European Environment Agency

Protein diversification — strategic risks and opportunities for sustainable food systems

EEA report

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Key messages

- In the EU, livestock systems contribute more than 65% of agricultural greenhouse gas emissions and are a major source of nitrogen pollution, while grazing and feed production account for more than half of agricultural land use. Addressing these pressures will require a rebalancing of livestock production and consumption patterns, particularly in highly feed-intensive systems, alongside continued improvements in livestock sustainability.
- European livestock systems rely on substantial feed inputs and significant fertiliser use. Dependence on imported feedstocks extends the environmental footprint of the EU protein system well beyond its borders and increases exposure to supply-chain disruptions, market volatility, climate-related shocks and geopolitical risks. Diversification of the protein supply can strengthen the resilience and security of European food systems.
- Pathways for protein diversification – including plant-based proteins, insects, biomass fermentation, precision fermentation and cultivated meat – offer different environmental, economic and social opportunities. Sustainability performance depends on choices around land management, energy sources and circular resource use, while uptake is influenced by enabling value chains and consumer awareness and acceptance.
- Boosting the use of plant-based protein sources offers the most immediate environmental benefits and would significantly reduce greenhouse gas emissions, nitrogen pollution and land-use pressures, while creating opportunities for nature restoration and generating new value across farming and food systems.
- Protein diversification is likely to unfold gradually and complement, rather than rapidly replace, livestock production. As the balance between animal- and plant-based protein sources evolves, measures will be needed to avoid market concentration, ensure affordability and manage labour-market impacts, particularly in livestock-dependent regions.
- Coherent governance, sustainability safeguards and targeted regional support can help ensure that protein diversification strengthens the resilience and competitiveness of Europe's food systems while contributing to climate and biodiversity goals and supporting a just transition in livestock-dependent regions.

Executive summary

Europe's protein system relies strongly on livestock production and imported feed. This generates environmental pressures within Europe and beyond its borders, while increasing exposure to supply-chain disruptions, market volatility and geopolitical risks. Yet livestock systems remain economically, socially and environmentally important in many regions, particularly where grassland-based systems support rural livelihoods, biodiversity conservation, landscape management and higher animal welfare standards. Protein diversification should therefore be understood not as a rapid replacement for livestock production, but as a gradual rebalancing of Europe's protein supply and consumption patterns alongside continued efforts to improve livestock sustainability.

Protein diversification can make food systems more sustainable, resilient and competitive. The most immediate opportunities come from plant-based protein sources, including pulses, legumes and plant-based meat and dairy alternatives. These generally have lower greenhouse gas emissions, nitrogen pollution and land-use requirements than livestock-derived proteins, particularly when substituting the most resource-intensive products. Greater integration of protein crops can support more diversified rotations, improve soil health, reduce fertiliser use and strengthen regional value chains and domestic supply. Reduced demand for feed crops and livestock production may also create opportunities for nature restoration and biodiversity recovery, including the restoration of wetlands, peatlands and other biodiversity-rich ecosystems.

This report suggests the benefits of protein diversification are likely to outweigh the associated risks and trade-offs, particularly as the transition towards a more diversified protein system is expected to unfold gradually rather than through abrupt structural change. This creates scope to manage adjustment costs, support livestock-dependent regions and guide investment towards environmentally robust, economically viable and socially accepted pathways. However, whether diversification delivers benefits in practice depends on how these pathways are designed, scaled and governed. This includes choices on land use, processing intensity, energy sources, feedstocks, market concentration and value distribution.

A portfolio approach is needed. Established plant-based proteins are likely to remain central in the near term due to their relatively high technological maturity, environmental performance and market readiness. Insects, biomass fermentation, precision fermentation and cultivated meat may play more specialised or longer-term roles across food, feed and ingredient markets. These pathways may offer environmental, technological or strategic advantages, including reduced land dependence and new opportunities across food and feed value chains. However, many continue to face constraints related to high production costs, infrastructure and energy requirements, regulatory complexity and uncertain levels of consumer acceptance and market uptake.

