



# Different Pathways, Common Ground:

Business Models for  
Modern Farming in Poland





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# Foreword

In recent decades, agricultural practices in Poland have undergone considerable change. Poland's membership in the European Union has helped improve production efficiency, exports and profitability.

Today, however, the sector faces new challenges. The development potential of Poland's agri-food sector is constrained by factors such as limited access to capital and low awareness of sustainable practices. Several trends will significantly shape the sector's direction in the coming years. These include reform of the Common Agricultural Policy, the reconfiguration of agricultural supply chains, and the need to attract private investment to agriculture.

On the one hand, improving the economic sustainability of agriculture is essential. On the other hand, environmental challenges are creating new requirements for the sector. Adverse climate conditions contribute to natural disasters, droughts and soil erosion, causing substantial economic losses for farmers. Yet the current model of economic development does not provide sufficient incentives for farmers to adapt their practices. On the contrary, it often introduces requirements that are difficult to meet.

Adaptation to new environmental conditions is clearly necessary, but this transition cannot take place without the right enabling conditions. This study is based on the premise that the transition will be successful only if it improves the economic sustainability of farms while also strengthening their competitiveness, understood as both profitability and resilience.

The diversity of the Polish agricultural sector, in terms of both farm size and production profile, presents a unique window of opportunity. Different business models can be developed, each focused on a specific aspect of sustainable farming. As we show in this report, farmers should focus on producing high-quality, higher-value products rather than simply maximizing yields. They can also build integrated value-chain systems. Finally, they can introduce innovative technologies designed to improve the efficiency of production processes.

All of these directions can reduce greenhouse gas emissions from industry. Moreover, the suggested practices can be applied to agricultural production in Poland. Thus, the challenge lies in scaling them and introducing them at the national level. The roles of all stakeholders (farmers, policymakers, financial institutions and private investors) will become critical.

Ultimately, these trends may have either a positive or negative impact on the sector's prospects for sustainable development. We hope that this research will contribute to the discussion on the future of Polish agriculture.

**Marcin Korolec**

President of the Sustainable Economy Institute

# Executive summary



## Context and key findings

- Polish agriculture is both highly exposed to climate risks and a significant source of national GHG emissions, accounting for around 10% of the country's total. Without additional measures, emissions are expected to rise, while droughts, extreme weather events and soil degradation are already causing growing economic losses.
- Polish farms can be divided into three structurally distinct segments that require differentiated policy responses: small farms, which account for over 80% of holdings; medium-sized farms; and large commercial farms, for which access to capital is less of a constraint than regulatory uncertainty. The transformation of all three groups is needed both to maintain their economic viability and to support effective climate action.
- Climate action can strengthen **productivity, resilience and farm income** rather than weaken them. Many mitigation practices — such as nitrogen optimization, improved soil management and greater feed efficiency — already deliver **direct economic benefits** through lower input costs, more stable yields and reduced exposure to climate risks. Yet this potential remains largely unrealized.
- **The core barrier is not technological but systemic.** Existing policies, market structures and incentives do not make climate action economically attractive for farmers. Common Agricultural Policy instruments tend to reward stability rather than transformation, supply chains compress margins, and regulatory uncertainty increases perceived risk.
- Farmers respond rationally to these structural conditions. Our engagement with farmers clearly shows that:
  - climate change is seen as a real risk to farm viability;
  - farmers want to build resilient business models but do not consider current support sufficient;
  - climate action is driven primarily by economic benefits, not environmental goals;
  - farmers are less willing to experiment when their income is uncertain;
  - trust depends on peer learning and credible advisory systems.
- Recent farmer protests reflect these structural tensions. Unless climate action is aligned with farmers' economic interests, it will continue to be perceived as a cost rather than an opportunity.

- The key implication is clear: **the transformation of agriculture will succeed only if it strengthens farm income, resilience and market position, and if its direction is supported by farmers themselves.**
- This report contributes to the debate by exploring how mitigation can be effectively integrated into viable development pathways for the Polish agri-food sector, and what forms of support are needed to enable this transition. The technological solutions and business models presented in this study are intended to **improve profitability, strengthen resilience and reduce emissions**. Importantly, they reflect approaches co-developed and endorsed by farmers and experts through a participatory research process conducted as part of the study.
- The report also emphasises that Poland has the capacity to shape its own pathway. EU frameworks, including the upcoming CAP reform, evolving private-sector demand and new financial instruments create an opportunity to align climate action with the sector's economic development.



### Prospective business models

- As part of the participatory research conducted for this study – including two full-day regional workshops with farmers, three full-day workshops with agricultural experts and changemakers, more than 20 in-depth interviews with farmers and experts, and a survey – three business-model pathways emerged as feasible in the Polish context:
  - 1) **Local, quality-based production** which enables farms – particularly small and medium-sized farms – to shift from volume-based competition to value-based strategies. By shortening supply chains and differentiating products, this model increases farm-gate margins, reduces dependence on external inputs and strengthens resilience through diversification and closer relationships with consumers.
  - 2) **Vertically integrated farming and processing**, which allow farmers to capture value beyond primary production and reduce their exposure to price volatility. Integration into processing and coordinated market access creates conditions for investment, improves resource efficiency and enables the circular use of inputs across the value chain.
  - 3) **High-tech agribusiness**, applicable primarily to larger commercial farms, where improved input management, digitalization and integration into formal supply chains can reduce costs and emissions at the same time, while positioning farms to benefit from emerging market demand for low-emission products.
- These models are not theoretical constructs; they can already be observed in practice in Poland. Importantly, they show that productivity, resilience and emissions reductions can be achieved simultaneously, rather than only through trade-offs.

- To scale up these models, this study identifies four areas where support is needed and where intervention could have a real impact: the post-2027 CAP, regulatory and market frameworks, private capital and financial instruments, and knowledge systems, networks and coordination.



## Key policy recommendations

The study led to a number of recommendations addressing the main challenges discussed in the report.

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### Public policy and CAP post-2027 CAP

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- Ensure that the CAP post-2027 secures ringfenced, outcome-oriented and adequate funding for effective environmental action and animal welfare objectives. The post-2027 CAP should, to a greater extent:
  - promote production diversification, particularly of fruit, vegetables, legumes and more drought-resilient crops, including through targeted coupled support and investment support aligned with climate adaptation objectives.
  - reward ecosystem services and the business models that deliver them (e.g. agroforestry, organic farming, landscape water retention, peatland rewetting and paludiculture) through multiannual, results-based contracts linked to measurable outcomes, including carbon storage, biodiversity and water retention. This support should come on top of area-based payments for organic farming and could also involve supplementary payments for each additional livestock unit of organically raised cattle.
  - incentivize the broad implementation of farming practices that simultaneously increase farms' resilience to extreme weather events and help reduce the use of emissions-intensive inputs, such as nitrogen fertilizers. These practices include cover crops, intercropping, undersowing, crop rotation, reduced tillage and no-till farming, precision farming, manure-management practices that reduce nutrient losses, and nature-based solutions that improve on-farm biodiversity. Payment levels should reflect the real risks and costs of transition, while ensuring that support is targeted at effective and ambitious practices that go significantly beyond minimum good standards of agricultural practice. Robust verification mechanisms must also be in place to ensure that these practices are genuinely implemented.
  - stimulate the uptake of technologies and practices that improve animal welfare while also delivering environmental and productivity benefits. Relevant practices include extensive grazing, particularly in areas of high biodiversity value and water-retention importance; feed-ration optimization; and genomic selection for low-CH<sub>4</sub> traits. Support should

also cover sector-level public goods, such as breeding programs and data infrastructure.

- Establish an explicit transition pathway within the post-2027 CAP for farms moving towards short supply chains and lower-input, quality-based, differentiated products. This pathway should include support to manage income risks during the transition period and to cover upfront investment costs.
- Establish a structured transition pathway within the post-2027 CAP to support the extensification of livestock systems, combining income stabilisation during the transition phase with a dedicated, lump-sum transformation payment for upfront investments (e.g. land acquisition, herd restructuring).
- Ensure ringfenced funding for rural development-type interventions and investments, including small-scale processing, storage, and distribution, and other enabling systems that allow farms to participate in short supply chains.
- Reshape current programs for forming producer groups to ensure long-term engagement beyond the fixed-term co-financing period. This should include support for entering and establishing themselves in profitable market niches. It could be achieved through improved market-oriented training, gradually decreasing public support linked to performance milestones, transition finance for groups that demonstrate market viability, and governance and management support to reduce failure rates among collective structures.
- Make investment co-financing and CAP support above a defined economic-size threshold conditional on documented evidence, comprehensive plans showing clear additional environmental benefits, and demonstrated financing gaps. Redirect the savings to small farms and new entrants, where public support is genuinely additional: insufficient capital and limited access to private finance would otherwise prevent investments from taking place.

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### **Regulatory and market frameworks**

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- Conduct a systematic audit of the requirements, criteria and certification schemes that determine access to high-quality product markets, with the aim of encouraging farmers to enter those markets and capture the associated economic benefits. For example, organic certification and other quality schemes should reliably ensure that price premiums reach producers and are not eroded at the processing or retail level.
- Develop simplified, risk-based regulation that makes it easier to scale up small- and medium-scale processing, including proportionate sanitary requirements, streamlined approval procedures and clear regulatory pathways for collective processing models.
- Promote diversified income streams on farms to strengthen economic resilience and enable farmers to invest in climate action and new business models. For example, removing the ban on agrivoltaics and establishing a clear permitting framework would create additional, stable income from energy production, reduce farmers' exposure to climate, geopolitical and

market risks, and thereby support their capacity to engage in more innovative and differentiated production systems. This should be accompanied by appropriate safeguards against land-use conflicts.

- Actively enforce reporting requirements for the largest in-scope companies and use the transition period to establish standardized, interoperable farm-level emissions accounting methodologies that make it feasible for primary producers to provide Scope 3 data.
- Promote local, high-quality food by expanding, modernising and promoting infrastructure for local direct sales, green public procurement, preferential access or terms for local producers in supermarkets, targets for the share of local produce, labelling schemes and public awareness campaigns. These measures should focus on communicating verifiable environmental and health attributes to consumers.
- Support the development of stronger contracting frameworks to facilitate collaboration between farmers and retailers, food-service companies and other private-sector partners.
- Develop national and regional food strategies that introduce additional, context-specific instruments to further encourage and normalise the adoption of the proposed business models. These instruments could include public procurement, publicly supported marketplaces such as farmers' markets, food hubs and shopping clubs, and links with public health, climate adaptation and regional development objectives.

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### **Private capital and financial instruments**

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- Develop financial instruments that address the distinct investment needs and risk profiles of the three business models, moving away from generic farm-modernisation support towards targeted, transition-oriented and value-chain-based financing.
- Mobilise private capital for shared infrastructure and value-chain development, including food hubs, shopping clubs or platforms, processing, storage and distribution systems. This should be supported by blended-finance vehicles that reduce the risks of early-stage investments and attract commercial finance.
- Support the emergence of collective and supply-chain-based financing models that enable producer organisations, cooperatives and digital platforms to access capital jointly, thereby improving creditworthiness and reducing transaction costs compared with fragmented farm-level lending.
- Facilitate the growth of supply-chain finance mechanisms, in which processors, retailers and food-service companies provide financing or co-investment linked to long-term sourcing relationships and environmental performance. This would allow farms to monetise efficiency gains and reductions in emissions intensity.
- Promote the development of alternative and locally rooted investment instruments, including community investment schemes, cooperative

shares and bond-based models, which enable food-system initiatives to raise capital from consumers and local stakeholders directly connected to emerging business models.

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### Knowledge systems, networks, and coordination

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- Strengthen the knowledge systems that enable farmers to adopt and expand new business models, moving away from fragmented advisory support towards **integrated advisory and knowledge systems** that are practical and connected to markets.
  - Reinforce the role of public advisory systems, such as ODR, and independent actors in supporting **whole-farm transitions**. This support should focus particularly on implementing technologies and resource-efficient practices, joining certification schemes, and navigating administrative and market requirements, with greater emphasis on practical application rather than compliance.
  - Expand **farmer-to-farmer learning systems** and demonstration networks, including model farms and peer-exchange platforms, and align them more closely with sustainability objectives. Examples include best-practice databases and the Polish Network of Demonstration Farms, which have proved particularly effective in accelerating the uptake of new practices and reducing perceived transition risks.
  - Develop **digital infrastructure and platforms** to support both production and market coordination. These should include tools for nutrient management, precision farming, logistics and aggregating environmental performance data, helping to reduce transaction costs and enabling participation in emerging value chains. These tools could be developed by public research institutes or through public-private partnerships.
- Strengthen **producer networks, cooperatives and intermediary organisations**, such as food hubs and aggregation platforms, that enable supply coordination, shared logistics and market access, particularly for farms that cannot access these markets on their own. This should be developed at the regional and local levels, in close coordination with public advisory services and local government authorities.
- Build **sector-wide coordination mechanisms and shared public goods**, including standardised farm-level carbon accounting systems, data-sharing frameworks, and breeding or innovation programmes. These would reduce barriers to entry and enable participation in supply chains that are increasingly shaped by environmental performance requirements.



# 1 | Introduction

Farming today is both a victim of and a contributor to climate change. Increasingly frequent droughts, irregular precipitation patterns, and extreme weather events are affecting crop yields, livestock productivity, and soil quality. This results in annual losses to the agricultural sector in the EU of more than €28 billion (6% of the value of production) (EIB & EC, 2025). In Poland, these losses amount to at least PLN 3 billion annually and account for over half of all climate-change-related damage to the Polish economy (IEP-NRI, 2025).

At the same time, agriculture remains a significant source of national greenhouse gas emissions (GHG). According to national inventories, **the sector accounts for roughly 10% of Poland's total emissions** (EEA, 2025). A large share (42.9%) originates from agricultural soils through nitrous oxide (N<sub>2</sub>O) emissions linked to fertilizer use and manure management, while another major component (41.9%)

comes from livestock production, particularly methane (CH<sub>4</sub>) released through enteric fermentation in ruminants and manure storage systems. Importantly, Polish agricultural emissions have largely stalled over the past decade. **Without additional measures, projections suggest that they may continue to rise toward 2030**, driven by growing livestock production, fertilizer use and production intensification linked to competitive pressures in the agri-food supply chain within the food system (Polish Ministry of Climate and Environment, 2024).

Despite this, **the debate on agricultural decarbonization in Poland remains politically sensitive** (Czubak et al., 2024). Although agricultural emissions need to be reduced and soil carbon management strengthened to maintain the sector's resilience, farmer organizations and many sectoral stakeholders voice concerns about the costs associated with this transformation. **Climate policy is hence frequently perceived as a source of economic pressure rather than an opportunity for modernization.**

At the European level, agriculture has become increasingly important in climate policy as the **EU moves toward its legally binding climate goals, and supported by modeling exercises that suggest that meaningful emission reductions in agriculture are technically feasible**. Various EU-wide scenarios indicate that agricultural emissions could be reduced by roughly 25% and even up to 59% by 2050 (Springer, 2025) depending on the combination of technological improvements, management changes, and dietary shifts. Importantly, research emphasizes that these reductions depend primarily on scaling up existing practices rather than relying on breakthrough technologies (Domínguez et al., 2016).

**To support this transition, the EU is developing several policy instruments.** The Common Agricultural Policy (CAP) has formally strengthened its climate objectives, for example through eco-schemes, although in practice its contribution to GHG emissions reductions remains marginal (ESABCC, 2026). At the same time, new voluntary frameworks, such as the Carbon Removal Certification Framework (CRCF), are being developed to mobilize private finance and reward climate-positive land management. In 2026, the European Commission is expected to present a climate package for 2031–2040, as well as a new framework on climate resilience. To encourage further action, some experts, including the European Scientific Advisory Board on Climate Change (2026), have even recommended introducing polluter-pays-principle mechanisms to price agricultural emissions.

Although the future of several of these measures remains unclear, if properly designed and implemented, these policies could drive more ambitious climate action in the agri-food sector across EU Member States. Polish agriculture would then face both increasing opportunities to invest in decarbonization and growing scrutiny—not only from policymakers, but also from financial institutions and food companies, which would have stronger incentives to demonstrate climate progress. **These debates can create anxiety among farmers operating in a sector already characterized by income volatility and high exposure to weather risks.** However, postponing this discussion would likely increase the risk of abrupt policy interventions in the future and leave farms less prepared for changes already emerging. **Addressing mitigation early therefore offers an opportunity to shape solutions that support both environmental and economic objectives.**

This report contributes to the ongoing debate by exploring how mitigation can be effectively integrated into viable development pathways for the Polish agri-food sector, and what forms of support this transition requires. The solutions and business models it presents are designed to **improve profitability, strengthen resilience, and reduce emissions**. Importantly, they reflect directions co-developed and endorsed by farmers and experts through a participatory research process conducted as part of this study. As such, they primarily represent pathways currently seen as viable and inclusive, and that could offer a meaningful first step forward for climate action in Polish agriculture.

The research process combined a review of the scientific literature with participatory activities including over 20 in-depth interviews with farmers, researchers, agronomists, industry representatives, financial institutions, and policymakers, complemented by five-day-long stakeholder and farmers workshops, as well as surveys. By combining these data and perspectives, the report proposes three concrete business models through which Polish farms—varying in size, production orientation, and supply chain position—can embed emission reduction into more profitable farming strategies. The means to this end is identifying mitigation solutions with the highest implementation potential in the Polish context and to clarify the barriers and enabling conditions that will determine their wider adoption.



## 2 | Characteristics of Polish agriculture

**Agriculture constitutes an important part of the Polish economy and identity, with over 1.2 million farms registered (Statistics Poland, 2025) and an average employment share of almost 8% over the last decade (World Bank, 2025). Over 95% of Polish farms are small and medium-sized farms (SMFs), defined here as holdings with a standard output<sup>1</sup> (SO) below €100,000. They manage around 84% of agricultural land and contribute approximately 70% of the value of national agricultural production (Statistics Poland, 2025; FADN, 2024). The most relevant mitigation decisions are therefore distributed across thousands of farms that vary in economic capacity, production profile, and exposure to market forces. This section maps this heterogeneity and draws out its implications for climate policy design.**

<sup>1</sup> SO is a measure used by Eurostat to classify the economic size and production orientation of agricultural holdings. It represents the 5-year average monetary value of agricultural production per hectare of crop or per head of livestock, calculated at the regional level and based on standardized coefficients reflecting typical production conditions. The total SO of a farm is obtained by summing the SO values of all its agricultural activities and is commonly used within the EU Farm Structure Survey and the CAP to compare farm economic performance and typology across regions and Member States (Eurostat, 2025).

## 2.1. Farm and production structure

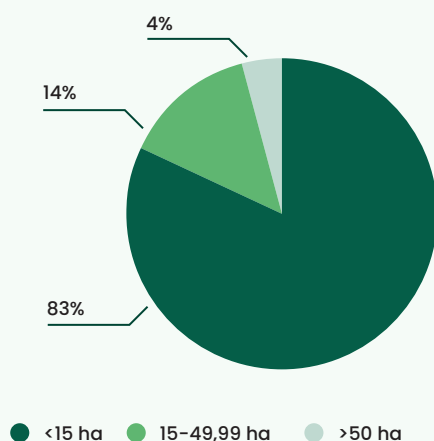
Around 83% of Polish holdings operate on less than 15 ha and generate a SO below €25,000. A further 14% fall in the €25,000–100,000 medium range. Only 3% exceed €100,000 SO (the large farm category), and farms above 50 ha

make up just 4% of holdings by area (Statistics Poland, 2025; FADN, 2024).

These distributions closely align: Polish area-size and economic-size gradients tell roughly the same story (see Figures 1 and 2).

**FIGURE 1.**

**Farm structure in Poland (%) by farm size.**



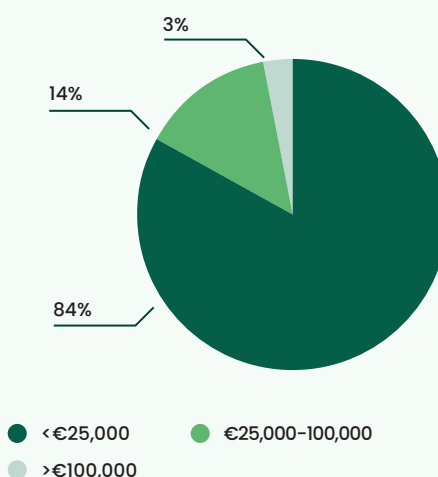
Source: own calculations based on Statistics Poland (2024a).

Figure 3 shows the relation between farms' economic size and their contribution to the aggregate output. Despite their varying levels of efficiency, all three categories we identified account for a similar share of total agricultural production in Poland. This means all three matter for the sector's transition, but engagement must be size-appropriate.

**Small farms (SO below €25,000)** manage over 50% of agricultural land, but produce only about a third of national agricultural output. Their economic constraints mean that mitigation uptake in this segment is likely to rely primarily on publicly funded advisory

**FIGURE 2.**

**Farm structure in Poland by standard output.**



Source: own calculations based on Statistics Poland (2024) and FADN (2024a).

services, cooperative arrangements, and simplified support instruments rather than capital-intensive technologies. Yet their aggregate contribution to N<sub>2</sub>O emissions could be significant, since their production profile is focused mostly on crops (see Figure 4). The challenge is therefore one of reach and institutional design, not technical feasibility.

