed tariffs and strong institutional coordination at the local level. A large share of installations is integrated into district heating networks, especially in rural areas. The planning system allows for the fast deployment of installations, supported by effective spatial regulation and positive public perception. Denmark combines high financial efficiency with strong environmental outcomes, making it a reference point for countries aiming to build community-based, circular energy systems.

France
In France, agricultural biogas development is driven by a system of contracts for difference (complément de rémunération), which guarantee long-term price stability. Public support is also targeted at small-scale units, particularly those using agricultural residues. Regional and national energy agencies play a key role in coordinating projects and ensuring alignment with broader climate and energy policy objectives. However, France's biogas sector shows moderate territorial integration and lower environmental efficiency compared to countries like Poland or Denmark. Spatial planning integration is improving but still lacks consistency across regions.

Czech Republic
The Czech biogas sector is based mainly on investment and operational subsidies, with a relatively stable number of installations. However, the spatial dimension of biogas planning is weak—there is little coordination between energy and land-use policy. Feedstock use is less sustainable, with lower levels of waste-based input. Biogas in the Czech Republic is treated more as a supplemental component of the energy mix than a strategic priority. Institutional capacity at the regional level remains limited, and public engagement in project development is modest compared to other countries studied.

To evaluate and compare national biogas systems, the study developed three synthetic performance indicators:
WEF (Financial Efficiency Index) – measures energy output (GWh) per €1 million of public support:

$$WEF = \frac{E_{bio}}{S_{fin}}$$

where: E_{bio} – total energy produced from biogas (GWh), S_{fin} – total public support (in million EUR).
WGT (Territorial Biogas Density Index) – reflects the number of installations per 1000 km² of agricultural land:

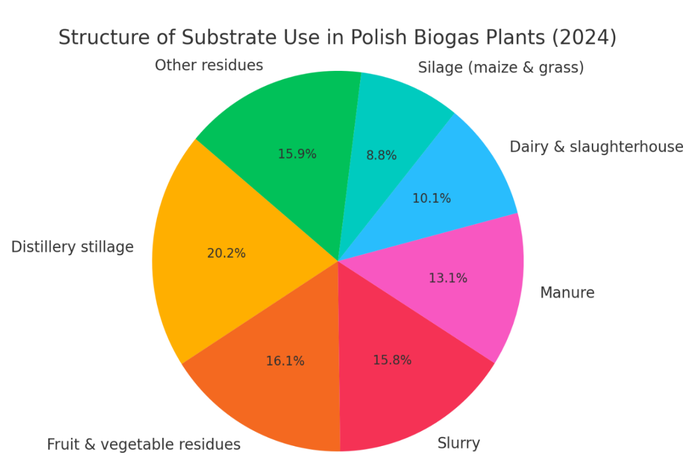
$$WGT = \frac{N_{bio}}{A_{agr}}$$

where: N_{bio} – number of agricultural biogas plants, A_{agr} – agricultural area (in 1000 km²).
WES (Substrate Sustainability Index) – assesses the share of waste-based feedstock in total input:

$$WES = \frac{V_{waste}}{V_{total}} \times 100\%$$

where: V_{waste} – waste-based substrates (tons), V_{total} – total substrates used (tons).
The research used triangulation of multiple sources: national databases (e.g., KOWR, URE, Eurostat), planning documents (MPZP, SUiKZP), statistical and spatial datasets (CLC, LPIS). Spatial analysis was conducted with GIS software and Principal Component Analysis (PCA) to identify regional clusters of biogas development potential.

Poland As of 2024, Poland had 181 registered agricultural biogas installations, with a total electricity output exceeding 1,012 GWh, of which about 831 GWh was fed into the grid. While this number reflects gradual development, Poland still ranks low among EU countries in terms of plant density and installed capacity per agricultural area. A notable strength of the sector is its exceptionally high environmental sustainability. According to national reports, 92% of substrates used are classified as waste—mainly distillery stillage (20.2%), fruit and vegetable residues (16.1%), slurry (15.8%), and manure (13.1%). This reflects strong alignment with EU circular economy goals and efficient use of agricultural and food processing by-products. However, the spatial distribution of installations is uneven. Kuyavian-Pomeranian (28 plants), Greater Poland (27), and Warmian-Masurian (21) voivodeships lead in development, while several regions (e.g. Opolskie, Świętokrzyskie) have only 2–3 plants.