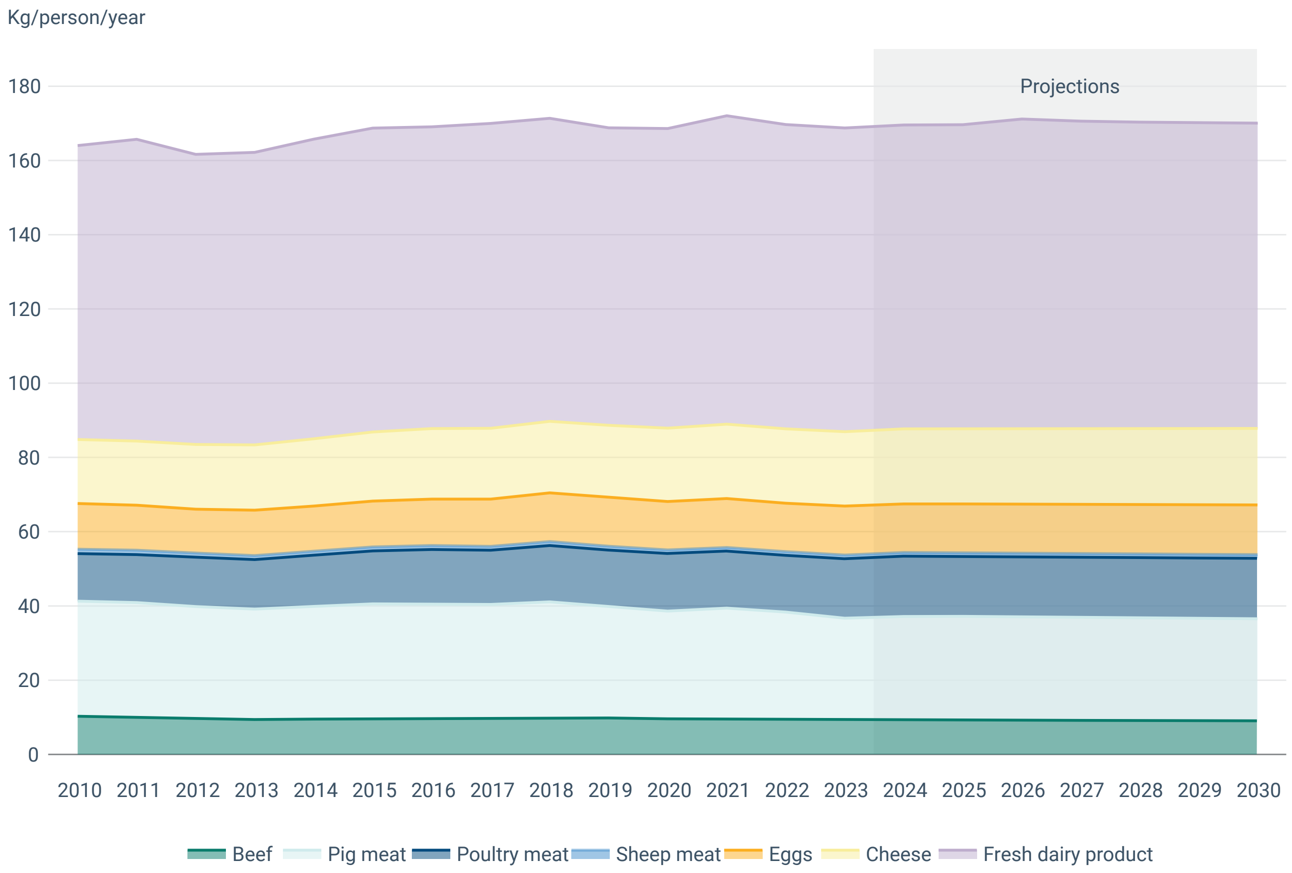
An EU protein strategy could provide strategic direction by helping to reduce concentrated dependencies, strengthen sustainable domestic protein production, maintain diversified trade relationships and support innovation and regional value chains, rather than pursuing full self-sufficiency. Effective implementation will require coherent governance across agriculture, climate, trade, innovation and health policies, alongside sustainability safeguards and monitoring to manage trade-offs and unintended impacts. Through adaptive governance, stakeholder engagement and targeted regional support for a just transition, protein diversification can contribute to more sustainable, resilient and competitive European food systems.