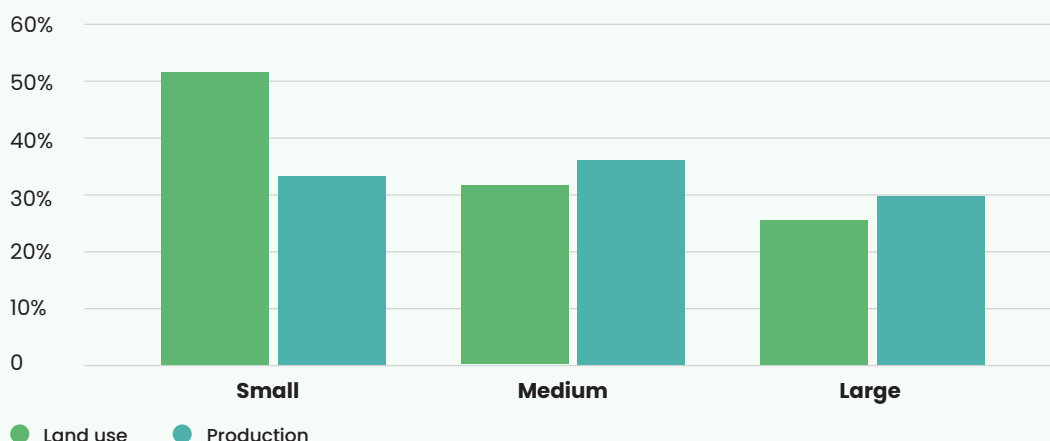
**Medium farms (€25,000–100,000)**, by contrast, have greater organizational capacity and access to credit. Their share of agricultural area exceeds 30%, and they produce about 37% of the output making them an important lever in the transition. They are the

most heterogeneous group. Those at the upper end have the organizational capacity and credit access to benefit from precision tools, improved nutrient management, and feed optimization. Those at the lower end of the medium bracket face greater uncertainty. Capital is available in principle but limited in practice, and transitions that carry short-term productivity risk are poorly suited to farms operating without financial buffers. The production profile of this group is also the most diverse. This complexity argues for comprehensive approaches rather than single-technology incentives.

Naturally, **large farms (of SO exceeding €100,000)** are the most productive. Although they manage only 15% of Poland's agricultural area, they produce around one-third of national agricultural output. As a result, they are best positioned to adopt capital-intensive mitigation technologies like precision agriculture equipment, slurry injection systems or biogas installations (Serebrennikov et al., 2020). They are more likely to be integrated into formal supply chains where climate-reporting requirements are beginning to create market incentives for adoption. Their small number means that, while per-farm mitigation potential is high, they cannot shift the national aggregate on their own.

**FIGURE 3.**

**The share of agricultural land use and agricultural production by economic farm size.**



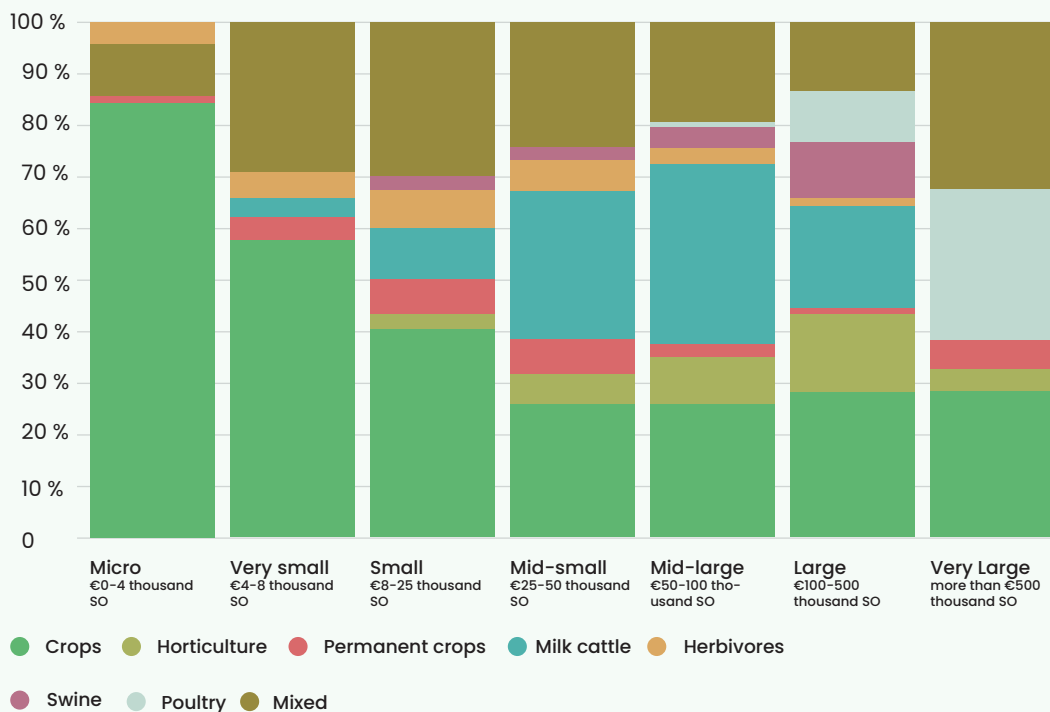
Source: own calculations based on FADN (2024) and Statistics Poland (2024).

**Production profiles also vary sharply across farm size classes**, so mitigation efforts will need to focus on different categories of agricultural products. Crop production dominates among smaller farms: around 85% of micro-holdings (SO below €4000) and 57% of very small farms (€4000–8000) report crop specialization. As farms move into the medium economic bracket, the structure diversifies markedly. The share of crop-only farms

drops from the majority of output to around 25%, while livestock and mixed operations expand to nearly 60% together. This means that soil nitrogen management is the primary mitigation lever for the majority of small farms, while livestock-related emissions become progressively more relevant as farm size increases (Figure 4).

FIGURE 4.

Share of farms engaging/specializing in distinct production categories by farm size.



Source: own calculation based on FADN (2024) and Statistics Poland (2025) data.

### Specialist crop farms have emissions concentrated in the nitrogen cycle.

Nitrogen optimization, cover crops, and rotation management are therefore the primary levers, and their cost profile is relatively favorable. **Livestock farms require a more complex bundle:** enteric emissions, manure management, and feed efficiency must be addressed simultaneously, requiring

higher investment and more sophisticated management capacity.

### Mixed farms may offer synergies:

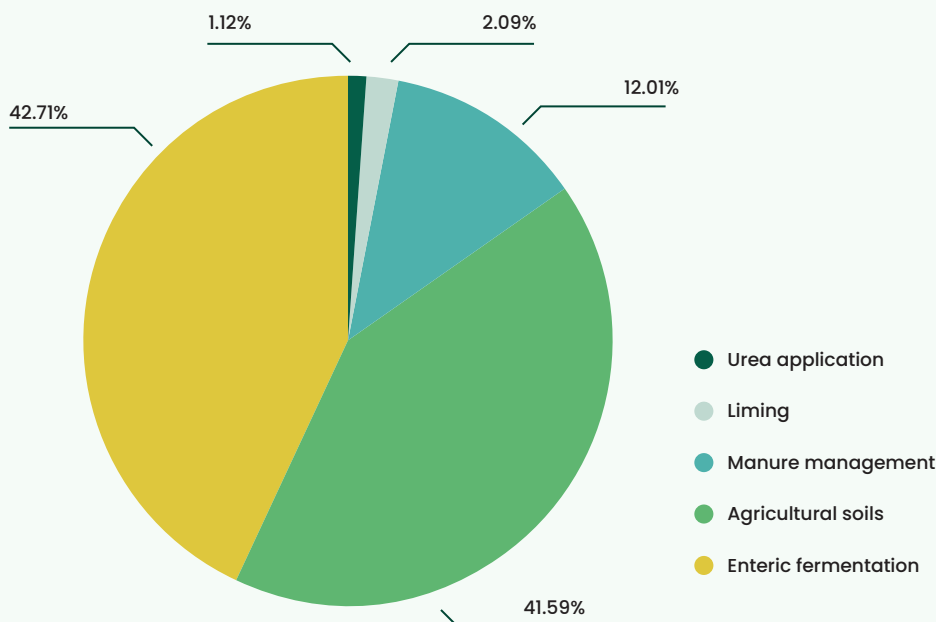
on-farm organic nitrogen can substitute for purchased synthetic fertilizers, reducing GHG emissions if managed well. However, realizing these synergies requires integrated farm-level management, a capacity that is unevenly distributed (as illustrated in Box 6).

## 2.2. GHG emissions profile

Polish agriculture is responsible for approximately 10% of total national GHG emissions<sup>1</sup>. The emission profile is characterized by **near-parity between two dominant sources:** agricultural soils (primarily N<sub>2</sub>O, currently 42.9% of

agricultural emissions) and enteric fermentation from livestock (CH<sub>4</sub>, 41.9%), followed by those stemming from manure management (12%) (see: Figure 5).

<sup>1</sup> When reporting on agricultural emissions, we adhere to the EEA sectoral classification. Therefore, we do not include agriculture-related emissions, which are included in the LULUCF category.

**FIGURE 5.****Shares of GHG emissions sources in total Polish agricultural emissions in 2023.**

Source: own elaboration based on EEA (2025).

The emerging emission profile is linked to types of production. Poland is one of the EU's largest crop producers.

**Cereals still dominate the arable landscape, but animal production is also growing markedly.**

The value of livestock output was nearly 2.5 times higher in 2023 than in 2010, with poultry as the primary driver, and Poland becoming its biggest producer in the EU (Kowalska et al., 2023; Statistics Poland, 2024a).

The growth of poultry and the concentration of pork production produce less CH<sub>4</sub> per animal than ruminants, but nevertheless they increase demand for nitrogen-intensive feed crops, which in turn raises soil emissions. (Olszańska et al., 2024). **Feed demand generated by this expansion has transformed the crop sector:** grain maize production (predominantly used as animal feed) increased almost fivefold between 2010 and 2023 (KOBIZE, 2025). This has a direct impact on the GHG profile

contributing to loss of nutrients and more N<sub>2</sub>O emissions. Meanwhile, cattle production, though growing less rapidly, remains the dominant source of enteric CH<sub>4</sub> (KOBIZE, 2025).

Additionally, **there was an increase recorded in nitrogen, phosphorus, and potassium (NPK) fertilizer use**, which rose from 102.4 kg/ha in 2004 to 121.9 kg/ha in 2023 (Statistics Poland, 2005; Statistics Poland, 2024b). N<sub>2</sub>O emissions from synthetic nitrogen fertilizers nearly doubled between 1991 and 2023. Contributing to this trend is the expansion of maize monocultures, which increased 40-fold over the same period (KOBIZE, 2025). Another reason is the high prevalence of acidic soils (more than 50% of arable land is "very acidic" and "acidic"), which reduce fertilizer efficiency and amplify N<sub>2</sub>O losses (Ochal & Smreczak, 2020).

Narrowing the focus to livestock, **CH<sub>4</sub> emissions from enteric fermentation grew by 12% from 2004 to 2023. Notably, non-dairy cattle emissions grew in this period from 128 to 212 kT CH<sub>4</sub>.** Without additional measures, agriculture is projected to become the largest single source of GHG in the EU and second-largest in Poland by 2040 (Polish Ministry of Climate and Environment, 2024; EC, 2024a).

Such a trajectory could make it significantly more expensive for Poland to reach its national climate targets, as reductions would then have to be made in other economic sectors with a higher contribution to national GDP, or through investment in carbon capture and storage (CCS), which is more costly (EC, 2024a).

## 2.3.

### Farmers' perceptions of climate action

Engagement with farmers as part of this research included workshops (16–19 farmers per group), 10 in-depth interviews with early adopters of mitigation technologies in agriculture, and surveys.

It consistently shows that Polish farmers primarily perceive climate change as a direct threat to farm viability, rather than as an area in which agriculture has a responsibility to mitigate impacts. The main issues relate to disrupted seasonality and water availability, with drought emerging as the most tangible risk. As a result, **most actions are framed in terms of adaptation rather than mitigation or responsibility for emissions.**

While farmers see climate change as a source of losses, there is also a widespread belief that the current production system, which incentivizes cost minimization and low-price output, is fundamentally at odds with emission reduction—especially if it imposes additional costs at the farm level. In this context, **farmers often point to emissions generated in other parts of the value chain, which they perceive as more significant**, particularly given existing value distribution.

**Farmers who have adopted mitigation-aligned practices consistently report that these decisions were driven by expected economic benefits rather than environmental motivations.** The most frequently cited reasons include efficiency gains, reduced input costs, improved soil water retention, and more stable yields. Climate benefits are typically described as secondary effects of improved agronomy. For example, higher milk yields per cow or improved feed efficiency in livestock systems are seen as ways to reduce emissions per unit of output.

Practices that contribute to these outcomes are more acceptable, as they align with farmers' core goal of maintaining or increasing performance. Similarly, practices that reduce emissions indirectly (e.g. reductions in nitrogen losses) are viewed positively. Conversely, measures that require short-term economic sacrifices for long-term environmental benefits encounter strong resistance. Farmers emphasise that, **at present, reducing emissions does not translate into tangible financial returns.** As a result, such practices are unlikely to be adopted unless they also generate immediate economic gains.

Trust is also seen as a critical factor shaping responses to external drivers of change. While processors and other supply chain actors are increasingly requiring emissions data, **farmers are not fully confident in the methodologies used and how such data might affect their market position.** There is concern that measurement requirements could disadvantage smaller farms that lack the capacity to document emission reductions or carbon sinks.

**Public advisory systems—mostly Polish Agricultural Advisory Units (ODR)—are generally perceived as more credible than private companies.** It underlines the importance of trusted intermediaries in shaping the acceptance of new practices. Confidence in mitigation solutions could be thus strengthened if their safety and effectiveness were clearly

documented and communicated through public channels.

Farmers who are highly focused on performance and optimization are also very cautious about introducing changes to feed composition, particularly in dairy production. Even small changes can affect milk yield, animal behavior, or stress levels, as well as potentially raising concerns about animal and human health. **Beyond doubts about the effectiveness of many mitigation solutions, there is also a perception that proposed “easy fixes” may conflict with the ethos of being a good farmer, understood as carefully managing every aspect of production.**

Overall, **farmers show a low willingness to experiment.** They are more likely to adopt practices that have demonstrated tangible results on

#### CASE STUDY:

##### **Disinformation as a barrier to mitigation?**

In late 2024, claims began circulating on Polish social media suggesting that dairy products produced by the cooperative Mlekovita contained the feed additive “Bovaer®”, allegedly posing risks to human health, including fertility. Despite their rapid spread and high engagement, these claims lacked by evidence. An analysis published by the fact-checking organization Demagog demonstrated that Mlekovita did not use Bovaer in its production processes and that any earlier discussions of the additive concerned limited, non-implemented trials at the feed level. Bovaer itself contains 3-nitrooxypropanol (3-NOP), a compound designed to reduce CH<sub>4</sub> emissions from ruminants and thus contribute to climate-change mitigation.

Crucially, scientific assessments, including those conducted by the European Food Safety Authority, indicate that the substance does not transfer into milk or meat and poses no risk to consumers when used as authorized. The health concerns raised online were shown to stem from misinterpretations of animal research rather than from established scientific evidence. This case illustrates how misinformation can become a significant barrier to the adoption of mitigation practices, even when those practices are grounded in robust scientific research and aim to deliver environmental benefits. Narratives framing climate-oriented innovations as threats to consumer safety can rapidly undermine public trust, amplify risk perceptions, and provoke resistance among both consumers and producers. As a result, the effectiveness of mitigation measures may be constrained not by technical feasibility, but by communication failures and the susceptibility of public discourse to emotionally charged and misleading claims.

Source: Demagog (2024).

comparable farms. At the same time, existing policy instruments, such as eco-schemes, are perceived as

supporting existing practices while offering limited incentives for more ambitious change.

## 2.4.

### Farming realities and barriers to climate action

The perceptions outlined in the previous section are closely linked to the actual structural and political conditions in which Polish agriculture operates.

A central challenge is the high **dependence on public transfers**, with little agricultural policy support for transformative development. Over the past two decades, **CAP funds have consistently accounted for more than 50% of farmers' income in Poland, exceeding the EU average** (Pawlak & Poczta, 2024; EC, 2024b). This reliance is reinforced by the prevalence of small farms whose commercial viability has not been sufficiently strengthened by agricultural policies. The CAP Strategic Plan for 2023–2027 has further deepened this dynamic by reallocating 30% of Pillar II funds to direct payments, prioritizing income support over structural and environmental investment (Heinrich-Böll-Stiftung Warsaw, 2025). In such a system, farmers are structurally oriented toward income stability, which limits their capacity to absorb the risks associated with mitigation measures.

A second challenge is the **weak bargaining position of farmers within agri-food supply chains**. Only around 15% of farms in Poland are organized, compared to over 90% in several Western European countries (ZPP, 2024). As a result, most farms operate without collective market representation and remain price takers. **This disadvantage is reinforced by the structure of the retail sector, where discount chains account for approximately**

**37% of the grocery market**, a relatively high percentage compared to the EU (Green Seed Group, 2025). Large retailers impose strict price and supply conditions, compressing farm-gate margins and shifting adjustment pressures onto primary producers, particularly during periods of input cost volatility (Żarzycka, 2025; interviews). Under these conditions, farmers are incentivized to minimize costs and maximize output, leaving limited scope for adopting practices that increase costs or introduce uncertainty.

As a result, farmers face **uncertainty not only about the direction of future regulation but also about its stability over time, while existing instruments provide limited support for decarbonization** (IEEP, 2023; ECA, 2024). These concerns are reinforced by past experiences with programs that were discontinued before delivering lasting benefits, which have made farmers cautious about committing to changes that depend on sustained policy support (Chlebosz, 2025). **The prospect of a reduction in the CAP budget after 2027 further deepens this sense of instability** (ECA, 2024).

## CASE STUDY:

**Farmer protests and their political instrumentalization (2023–2025)**

Between 2023 and 2025, Polish farmers participated in three successive waves of protest: against the EU's Green Deal, Ukrainian agricultural imports, and the EU–Mercosur agreement. Although these protests had distinct triggers, they overlapped in their political logic.

The first and largest wave began in February 2024, when Rural Solidarity called a general strike that led to blockades of over 260 roads nationwide. European Green Deal strategic goals on pesticides use, fallow land, and emissions were framed as existential threats, while Ukrainian grain, poultry, and eggs were accused of undercutting Polish prices by around 40% in 2023. Research based on focus-group interviews with protest participants found that the degree to which these demonstrations were carried out under a “substitute banner,” real economic grievances channeled into anti-climate rhetoric, remains an open analytical question.

Politicians on both sides of the divide competed to validate the protests. Agriculture minister Siekierski (PSL) declared that farmers were “protesting for a just cause” and compared certain Green Deal requirements to communist-era directives. Prime Minister Tusk announced he would push for Green Deal amendments. PiS leader Kaczyński organized a mass Warsaw march explicitly around Green Deal abolition and the Ukrainian grain embargo; PiS MPs physically accompanied a splinter protest group that occupied the Sejm corridor. The Polish protests were part of similar demonstrations by farmers in other countries (including Germany and France). They led to real environmental concessions, including withdrawing from the Sustainable Use of Pesticides Regulation target of reducing the use of pesticides by half until 2050, as well as a series of CAP flexibilities and simplifications.

The pattern matters for decarbonization strategy: legitimate economic anxieties about competitive displacement and income instability were absorbed into opposition to EU climate policy, making it harder to address systemic causes. Any credible mitigation pathway must resolve the economic conditions that make this dynamic possible, not simply assert the urgency of emission reduction.

*Source: Mateja (2025); Zalewski (2025); Notes From Poland (2024).*



### 3 | Mitigation technologies

The analysis of the preceding chapters identifies *what* needs to change in Polish agriculture when it comes to climate action and *why*. This chapter asks what is actually *available* to make that change happen. It surveys the mitigation technologies with the highest implementation potential in the Polish context, covering both crop and animal production. Each practice is assessed along four dimensions: its technical maturity, its cost and risk profile for farms of different sizes, its social acceptability among farmers and consumers, and conditions that currently prevent wider deployment.

### 3.1.

## Crop production

Across the interviews, crop production is consistently portrayed as the part of agriculture where mitigation can be introduced relatively quickly because many of these measures are management-based rather than infrastructure-heavy. The key message is that the highest-potential crop-side interventions are those that simultaneously reduce N<sub>2</sub>O emissions through better

nitrogen management and rebuild soil function, making farms more resilient to drought and yield volatility. Crop mitigation is thus framed less as a stand-alone climate agenda and more as a pathway to restore agroeconomic efficiency and reduce input dependence. Below, we present the main practices that fulfill these criteria, grouped into broader categories.

### Nitrogen optimization

A first cluster of practices with strong implementation potential concerns nitrogen optimization, particularly through **systematic soil diagnostics** and **agronomic decision-making** that moves farms away from routine dosing. Previous studies found that the use of mineral fertilizers has been gradually increasing in Poland for at least a decade. Although farmers do not view this trend positively by farmers, they feel that it is necessary to maintain market share (Sobiesiak-Penszko et al., 2019). The interviews confirm this observation, as they repeatedly highlight that many Polish farms operate with limited measurement discipline: soil is tested infrequently, results are focused on a few macronutrients and recommendations are not translated into field-level management. Meanwhile, where more advanced diagnostics are used, like regular testing including organic matter indicators and a fuller nutrient profile, fertilizer inputs can often be reduced dramatically without compromising yields (Singh et al., 2021).

This matters because excessive nitrogen application drives N<sub>2</sub>O emissions. A complementary measure within this cluster is the use of nitrification inhibitors, compounds added to nitrogen fertilizers that temporarily block the bacterial conversion of ammonium

to nitrate, thereby slowing the denitrification pathway that produces N<sub>2</sub>O. However, adoption in Poland remains very low, primarily due to the higher cost of inhibitor-treated fertilizers and limited awareness among farmers. The technology is most suitable for light, permeable soils, where the risk of nitrogen leaching is highest.

Yet, the technological maturity of nitrogen optimization practices is high, the bottleneck is thus primarily behavioral and organizational. Small farms can implement simplified soil testing and basic dose adjustment with relatively low financial barriers, especially if advisory services or cooperative schemes reduce transaction costs. Medium and large farms are better positioned to adopt more advanced diagnostics, including regular organic matter monitoring, precision application technologies, and digital decision-support tools.