This disparity is mainly due to differences in substrate availability, grid access, and the presence or absence of local spatial development plans (MPZP).Despite growing interest, micro-biogas plants (up to 50 kW) remain underdeveloped. At the end of 2024, only 65 units were connected to the grid, generating just over 4.2 GWh. Key barriers include complex permitting procedures, limited support instruments, and lack of integration with municipal energy planning. To unlock the sector's full potential, improved planning integration, targeted support for small-scale units, and regional strategies tailored to local feedstock and infrastructure conditions are essential.

The location of agricultural biogas installations in Poland is shaped by several spatial and infrastructural determinants. Key factors include the availability of substrates in regions with high livestock density and food processing industries, the structure of land use based on CORINE and LPIS data (favoring agricultural-dominated areas), and the accessibility of electrical grid infrastructure, which remains insufficient in many rural zones. Crucially, the existence of Local Spatial Development Plans (MPZP) is a legal condition for investment approval; however, such plans cover only a limited share of Polish municipalities. Despite favorable substrate conditions, the sector faces major development barriers.

These include low planning integration, inadequate technical infrastructure, instability of financial support mechanisms, and weak coordination among national, regional, and local institutions. Additionally, local communities are rarely involved in project planning, which hampers social acceptance and delays implementation. To address these challenges, several measures are recommended. Energy policy must be better integrated with spatial planning, especially at the municipal level. Support schemes should be diversified and adapted to local conditions—particularly by introducing mechanisms suitable for small-scale and micro-biogas units. Investment in grid infrastructure and substrate logistics is needed, especially in high-potential but underdeveloped eastern regions. Lastly, a shift toward place-based and multilevel governance is essential, enabling more effective cooperation among municipalities, energy actors, and rural stakeholders.

Country	WEF	WGT	WES [%]
Germany	9,00	55,95	55,00
Denmark	11,10	7,41	62,00
France	7,30	3,61	49,00
Czechia	6,10	2,77	48,00
Poland	6,75	1,27	92,00

Table 2. Indicator Comparison (WEF, WGT, WES)

RESULTS The table presents a comparative assessment of three key performance indicators used to evaluate the development of agricultural biogas sectors in five EU countries: Germany, Denmark, France, Czechia, and Poland.
WEF (Financial Efficiency) expresses the amount of energy generated (in GWh) per €1 million of public support. Denmark achieves the highest value (11.10), indicating excellent financial productivity of its biogas sector, followed by Germany (9.00). Poland's WEF (6.75) is lower, suggesting relatively less efficient use of public funds.
WGT (Territorial Density) shows the number of agricultural biogas plants per 1000 km² of agricultural land. Germany stands out with a remarkably high density (55.95), reflecting strong spatial integration. Poland ranks the lowest (1.27), highlighting its limited spatial penetration and underdevelopment of the sector.
WES (Substrate Sustainability) measures the share of waste-based substrates in total feedstock input. Here, Poland leads with 92%, showing strong alignment with circular economy principles. In contrast, countries like France and Czechia demonstrate lower environmental efficiency (WES below 50%).
The comparison reveals that while Poland excels in waste utilization, it lags behind in both spatial distribution and cost-efficiency of biogas support mechanisms. The findings support the need for better spatial planning, localized policy instruments, and improved institutional coordination

CONCLUSION
Poland's agricultural biogas sector demonstrates strong environmental potential due to its dominant use of waste-based substrates, but remains spatially underdeveloped and institutionally fragmented. The analysis highlights that the sector's limited territorial reach, low investment density, and administrative complexity significantly constrain its growth. In contrast to countries such as Germany and Denmark, where biogas is fully integrated into spatial planning and local governance, Poland lacks effective coordination between planning, infrastructure, and policy frameworks. To advance biogas development, Poland must adopt a more strategic, regionally differentiated approach that integrates spatial and energy policies, strengthens local planning instruments, and supports decentralized, community-driven initiatives. Lessons from other EU countries confirm that long-term policy stability, infrastructure readiness, and active stakeholder involvement are critical to building a resilient and territorially anchored biogas system.