1 Europe's protein challenge

Proteins are essential to human nutrition and health. Yet how they are produced, traded and consumed has environmental, economic and social implications. In Europe, protein supply is shaped by persistent structural constraints linked to production systems and trade dependencies. Despite its large agricultural sector, the EU produces only a limited share of the high-protein feed ingredients required for livestock production and remains heavily reliant on imports. This reflects a production model oriented towards livestock feed rather than the direct provision of plant proteins for human consumption. This dependence increases Europe's exposure to trade volatility, supply-chain disruptions and geopolitical risks, while constraining efforts to address climate change, biodiversity loss and broader food-system resilience (EEA, 2024a).

Consumption patterns reinforce these structural constraints. The average protein intake among adults in the EU is around 80-85 grams per person per day, exceeding dietary requirements for most population groups (EFSA, 2012). Animal-based products account for roughly 60% of total protein intake (FAO, 2023). Although dietary shifts that incorporate more plant-based foods are emerging in some Member States, sustained demand for livestock-derived foods continues to shape production systems, associated feed demand and broader agricultural markets (Figure 1.1). This, in turn, reinforces existing production structures, trade dependencies and policy incentives, including those embedded within the common agricultural policy (CAP), thereby limiting the pace of transition towards more diversified and resource-efficient protein systems.

Figure 1.1 **Trends in consumption of selected livestock-derived foods in the EU, 2010–2030**



Notes: Values from 2024 onwards represent projections based on OECD-FAO Agricultural Outlook modelling and should therefore be interpreted as indicative estimates rather than forecasts. The figure illustrates relatively stable consumption patterns across selected livestock-derived food categories in the EU despite emerging dietary shifts in some Member States. Differences in nutritional composition, environmental performance and production systems are not reflected. Future consumption patterns may be influenced by policy developments, market conditions, technological innovation and changing dietary preferences.

See the interactive version of the chart.

Source: OECD-FAO Agricultural Outlook, 2024-2033.

These patterns generate substantial climate and environmental pressures. Livestock systems dominate land use across the EU, with grazing and feed production together accounting for more than half of total agricultural land use, while around 42% of arable land is devoted to fodder production (Eurostat, 2023). At the same time, a substantial share of EU livestock production is concentrated in relatively intensive and feed-dependent systems, particularly in the pig and poultry sectors, with important implications for feed demand, import dependency and associated environmental pressures. Agricultural systems in Europe nevertheless remain highly heterogeneous. Permanent grasslands account for around one-third of the EU's utilised agricultural area and provide forage resources for cattle, sheep and goat production on land that is often unsuitable for arable cultivation. Extensive grazing systems can also support biodiversity and ecosystem services, with around one in three protected habitats in Europe depending on grazing for their conservation and management (EEA, 2026b).

Europe's dual land-use structure, where feed-intensive livestock production relying on arable protein crops co-exists with grassland-based systems, results in varied environmental outcomes. Low-intensity grazing systems using species-rich semi-natural grasslands can support biodiversity, landscape management and ecosystem services, whereas regionally concentrated intensive livestock systems are a major source of environmental pressures. Livestock production accounts for more than 65% of agricultural greenhouse gas emissions in the EU, driven primarily by methane from enteric fermentation and manure management, alongside nitrous oxide emissions associated with manure application and synthetic fertiliser use (EEA, 2023). Nitrogen pollution linked to livestock production and fertiliser use further contributes to water contamination, eutrophication and air pollution across Europe (EEA, 2024b).

Europe's protein footprint also extends beyond its territory through imported feed (EC, 2022b). Soy expansion, in particular, is linked to deforestation and biodiversity loss in parts of South America (Pendrill et al., 2019). The EU imports around 30 million tonnes of soybean and soybean products each year, the majority of which is used for animal feed (EC, 2026). While deforestation dynamics are shaped by multiple markets and actors, EU demand contributes to environmental pressures embedded in global supply chains. At the same time, high livestock densities within parts of Europe generate additional pressures linked to greenhouse gas emissions, nutrient surpluses, ammonia emissions and water pollution. Together, these patterns create environmental impacts both within the EU and in exporting regions connected to European feed demand (Roux et al., 2025). International trade is nevertheless likely to remain an important component of the EU food system, helping to ensure stable supplies, buffer domestic shortfalls and strengthen resilience to climate- and market-related shocks.