Although larger farms may spend significant sums annually on diagnostics, the interviews suggest that these expenditures can pay back quickly through reduced fertilizer purchases. The most important co-benefit is economic, namely lower input costs and reduced exposure to fertilizer price shocks. Nevertheless, a key

implementation barrier is the absence of a strong culture of record-keeping and the perception that more fertilizer is synonymous with more security. The interview evidence confirms the broader analytical consensus that nitrogen optimization represents

a no-regret mitigation measure, provided institutional support (advisory and/or regulatory tools (like CAP-based mandatory nutrient budgeting requirements for smaller farms) are strengthened.

### Building soil cover and diversifying rotations

A second cluster involves building soil cover and diversifying rotations through **cover crops, intercropping or undersowing**, and **more robust crop rotation planning**. These practices are repeatedly discussed as central components of regenerative approaches, but the interviews are careful to stress that single measures in isolation are rarely sufficient. The agronomic logic is straightforward: keeping living roots in the soil for longer periods improves soil structure, fosters biological activity, enhances nutrient retention, and increases water infiltration and storage.

From a climate standpoint, these mechanisms can reduce emissions in two ways. First, by improving nitrogen cycling and reducing losses, they can lower N<sub>2</sub>O emissions, especially when paired with better fertilization strategies. Second, by increasing biomass inputs to soil, they can support soil carbon maintenance and, in some contexts, net sequestration<sup>2</sup>. Interviewees consistently frame these practices as having particularly high deployment potential because they do not necessarily require major capital expenditure. What they require is planning, knowledge, and confidence that the system will remain profitable during the transition.

The suitability of these practices spans farm types, but feasibility varies with constraints. Larger commercial arable

farms typically have better access to machinery and agronomic services, which can make experimentation easier, yet they may also face greater pressure to maximize short-term yields. Nevertheless, most small and medium-sized farms can implement them using standard cereal seed drills, basic broadcast spreaders, or minor drill adjustments rather than investing in specialized machinery (Kientzy et al., 2023). The financial barrier is therefore primarily the cost of planting seeds for various catch crops and agronomic knowledge, not capital expenditure. This makes these practices particularly scalable in Poland's farm structure, where many holdings operate on 10–50 ha and cannot afford high-tech precision planters but already possess the core machinery.

The main barrier to the use of crop rotation is the lack of sales and low prices of some crops and plus cost and availability of machinery for rent (e.g. for harvesting legumes) (Kuś, 2015). Another barrier is transitional risk: farmers worry about yield penalties, pest pressure, or operational complexity. The interviews strongly suggest that social acceptance depends on peer validation. Adoption accelerates when farmers see neighbors demonstrating tangible improvements like better moisture retention during drought, more stable yields and lower fertilizer bills. This points to a social diffusion dynamics where demonstration

<sup>2</sup> However, the relationship between plant residues and N<sub>2</sub>O is not straightforwardly positive: residue decomposition can itself be a significant source of N<sub>2</sub>O emissions, with the magnitude depending on residue biochemical quality, timing of incorporation, and soil conditions (Olesen et al., 2023). This trade-off should be considered when evaluating the net climate benefit of residue management practices.

effects matter as much as technical evidence. Technological maturity is moderate to high; while the principles are well-known, optimal practice

design is highly context-specific, making advisory services and on-farm learning central.

#### CASE STUDY:

### Precision farming in Poland

Precision agriculture is a set of many different technologies applied precisely by appropriately selected agricultural techniques. Table 1 is based on the experiences of several Polish medium-sized and large farms. These include mixed farms, producing both crops and livestock, and specialized crop farms operating on large areas and with significantly dispersed fields. A common feature of the analyzed cases is the gradual implementation of precision farming technologies in response to cost, logistical, and environmental challenges, rather than a one-time technological transformation. Precision agriculture technologies are implemented sequentially, often starting with guidance systems that eliminate overlaps and skips and then expanded with more advanced features related to data management and diversifying agrotechnical practices.

In the examined cases in Poland, emission reductions result primarily from limiting the excessive use of mineral fertilizers and reducing fuel consumption. Variable-rate fertilizer application allows fertilizer use to be reduced by up to approximately 10% while maintaining the same yield level, which translates into a reduction in N<sub>2</sub>O emissions from the soil. Automated machine guidance and section control systems, in turn, reduce the number of passes and eliminate double application of fertilizers, leading to measurable fuel savings of several percent depending on the type of operation.



Crucially, in all cases, emission mitigation is a side effect of cost optimization. Farmers report measurable savings in fuel, fertilizer, and plant protection product consumption, as well as better utilization of machine and operator time. On some farms, the implementation of variable-rate sowing and fertilization simultaneously led to increased yields in more productive areas of the fields. Case studies also indicate that the main barriers are the initial costs of the technology, the need for digital skills, and access to agronomic and technical advice. Precision farming is scalable and adaptable to various farm types thanks to the technology's modular structure and gradual implementation paths. A key prerequisite for replication is training support and access to reliable agronomic data, which enable the full mitigation potential of precision technologies.

Source: John Deere (2025), Tomaszewski (2025).

Table 1. Comparison of farms applying precision farming technologies.

| Case study              | Farm type                                                                | Goal                                                                      | Precision technologies                                                                                  | Economic effect                                                                                 | Mitigation effect                                                                                                                         |
|-------------------------|--------------------------------------------------------------------------|---------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------|
| Kashubian Lakeland      | Family-owned farm; large acreage; potato production (up to 20,000 tons)  | Optimization of operations on hilly terrain with limited labor resources  | Yield mapping, soil sampling, auto-steering, integrated farm management system                          | Improved profitability and production stability on difficult soils; better use of machinery     | Reduced over-fertilization on low-potential zones; lower N <sub>2</sub> O emissions; fewer field passes; reduced fuel use                 |
| Agro-Masz               | Large arable farm; maize production                                      | Variable-rate seeding and fertilization across spatially dispersed fields | Variable-rate application of seeds and fertilizer, productivity zone maps, integrated digital platforms | Fertilizer savings of up to ~10% with maintained yields; yield increase in high-potential zones | Direct reduction of N <sub>2</sub> O emissions through lower surplus nitrogen application                                                 |
| Farm Service            | Medium-to-large farm (~280 ha) with agricultural services                | Fleet and operations management across multiple locations                 | Telematics, auto-steering, section control, variable-rate application                                   | Significant fuel and labor-time savings; improved cost control                                  | Reduced CO <sub>2</sub> emissions due to fewer overlaps and optimized machinery use                                                       |
| Przechadzcy family farm | Large-scale crop farm; rapeseed, maize, silage; fields up to 20 km apart | Reduction of losses from overlaps and inefficient field logistics         | Auto-steering, section control, variable-rate seeding and fertilization                                 | Measured savings in fuel, fertilizers and crop protection products; improved operator comfort   | Direct reduction of CO <sub>2</sub> (fuel use) and N <sub>2</sub> O (fertilizer application) emissions through precision input management |

Source: own elaboration based on John Deere (2025).

## Reduced tillage and no-till

A third practice area is **reduced tillage** and **no-till**. The interviews resist presenting “stop ploughing” as a silver bullet. Instead, reduced disturbance is described as valuable when embedded in broader soil management, especially alongside cover crops, rotations, and nutrient optimization. The mitigation contribution comes from reduced fuel consumption and potentially slower mineralization of soil organic matter (Ogieriakhi & Woodward, 2022). Additional benefits may also arise from improved field biodiversity. However, interviewees implicitly acknowledge a maturity nuance.

Reduced tillage is widely practiced in some segments but can create new

agronomic challenges, e.g. weed pressure, reliance on herbicides, or the need for improved plant residue management. Costs and barriers therefore vary sharply by context. For farms already equipped for reduced tillage, marginal costs can be low and fuel savings immediate. For others, the transition may involve machinery changes, learning costs, and risk during the first seasons. Social acceptance is mixed but improving; it is generally accepted as a modern farming practice, yet it can be criticized if it increases herbicide dependence. The key mitigation conclusion is that reduced tillage has deployment potential, but only as part of an integrated package rather than a stand-alone measure.

## Nature-based solutions and biodiversity improvements

A fourth set of crop-side practices focuses on biodiversity and landscape measures that can deliver mitigation alongside adaptation and ecosystem co-benefits. Interviewees discuss **field margins**, **shelterbelts**, and **tree planting** as particularly practical entry points for smaller farms or those with limited capacity for systemic agronomic redesign. Tree planting and agroforestry-type elements can contribute to carbon storage in biomass and soils and can also reduce wind erosion, improve microclimates, and support water retention. Similarly, measures such as rewetting or restoring peatlands are framed as highly climate-relevant due to the emission intensity of drained organic soils.

Yet, interviews show that these practices are highly heterogeneous in their applicability: they are most feasible where land can be taken out of

production without threatening farm viability, and where administrative support exists. Costs can be moderate or even high when establishment and maintenance are included, and benefits may accrue over longer horizons. Barriers therefore include opportunity cost of land, delayed payback, and in some cases regulatory complexity. Social acceptance is high. However, it is still conditional on whether farmers perceive them as productive.

Table 2 summarizes the crop production mitigation practices analysis presented above and supplements it with estimates of reduction potential obtained from the Polish National Research Institute of Animal Production. Importantly, these estimates are based primarily on international studies and therefore do not apply specifically to the Polish context.

## CASE STUDY:

**Regenerative agriculture cooperative in Slovakia**

PD Krakovany–Stráže is a regenerative agricultural cooperative in Trnava Region, Western Slovakia. It manages approximately 640 ha of arable land as a collective of 54 shareholders. Beginning around 2011, the cooperative gradually shifted away from conventional intensive farming toward regenerative practices. They reduced machinery use, introduced cover crops across all fields by 2013, and progressively adopted no-till seeding between 2016 and 2018 to prevent soil degradation. The farm cultivates a diversified crop mix (durum wheat, maize, peas, soybeans, sunflower, barley, poppies, mustard, and buckwheat) enhancing biodiversity and reducing pest and disease pressure. Over time, it has stopped using insecticides, fungicides, and synthetic fertilizers, and aims to phase out glyphosate for weed control. Organic fertilizers and compost are applied at the surface to further nurture soil life. Regenerative management has delivered measurable soil health gains: in some fields organic carbon content increased from 1.7% (2013) to 2.6% (2021), indicating improved soil structure and carbon storage. The cooperative estimates it sequestered roughly 40 t CO<sub>2</sub>/ha between 2017 and 2022, with annual figures over 15 000 t CO<sub>2</sub> captured and monetized through carbon schemes. Despite reduced chemical inputs, crop yields have remained at or above local averages, and input costs have fallen significantly. The farm actively shares its experience with farmers, researchers, students and the public. Weekly open-farm days, soil health events (e.g., *Living Soil Day*), and educational visits have engaged hundreds of participants, supporting knowledge exchange and demonstration of regenerative systems. This cooperative functions as a *Community of Practice* under the PREPSOIL initiative, illustrating how diversified rotations, soil covering, reduced tillage, and low-input management can enhance soil resilience, cut erosion, support biodiversity, and maintain productivity.



Source: [pdkrakovany.sk](http://pdkrakovany.sk)

Source: PREPSOIL (2026).

**Table 2. Summary of mitigation technologies in crop production**

| Mitigation practice                              | Technical maturity                                                                          | Costs                                                                                                      | Social acceptability                                                                                              | Conditions                                                                                                                                                | Reduction potential                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|--------------------------------------------------|---------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Nitrogen optimization</b>                     | High<br>Established tools, no innovation needed                                             | Low–moderate<br>All farm sizes: fast payback<br>Low transitional risk                                      | High (economic logic)<br>Less input, same yield possible<br>Resistance based on “more is better” mindset          | Barriers: no record-keeping culture; no mandatory nutrient budgets<br><br>Enablers: fertilizer prices; advisory services; CAP nutrient rules              | Reducing mineral N doses by 20–30% cuts N <sub>2</sub> O dispersion from the field by up to 0.75 kg/ha<br><br>Compared to pre-reduction baseline, N <sub>2</sub> O mitigation per hectare can reach 30% If nitrification inhibitors are also applied, N <sub>2</sub> O emissions can be reduced by up to 80%, although this practice remains rare in Poland                                                                                                           |
| <b>Soil cover &amp; rotation diversification</b> | Moderate–high<br>Principles known; site-specific design needed                              | Low<br>Standard machinery sufficient<br>Main cost: seed and knowledge                                      | Moderate–high<br>Could be framed as better agronomy, not climate action itself<br>Peer validation drives adoption | Barriers: yield risk during the transition; limited legume markets<br><br>Enablers: demo farms; drought resilience co-benefit; eco-schemes                | The primary effect is indirect: improved nitrogen cycling reduces surplus N in the soil, which in turn lowers N <sub>2</sub> O losses—quantifiable only in combination with nitrogen management practices                                                                                                                                                                                                                                                             |
| <b>Reduced tillage &amp; no-till</b>             | Moderate<br>Widely practiced but context-dependent<br>Needs integration with other measures | Variable<br>Equipped farms: low cost plus fuel savings<br>Others: machinery investment plus learning curve | Mixed<br>Accepted as modern practice<br>Criticized if herbicide use rises                                         | Barriers: weed pressure; herbicide dependency; transition risk<br><br>Enablers: fuel savings; soil health narrative; peer evidence                        | Shifting from conventional ploughing to no-till can reduce CO <sub>2</sub> emissions from soil by approximately 36% and cut fuel-related CO <sub>2</sub> by up to 60% (from approx. 111 kg CO <sub>2</sub> /ha to 44 kg CO <sub>2</sub> /ha in winter cereals) The overall GHG reduction potential is estimated at 10–30%<br><br>N <sub>2</sub> O effects are ambiguous: soil compaction in no-till systems may slightly increase N <sub>2</sub> O in some conditions |
| <b>Nature-based solutions &amp; biodiversity</b> | Moderate<br>Field margins/shelterbelts: mature<br>Agroforestry/peatland rewetting: complex  | Moderate–high<br>Opportunity cost of land<br>Long payback horizon                                          | Accepted if linked to productivity<br>Peatland rewetting: contentious                                             | Barriers: land opportunity cost; delayed returns; CRCF methodologies pending<br><br>Enablers: results-based CAP payments; EU CRCF; adaptation co-benefits | Carbon sequestration potential varies considerably by practice type, soil condition, and time horizon<br><br>Peatland rewetting carries the highest per-hectare potential; agroforestry and field margins offer moderate, long-term accumulation                                                                                                                                                                                                                      |

Source: own elaboration based on the interviews and National Research Institute of Animal Production (2025).

## 3.2. Animal production

Animal production emerges from the interviews and workshops as the most sensitive and politically charged domain of agricultural mitigation. This is due both to the Polish model of agricultural development, which focuses on expanding animal production, and to the cultural significance of meat that still persists in Poland. Livestock

mitigation is inseparable from CH<sub>4</sub> emissions, manure handling, and the size and organization of herds. Across the interviews, it is also presented as an area where both incremental technological improvements and deeper changes are possible, albeit with very different cost profiles, time horizons, and social acceptability.

### Herd management and feeding

A first cluster of practices with high implementation potential concerns herd-level efficiency improvements, especially in dairy systems. Several interviewees point out that emissions are often discussed on an animal-by-animal basis, whereas mitigation logic should, in their view, focus on emissions per unit of output (e.g., per liter of milk). Improving feed efficiency, animal health, and lifetime productivity can significantly reduce methane intensity without necessarily reducing herd size. These practices include **optimizing feed composition and feeding strategies tailored to the animal's needs, improving ration formulation and reducing excess protein where possible, reducing disease incidence through improving animal welfare that translates into higher productivity (e.g. free-stall barns), better monitoring, and shortening calving intervals.**

Feed optimization and herd health monitoring are established components of modern dairy management. Technological maturity in this area is high. Digital sensors, data platforms, and performance monitoring tools are increasingly available, although especially to medium and large commercial farms. The mitigation potential lies in reducing enteric CH<sub>4</sub> emissions per unit of milk and lowering

replacement rates through improved longevity. While emission intensity can be reduced, their absolute level may increase if herd size grows (National Research Institute of Animal Production, 2025).

Costs vary. Feed reformulation may increase feed costs but can also improve feed conversion efficiency and reduce waste. Health monitoring technologies, such as sensors tracking rumination or temperature require upfront investment but can reduce veterinary costs and productivity



Source: topfarms.com

losses. Barriers include capital constraints, limited advisory access in smaller farms, and, in some cases, skepticism toward data-driven management. Social acceptance is high, as these measures align with a narrative of modernization and productivity enhancement rather than reduction.

Another frequently mentioned mitigation lever in livestock systems concerns **feed additives designed to reduce enteric CH<sub>4</sub> emissions**. Such additives can directly suppress methanogenesis in the rumen, achieving significant percentage reductions in CH<sub>4</sub> emissions per animal under controlled conditions. However, their implementation profile is more complex. The technology is still in diffusion stages. Costs are ongoing and high, with no clear motivation for the practice uptake from the individual farmer perspective (interviews) reflecting a classic coordination problem. Applicability is greater in confined feeding systems where feed composition can be tightly controlled. In extensive grazing systems applications face logistical challenges. Social acceptance is more uncertain compared to genetic or management

measures. Among the farmers, CH<sub>4</sub>-reducing feed additives are often perceived as a shortcut or an “easy fix.” One farmer described it as going out into the cold every day without proper clothing and then taking aspirin instead of addressing the root cause.

Moreover, there is also considerable skepticism regarding their potential impacts on both animal and human health. Mixed signals from the market reinforce this. For example, one dairy processor tests such additives and then withdraws, while another refuses to accept milk from farms that use them. This creates a sense among farmers that something may not be right with these solutions. Regulatory approval and public perception thus become central barriers. Attempts to scale up this practice are taking place in the EU, e.g. Denmark is requiring all conventional dairy producers with more than 50 dairy cows to use feed additives, and this is complemented by a subsidy scheme to support uptake (CONCITO, 2025). Technological maturity is advancing but not yet fully normalized across all markets.

### Genomic selection

A second long-term mitigation pathway repeatedly emphasized is genomic selection targeting CH<sub>4</sub> intensity and feed efficiency. Rather than relying solely on management adjustments, this strategy seeks to embed lower CH<sub>4</sub> emissions into the genetic profile of future herds. **By integrating CH<sub>4</sub>-related traits or feed efficiency indicators into breeding indices**, cumulative reductions can be achieved across generations. Annual genetic gains may appear modest, but over a decade or more they compound into meaningful shifts.

This technology is most applicable to medium and large herds integrated

into formal breeding systems with access to genomic testing and performance recording. The initial investment burden lies not at the individual farm level but at the sectoral level which means building reference populations, collecting methane-related phenotypic data, and developing breeding indices. Once incorporated into standard breeding catalogs, adoption becomes relatively low-cost for farmers. On the other hand, it can be assumed that traits related to productivity and health will be much more important for breeders and without additional pressure from the regulator, the choice of traits that reduce emissions will be of secondary importance.

The mitigation potential is durable and systemic. Unlike feed additives that must be continuously applied, genetic improvements persist once integrated into the herd. Costs at farm level (genotyping animals) are moderate and declining. Barriers include data infrastructure gaps, limited national coordination, and the time lag between selection decisions and realized emission reductions. Social acceptance

is generally high because the practice does not alter the visible nature of products nor introduce controversial inputs. Technological maturity is advanced in countries with strong breeding institutions, though methane-specific indices are still evolving. In Poland so far there is no such indicator and no plans to introduce it either (interviews).

#### CASE STUDY:

##### German dairy barn of the future

A research consortium led by the Institute of Animal Biology (FBN) and the University of Applied Sciences in Neubrandenburg has developed a design for a *barn of the future* aimed at reconciling animal welfare, operational efficiency, and transparency in dairy production. The concept integrates all production groups i.e. lactating cows, dry cows, calves, heifers, and young bulls, within a single, open-housing system structured into functional zones for resting, feeding, recovery, and movement. A central innovation is the cow-calf system, where calves are raised alongside their mothers in dedicated areas, supporting natural maternal behavior and welfare standards that exceed conventional separation practices.

Full automation underpins herd management. Intelligent feeding gates equipped with RFID technology allocate individualized rations, while centrally located automated milking systems minimize animal stress and optimize workflow efficiency. A dense sensor network continuously monitors activity, rumination, health parameters, and social interactions, enabling real-time data-driven decision-making. The physical environment is designed to approximate natural conditions: compost-bedded resting areas, ventilated flooring systems, robotic cleaning units, and even integrated tree plantings within the barn structure provide shade,



microclimate regulation, and behavioral enrichment. Dedicated visitor pathways and observation corridors allow public access and transparency while maintaining strict biosecurity protocols.

The design accommodates a full dairy herd with approx. 60 lactating cows, dry cows, 12 young calves, and 50 heifers and young bulls plus access to significant outdoor space of around 20 ha pasture and winter concrete yard. The concept responds to growing societal expectations around animal welfare and transparency in milk production. It aims to enhance welfare outcomes, data-driven management, and operational efficiency simultaneously. The barn has been developed as a *design and demonstration concept*, not yet constructed; its real-world viability depends on investor interest and future implementation trials. Yet, it highlights how next-generation barn design can potentially shape future standards in dairy housing and inform discussions on intensive livestock production modernization.

## CASE STUDY:

**Tarnicki farm: integrated nitrogen management across the whole cycle**

Jarosław Tarnicki operates a family farm in Kuyavian–Pomeranian Voivodeship (Northern Poland) combining pig production with arable crops. Over three generations, the family has built a system centered on minimizing nitrogen losses at every stage of production. Core practices include a diversified multi-year crop rotation; year-round soil cover through cover crops and undersowing; conservation tillage; and a closed manure loop in which liquid manure is fermented with nitrogen-fixing bacteria before precision field application, timed to plant growth phases. The farm limits pesticide use and plans fertilization needs based on regular soil tests.



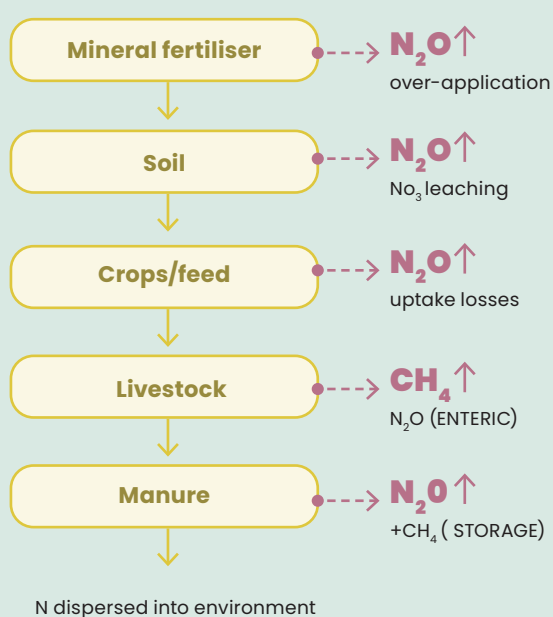
Photo by Kinga Tarnicka.

Feed rations include additives that reduce nitrogen excretion by up to 30%. The farm also uses photovoltaic panels and has a biogas installation planned around agricultural waste.

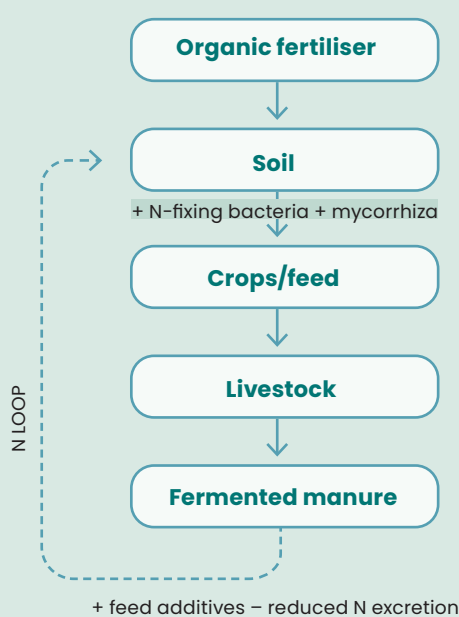
The results are striking: synthetic fertilizer consumption reduced by approximately 40% in recent years while maintaining yields; soil organic matter improved to 80 cm depth on class-4 soils; drought resilience substantially enhanced. Mr. Tarnicki describes this as good farming practice, not climate action. As he puts it: "soil is like a cow, it has to eat all the time." The case illustrates how an integrated approach to nitrogen can simultaneously reduce both  $N_2O$  and  $CH_4$  emissions, delivering economic benefits alongside environmental ones. It also shows that this kind of systems-level management depends on accumulated knowledge and long-term investment that cannot be substituted by a single technology or policy instrument. The scheme below shows the difference between a conventional nitrogen cycle where nitrogen flows into the atmosphere and the closed cycle illustrated by the case study.

**Conventional flow**

Losses at every stage

**Closed loop**

Nitrogen circulates within the farm



## Manure management

A third area with strong mitigation potential is manure management, particularly through **rapid incorporation and improved storage systems**. Several interviews emphasize that simple changes in manure handling, such as quickly incorporating slurry into soil rather than surface spreading can significantly reduce  $\text{N}_2\text{O}$  emissions and ammonia volatilization. From a technological standpoint, this is highly mature. Equipment for injection or rapid incorporation exists and is widely used in more advanced systems.

This practice is relevant across livestock farm types but is especially

impactful in medium and large operations with significant manure volumes. Costs are moderate if equipment must be purchased, though contracting services or cooperatives can reduce capital barriers. The mitigation potential per unit of manure is substantial relative to cost, making it one of the more cost-effective interventions. Barriers are largely logistical: timing, field access, and labor availability. Social acceptance is uncontroversial, as it aligns with environmental protection norms and often reduces odor complaints.

## Biogas and biomethane

Beyond incremental manure improvements, several interviews discuss **biogas and biomethane production from manure and other substrates**. This is among the most visible and capital-intensive mitigation technologies in livestock systems. They capture  $\text{CH}_4$  that would otherwise be emitted from manure storage and convert it into electricity and/or heat. It is therefore also an opportunity to substitute energy from fossil fuels, importantly also those imported from abroad (e.g. Russian gas). The mitigation potential per installation can be significant, particularly in large dairy or mixed operations.

However, biogas is highly scale-dependent. It is economically viable primarily on large farms or in cooperative models aggregating manure from multiple farms. Capital costs are high, and projects often depend on policy support or corporate co-financing. Interviewees point out that some processors are co-investing in farm-level biogas facilities to secure lower Scope 3 emissions and stable supply chains. This suggests potential

for a supply-chain-integrated solution rather than purely farm-driven adoption.

Barriers include regulatory complexity, grid connection issues, financing constraints, and in some regions local opposition due to odor or traffic concerns (Molenda, 2026). Technological maturity is high, but scalability in the fragmented Polish farming system is limited. Social acceptance varies regionally but is generally higher when installations are perceived as waste-to-energy solutions rather than industrial expansions.

Table 3 summarizes the animal production mitigation practices analysis presented above and supplements it with estimates of reduction potential obtained from the Polish National Research Institute of Animal Production. Importantly, these estimates are based primarily on international studies and therefore do not apply specifically to the Polish context.

**Table 3. Summary of mitigation technologies in animal production**

| Mitigation practice      | Technical maturity                                                                                                        | Costs                                                                                                                                                      | Social acceptability                                                                                                | Conditions                                                                                                                                                                                                                                                               | Reduction potential                                                                                                                                                                                                                                                                                                                                                                                       |
|--------------------------|---------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Herd management</b>   | High<br>Established in modern dairy<br><br>Digital tools increasingly available                                           | Variable<br><br>Feed reformulation: low–moderate<br><br>Health sensors: high upfront investment, but fast payback<br><br>Best suited to medium–large farms | High<br><br>Modernization, not reduction<br><br>Aligns with productivity narrative                                  | Barriers: capital constraints on small farms; advisory access gaps; skepticism toward data-driven management<br><br>Enablers: emission-intensity framing (per liter, not per animal); supply-chain efficiency pressure                                                   | Breeding progress and improved herd productivity are estimated to reduce enteric CH <sub>4</sub> by approximately 0.2% per animal per year, equivalent to 5.73 kg CO <sub>2</sub> e per head annually<br>Projected cumulative effect: roughly 3% reduction in total dairy CH <sub>4</sub> by 2030<br><br>Expressed per unit of output, this translates to approximately 7% lower emissions per kg of milk |
| <b>Feed additives</b>    | Advancing, but not normalized<br><br>Effective in confined systems<br><br>Not viable for extensive grazing                | Ongoing cost<br><br>Must be continuously administered<br><br>No one-time investment logic                                                                  | Uncertain, contested<br><br>Health concerns (both animal and human) circulating<br><br>Market signals contradictory | Barriers: disinformation risk; processor inconsistency; regulatory uncertainty across markets; confined-system only<br><br>Enablers: Scope 3 pressure; clearer safety evidence from EFSA; processor co-financing                                                         | 3-NOP supplementation reduces enteric CH <sub>4</sub> production by approximately 35% per animal, equivalent to 1,003 kg CO <sub>2</sub> e per head per year<br><br>This is one of the highest single-practice reduction potentials available in livestock systems<br><br>The effect is maintained only as long as the additive is continuously administered; it ceases upon withdrawal                   |
| <b>Genomic selection</b> | Advanced in leading countries<br><br>Poland: no national index, no plans<br><br>Long horizon (10–15 years to full effect) | Low at farm level (genotyping)<br><br>High at sector level (reference population, data infrastructure)<br><br>Gains are permanent once integrated          | High<br><br>No visible product change<br><br>No controversial inputs<br><br>Framed as breeding improvement          | Barriers: no national phenotyping program; data infrastructure gaps; time lag; productivity traits dominate breeding goals without regulatory pressure<br><br>Enablers: public sector coordination; CAP post-2027 funding; international reference populations available | Related breeding progress suggests a trajectory of approx. 7% reduction in CH <sub>4</sub> intensity per kg of milk by 2030<br><br>Genomic selection, if a national low-CH <sub>4</sub> index were established, could accelerate and deepen this trajectory – but realization requires a 5–7 year investment in phenotyping infrastructure before any breeding impact materializes                        |

| Mitigation practice            | Technical maturity                                                                     | Costs                                                                                                                                   | Social acceptability                                                                                                                     | Conditions                                                                                                                                                                                                                                                                                         | Reduction potential                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|--------------------------------|----------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Manure management</b>       | High<br>Technology widely used in advanced systems                                     | Moderate<br>Equipment purchase or contracting<br>Cooperatives reduce capital barrier<br>High mitigation per cost unit                   | High, uncontroversial<br>Reduces odor –community benefit<br>Aligns with environmental norms                                              | Barriers: logistical (timing, field access, labor); capital for small farms<br><br>Enablers: odor-reduction co-benefit; contracting models; straightforward regulatory compliance path                                                                                                             | Covering slurry storage tanks with an impermeable membrane or roof reduces CH <sub>4</sub> emissions by 50–80%<br><br>If gas flares are installed to combust the captured CH <sub>4</sub> , the reduction can reach 95%<br><br>In absolute terms: 284 kg CO <sub>2</sub> eq per dairy cow per year, 118 kg CO <sub>2</sub> e per pig per year, and 3 kg CO <sub>2</sub> eq per poultry unit per year in zero-litter systems                                                                                     |
| <b>Biogas &amp; biomethane</b> | High (technology)<br>Limited (Polish deployment)<br>163 installations vs. 2,000 target | High capital cost<br>Viable only at large scale or in clusters<br>40–60% public co-financing needed<br>Processor co-investment emerging | Regionally variable<br>Higher when framed as waste-to-energy<br>Local opposition: odor, more traffic<br>Risk of energy crop monocultures | Barriers: support legal scheme instability; grid access; financing; fragmented farm structure; risk of monoculture substrate dependency, risk of CH <sub>4</sub> leakages<br><br>Enablers: Scope 3 co-financing by processors; long-term difference contracts (needed); biomethane auction pathway | When slurry is processed in a biogas installation with covered post-digestion tanks, CH <sub>4</sub> emissions from manure storage can be reduced by up to 90% and N <sub>2</sub> O emissions by approximately 30%<br><br>The captured CH <sub>4</sub> is converted to electricity and/or heat, substituting fossil energy sources and generating a further indirect emission reduction (substitution effect).<br><br>Each installation also emits 10–15% of produced CH <sub>4</sub> through unavoidable leaks |

Source: own elaboration based on interviews and National Research Institute of Animal Production (2025).



## 4 | Strategic objectives for Polish agriculture

The structure of Polish agriculture, its emission profile and technological options define the starting conditions for climate strategy. Next, clarity about the *direction* of transformation is needed. The reform should be considered fair, beneficial and acceptable by the diverse actors of the agri-food value chain, and farmers in particular. This chapter examines the directions for the future of Polish farming identified through our participatory research process involving both farmers and researchers.

## 4.1. Expert perspectives on the future of Polish farming

There is broad expert agreement that the current model, the one oriented toward commodity production, heavily subsidized, and reliant on a narrowing crop base, faces compounding pressures that make transformation necessary rather than optional. The views on the structural direction of Polish agriculture divide into two broad camps, with an emerging third perspective.

**The first camp** holds that consolidation toward larger, more capitalized commercial farms is the long-run equilibrium. Only farms above a certain scale can amortize precision technology, meet evolving sustainability certification requirements, and generate sufficient margin to invest in emission-reducing infrastructure such as biogas or advanced manure systems.

**The second camp** argues that this trajectory is socially unacceptable in a country where SMFs manage the majority of agricultural land, produce most food, and provide livelihoods for a large rural population. In this view, the policy objective should be to improve the commercial viability of smaller farms through better value chain integration and collective organization, not to accept their displacement.

**A third perspective**, consistent with emerging research on regional food systems (see Ossowska et al., 2026), focuses less on farm size than on farm function and market embeddedness. The most resilient and climate-compatible model is one that captures value through differentiation and proximity to end consumers, manages the farm as an ecosystem as well as a production unit, and reduces dependence



Source: [topfarms.com](https://topfarms.com)

on purchased inputs and commodity price signals. This is achievable across a range of scales, but requires

a fundamentally different policy architecture than the current area-payment system.

## 4.2. Future of Polish farming through the eyes of farmers

By small and medium farmers themselves the future of Polish agriculture is framed less in terms of system optimization and more as **maintaining continuity, dignity, and economic viability**.

Farmers emphasize the importance of family traditions, often sustained across generations, and the responsibility of passing farms on to their children. This is closely linked to pride in producing high-quality food and maintaining the land. At the same time, these positive elements coexist with **frustration and uncertainty**—directed at political decisions, market conditions, and a perceived lack of respect for farmers' work—as well as concerns related to climate risks and future income.

Farmers' vision of the future is built around several enabling conditions. Central among these are **shorter and more equitable supply chains**, ensuring fair prices and closer relationships with consumers. Participants of the workshops and our interviewees also emphasize the need for **stable market conditions, fair import rules, and simplified regulations that reduce administrative burdens. Access to technology and practical support** from science is seen as essential for adapting to climate change. Equally important is the expectation of **consistent, long-term agricultural policy** delivered by credible and accountable decision-makers. Beyond production, farmers highlight **quality of life** as a key objective. The desired future includes less stress, more time for family, and

a better work-life balance, alongside a rural environment that remains socially vibrant and attractive to live in.

**What emerges from the above is the idea of complementarity of different farm types.** Some of them, especially SMFs, can be based on local, self-sufficient agriculture embedded in strong rural communities. Production focuses on natural methods and local markets, supported by cooperatives and direct sales. Farms diversify income through activities such as agrotourism and energy production, while maintaining close relationships with consumers and strengthening local economic resilience.

**At the same time, highly technological farms could operate**, where the farmer acts as a manager, using automation, precision technologies, and digital tools to increase efficiency and reduce physical labor. Production focuses on climate-resilient crops and improved resource management, with sales increasingly organized through digital channels. These diverse farm types are not seen as mutually exclusive, but as parallel pathways. Larger farms are expected to adopt automation and scale efficiencies, while smaller farms strengthen viability through diversification and local market integration.

### 4.3. Transforming farming: three pathways and the triple objective

Three distinct pathways of transformation emerged from the above-described research process. **These are not competing scenarios**, but analytically distinguishable pathways suited

to different farm types, regional conditions, and market positions and capable of coexisting within the Polish agri-food system.

#### PATHWAY 1:

##### Local, quality-based production

SMFs can increase profitability by **differentiating their products** (e.g. with quality, origin, low-input methods) and **embedding operations in shortened supply chains**, turning sustainability

into a price premium rather than a cost. In Poland, similar models—where committed consumers provide a major share of farm income—are marginal, but growing.

#### PATHWAY 2:

##### Vertically integrated farming and processing

The second pathway addresses the supply-chain weakness identified in section 2.4 by investing in on-farm or collectively shared processing capacity that allows farms to capture value currently surrendered to intermediaries. Individual operations with sufficient scale **move downstream into processing, branding, and direct**

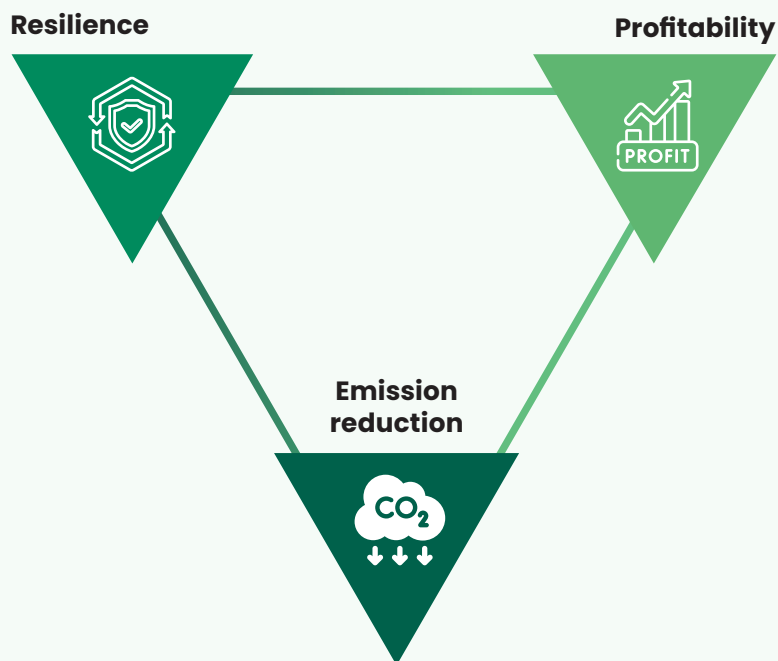
**market access, retaining the margin that the processing step generates**. Horizontal coordination among farms plays a supporting role, enabling smaller operations to pool the capital that processing infrastructure requires, and to jointly invest in mitigation equipment that no single farm could finance alone.

#### PATHWAY 3:

##### Hi-tech agribusiness

This pathway targets large farms, where precision agriculture improves input efficiency; **reducing emissions while lowering costs**. It **relies on access to capital, digital infrastructure, and advisory support, with growing supply-chain pressure** (e.g. Scope 3 requirements) already creating market demand in sectors like dairy and poultry in Poland.

Drawing on the preceding analysis of Poland's contextual framework and the emerging visions, **three strategic objectives must be pursued simultaneously if Poland's agricultural transformation is to be both climatically meaningful and socially durable** (see Figure 6). All three elements are intended to reinforce each other as suggested by Kabato et al. (2025).

**FIGURE 6.****Three final goals of the transformation of farms in Poland.**

The first is **maintaining and improving profitability**. Not in the narrow sense of maximizing output per hectare, but in the broader sense of generating sufficient commercially-derived income to make farms viable with less dependence on direct transfers. This requires improving the value farms capture relative to total food chain value, through market positioning, product differentiation, collective infrastructure, and stronger linkages to processing and retail that would also in turn improve farmers' market integration, their competitiveness and market access

The second is **building climate and market resilience**. The active capacity of farms to absorb shocks from drought, input price volatility, and market disruption. Practices that build soil organic matter, diversify rotations, and reduce purchased input dependency are central to this objective. Considering that droughts have accounted for 77% of agricultural

losses caused by extreme weather events in recent years (Siwiec, 2022), resilience is not an add-on to production strategy but a key precondition for continued viability.

The third is **reducing GHG emissions**. The key analytical point, supported by both research and field experience, is that many of the most effective mitigation practices also reduce input costs and improve resilience, creating a potential triple alignment that policy must make visible and economically rewarding rather than leaving it latent. At the same time the identified pathways might not always reduce emissions or hinder emissions from increasing further. Therefore, other measures might be needed to ensure emissions decline, including policies facilitating a shift in diets.



## 5 | Modern business models for Polish farming

Based on the identified pathways for the future of Polish agriculture, viable technologies, as well as the economic, social and political conditions, this chapter attempts to develop three distinct business models through which Polish farms of different sizes, production profiles, and market embeddedness can integrate emission reduction into their core economic logic.

Each of the proposed business models targets a distinct farm profile. At the same time, they all leave enough flexibility for farmers to adopt parts of alternative pathways in line with their individual needs and aspirations.

At the core of each model are three tightly connected elements. First, the **value proposition** asks what is actually sold differently. This may involve product differentiation – such as organic or low-emission production – but it may also include the provision of non-market value, such as environmental or climate benefits, where these are recognized by consumers, supply chains, or public schemes.

Second, the **core mitigation mechanisms** identify which emissions are reduced or sequestered and how. Categories of such mechanisms range from more resource efficient primary production and crop related measures through feed optimisation to reducing GHG from transport and energy sources. The framework requires that these mechanisms are clearly linked to measurable outcomes rather than general sustainability claims.

Third, the **economic logic** examines how the model translates value into viable and resilient farm income. This includes the revenue streams, upfront investments, operating costs, and risk exposure. Different models imply different combinations of income sources – such as market revenues, contractual payments, public support, or cost savings, as well as different exposure to price volatility, climate impacts, and regulatory changes.

The key question here is what forms of financial support are required to realize the value of these models, and which actors– markets, supply chains, or public policy– are best placed to provide them. Beyond the farm level, we embed each model in its **systemic conditions**.

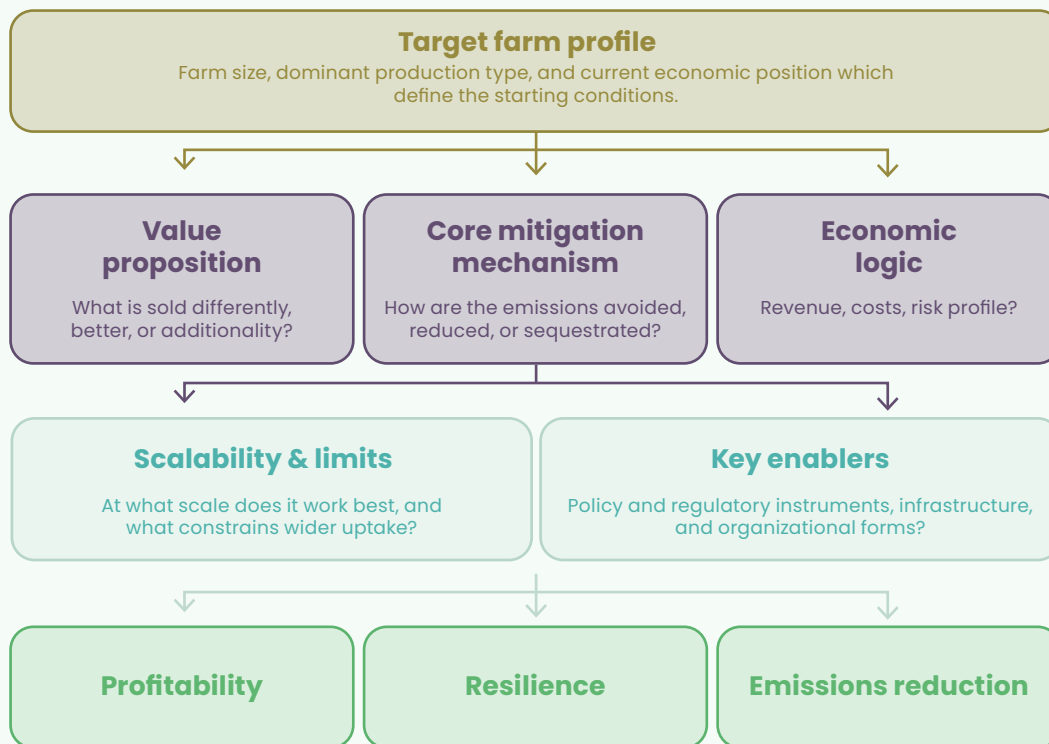
We assess **scalability and limits**: to what extent the model can be adopted by different farm types, on what scale, and what structural, economic or regulatory constraints may hinder its wider uptake.