Taken together, current patterns of protein production and consumption in Europe constitute a systemic challenge. The large land footprint and associated emissions of feed-intensive livestock systems constrain opportunities for nature restoration, carbon sequestration and more diversified cropping patterns. Meanwhile, continued dependence on livestock-derived protein, limited domestic feed-protein production and concentrated import dependencies weaken resilience and increase Europe's exposure to economic volatility, supply-chain disruptions and geopolitical risks (ESABCC, 2026). This report examines the environmental, economic and societal implications of protein diversification in Europe. It assesses different diversification pathways and explores the governance conditions needed to support more sustainable, resilient and competitive food systems.

2 Why diversify?

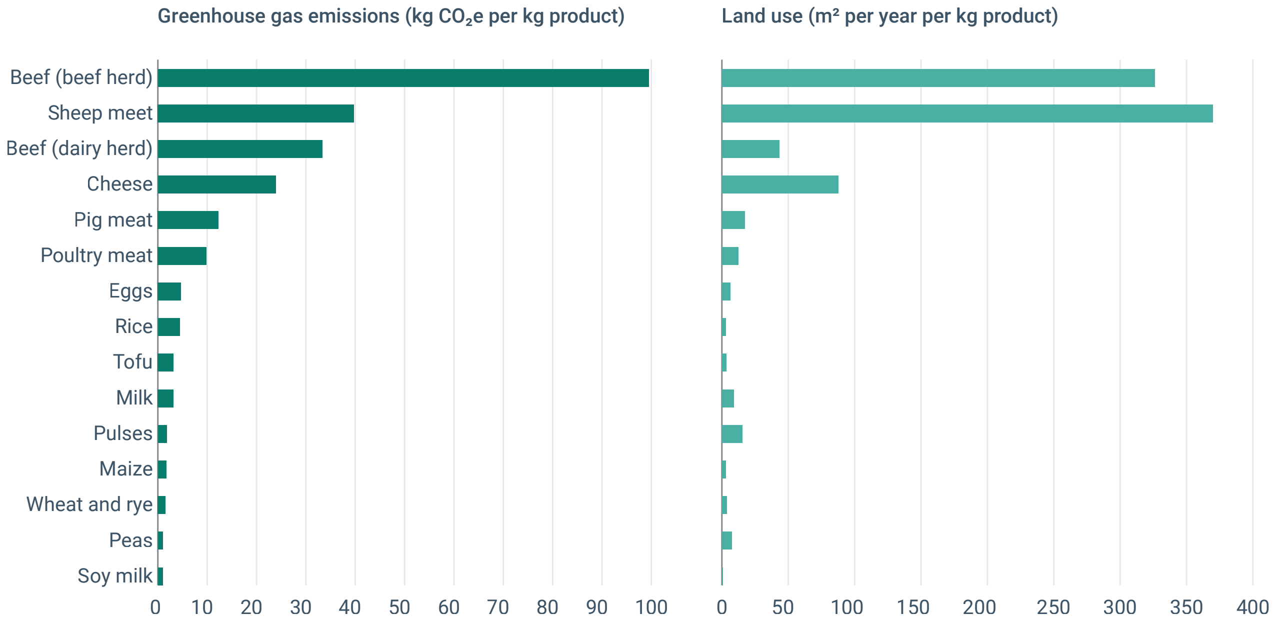
Protein diversification — expanding the range of protein sources across production and consumption — is increasingly recognised as a strategic lever for strengthening sustainability, resilience and food security across European food systems (Smith, Etienne and Montanari, 2024) ([1]). By increasing the role of plant-based and other alternative protein sources, diversification can improve resource efficiency, lower greenhouse gas emissions and nitrogen pollution and decrease dependence on imported feed. Rather than a simple substitution between protein sources, diversification entails a systemic transition involving coordinated changes across production, trade and consumption. It should complement more sustainable livestock systems while supporting rural livelihoods and regional economies. When supported by coherent governance and enabling conditions, diversification can reduce environmental pressures, strengthen resilience to external shocks, enhance competitiveness and support healthier dietary outcomes.