We then move on to identifying **key enablers**, mostly structural support: well-tailored financial architecture (based both on CAP and private capital), proper regulations, access to infrastructure necessary for technology adoption, efficient institutions (producer groups, advisory centers), or digital platforms that aggregate environmental performance data.

Finally, each business model is evaluated against three strategic objectives: **productivity, resilience, and emissions reduction**. The framework is summarized by Figure 7.

FIGURE 7.

Analytical framework for new business models in Polish agriculture.



## 5.1. Business model 1: Local, quality-based production



**Value proposition:** Quality competition and short supply chains

The first model is built around **quality-based competition, in which lower-emission management is a commercial asset**. The farms best suited to this model are SMFs that have not yet engaged in large capital investments oriented toward commodity production or willing to shift away from it.

**These farms could use direct sales channels** such as on-farm sales, local markets, Community Supported Agriculture (CSA), or online direct sales platforms (e.g., FoodFarmer, Lokalny Rolnik). If they are not willing to sell directly, or in addition to direct sales, they could benefit from other forms of

shorter supply chains. These include tenders for local schools and public institutions, dedicated local sections in shops and supermarkets, as well as membership in cooperatives (e.g., Kooperatywa Dobrze).

emissions from long-distance transport, enhances transparency, creates stronger trust-based relationships, and improves consumers' access to higher-quality, healthier food.

**A core benefit of this model is that it aligns environmental performance with value creation.** Shorter supply chains limit the role of intermediaries in value creation and allow farmers to retain a greater share of the final product price, while direct relationships with customers create incentives for lower synthetic input production (Chiaverina et al., 2024; Zhang & Yu, 2021). Apart from direct farm resilience and climate benefits, this model reduces

#### CASE STUDY:

### **Community Supported Agriculture (CSA): Linking agroecology, markets and community**

**Farm profile and value proposition.** CSA is based on a direct partnership between a farmer and a defined group of consumers who commit to supporting the farm over a production season. Members typically pay upfront and agree to share the inherent risks of farming, including yield variability due to weather or other external factors. In return, they receive regular shares of seasonal produce and access to food whose origin, production methods, and values are fully transparent.

The value proposition extends beyond the product itself. Food is framed as a social, cultural, and health-related good rather than a commodity, and trust plays a central role. While organic certification is not always required, production practices are typically aligned with agroecological principles, and transparency is ensured through continuous communication and, in many cases, direct on-farm engagement.

**Economic logic.** The pre-financing of production through member contributions, stabilizes farm income relative to conventional market channels, where farmers bear full exposure to price volatility and yield uncertainty. By eliminating intermediaries, CSA farms retain a larger share of the final consumer price. In practice, most Polish CSA farms do not rely exclusively on this model for their livelihood. Many supplement their income through additional sales channels or off-farm work, particularly outside the growing season. The model entails significant organizational and communication demands, as farmers must manage not only production but also group coordination, logistics, and member relations.



Source: RWS Dobrzyńskie Warzywa Facebook profile (@rwsdobrzyń).

**Emissions relevance.** CSA farms are typically small-scale and diversified, supporting crop rotation, soil health, and on-farm biodiversity. Production aligned with agroecological principles reduces GHG emissions thanks to reduced reliance on synthetic input, crop-livestock integration and higher animal welfare standards. Short supply chains reduce transport, storage, and packaging requirements, while production for a fixed group of consumers lowers overproduction and food waste.

**Scalability and conditions for replication.** CSA remains niche but established in Poland, with around a dozen active initiatives serving approximately 1,200 households and several new groups emerging. Farms range from a few to several dozen hectares and vary widely in structure. Examples such as the CSA in Dobrzyń nad Wisłą demonstrate that scaling to several hundred households is possible within a relational model.

The main constraint is not production capacity but the need to build and sustain a committed consumer base willing to pre-finance and share risk. The model is organizationally intensive, requiring ongoing communication and coordination. Proximity to urban markets and access to convenient distribution points are critical enabling factors. As a result, CSA is more likely to scale through replication of local units than through consolidation.



Source: RWS Green Leaf Kąkolewice Facebook profile.

Source: interview with an expert, Kujawsko-Pomorski Ośrodek Doradztwa Rolniczego w Minikowie (2024.)



### Mitigation mechanism: low-cost, nature-based solutions and ecosystem services

Mitigation in this model relies on developing more resource-efficient primary production systems mostly centered around **low-cost or nature-based solutions, ideally aligned with the principles of organic farming.**

For plant producers, mitigation follows directly from the agronomic logic of quality orientation. Lower nitrogen application reduces N<sub>2</sub>O emissions. Legume-based rotations and cover cropping improve soil nitrogen cycling and reduce fertilizer dependency.

Diversified systems (intercropping, catch crops, protein crops, year-round green cover, agroforestry elements) generate sequestration and ecosystem service co-benefits.

For livestock producers, the shift toward quality over volume reduces enteric CH<sub>4</sub> per farm through smaller, better-managed herds. More efficient manure storage and precision of application further cut emissions, and where scale allows, anaerobic digestion might help close the nutrient loop.

Stronger crop-livestock integration reinforces circularity across both types of producers. Importantly, access to digital tools lowers the knowledge barriers for adopting these practices. Platforms such as OneSoil, SatAgro, or FarmPortal provide a satellite-based

monitoring, nutrient management support, and decision-making tool accessible even to smaller farms, and enabling more precise and resource-efficient management without requiring large capital investments.



### Economic logic: higher margins and environmental stewardship rewards

The economic logic rests on four revenue streams operating simultaneously, which together reduce dependence on commodity markets and increase resilience.

The primary one is a **higher share of farm-gate price captured by the farmer through short supply chains**. Evidence from CSA in Poland suggests that on well-embedded farms, subscription-based direct sales can constitute most of the farm income, providing both a premium and the income stability that commodity markets rarely offer (Onyszkiewicz & Sylla, 2025). At the same time, consumers of such schemes report similar, or even lower, product costs from CSA boxes compared to equivalent products available in traditional grocery stores (interviews). Moreover, in their latest study, the Grunt Institute of Food Strategies (2026) found that as many as 78% of Poles are ready to pay a premium for higher-quality products (61% are ready to pay up to 10% more). This shows a clear demand for high-quality local products in Poland.

The second stream comes from **environmentally beneficial production practices**, such as extensive grazing, improved manure management and storage, crop diversification, as well as nitrogen optimization and the use of organic fertilizer. The revenue in this

case would come from CAP subsidies for implementing such solutions, and from certification systems' ability to transmit price premiums to producers.

The third stream is **payment for ecosystem services**. Practices such as maintaining permanent grasslands, integrating agroforestry elements, and restoring wetland areas including peatlands and buffer zones can contribute to carbon sequestration, long-term carbon storage, or the avoidance of significant emissions, alongside broader environmental benefits. The implementation of such services is not currently rewarded under the CAP Strategic Plan, so unlocking this income stream will require changes to the CAP funding structure post-2027. While frameworks to support these outcomes (e.g. CRCE, nature credits) are emerging at the EU level, they remain at an early stage and are not yet widely accessible, and it is unclear to what extent they could represent a significant future revenue opportunity for farms in this model.

The fourth economic potential lies in **cost of production savings and on-farm income sources diversification enabled by a more resource-efficient production model**. Practices such as optimized input use – improved nutrient cycling, reduced reliance of synthetic fertilizer and external feed

directly lower operating costs, increasing net margins even without changes in input prices. At the same time, farms can generate additional savings and even additional income through the

integration of complementary activities, such as small-scale energy production (e.g. agrivoltaics or biogas from manure and residues), or some forms of agri-tourism.

#### FARM CASE STUDY:

### Lubuskie Angusowo (Droszków, Lubuskie Voivodeship)

**Farm profile and value proposition.** Lubuskie Angusowo is a family farm established in 2014 by Karina and Tomasz Jakiel. The farm area is 18 ha and currently maintains a herd of over 700 Red Angus cattle alongside pasture-raised broilers and laying hens, with all products sold directly to consumers by phone order. The value proposition is built on three interlocking elements: provenance (everything is raised and processed on-site), welfare conditions that visibly exceed commercial norms, and a production philosophy explicitly opposed to extractive farming. The farm's operating motto: *give animals the best possible life, so that only one day in their entire life is unhappy*, functions both as an ethical commitment and as a market signal to consumers willing to pay a premium for traceable, low-intensity animal products.

**Economic logic.** Revenue is generated entirely through direct sales, bypassing both wholesalers and retail intermediaries. This structure allows the farm to retain the full consumer-facing price, which for pasture-raised poultry and Red Angus beef is substantially above commodity levels. A secondary revenue stream has emerged organically: the farm now offers training workshops for other farmers interested in regenerative practices, monetizing accumulated knowledge alongside production. The farm has also developed a sales channel for Red Angus weaners to other cattle breeders, diversifying income across production, knowledge services, and breeding stock, which reduces exposure to any single market's price volatility and provides the income stability that commodity routes rarely offer SMFs.

**Emissions relevance.** The mitigation contribution of this model follows directly from the production system. Extensive grazing systems typically generate more CH<sub>4</sub> per unit animal than intensive systems, but offer other environmental benefits. Rotational paddock management (the farm moves its poultry to a fresh section of pasture every 24 hours) prevents overgrazing, promotes grassland botanical diversity, and maintains year-round soil cover, supporting soil organic matter accumulation and reducing nitrogen losses. The complete absence of synthetic fertilizers and the reliance on animal-integrated nutrient cycling eliminate the N<sub>2</sub>O emissions associated with manufactured nitrogen inputs.



**Scalability and conditions for replication.** The replication constraint is not technical knowledge but market infrastructure. The model depends on consumers within reach who are willing to pay a premium and engage in direct purchasing relationships, which currently favors farms with proximity to urban demand centers. The training workshops the farm offers are a notable enabling mechanism for wider diffusion: by systematically sharing practice-level experience with other farmers, Lubuskie Angusowo performs the peer-learning function that the broader evidence base identifies as the most effective driver of practice adoption in Polish agriculture.

Source: Lubuskie Angusowo (n.d.).



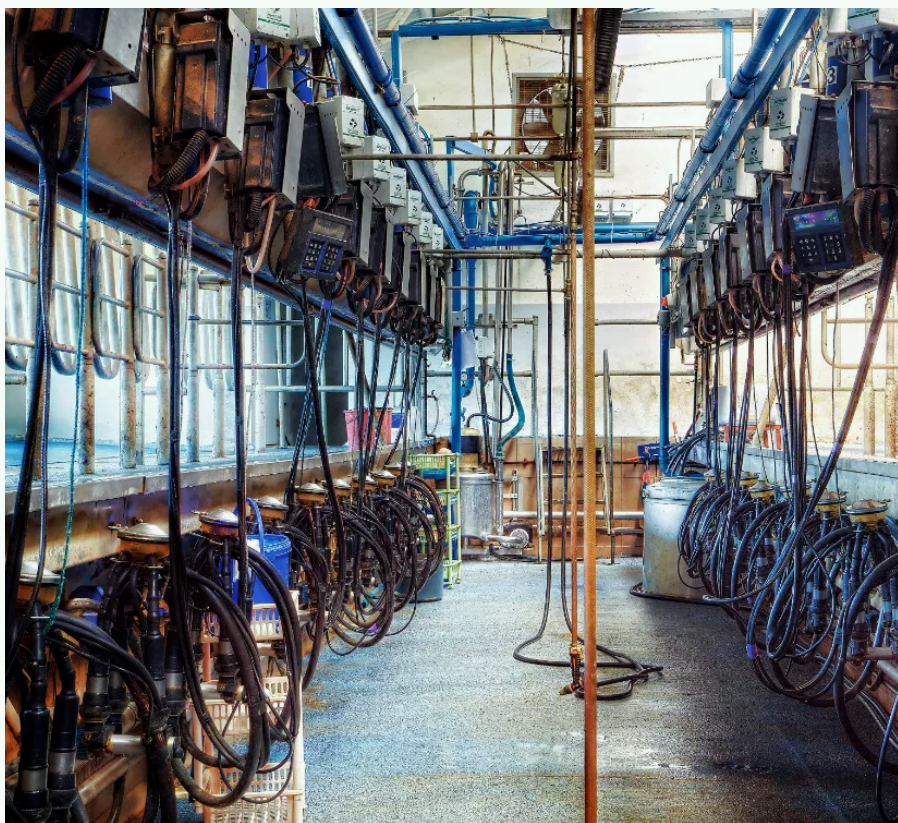
## Scalability and limits

This model scales through **replication across farms** and the thickening of local market infrastructure (local markets, food pick-up points, cooperatives, CSA), and to a lesser extent through the growth of individual entities. Farms in short supply chains face hard limits in workforce, logistics capacity, skills, and capital, as well as real support in implementing practices with environmental benefits (Bayir et al., 2022).

Even though CAP eco-schemes offered in the current CAP have attracted a lot of interest from farmers in Poland, their level of ambition is usually too low to meaningfully contribute to achieving the EU's environmental objectives. On the other hand, in the case of practices with higher environmental impact, their uptake remains below potential because payment rates do not adequately compensate for the perceived risk of transitioning (IZG own analysis based on data from ARiMR). Moreover, **the organic certification system is currently ineffective**, as exemplified by the lack of an automatic price premium for producers from processors in the case of beef.

**The dual land use for food and energy production is currently banned in Poland by law**, and despite growing interest of many stakeholders in agrivoltaics the Polish Ministry of Agriculture and Rural Development remains reluctant to support such a solution. Moreover, the technologies needed for agrivoltaics or bio-gas production would in the case of smaller farms require both some capital access support as well as grid or market access for energy sales.

On the demand side, scaling is further constrained by **infrastructural deficiencies in rural logistics, legislation insufficiently promoting local production** and **weak producer cooperation**. Eventually, as mentioned before, the dominance of discount retail in Poland concentrates purchasing power in channels incompatible with the quality premium logic, confining this model to just a consumer segment. In recent years, there have been some small steps in the right direction, such as the PLN 68 million construction of the EkoHala in Bronisze (Rzeczpospolita, 2025). This trend should be continued on a much larger scale to truly shorten the value chain and solidify the market for high-quality, readily available food.



Source: topfarms.com



## Enabling conditions

Scaling therefore depends on addressing four interlinked bottlenecks: (i) weak support for short supply chains, (ii) CAP incentives that favor commodity

production, (iii) missing remuneration for ecosystem services, and (iv) limited access to finance, coordination, and knowledge systems.

### Public policy and CAP post-2027: Reorientation of CAP toward short supply chains and ecosystem-based income streams

First, the post-2027 CAP should **introduce dedicated transition pathways for farms shifting from commodity production to short-supply-chain and quality-based models**. This can be made directly possible in the CAP 2028-2034 proposal thanks to the potential introduction of the farm-level transition support instrument under Article 10 that aims to support “voluntary transition towards resilient production systems” based on an approved transition action plan. In this context, Poland should explicitly recognize transitions to short supply chains as an eligible pathway, supporting conversion to organic production, and whole-farm input reduction strategies based on crop rotation, legumes, cover crops, and improved nutrient cycling. Support should cover both temporary income risks and upfront investments.

Second, increased support for environmental measures in the CAP is crucial for this model to deliver and for Polish farming to maintain its resilience in the long-run. Current instruments fail to bring about real environmental benefits and the 2028-2034 CAP proposal creates major risks that spending for environmental and climate purposes will be further downgraded. Poland should support reinstating a dedicated CAP ring-fencing for interventions with explicit environmental, climate and animal welfare objectives,

since without it the types of measures relevant for delivering this business model are likely to be crowded out by area-based income support and production-oriented allocations.

Third, CAP spending needs to be to a greater extent rebalanced toward local value chain infrastructure, including small-scale processing, storage, and distribution, and other enabling systems that allow farms to participate in short supply chains. At the governance level, the risk is that the removal of EAFRD-equivalent ring-fencing under the new Multiannual Financial Framework (MFF) will crowd out precisely the rural development expenditure on which this model depends, in favor of production-oriented coupled support. Without restoring a stronger role for rural development-type interventions, investments essential for this model will continue to be crowded out.

CAP should also begin to integrate ecosystem services as a stable income stream, including payments for agroforestry, permanent grasslands, or peatland restoration. Farms engaging in such practices should be able to access multiannual, results-based contracts that reward measurable outcomes such as carbon sequestration, biodiversity gains or water retention rather than only specific production practices.

Recognizing these activities as valuable contributions by farms to broader biodiversity and nature restoration objectives – beyond food production – should be one of the most important objectives in the upcoming financing period. This recognition should be appropriately reflected in policy design, thereby providing farmers with an additional source of income.

Finally, implementation of this business model requires embedding

short, quality-centered supply chains in national, regional and local food system strategies. Integration with regional development, climate adaptation, and public health policies would strengthen demand for high-quality food while reinforcing resilience objectives. Urban–rural linkages, in particular, can provide stable market outlets and reduce dependence on volatile commodity channels.

### **Regulatory and market frameworks: Promotion and procurement of local food**

Reduction of administrative burdens in certification systems, and clearer frameworks for cooperative logistics and food hubs would directly support value capture by farmers. At the same time, removing regulatory barriers to complementary activities – such as agrivoltaics – would unlock important diversification opportunities already identified in the model's economic logic (Czyżak & Mindekova, 2024).

On the demand side, expansion and modernization of direct sales infrastructure, green public procurement, preferential terms for local sellers in supermarkets, and consumer-facing policies can play a key role in stabilising markets for this model. Enabling and incentivizing local authorities to

source food for schools, kindergartens, hospitals, and public canteens from nearby farms would constitute a strong policy lever. This could be achieved by introducing quality and sustainability criteria into procurement guidelines, splitting large tenders into smaller lots to facilitate participation of small and medium-sized farms, and incorporating distance- or locality-based criteria in the evaluation of bids.

In parallel, promoting local, high-quality food through labeling schemes and public awareness campaigns would help translate environmental performance into reliable price premiums, extending demand beyond public procurement into private markets.

### **Private capital and financial instruments: Development of transition finance and investment vehicles for local food systems**

Existing financial solutions are beginning to address parts of this gap, but remain uneven in their reach. Some impact-oriented funds already provide long-term capital to sustainable food businesses, particularly at the level of market infrastructure, such as platforms connecting producers directly with consumers (e.g. Triodos Food Transition Europe Fund, n.d.). Further

downstream, supply chain finance mechanisms are emerging, in which food processors and retailers with ESG commitments partner with financial institutions to offer preferential loans to farmers conditional on sustainability performance. These instruments can reduce the cost of capital for farms already embedded in formal supply chains (EDF, 2025), but are less

accessible to those operating primarily through local or direct sales channels.

In parallel, blended finance structures – combining public or philanthropic first-loss capital with private co-investment – are increasingly used to reduce investment risk and crowd in commercial actors. Their relevance for agriculture is underscored by the European Investment Bank's (EIB) estimate of a €62 billion financing gap in the sector (IEEP & CONCITO, 2025). Instruments remain at an early stage of development and are not yet systematically aligned with the needs of small-scale, locally embedded production models. However, EIB has been mandated to support small and medium farmers in the 'Vision for the future of agriculture'

with €3 billion which should be scaled to much more.

Given these constraints, the most effective entry point for private capital lies not at the level of individual farms, but in shared market infrastructure – including food hubs, aggregation platforms, storage, and distribution systems – which can generate stable and scalable returns. To fully support this model, additional instruments are needed, particularly transition finance for small farms, aggregation-based lending mechanisms, and regional blended-finance vehicles aligned with local food-system strategies.

#### ENABLER CASE STUDY:

##### **Mobilna Marchewka Bonds: A financial innovation for local food markets**

**Model overview.** Mobilna Marchewka is a Kraków-based online local food market created by a consortium of six farmers and a technology partner (IsoTech). The current model is based on a digital system (APPETIT), which enables coordinated sales between multiple producers and consumers, with producers independently deciding on prices, product availability, and participation in sales sessions.

The platform allows for coordinated marketing and logistics, which reduces the time farmers need to spend on sales activities and enables them to focus on production. As a result, the system becomes more automated (including payments and invoicing), transparent, predictable, and scalable, while maintaining direct relationships between producers and consumers.

**Financing mechanism.** To support further development, the consortium introduced Mobilna Marchewka Bonds – a private bond issuance of PLN 200,000 intended to finance investments in logistics, collection points, onboarding of new users, and marketing.

The bond mechanism is designed as a business-based financing tool, rather than relying on grants or project-based funding. It enables the consortium to access capital at the moment it is needed, supports planning and predictability, and strengthens the financial independence of participating producers. At the same time, it introduces financial discipline by linking investment decisions to the responsibility for market development.

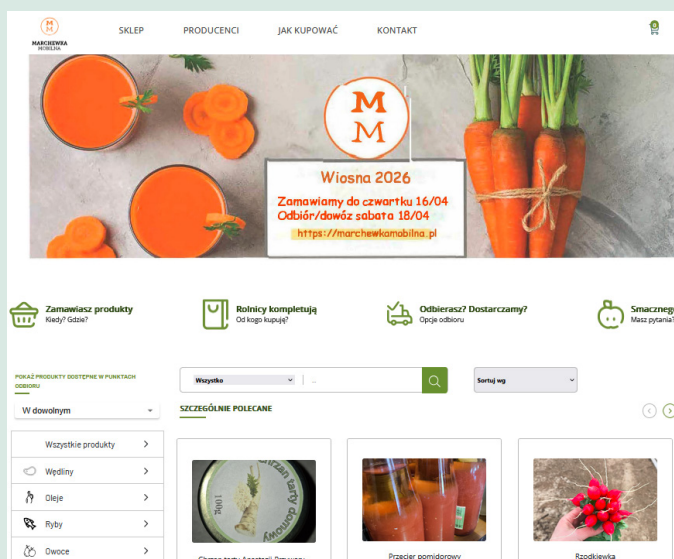
**Innovation and system relevance.** The key innovation lies in applying a bond-based financing mechanism – commonly used in financial markets – to the development of a local food market based on collective direct sales. In this model, financing becomes an integral part of the business structure rather than an external support mechanism.

This approach addresses a key challenge identified by the consortium: the difficulty of securing investment capital at the appropriate moment in the agricultural cycle to support both individual and collective sales. By enabling timely investment in shared infrastructure and market development, the model contributes to increasing sales, improving logistics, and strengthening the stability and predictability of the local food market.

The solution has been developed and tested by a consortium with long-term experience in building local food systems and is intended to be further refined and potentially replicated in other locations where similar digital and organizational models can be adapted.

**Benefits for investors.** For investors, Mobilna Marchewka Bonds represent a three-year investment (with entry levels between PLN 1,000 and 20,000), after which the invested capital is returned. During this period, investors receive interest payments and have the option to convert bonds into shares in a future company structure.

In addition to financial returns, investors become part of a community that supports the development of local food markets. For local investors, this results in a more stable and diverse food offer, while investors from other regions gain insight into practical solutions for developing similar markets in their own contexts.



Source: own elaboration based on Iso-Tech (n.d.).

### Knowledge systems, networks, and coordination: Strengthening agroecological advisory systems and farmer-led market coordination

Beyond finance, scaling depends on the availability of knowledge, advisory support, and collective organization. Strengthening the role of ODR would be critical, particularly in areas such as sharing with farmers the latest knowledge about methods, technologies and benefits of implementing more environmentally positive practices, as well as providing support in going through the administrative processes as part of quality certification frameworks and CAP support programs.

Equally important is the development of producer networks and cooperatives, which enable supply

aggregation, shared logistics, and improved market access (including local food markets). At the same time, it is important to inform and support local farmers about the availability of online sales platforms to encourage their participation.

Farmer-to-farmer learning systems, demonstration farms, and digital tools supporting both production and distribution can further accelerate adoption while reducing transaction costs. The key strategic direction of all of the above should be a sustainability focus.

# Local, Quality-based Production

## VALUE PROPOSITION



Quality competition and short supply chains



Small and medium, family farms



Demand from quality-seeking consumers (a large proportion of Polish population)

### 01. FOUNDATIONS OF THE MODEL



**Direct sales** farm-to-consumer channels (local markets, CSA, on-line sales)



**Short supply chains** cooperatives, green public procurement, local market access



**Access to smart-tech** mobile digital tools for small farms



**Eco-compliance and community** Environmental and ecosystem services, community trust

### 02. MITIGATION MECHANISMS



#### CROP PRODUCTION

##### Less nitrogen

soil diagnostics & optimised dosing → lower N<sub>2</sub>O emissions

**Better soil health** organic farming: cover crops, rotations, reduced tillage, diversified systems, etc.

##### Nature-based solutions

field margins, agroforestry, peatland management → carbon sequestration



#### ANIMAL PRODUCTION

##### Extensive grazing

pasture-based systems  
lower CH<sub>4</sub> per unit of land

##### Closed loop of nitrogen

manure recycled as fertilizer → reduced synthetic N input

##### Mixed-production benefits

crop-livestock integration → shared nutrient cycling & resilience

#### FARM CASE STUDY



#### Lubuskie Angusowo

Revenue through direct sales of low-emission cattle production

### 04. ENABLERS



**CAP & public policy:** CAP support for short supply chains and ecosystem-based income streams; post-2027 transition pathways



**Supportive market frameworks:** Green public procurement, preferential terms for local sellers, consumer-facing policies



**Private finance:** Innovative, community-based, and blended finance; impact capital for local market infrastructure



**Knowledge and networks:** Agroecological education; farmer-led market coordination skills; technical support with accessing modern sales platforms

#### ENABLER CASE STUDY



#### Mobilna Marchewka Bonds

Private bond issuance for online food market replacing grant dependency

### 03. ECONOMIC LOGIC



#### HIGHER MARGIN

Higher share of the final product price captured directly by the farmer



#### QUALITY PREMIA

CAP support for environmentally-friendly practices, organic certification



#### ECOSYSTEM SERVICES PREMIUM

CAP payments for agro-environmental measures (e.g. planting trees, rewetting peatlands)



#### SAVINGS & DIVERSIFICATION

Lower inputs, agri-PV and on-farm energy production, agritourism

### 05. OUTCOMES

|               |   |   |   |   |
|---------------|---|---|---|---|
| Profitability | ● | ● | ● | ○ |
| Resilience    | ● | ● | ● | ○ |
| GHG reduction | ● | ● | ○ | ○ |

## 5.2. Business model 2: Vertically integrated farming and processing



**Value proposition:** Integration of production with processing and market access

This model proposes **integration of production with processing and market access**, enabling producers to control product quality, positioning, and sales.

This integration can take multiple organizational forms:

- individual farm-level processing,
- collective ownership through producer groups or cooperatives,
- or hybrid arrangements combining both.

The model targets medium-sized or sometimes even small farms but keen

to engage with more modern sales channels.

The value proposition is threefold. First, margin capture: participation in processing allows producers to retain value that would otherwise accrue downstream. Second, market access: integration enables delivery of consistent volumes and standardized quality required by retail, food service, and public procurement. Third, product differentiation: producers can develop branded, traceable, and origin-linked products that are not feasible within commodity supply chains.



**Mitigation mechanism:** Circularity and shared infrastructure

Mitigation in this model operates at the level of the integrated production–processing system, where economic incentives extend beyond farm output to overall value chain performance.

First, vertically integrated models producing branded or origin-linked products often face stronger expectations regarding quality and production methods. Similarly to model 1, where credible, these create incentives to reduce inputs and adopt more

sustainable practices as part of the product's value proposition.

Moreover, when production is linked to processing, these costs directly affect margins, creating incentives to optimize nitrogen use and improve feed efficiency – aligning cost reduction with lower N<sub>2</sub>O and CH<sub>4</sub> emissions.

Second, nutrient circularity becomes feasible. Integration allows by-products (e.g. organic residues, whey, manure) to be reused as feed or fertilizer, reducing

synthetic input use and associated emissions.

Third, scale enables investment in mitigation infrastructure. Integrated systems can justify investments in manure

management, anaerobic digestion, or water systems that are not viable at the individual farm level, reducing CH<sub>4</sub> emissions and improving nutrient stability.

#### FARM CASE STUDY:

#### Kozłonoga – goat farm in Klecin (Lower Silesia)

##### Farm profile and value proposition.

Kozłonoga is a certified organic goat farm located in Klecin, Lower Silesia. It combines free-range animal husbandry, artisanal milk processing, traditional bread baking, educational activities, and agritourism in a single business model. Animal welfare is paramount. The goats graze on ten hectares of species-rich meadows, and the kids remain with their mothers for the first three months of their lives. The farm prioritizes quality, ecosystem health, and building a recognizable brand identity. Visitors can stay on the farm, participate in goat milking sessions, bread-making workshops, volunteer as part of “Rake Week”, or participate in educational activities focused on ecology, herbal medicine, and traditional food production.

**Economic logic.** The farm generates value by processing relatively small quantities of milk into premium products sold under a strong local brand. It stands out for its production methods, animal welfare, quality, and customer service. Cheese varieties such as Fetamina and Kozia Rebelia are marketed as artisanal products with a known origin. Milk processing, bread production, agritourism, workshops, volunteer programs, and sales in farm shops reduce reliance on a single source of income. The farm also serves as a platform for other local producers, selling products from partner farms.



Source: Kozłonoga Gospodarstwo Kozie Facebook profile.

**Emissions relevance.** These practices provide environmental benefits. Extensive grazing reduces dependence on external feed and supports the maintenance of permanent grasslands. The meadows are only mown twice a year, helping to preserve biodiversity and habitat quality. Manure remains integrated into the local nutrient cycle, and short supply chains reduce the need for transportation. The farm also minimizes waste by using biodegradable and returnable packaging. Milk, kefir, and yogurt are sold in reusable glass containers, while cheeses are sold without plastic packaging.

**Scalability and conditions for replication.** This model is most suitable for small and medium-sized farms located near urban markets or tourist destinations. It doesn't require advanced technologies but depends largely on entrepreneurial potential, processing skills, consumer engagement, and access to direct sales channels. The main barriers include labor intensity, sanitary regulations regarding small-scale processing, and the time required to build a trusted brand.

*Source: Krajowa Sieć Gospodarstw Demonstracyjnych (n. d.).*



### Economic logic: Margin capture, cost efficiency, and market access

The economic viability of this model rests on capturing value beyond the farm gate while improving cost efficiency across the integrated system.

First, processing margin capture. By integrating with processing – either individually or collectively – farms retain value that would otherwise accrue to intermediaries. In many agri-food chains, processing accounts for a substantial share of final product value, making this the primary source of income improvement.

Second, cost reduction through input efficiency and circularity. As fertilizers and feed are both major cost items and emission drivers, optimizing their use reduces operating costs while improving environmental performance. Integration further enables the reuse of by-products as inputs, lowering dependence on external inputs and stabilizing production costs.

Third, similarly to Model 1, CAP payments for implementing ambitious agro-environmental practice and ecosystem services.

Fourth, **income stabilization through structured market relationships.** Vertically integrated systems can establish longer-term relationships with buyers, including retailers, food service operators, and public institutions, often based on agreed volumes and pricing arrangements. Where such contracts exist, they reduce exposure to short-term commodity price fluctuations and improve revenue predictability. In addition, product differentiation can partially decouple prices from commodity markets. However, these effects depend on the strength of market positioning and the ability to secure stable buyers.

Fifth, access to higher-value market segments. Integration enables

product differentiation through branding, traceability, and quality attributes. When credible, they support price premiums and align with emerging demand for sustainable and transparent supply chains.

Additional benefits include input of production savings as well as

additional income generated through engaging in activities outside of traditional food production, such as energy production (e.g. agrivoltaics) or agro-tourism. However, the model requires significant upfront investment in processing and coordination, and its success depends on effective management and market positioning.



### Scalability and limits

Scaling of this model is constrained by several structural factors.

First, capital intensity. Processing and logistics infrastructure require high upfront investment and long payback periods, which limits entry even for commercially viable farms. Second, organizational and managerial capacity. Collective models depend on effective governance, coordination, and trust. Weak management is a well-documented cause of failure in producer organizations. Third, regulatory and administrative burden, particularly in food processing and compliance, which disproportionately affects smaller or newly established operations. Fourth, market access constraints. Integration only improves income stability where farms can secure stable buyers or credible product differentiation. Without this, producers remain exposed to price pressure from larger market actors.

Finally, path dependency of existing supply chains. Many farms are locked into established contractual relationships or production systems, which reduces their ability or incentive to reorganize toward integrated models.

As a result, scaling is incremental and context-dependent, typically building on existing producer groups or successful individual integrations rather than emerging rapidly at scale.



Source: [dobrze.waw.pl](http://dobrze.waw.pl)

## ENABLER CASE STUDY:

**Regional Food Hubs: Unlocking scalable access to sustainable local food**

**Role and value proposition.** Regional Food Hubs are organizational platforms providing physical and digital infrastructure that enable local, environmentally sustainable food to reach larger markets, including businesses and public institutions. Their primary function is aggregation: by consolidating supply from multiple producers, hubs enable the volumes, consistency, and administrative capacity required to access markets that are otherwise inaccessible to individual farms (they are not food aid or direct sales). In this sense, they act as **critical system infrastructure**, bridging the gap between small to medium-scale production and scalable distribution.

Food Hubs integrate several functions that are typically fragmented at farm level: aggregation, storage, order management, distribution logistics, and customer coordination. This reduces transaction costs and allows producers to participate in formal markets—particularly business-to-business (B2B) and public procurement—without individually managing compliance, logistics, and sales. For buyers, hubs provide a single access point to diverse local products, simplifying procurement while maintaining traceability and origin transparency.

**Conditions for success and scaling.** First, clear and concentrated demand is essential—particularly from anchor buyers such as public institutions or large businesses. Second, hubs require a diverse supplier ecosystem, combining smaller farms with larger or more established producers to ensure consistent supply while allowing local production to grow over time. Third, a strategic customer mix is critical: a small number of large, reliable B2B clients can provide financial stability, while smaller buyers or households can be added where logistics remain viable.

Equally important is organizational capacity and entrepreneurial leadership. Food Hubs require teams capable of managing logistics, finance, supplier relations, and market development simultaneously, especially in early stages. Finally, inter-hub collaboration can significantly accelerate development, allowing newer hubs to access shared knowledge, templates, and even supply networks.



Source: Organic North Facebook page

**Public policy and enabling environment.** The development of Food Hubs is highly dependent on enabling ecosystems. On the public side, procurement reform is critical: contracts must be structured in a way that allows small and medium producers to participate, including smaller lot sizes, less price-only evaluation, and more frequent contract cycles. Local authorities can further support hubs through access to infrastructure (e.g. storage, distribution space), incubator funding, and business rate relief.

At the national level, support is needed for horticulture expansion, local supply chain development, and correction of structural market failures that disadvantage smaller producers. Public funding and policy should explicitly include supply chain infrastructure — not only production — as a priority area.

**Financing and investment needs.** Private and philanthropic funders play a catalytic role in early-stage development. Better Food Traders Programme learning highlights the importance of funding regional cohorts of Food Partnerships to co-develop local food infrastructure plans and make regions “investment-ready”, as well as supporting national marketing campaigns to build demand for local, climate-friendly food.

Early-stage growth typically depends on grant funding, which plays a dual role: enabling initial investment in fixed assets and improving the hub’s financial position to access additional financing. Beyond grants, hubs require access to patient, low-interest loan capital, ideally accompanied by technical assistance to support business development and operational viability.

Crucially, the model would also benefit from alternative sources of private capital, including equity-like or flexible funding from cooperative membership, community investment schemes, crowdfunding, and impact-oriented investors. These instruments help bridge the financing gap that conventional finance does not cover, particularly in early and scaling phases.

Poland does not yet have a mature Food Hub ecosystem; instead, it has a range of partial or emerging models (buying groups, cooperatives) that perform some Food Hub functions but do not yet operate at scale or in institutional markets.



Source: Cambridge Food Hub Facebook profile.

Source: own elaboration based on Better Food Traders (2026), Barham et al. (2012).



## Enabling conditions

### Public policy and CAP post-27: Reorientation of CAP toward value chain integration and downstream investment

First, investment support for processing and logistics infrastructure. The key bottleneck is access to capital for assets with long payback periods, including processing facilities, storage, and distribution systems.

Support for producer organizations should be redesigned to reflect their role as commercial entities operating in processing and markets, not only as coordination platforms. This requires longer-term instruments combining

capital support with business development and governance advisory.

Public procurement plays a different role than in Model 1. Rather than primarily supporting local sourcing, it should create **stable, volume-based demand** that justifies investment in processing and logistics, including contracts of sufficient duration and

scale. Moreover, integration with processing industries, logistics systems, and regional supply chains is critical. Regional clustering of producers, processors, and buyers can significantly improve efficiency and enable scaling. Without such embedding, integrated models remain fragmented and struggle to compete with established supply chains.

### Regulatory and market frameworks: Enabling entry into processing and formal B2B markets

The main regulatory barrier is entry into processing and formal B2B markets. Existing sanitary, administrative, and certification requirements create disproportionate costs for farms and groups moving downstream. Simplified, risk-based regulation is

needed to enable scaling of small- and medium-scale processing. In parallel, stronger frameworks for contracting and standardization are required to support participation in retail, food service, and public procurement markets.

### Private capital and financial instruments: Mobilization of long-term capital for processing and logistics infrastructure

The central financing gap concerns long-term investment in fixed assets, not working capital or on-farm modernization. Processing and logistics infrastructure require financing instruments with longer horizons and higher risk tolerance.

value chain infrastructure, not individual farms. Compared to Model 1, this model offers clearer revenue streams, making it more accessible to private capital—but only once initial risks are reduced.

Blended finance and cooperative lending are particularly relevant, but must be explicitly structured around

Early-stage investments remain high-risk and require public or philanthropic participation to crowd in private investors.

### Knowledge systems, capabilities, and coordination: Building commercial and managerial capabilities for integrated value chains

Capability development in market access and production practices. Farms must acquire skills that go beyond primary production, including branding, product development, quality management, and negotiation with buyers in modern food markets. At the same time, improving resource efficiency requires knowledge of practices such as nutrient optimization, feed

management, and circular resource use. Strengthening advisory systems and targeted training—particularly through ODR and peer-learning networks—is therefore critical to reduce both commercial and operational barriers to integration.

# Vertically Integrated Farming And Processing

## VALUE PROPOSITION



Downstream value capture through on-farm processing



Medium farms, commercially oriented, cooperative structures



Demand from retailers, food service and institutional markets

### 01. FOUNDATIONS OF THE MODEL



**Vertical integration**  
farm → processing → branding → market



**Producer groups**  
pooled capita & infrastructure



**Collective logistics**  
Shared processing, storage & distribution



**Certification quality,**  
sustainability and origin standards

### 02. MITIGATION MECHANISMS



#### CROP PRODUCTION

**Closed nutrient loops**  
processing waste → organic fertilizer → reduced synthetic N

**Diversified rotations** aligned to processing supply needs

**Carbon sequestration** agroforestry & soil carbon management



#### ANIMAL PRODUCTION

**Cluster manure management**  
injection & covered slurry storage

**Shared biogas installation**  
pooled substrates across member farms

**Herd efficiency at group scale**  
feed optimization & collective MRV

#### FARM CASE STUDY



#### Kozlonoga

Capturing full field-to-product margin by eliminating the processing intermediary

### 04. ENABLERS

- ✓ **CAP & public policy:** Long-term producer group support; post-2027 transition pathways for cooperative processing investment
- ✓ **Supportive market frameworks:** Simplified cooperative law; public procurement favouring local processors; expansion and modernization of direct sales channels
- ✓ **Private finance:** Patient equity for processing assets; blended finance for shared mitigation infrastructure
- ✓ **Knowledge and networks:** Cooperative governance training; collective carbon accounting platforms; public advisory support

#### ENABLER CASE STUDY



#### Regional Food Hubs

Platforms aggregating supply from multiple producers to access B2B and public procurement

### 03. ECONOMIC LOGIC



#### HIGHER VALUE PRODUCTION

Processing margin captured collectively; intermediary eliminated



#### QUALITY PREMIA

Pro-environmental practices, certification, access to higher value segments



#### STABLE CONTRACTS

Long-term commercial buyers reduce price volatility



#### SAVINGS & DIVERSIFICATION

Input efficiency and circularity, pooled MRV & logistics costs

### 05. OUTCOMES

|               |   |   |   |   |
|---------------|---|---|---|---|
| Profitability | ● | ● | ● | ○ |
| Resilience    | ● | ● | ● | ● |
| GHG reduction | ● | ● | ○ | ○ |

Moreover, successful integration often requires actors that can organize supply, manage relationships with buyers, and coordinate logistics. Strengthening producer networks and intermediary

structures (such as food hubs) can reduce transaction costs and enable participation of farms that would not be able to integrate individually.

### 5.3. Business model 3: High-tech agribusiness



**Value proposition:** Input efficiency and access to technology

The third model targets a numerically small but economically and climatically significant segment of Polish agriculture: large commercial farms (e.g. those above 50 ha and/or €100,000 in SO, as defined earlier). Their advantage is being already integrated into formalized supply chains and having the capital to invest in more expensive, precise technologies.

The value proposition here is distinct from the other two models since large commercial farms compete on input efficiency. The core argument is that the same management decisions that reduce costs simultaneously cut emissions, making climate-compatible practice a rational consequence of commercial logic rather than a separate policy objective. A global meta-analysis integrating 85 empirical studies and 1,472 farm observations finds that precision agriculture technologies increase average return on investment by 22.3% and improve nitrogen use efficiency by over 15% with an associated reduction in GHG emission intensity of 9.4% across adopting farms (Lan & Ban, 2025).

Yet, these returns are not uniformly distributed across farm sizes. Analysis of FADN data for Poland, Germany, France, and Romania demonstrates that the

net present value of precision agriculture investment turns positive only for farms at or above €100,000 in SO, confirming that the target segment of this model is actually defined by the scale at which the technology becomes commercially rational (Sanyaolu & Sadowski, 2024). Moreover, a systematic review of field-trial evidence reinforces this finding, noting that benefits of variable-rate and real-time digital management consistently outweigh investment costs on cereal holdings larger than 75 ha, while evidence for smaller operations remains less robust (Ruder et al., 2026).

However, the prospective dimension of such a value proposition is even more consequential. Under the Corporate Sustainability Reporting Directive (CSRD), approximately 50,000 EU companies are now required to disclose Scope 3 emissions (namely: those embedded in their value chains) with the same rigor applied to financial accounts. For food processors and retailers upstream agricultural production accounts for up to 90% of the total climate footprint, making primary producers the central node of corporate decarbonization strategies (WBCSD, 2023).