2.1 Environmental pressures and resource efficiency

A central rationale for diversification lies in the large and persistent differences in environmental intensity across protein sources. A comprehensive meta-analysis shows that even the lowest-impact animal-source foods generally have higher greenhouse gas emissions and land-use requirements than plant-based alternatives, although performance varies across systems, regions and production practices (Poore and Nemecek, 2018). For example, producing one kilogram of beef can generate median life-cycle greenhouse gas emissions ranging from approximately 33 to 99 kilograms CO_2 equivalent (kgCO_2e), compared with less than 5 kgCO_2e for cereals and pulses (Figure 2.1). Although protein sources differ in nutritional composition and dietary function, complementary analyses point to similar overall patterns, with animal-source proteins generally associated with higher greenhouse gas emissions and land use per unit of protein than plant-based alternatives (Willett et al., 2019).

([1]) This report focuses on terrestrial protein diversification pathways, including plant-based proteins and emerging alternative proteins. Fisheries and aquaculture are not examined and therefore fall outside the scope of this assessment.

Figure 2.1 **Median greenhouse gas emissions and land-use requirement of selected food products**



Notes: Values represent median life-cycle greenhouse gas emissions and land-use requirements per kilogram of food product, based on global production data compiled by Poore and Nemecek (2018). Estimates include impacts across food supply chains, including land-use change, feed production, farming, processing, transport and retail. Median values are used to reflect typical production conditions and reduce the influence of extreme outliers. Greenhouse gas emissions are expressed as kg CO_2-equivalent per kilogram of product, while land use is expressed as square metre-years per kilogram of product. Results are presented per kilogram of food product and do not account for differences in protein content or nutritional composition.

See the interactive version of the chart.

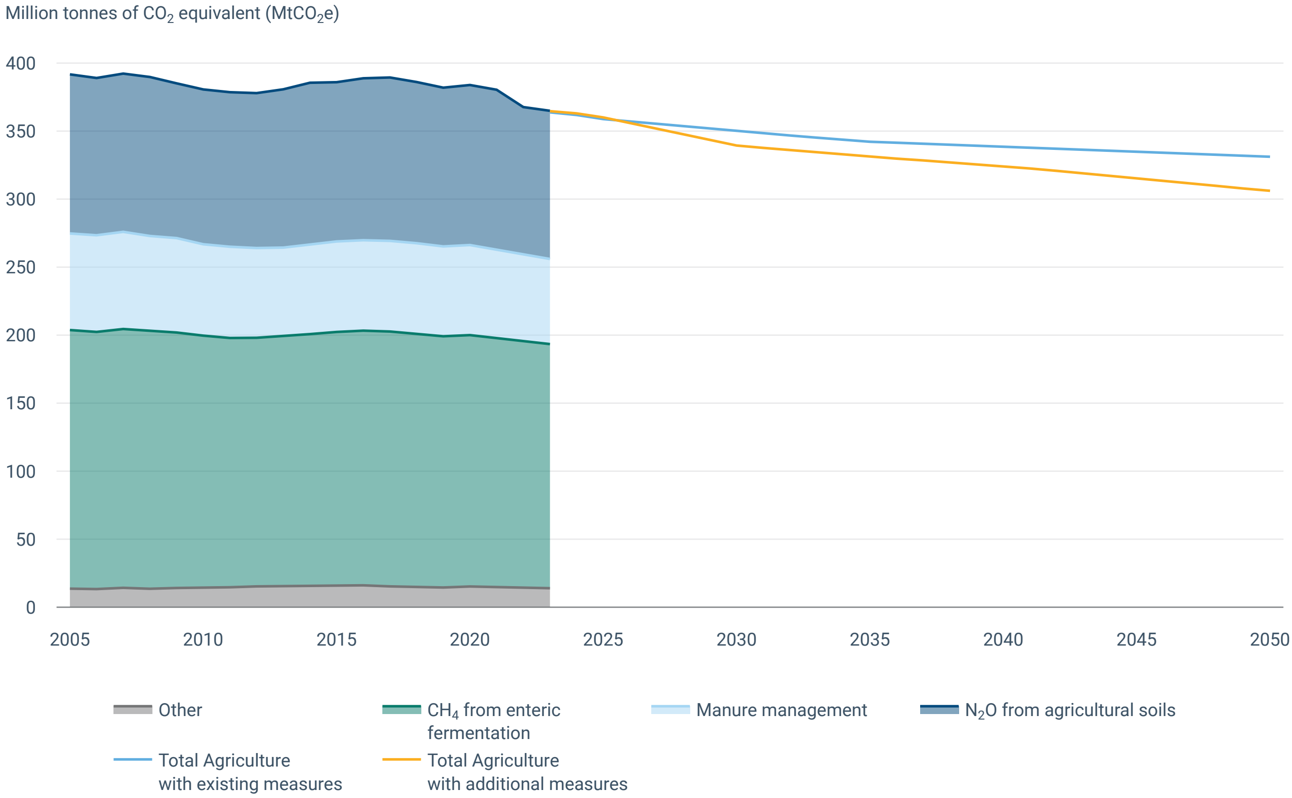
Source: Poore and Nemecek, 2018.