### Mitigation mechanisms: Precision, biology, and circular

The mitigation logic of this model operates through three mechanisms. Each corresponds to a different source of agricultural emissions and technological entry point.

The first one is **precision, technologically advanced nitrogen management**. Variable-rate application of fertilizers, guided by soil diagnostic data and in-season yield mapping, reduces nitrogen inputs while maintaining yields by eliminating surplus application, which drives  $\text{N}_2\text{O}$  emissions. At the field scale, improved “4R” nitrogen management (meaning: *Right Source at the Right Rate, Right Time, and Right Place*) has been shown to reduce growing-season  $\text{N}_2\text{O}$  emissions by up to 57% without yield penalty. Automated GPS guidance and section control systems generate additional fuel savings, eliminating overlap on headlands and reducing diesel consumption by several percent per ha, a modest but permanent gain that requires no change in farm system (Ferland et al., 2024).

The second mechanism addresses livestock. **Feed ration optimization** reduces  $\text{CH}_4$  emission intensity (the volume emitted per kilogram of milk or meat), without requiring herd reduction. The most evidenced measure is the feed additive Bovaer—3-nitrooxypropanol (3-NOP), an EU-approved  $\text{CH}_4$  inhibitor that selectively targets the methanogenesis pathway in rumen archaea. Meta-analysis of dairy trials finds a consistent reduction of approximately 31% in enteric  $\text{CH}_4$  production at standard doses, with no adverse effect on milk yield or composition (Kebreab et al., 2023).

Next, **genomic selection for low- $\text{CH}_4$  traits** is a fourth, longer-orizon mechanism.  $\text{CH}_4$  yield in dairy cattle is a heritable trait with estimated heritability around 0.21, and Dutch modeling demonstrates that incorporating a  $\text{CH}_4$  index into national breeding goals could reduce emission intensity by 24% by 2050, a permanent, cumulative gain that, once incorporated into the breeding population, propagates without further per-farm investment (de Haas et al., 2021).

The last mechanism is **biogas production and nutrient circularity**, although only under regulatory protection against the negative effects of these solutions on broader sustainability (Profundo, 2025). Anaerobic digestion of manure and co-substrates is applicable at both the individual large farm and cluster level. It captures  $\text{CH}_4$  that would otherwise be released from open slurry storage, converts it into electricity and heat or into upgradeable biomethane, and returns stabilized digestate to fields as a mineral fertilizer substitute, thereby reducing both direct  $\text{CH}_4$  emissions from storage and the  $\text{NO}$  emissions associated with synthetic nitrogen inputs (IEA Bioenergy, 2024).

The potential for increasing power from renewable energy sources also lies in **seeking synergies with other entities**. For example, the development of Agrivoltaics in Poland is currently hampered by legal regulations. Meanwhile, reports from the US show that cooperation between a farmer (landowner) and the owner of a photovoltaic installation can lead to diversification of the former's income and, consequently, increased farm profitability (Kennedy,

2026), as well as improve water retention and in the case of some plants even increase their yields (Czyżak & Mindekova, 2024). In the example cited, the farmer, in addition to selling

meat, receives an additional stream of income as compensation for his animals cleaning under the panels under which they graze (Kennedy, 2026)



### Economic logic: big scale and diverse income

The primary and most immediately realizable stream is **operational cost reduction**. Precision agriculture investments are justified first and foremost by savings on fertilizer, fuel, and labor. According to Sanyaolu and Sadowski (2024), the investment payback for large farms is driven by 15–20% reductions in crop protection and fertilizer expenditure. Notably, these returns accrue even when commodity prices are low, making them the anchor of the model.

The second stream is a **prospective premium for documented low emission intensity in formal supply chains**. Under CSRD, agricultural production represents up to 90% of food processors' Scope 3 footprint, creating a market incentive for downstream buyers to fund and reward on-farm mitigation (WBCSD, 2023). The Danone case described below illustrates the mechanism; its extension to Polish-owned processors depends on the depth and speed of the regulation enforcement reaching their supply chains (see Box 14).

The third potential stream is **direct monetization of soil carbon improvements** through voluntary markets or the EU CRCF, although this remains at an early stage. Agricultural carbon credits currently trade at approximately \$4–6 per ton CO<sub>2</sub>e in voluntary markets, and CRCF certification methodologies for carbon farming

are expected only in 2026–2027 (BIS Research, 2024). Until prices rise, methodological standards consolidate, and Monitoring, Reporting, and Verification (MRV) costs fall further, carbon farming will not constitute a real option for most Polish operations. Moreover, the commodification of natural resources carries many risks, from lack of additionality to outright fraud (Fiore & Grabbe, 2025).

The last stream is **energy and biogas revenue**. Anaerobic digestion installations—whether at individual large farm or cluster scale—generate electricity and heat for autogenous consumption or grid sale, and biomethane eligible for injection into the gas network. In Poland, a case study of a 0.499 MW dairy farm biogas installation shows that public co-financing of 40–60% of capital cost is required to achieve satisfactory internal rate of return under typical energy price conditions, confirming both the revenue potential and the current financing gap (Kusz et al., 2024).



## Scalability and limits

Model 3 scales through deeper adoption within the existing segment of large commercial farms, not through replication across the broader farm population. Its aggregate climate contribution depends on the depth of adoption within a narrow but disproportionately emitting stratum.

The principal investment barrier is not capital access but **regulatory uncertainty**. This distinction matters: the access-to-finance problem documented in European agriculture is concentrated overwhelmingly among SMFs and young farmers. The EC's assessment (2023) puts the EU-wide financing gap for primary producers at €62 billion, but attributes it primarily to collateral deficits, limited credit history, and income volatility that define small-scale farming, not the operating profile of large farms potentially subject to Model 3 implementation (see also EIB, 2020).

The aforementioned Polish biogas case shows that agricultural biogas plants of viable capacity require high public co-financing to achieve satisfactory rates of return not because farms lack creditworthiness, but because the operating economics of biogas depend on the Renewable Energy Sources (RES) Act support scheme design that has shifted repeatedly and remains in flux (Kusz et al., 2024). Carbon accounting infrastructure faces an analogous problem: investment in farm-level MRV is rational only if it generates a price signal from downstream buyers or a certified CRCF credit, neither of which is yet systematically available in Poland. Farmers and financiers are therefore rational to withhold commitment to infrastructure



*Hala Mirowska market hall in Warsaw, photo by Filip Kwiatkowski.*

whose returns depend on regulatory frameworks that are not settled.

**A second constraint operates at the supply-chain level.** The Scope 3 mechanism that creates market incentives for documented low-emission production currently reaches Polish farms primarily through multinational processors operating under science-based targets. For the majority of large Polish livestock producers (supplying domestically-owned processors not yet under comparable CSRD reporting pressure) the price signal that would reward emission intensity reduction has not yet materialized. Until law enforcement cascades through Polish supply chains sufficiently deeply, the model's prospective revenue from emission-intensity premiums depends on the presence of multinational buyers, thereby concentrating early adoption geographically and sectorally.

## COMPARATIVE CASE STUDY OF MODEL 3 IN POLAND:

**Corporate scale vs. family ambition**

The two cases below represent different entry points into the Model 3 logic: one from the top of the size distribution, one from its upper edge. Neither fully instantiates the model in climate terms, but together they map what already exists and what remains to be built.

**Top Farms Group** operates across more than 23,000 ha in four voivodeships (Greater Poland, Opole, Lubusz, Warmia–Masuria) as part of Spearhead International, a pan-European farming enterprise covering approximately 75,000 hectares. Its diversified production base (cereals, oilseeds, potatoes, sugar beet, dairy) and downstream processing through an in-house seed company, distillery, and juice operation shows the scale at which precision nitrogen management, reduced tillage, and carbon footprint tracking fully become commercially rational. The Group has formally embedded regenerative principles into its operations and offers carbon accounting as a service to partner farms. Its “symbiotic model”—structured agronomic cooperation with 151 family farms across 2,460 ha of contracted land—provides these smaller operations with variety selection, precision services, and



Source: CONCITO.

machinery access they could not otherwise afford. Top Farms is the closest existing Polish analogue to the knowledge-transfer and supply-chain integration functions that Model 3 requires at sectoral scale. The mitigation mechanisms it employs are viable precisely because corporate scale enables cost amortization unavailable to individual farms.

**Hądzlik-Lipowczyk farm** in Drzewce (Greater Poland) represents the upper boundary of what a commercially ambitious family operation can achieve within a formal supply chain. The 365 ha dairy farm is run by the president of the Polish Federation of Cattle Breeders and Dairy Farmers and maintains 1,300 head of cattle including 500 dairy cows across two modern free-stall barns built over nine years, and supplies milk to Mlekovita under a long-term contractual arrangement. It is among the first farms in Poland to produce A2A2 milk, a differentiation strategy that demonstrates how supply-chain integration can generate market pull for farm-level capital investment. A biogas installation is in the planning phase. The farm illustrates the economic logic of Model 3: stable processor relationships reduce price volatility and create the income predictability needed to plan expensive transitions. What it does not yet demonstrate is the climate logic. There is no systematic carbon accounting, no documented emission intensity target, and no genomic selection program for low-CH<sub>4</sub> traits. The farm stands at the threshold of Model 3 without having crossed it in environmental terms.

This is diagnostic: the commercial preconditions are in place, but the regulatory and market signals that would make the next step rational are not.

**The comparison matters** because it identifies where the constraint lies. For Top Farms, scale is the enabler, mitigation is a co-product of efficiency at a size most Polish farms will never reach. For Hądzlik-Lipowczyk, the economic architecture of Model 3 is present but the climate layer is missing, not because of incapacity but because no instrument currently makes it financially worthwhile to add it. Closing that gap is a policy task, not a farm-level one.

Source: Top Farms (n.d.); Fermy Drobiu Lipowczyk (n.d.).

The genomics constraint, unlike the others, is not a financing or market failure but a **public-goods problem**: no national index for low-methane traits in cattle exists in Poland, and none is currently in development.

Building the reference population, collecting phenotypic data, and validating the index is a sectorally-organized investment that no individual farm can make unilaterally.



## Enabling conditions

### Public policy and CAP post-2027

The current investment support instrument allocates funding to agricultural modernization without conditioning eligibility on demonstrated market failure. OECD monitoring (2025) documents that approved plans predominantly favor economic over environmental outcomes, with limited climate ambition. For Model 3, public co-financing is only justified where investment Net Present Value (NPV) is negative due to genuine regulatory uncertainty—primarily large biogas installations and carbon accounting infrastructure—not

where market returns are positive and private capital is accessible (IEEP & CONCITO, 2025; CIP, 2026). The Polish CAP Strategic Plan should introduce explicit additionality criteria: applicants above €100,000 SO should document a financing gap attributable to regulatory risk and ambitious climate criteria, not merely investment cost. This would direct scarce rural development funds toward genuine leverage points and signal that Model 3's bankable investments should progressively move to private markets.

### Regulatory and market frameworks

Under the Renewable Energy Sources (RES) Act of 20 February 2015, installations above 1 MW must enter annual competitive auctions with support awarded for one year at a time, creating exactly the horizon mismatch that deters investment commitment

(URE, 2023). Even a 0.499 MW dairy farm biogas plant requires substantial public co-financing not due to poor economics but because current schemes fail to provide the long-term revenue certainty lenders require (Wróbel-Jędrzejewska et al., 2024).

The response Poland needs is a different instrument—long-term difference contracts guaranteeing a stable spread over a 15-year horizon. The 2025 RES Act amendment introduced a biomethane auction pathway above 1 MW, but the framework for large electricity-generating biogas installations remains underdeveloped (Bird & Bird, 2025). Regulatory design must also guard against perverse incentives: German experience shows that biogas expansion without appropriate land-use constraints can entrench energy crop monocultures and increase

competition between food and energy production (Scherger, 2026). On the carbon side, the Omnibus package adopted in April 2025 delayed CSRD reporting by two years and reduced the number of in-scope firms by approximately 90%. This risks slowing the Scope 3 transmission through Polish food supply chains precisely when it was beginning to materialize. Poland should resist deferring compliance for its largest domestic food processors and treat the interval as a window to build MRV infrastructure, so that

#### ENABLER CASE STUDY:

##### **Danone Poland: feed additive and biogas programme with milk suppliers**

**Model overview.** Danone Poland has committed to covering the cost of CH<sub>4</sub>-reducing feed additives for its contracted milk suppliers, with a target of 30% of the contracted herd reached by 2025 and 60% in subsequent years. The company is also co-financing biogas installations at supplier farms. The intervention is initiated and financed or co-financed by the processor, not solely by the farmer.

**Economic logic.** The mechanism works because Danone operates under science-based targets and ESG reporting obligations that require it to account for Scope 3 emissions. Reducing enteric CH<sub>4</sub> at the farm level directly improves the company's reported emission intensity. Co-financing on-farm mitigation is therefore not philanthropy but a procurement strategy. It secures lower-emission supply, reduces the cost of corporate climate compliance, and strengthens long-term supplier relationships. For the farm, participation is financially risk-free and often requires no capital commitment.

**Emissions relevance.** Feed additives administered under this programme are projected to reduce enteric CH<sub>4</sub> by approximately 30% per animal. Biogas co-financing delivers a further reduction by capturing CH<sub>4</sub> from manure storage that would otherwise be released directly to the atmosphere. Both mechanisms target the two largest sources of emission in dairy production simultaneously.

**Scalability and conditions for replication.** The systemic significance of this case lies less in its scale than in what it reveals about preconditions. Danone can initiate this mechanism because it operates under binding Scope 3 reporting obligations and global science-based targets. Polish-owned processors — who handle the majority of domestic milk supply face no comparable pressure and have not replicated the model.

The result is a **two-speed system**: farms integrated into multinational supply chains receive funded mitigation support, while the vast majority of Polish livestock producers receive no equivalent signal from their buyers. Replication at scale therefore depends not on farmer willingness or farm economics, but on extending CSRD enforcement to the largest domestic food processors and on building the standardized emission accounting infrastructure that would make Scope 3 co-financing arrangements auditable and credible across the Polish supply chain.

farms can respond credibly when the supply-chain signal arrives.

### Private capital and financial instruments

Large commercial farms generally have the creditworthiness to finance standard precision agriculture investments through commercial channels (EIB, 2020). Public instruments are therefore most impactful where private capital genuinely cannot reach: biogas installations facing regulatory risk, carbon accounting

infrastructure without established revenue streams, and novel investment categories without a performance track record (IEEP & CONCITO, 2025; CIP, 2026). Systematically directing EAFRD-equivalent funds toward investments where commercial banks would lend displaces rather than catalyzes private capital.

### Knowledge systems, networks and coordination

Two pieces of public infrastructure require coordinated sectoral investment that no individual farm can finance. First, a national genomic program for low-CH<sub>4</sub> cattle: building a reference population, collecting phenotypic data across sufficient commercial dairy operations, and validating a national breeding index is a public good with a 5- to 7-year horizon. Achieving the required prediction reliability requires data from at least 100 farms, with an average of 150 cows per farm, over a minimum of two years (de Haas et al., 2021). Where such investment has been made (Denmark, the Netherlands, Sweden), results are replicable and transferable; heritability estimates for CH<sub>4</sub> yield and intensity of 0.30 and 0.38, respectively have been documented across Canada, Australia, Switzerland and Denmark (Manzanilla-Pech et al., 2021). In Poland, no such program exists or is planned.

A consortium coordinated by KOWR, IZ PIB, and breeders' associations, initiated under the CAP post-2027 cross-cutting digitalization objective, could yield a validated national index by the mid-2030s. Second, a national farm-level carbon accounting platform—co-financed through CAP Pillar 2 and interoperable with processors' Scope 3 reporting systems—would socialize MRV infrastructure costs and enable farm participation without individual certification expenses. The complexity of MRV implementation across diverse conditions is currently identified as the primary barrier to carbon market participation in Poland.

# High-tech agri-business

## VALUE PROPOSITION



Input efficiency as competitive position



Large commercial farms



Prospective Scope 3 compliance premium

### 01. FOUNDATIONS OF THE MODEL



**Precision agriculture**  
variable-rate application, GPS guidance, sensors



**Digital decision tools**  
farm management systems, MRV platforms



**Supply chain integration**  
formal contracts, Scope 3 reporting



**Capital access**  
commercial credit, risk-sharing instruments

### 02. MITIGATION MECHANISMS



#### CROP PRODUCTION

##### Precision N management

Replace, Reduce, Reuse, Recycle (4R) approach → less N<sub>2</sub>O without yield penalty

##### Variable-rate application

GPS-guided inputs → less fertilizer, lower emissions

##### Carbon accounting & MRV

farm-level tracking, CRCF credits & Scope 3 premiums



#### ANIMAL PRODUCTION

##### Feed additives (3-NOP)

less enteric CH<sub>4</sub> per animal at standard doses

##### Biogas & nutrient circularity

manure → energy + digestate → less CH<sub>4</sub> from storage

##### Genomic selection

low-CH<sub>4</sub> breeding index  
permanent cumulative gains

#### COMPARATIVE CASE STUDY



##### Top Farms Group vs Hądzlik-Lipowczyk farm

precision nitrogen management, regenerative tillage and carbon tracking at corporate scale vs single-farm level with stable contracts enabling capital-intensive investment

### 04. ENABLERS



**CAP & public policy:** Environmental additionality criteria for large-farm investment support; public finance directed to genuine market failures only



**Supportive market frameworks:** CSRD enforcement for largest processors; agrivoltaics, support sustainable biogas investments.



**Private capital:** Additionality tests for guarantees; supply chain climate finance framework for Scope 3 co-financing



**Knowledge and networks:** National genomic programme; national farm-level carbon accounting platform

#### ENABLER CASE STUDY



##### Danone Poland

Funding on-farm mitigation by global processor pressured by Scope 3

### 03. ECONOMIC LOGIC



#### OPERATIONAL COST REDUCTION

15–20% savings on fertilizer & crop protection: primary and immediate return



#### ENERGY & BIOGAS REVENUE

Electricity, heat, biomethane from anaerobic digestion of manure & co-substrates



#### SCOPE 3 SUPPLY CHAIN PREMIUM

Processor-funded mitigation via CSRD: low-emission supply rewarded by downstream buyers



#### ADDITIONAL ENVIRONMENTAL SCHEMES

CRCF credits & voluntary markets; viable once MRV methodologies develop and costs fall further

### 05. OUTCOMES

|               |   |   |   |   |
|---------------|---|---|---|---|
| Profitability | ● | ● | ● | ● |
| Resilience    | ● | ● | ○ | ○ |
| GHG reduction | ● | ● | ● | ○ |



## 6 | Conclusions

**The findings of this report point to a clear and consistent message: there is no single pathway for the future of Polish agriculture, nor should there be. The diversity of farm structures, production systems, and regional conditions is not a constraint, but a strategic asset. Polish agriculture both can and should build its transition on this diversity.**

The business models identified in this study demonstrate that climate action can be embedded in viable and profitable farming strategies across all farm types. Whether through local, quality-based production, cooperative and vertically integrated models, or high-tech precision systems, farms can simultaneously improve resilience, strengthen income, and reduce emissions. Crucially, these pathways are not theoretical. They reflect real practices already emerging across Poland and were co-developed through a participatory research process involving farmers and sector experts.

At the same time, the transition will not happen automatically. The core barrier is not a lack of solutions, but a lack of enabling conditions. For most farms, especially small and medium ones, engaging in environmental action requires first building economic stability and resilience. Where income is uncertain, risk-taking is low. Climate action will therefore only scale if it aligns with farmers' economic logic and is supported by policies, markets, and financial instruments that reduce transition risk.

Farmers must be at the center of this process. Their experience, knowledge, and trust networks are essential for shaping credible and scalable solutions. As this study shows, adoption is driven less by abstract environmental goals and more by demonstrated economic and agronomic benefits. Strengthening peer learning, advisory systems, and farmer-led innovation will be critical to accelerating change.

Ultimately, the transition of Polish agriculture is not about choosing between farm types or development models. It is about enabling multiple pathways to coexist and contribute to a shared objective: a sector that is economically viable, resilient to climate risks, and capable of delivering meaningful environmental outcomes. There is both space and need for all farms to take part in this transformation, provided the conditions are in place to make it possible.

# References

- B Barham, J., Tropp, D., Enterline, K., Farbman, J., Fisk, J., & Kiraly, S. (2012). Regional food hub resource guide. U.S. Department of Agriculture, Agricultural Marketing Service. <https://www.ams.usda.gov/sites/default/files/media/Regional%20Food%20Hub%20Resource%20Guide.pdf>
- Bayir, B., Charles, A., Sekhari, A., & Ouzrout, Y. (2022). Issues and challenges in short food supply chains: A systematic literature review. *Sustainability*, 14(5), 3029. <https://doi.org/10.3390/su14053029>
- Better Food Traders. (2026). Regional Food Hubs Support Program: Learning summary. <https://betterfoodtraders.org/procurement-toolkit-launch/>
- Bird & Bird. (2025, March 26). Poland introduces auction-based support system for biomethane production in installations above 1 MW. <https://www.twobirds.com/en/insights/2025/poland-introduces-auction-based-support-system-for-biomethane-production-in-installations-above-1-mw>
- BIS Research. (2024). Carbon credits market for agriculture, forestry, and land use: Global and regional analysis, 2025–2035. <https://bisresearch.com/industry-report/carbon-credit-market.html>
- Chiaverina, P., Drogué, S., & Jacquet, F. (2024). Do farmers participating in short food supply chains use less pesticides? Evidence from France. *Ecological Economics*, 216, Article 107985. <https://doi.org/10.1016/j.ecolecon.2023.107985>
- Chlebosz, M. (2025, December 13). Miliardy złotych nie pomogły. Co blokuje rozwój grup producenckich? [Billions of zlotys did not help. What is blocking the development of producer groups?]. <https://www.farmer.pl/fakty/miliardy-zlotych-nie-pomogly-co-blokuje-rozwoj-grup-producenckich,169999.html>
- CIP [Climate Policy Initiative]. (2025, June 26). Blended finance playbook for climate-smart agrifood systems. <https://www.climatepolicyinitiative.org/publication/blended-finance-playbook-for-climate-smart-agrifood-systems/>
- CONCITO. (2025). From farm to framework: Designing CRCF methodologies for livestock emissions. <https://concito.dk/en/udgivelser/from-farm-to-framework-designing-crcf-methodologies-livestock-emissions>
- Czubak, W., Kalinowski, S., & Pepliński, B. (2024). Ziarno niezgody: Analiza protestów rolniczych [The grain of discord: An analysis of farmers' protests]. Instytut Finansów Publicznych. [https://www.ifp.org.pl/wp-content/uploads/2024/03/IFP\\_raport\\_Ziarno\\_niezgody-analiza\\_protestow\\_rolniczych.pdf](https://www.ifp.org.pl/wp-content/uploads/2024/03/IFP_raport_Ziarno_niezgody-analiza_protestow_rolniczych.pdf)
- Czyżak, P., & Mindeková, T. (2024). Empowering farmers in Central Europe: The case for agri-PV. Ember.

de Haas, Y., Veerkamp, R. F., De Jong, G., & Aldridge, M. N. (2021). Selective breeding as a mitigation tool for methane emissions from dairy cattle. *Animal*, 15, Article 100294.

Demagog.org.pl. (2024, December 23). Czy w produktach Mlekovity znajdziemy Bovaer? Wyjaśniamy, co to za składnik i czy jest niebezpieczny [Can Bovaer be found in Mlekovita products? We explain what this ingredient is and whether it is dangerous]. Demagog – weryfikacja faktów. Retrieved 2 March 2026, from [https://demagog.org.pl/fake\\_news/czy-w-produktach-mlekovity-znajdziemy-bovaer-wyjasniamy-co-to-za-skladnik-i-czy-jest-niebezpieczny/](https://demagog.org.pl/fake_news/czy-w-produktach-mlekovity-znajdziemy-bovaer-wyjasniamy-co-to-za-skladnik-i-czy-jest-niebezpieczny/)

Domínguez, I. P., Fellmann, T., Weiss, F., Witzke, P., Barreiro-Hurlé, J., Himics, M., ... & Leip, A. (2016). An economic assessment of GHG mitigation policy options for EU agriculture. JRC Science for Policy Report, EUR 27973. <https://doi.org/10.2791/843461>

EC [European Commission]. (2023, October 12). Access to finance remains insufficient for farmers and agri-food SMEs. [https://agriculture.ec.europa.eu/media/news/access-finance-remains-insufficient-farmers-and-agri-food-smes-2023-10-12\\_en](https://agriculture.ec.europa.eu/media/news/access-finance-remains-insufficient-farmers-and-agri-food-smes-2023-10-12_en)

EC [European Commission]. (2024a). Impact assessment report accompanying the document “Communication from the Commission to the EU: Securing our future — Europe’s 2040 climate target and path to climate neutrality by 2050, building a sustainable, just and prosperous society” SWD(2024) 63 final.

EC [European Commission]. (2024b). Income support explained. Directorate-General for Agriculture and Rural Development. [https://agriculture.ec.europa.eu/common-agricultural-policy/income-support/income-support-explained\\_en](https://agriculture.ec.europa.eu/common-agricultural-policy/income-support/income-support-explained_en)

ECA [European Court of Auditors]. (2024). Common Agricultural Policy plans: Greener but not aligned with the EU’s climate and environmental ambitions Special Report No. 20/2024. [https://www.eca.europa.eu/ECAPublications/SR-2024-20/SR-2024-20\\_EN.pdf](https://www.eca.europa.eu/ECAPublications/SR-2024-20/SR-2024-20_EN.pdf)

EDF [Environmental Defense Fund]. (2024, October 21). The impacts of climate change and sustainability on agricultural finance. <https://library.edf.org/AssetLink/ry78005v23wb5nt4vprg4o7fllgb2mml.pdf>

EEA [European Environment Agency]. (2025, April 16). GHG data viewer: Data on total greenhouse gas emissions and removals in the EU. Retrieved 12 September 2025, from <https://www.eea.europa.eu/en/analysis/maps-and-charts/greenhouse-gases-viewer-data-viewers>

EIB [European Investment Bank]. (2020, June 11). Financial needs in the agriculture and agri-food sectors: 24 fi-compass country reports published. <https://www.eib.org/en/press/news/financial-needs-in-the-agriculture-and-agri-food-sectors-24-fi-compass-country-reports-published>

EIB [European Investment Bank] & EC [European Commission]. (2025). Insurance and risk management tools for agriculture in the EU. fi-compass / EAFRD.

ESABCC [European Scientific Advisory Board on Climate Change]. (2026). Climate adaptation and mitigation in the agri-food system: Recommendations for coherent EU policies. <https://climate-adv>

sory-board.europa.eu/reports-and-publications/climate-adaptation-and-mitigation-in-the-agri-food-system-recommendations-for-coherent-eu-policies

Eurostat. (2025). Glossary: Standard output SO. European Commission. [https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Standard\\_output\\_\(SO\)](https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Standard_output_(SO))

FADN. (2024). Farm Accountancy Data Network — Poland. European Commission.

Ferland, D., Wagner-Riddle, C., Brown, S. E., Bourgault, M., Helgason, W., Farrell, R. E., & Congreves, K. A. (2024). Improved nitrogen fertilizer management reduces nitrous oxide emissions in a northern Prairie cropland. *Science of the Total Environment*, 956, Article 177211. <https://doi.org/10.1016/j.scitotenv.2024.177211>

Fermy Drobiu Lipowczyk. (n.d.). Fermy Drobiu Lipowczyk. Retrieved 3 April 2026, from <https://lipowczyk.pl/>

Fiore, A., & Grabbe, H. (2025). Nature markets: How can credits and shares provide durable, additional finance? Bruegel Policy Brief No. 20/2025.

Green Seed Group. (2025, January 13). Food retailing insights in Poland 2024. <https://greenseedgroup.com/food-retailing-insights-in-poland-2024>

Grodziskie Sery. (2025). Grodziskie Sery. <https://www.grodziskiesery.pl/>

Grunt Institute of Food Strategies. (2026). Łowca okazji czy strategiczny menedżer? Relacja ze spotkania Instytutu Strategii Żywnościowych Grunt [Bargain hunter or strategic manager? Report from a meeting of the Grunt Institute of Food Strategies]. <https://instytutgrunt.org/aktualnosci/lowca-okazji-czy-strategiczny-menedzler/>

Heinrich-Böll-Stiftung Warsaw. (2025). Co dalej z WPR? Kierunki zmian Wspólnej Polityki Rolnej po 2027 roku [What next for the CAP? Directions for the Common Agricultural Policy after 2027]. Heinrich-Böll-Stiftung. [https://pl.boell.org/sites/default/files/2025-06/co-dalej-z-wpr\\_web\\_2025.06.10\\_0.pdf](https://pl.boell.org/sites/default/files/2025-06/co-dalej-z-wpr_web_2025.06.10_0.pdf)

IEA Bioenergy. (2025). Potential for manure-based anaerobic digestion: Motivations, barriers and approaches in six countries Task 37. <https://www.ieabioenergy.com/wp-content/uploads/2025/09/IEA-Bioenergy-Task-37-Manure-utilization-2025.pdf>

IEEP [Institute for European Environmental Policy]. (2023). Environment and climate assessment of Poland's CAP Strategic Plan. [https://ieep.eu/wp-content/uploads/2023/02/Environment-and-climate-assessment-of-Poland's-CAP-Strategic-Plan\\_IEEP-2023.pdf](https://ieep.eu/wp-content/uploads/2023/02/Environment-and-climate-assessment-of-Poland's-CAP-Strategic-Plan_IEEP-2023.pdf)

IEEP [Institute for European Environmental Policy] & CONCITO. (2025, December 12). Financing the green transition in EU agriculture and the role of the European Investment Bank. <https://ieep.eu/publications/financing-the-green-transition-in-eu-agriculture-and-the-role-of-the-european-investment-bank/>

IEP-NRI [Institute of Environmental Protection – National Research Institute]. (2025). Od krajowych strategii do lokalnych działań. Rolnictwo w obliczu zmiany klimatu [From national strategies to local action: Agriculture in the face of climate change]. <https://ios.edu.pl/aktualnosci-en-pl/od-krajowych-strategii-do-lokalnych-dzialan-rolnictwo-w-obliczu-zmian-klimatu/>

Iso-Tech. (n.d.). Marchewka Mobilna. <https://www.isotech24.net/marchewka-mobilna>

John Deere. (2025). Oszczędności w rolnictwie precyzyjnym: Raport z analiz i wdrożeń technologii precyzyjnych w Polsce [Savings in precision agriculture: Report on analyses and implementation of precision technologies in Poland]. <https://bs.net.pl/wp-content/uploads/2025/11/raport-oszczednosci-w-rolnictwie-precyzyjnym-pl.pdf>

Kabato, W., Getnet, G. T., Sinore, T., Nemeth, A., & Molnár, Z. (2025). Towards climate-smart agriculture: Strategies for sustainable agricultural production, food security, and greenhouse gas reduction. *Agronomy*, 15(3), 565.

Kebreab, E., Bannink, A., Pressman, E. M., Walker, N., Karagiannis, A., van Gastelen, S., & Dijkstra, J. (2023). A meta-analysis of effects of 3-nitrooxypropanol on methane production, yield, and intensity in dairy cattle. *Journal of Dairy Science*, 106(2), 927–936. <https://doi.org/10.3168/jds.2022-22211>

Kennedy, R. (2026, March 26). Solar sheep grazing delivers margins up to 40% in new study. *pv magazine*. <https://www.pv-magazine.com/2026/03/26/solar-sheep-grazing-delivers-margins-up-to-40-in-new-study/>

Kientzy, D., Milhollin, R., Ellis, C., & Massey, R. (2023). Understanding equipment management for planting cover crops. *Journal of Soil and Water Conservation*, 78(6), 113A–117A.

KOBIZE [National Centre for Emissions Management]. (2025). Krajowy Raport Inwentaryzacyjny 2025 [National Inventory Report 2025]. Krajowy Ośrodek Bilansowania i Zarządzania Emisjami.

Kowalska, A., Olszańska, A., Szymańska, J., & Paskudzka, K. (2023). International competitiveness of the poultry sector in Poland over the last 20 years. *Roczniki Naukowe Stowarzyszenia Ekonomistów Rolnictwa i Agrobiznesu*, 24(4).

Kujawsko-Pomorski Ośrodek Doradztwa Rolniczego w Minikowie. (2024a). Czym jest RWS [What is CSA?].

Kujawsko-Pomorski Ośrodek Doradztwa Rolniczego w Minikowie. (2024b, July 4). Rolnictwo wspierane społecznie – RWS [Community-supported agriculture – CSA]. <https://row.kpodr.pl/index.php/2024/07/04/rolnictwo-wspierane-spoecznie-rws/>

Kuś, J. (2015). Znaczenie płodozmianu we współczesnym rolnictwie [The importance of crop rotation in modern agriculture]. *Studia i Raporty IUNG-PIB*, 43(17), 65–87. [https://iung.pl/sir/zeszyt43\\_4.pdf](https://iung.pl/sir/zeszyt43_4.pdf)

Kusz, D., Kusz, B., Wicki, L., Nowakowski, T., Kata, R., Brejta, W., Kasprzyk, A., & Barć, M. (2024). The economic efficiencies of investment in biogas

plants: A case study of a biogas plant using waste from a dairy farm in Poland. *Energies*, 17(15), 3760. <https://doi.org/10.3390/en17153760>

Lan, J., & Ban, X. (2025). The farm-level economic and environmental benefits of precision agriculture technologies: A meta-analysis. *Sustainability*, 17(24), 11223. <https://doi.org/10.3390/su172411223>

Lubuskie Angusowo. (n.d.). O nas [About us]. <https://lubuskie-angusowo.pl/index.php/o-nas/>

Manzanilla-Pech, C. I. V., Løvendahl, P., Gordo, D. M., Difford, G. F., Pryce, J. E., Schenkel, F., ... & Lassen, J. (2021). Breeding for reduced methane emission and feed-efficient Holstein cows: An international response. *Journal of Dairy Science*, 104(8), 8983–9001.

Mateja, M. (2025). The rhetoric of anger: A case study of Polish farmers' protests against the import of grain from Ukraine. *Res Rhetorica*, 12(2), 95–114.

Molenda, A. (2026, April 9). Biogaz w Polsce stoi w miejscu. Branża wskazuje winnych: brak strategii i chaos legislacyjny [Biogas in Poland is standing still. The sector points to the causes: Lack of strategy and legislative chaos]. *AgroNews*. <https://agronews.com.pl/artukul/biogaz-w-polsce-stoi-w-miejscu-branza-wskazuje-winnych-brak-strategii-i-chaos-legislacyjny/>

National Research Institute of Animal Production. (2025). Metody mitygacji i sekwestracji. Kalkulator GHG [Mitigation and sequestration methods. GHG calculator]. <https://kalkulatorghg.iz.edu.pl/katalog/>

Notes from Poland. (2024, February 9). Polish farmers launch 30-day protest, blocking roads and Ukraine border crossings. <https://notes-frompoland.com>

Ochal, P., & Smreczak, B. (2020). Zakwaszenie gleb i aktualne zagadnienia wapnowania [Soil acidification and current issues in liming]. *Studia i Raporty IUNG-PIB*, 63(17), 9–19. <https://doi.org/10.26114/sir.iung.2020.63.01>

OECD. (2025). Agricultural policy monitoring and evaluation 2025: Making the most of the trade and environment nexus in agriculture. OECD Publishing. <https://doi.org/10.1787/a80ac398-en>

Ogieriakhi, M., & Woodward, R. T. (2022). Why do farmers adopt soil conservation tillage? SSRN. <https://ssrn.com/abstract=4149579>

Olesen, J. E., Rees, R. M., Recous, S., Bleken, M. A., Abalos, D., Ahuja, I., ... & Topp, C. F. (2023). Challenges of accounting nitrous oxide emissions from agricultural crop residues. *Global Change Biology*, 29(24), 6846–6855.

Olszańska, A., Kowalska, A. S., Szymańska, J., Paskudzka, K., & Soukal, I. (2024). Trends in the livestock and pork market in Poland with regard to the environmental impact of this production direction. *Ekonomia i Środowisko — Economics and Environment*, 88(1).

Onyszkiewicz, M., & Sylla, M. (2025). Current status of the community-supported agriculture model in Poland: Exploring key areas of sustainable operations. *Sustainability*, 17(7), 2965.

Ossowska, L., Janiszewska, D., Kurdyś-Kujawska, A., Wieliczko, B., & Kwiatkowski, G. (2026). Innovation opportunities in the rural regional food sector in Poland: Implications for creating effective policies. *Sustainability*, 18(2), 660.

Pawlak, K., & Poczta, W. (2024). Twenty years of Poland's EU membership: What is progress in the agri-food sector? *Agriculture*, 15(1), 49. <https://doi.org/10.3390/agriculture15010049>

Polish Ministry of Climate and Environment. (2024). Annex 2 to the update of the National Energy and Climate Plan NECP: With Existing Measures WEM scenario. Ministry of Climate and Environment.

PREPSOIL. (2026). PD Krakovany – Stráže Agricultural cooperative Krakovany – Stráže. <https://prepsoil.eu/communities-of-practice/pd-krakovany-straze-agricultural-cooperative-krakovany-straze>

Profundo. (2025). Biogas policies in the EU: Leveling up or locking in? [https://eeb.org/wp-content/uploads/2025/10/Biogas-policies-in-the-EU\\_Leveling-up-or-locking-in\\_.pdf](https://eeb.org/wp-content/uploads/2025/10/Biogas-policies-in-the-EU_Leveling-up-or-locking-in_.pdf)

Ruder, S. L., Faxon, H. O., Orzel, E. C., Devkota, R., & Bronson, K. (2026). Reviewing the evidence on precision agriculture and environmental sustainability. *npj Sustainable Agriculture*, 4, Article 9. <https://doi.org/10.1038/s44264-026-00128-x>

Rzeczpospolita. (2025, December 3). Żywność ekologiczna dostaje własną halę. Minister: przejęcie Carrefoura warte analizy [Organic food gets its own market hall. Minister: Carrefour takeover worth analyzing]. <https://www.rp.pl/przemysl-spozywczy/art43446221-zywnosc-ekologiczna-dostaje-wlasna-hale-minister-przejecie-carrefoura-warte-analizi>

Sanyaolu, M., & Sadowski, A. (2024). The role of precision agriculture technologies in enhancing sustainable agriculture. *Sustainability*, 16(15), 6668. <https://doi.org/10.3390/su16156668>

Scherger, S. (2026, February 13). Learning from Germany's decades of public biogas support. ARC2020. <https://www.arc2020.eu/learning-from-germanys-decades-of-public-biogas-support/>

Serebrennikov, D., Thorne, F., Kallas, Z., & McCarthy, S. N. (2020). Factors influencing adoption of sustainable farming practices in Europe: A systematic review of empirical literature. *Sustainability*, 12(22), 9719.

Singh, V. K., Gautam, P., Nanda, G., Dhaliwal, S. S., Pramanick, B., Meena, S. S., ... & Hossain, A. (2021). Soil test-based fertilizer application improves productivity, profitability and nutrient-use efficiency of rice (*Oryza sativa* L.) under direct-seeded conditions. *Agronomy*, 11(9), 1756.

Siwiec, E. (2022). Atlas skutków zjawisk ekstremalnych w Polsce [Atlas of the impacts of extreme events in Poland]. Instytut Ochrony Środowiska – Państwowy Instytut Badawczy. <https://ios.edu.pl/raporty-i-analizi/zmianyklimate/atlas-skutkow-zjawisk-ekstremalnych>

Sobiesiak-Penszko, P., Pazderski, F., & Jakubowska-Lorenz, E. (2019). Perspektywy zrównoważonego rolnictwa w Polsce. Analiza społeczno-polityczna [Prospects for sustainable agriculture in Poland: A socio-political analysis]. Fundacja Instytut Spraw Publicznych.

Springer, K. (2025). Residual emissions in EU agriculture: Analysis of emission reduction scenarios. Institute for European Environmental Policy.

Statistics Poland. (2005, January 10). Środki produkcji w rolnictwie w 2004 r. [Means of production in agriculture in 2004]. <https://stat.gov.pl/obszary-tematyczne/rolnictwo-lesnictwo/rolnictwo/srodki-produkcji-w-rolnictwie-w-2004-r-6,2.html>

Statistics Poland. (2024a). Charakterystyka gospodarstw rolnych w 2023 r. [Characteristics of agricultural holdings in 2023]. Główny Urząd Statystyczny.

Statistics Poland. (2024b, November 28). Środki produkcji w rolnictwie w roku gospodarczym 2022/2023 [Means of production in agriculture in the 2022/2023 farming year]. <https://stat.gov.pl/obszary-tematyczne/rolnictwo-lesnictwo/rolnictwo/srodki-produkcji-w-rolnictwie-w-roku-gospodarczym-20222023,6,18.html>

Statistics Poland. (2025). Rocznik statystyczny rolnictwa 2025 [Statistical yearbook of agriculture 2025]. <https://stat.gov.pl/obszary-tematyczne/roczniki-statystyczne/roczniki-statystyczne/rocznik-statystyczny-rolnictwa-2025,6,19.htm>

Tomaszewski, D. (2025, November 3). Rolnictwo precyzyjne w praktyce – dane zamiast domysłów [Precision agriculture in practice: Data instead of guesswork]. Agroprofil. <https://agroprofil.pl/wiadomosci/rolnictwo-precyzyjne-w-praktyce-dane-zamiast-domyslow/>

URE [Polish Energy Regulatory Office]. (2023, September 29). Amendment of the RES Act: New support systems, material solutions for local power generation and additional duties for the President of URE. <https://www.ure.gov.pl/en/communication/news/359,Amendment-of-the-RES-Act-new-support-systems-material-solutions-for-local-power-.html>

WBCSD [World Business Council for Sustainable Development]. (2023, November 24). Tackling Scope 3 emissions in agricultural and food value chains. <https://www.wbcsd.org/resources/tackling-scope-3-emissions-in-agricultural-food-value-chains/>

World Bank. (2025). Employment in agriculture % of total employment – Poland SL.AGR.EMPL.ZS. World Bank Open Data. <https://databank.worldbank.org/reports.aspx?source=2&series=SL.AGR.EMPL.ZS&country=POL>

Wróbel-Jędrzejewska, M., Klepacka, A. M., Włodarczyk, E., & Przybysz, Ł. (2024). Carbon footprint of milk processing: Case study of Polish dairy. *Agriculture*, 15(1), 62.

Wulf, R., Demba, S., Röttgen, V., Langbein, J., Düpjan, S., Weise, B., ... & Bachmann, L. (2025). Invited review: Development of a dairy barn concept to improve animal welfare. *Journal of Dairy Science*.

Zalewski, A. (Ed.). (2025). Rynek środków produkcji dla rolnictwa. Stan i perspektywy. Nr 52. Analizy Rynkowe [The market for agricultural means of production: Current state and prospects. No. 52. Market analyses]. IERiGŻ-PIB.

Zarzycka, A. M. (2025). Trendy w rozwoju handlu detalicznego w Polsce. Przegląd literatury [Trends in the development of retail trade in Poland: A literature review]. *Kwartalnik Nauk o Przedsiębiorstwie*, 78(4), 63–71.

Zhang, X., & Yu, X. (2021). Short supply chain participation, and agro-chemicals' use intensity and efficiency: Evidence from vegetable farms in China. *China Agricultural Economic Review*, 13(4), 721–735.

ZPP [Union of Entrepreneurs and Employers]. (2024). Memorandum: Challenges for the Polish agricultural sector. <https://zpp.net.pl/en/memorandum-zpp-challenges-for-the-polish-agricultural-sector/>