These differences reflect underlying resource efficiency, as livestock systems generally require more feed, land and nutrient inputs per unit of edible protein. In the EU, around 47% of biomass is used for food, feed and bedding. Of this, approximately 38% is allocated to animal feed, compared with only 9% used for plant-based food for direct human consumption, highlighting the land-use implications of livestock-based protein supply (Camia et al., 2025). Beyond reducing greenhouse gas emissions and resource use, protein diversification may also create opportunities for nature restoration. Lower demand for feed crops and livestock production could, over time, reduce pressure on agricultural land, supporting the restoration of wetlands, peatlands and other ecologically valuable ecosystems (Rockström et al., 2025). Realising these benefits will depend on land-use choices, policy frameworks and socio-economic conditions, as well as the extent to which nature restoration objectives are integrated into protein diversification strategies.

Nitrogen pollution adds to these pressures, although its sources and mitigation pathways are heterogeneous. Agriculture accounted for around 94% of ammonia (NH_3) emissions in the EU in 2023. A substantial share of these emissions was linked to livestock production through manure management and manure application, alongside emissions associated with mineral fertiliser use and other agricultural sources (EEA, 2025a). Ammonia is an important precursor of fine particulate matter ($PM_{2.5}$), an air pollutant linked to an estimated 206,000 premature deaths in the EU in 2023 (EEA, 2025b). Nitrogen deposition continues to exceed critical loads across large areas of Europe, contributing to eutrophication, biodiversity loss and ecosystem degradation.

In 2024, emissions from enteric fermentation and manure management accounted for more than 65% of agricultural greenhouse gas emissions reported in the EU greenhouse gas inventory (EEA, 2026c) [(2)]. However, the drivers of agricultural emissions vary across Member States and production systems, reflecting differences in livestock production, nitrogen inputs, land-use practices and policy responses. As a result, EU-level aggregates can mask important regional differences in both environmental pressures and mitigation opportunities (EEA, 2026d). At the same time, European livestock systems operate under increasingly stringent environmental regulation and have achieved gradual emission reductions in recent decades, reflecting improvements in feed efficiency, manure management, technological measures and broader structural change within the sector. Between 2005 and 2023, total EU agricultural greenhouse gas emissions declined by approximately 6% (Figure 2.2). While this demonstrates the contribution of efficiency improvements and technological measures, the relatively modest pace of reduction also highlights the importance of broader system-level change alongside continued improvements in livestock sustainability (EEA, 2025a).

Figure 2.2 EU agricultural emissions by source and projected emissions, 2005-2050



Notes: The figure shows historical and projected greenhouse gas emissions from EU agriculture by major emission sources. Projections reflect scenarios with existing and additional mitigation measures. Enteric fermentation, manure management and agricultural soils represent the three largest sources of agricultural greenhouse gas emissions. Emissions from agricultural soils arise from fertiliser use, manure application and other soil management practices associated with both crop and livestock systems.

See the interactive version of the chart.

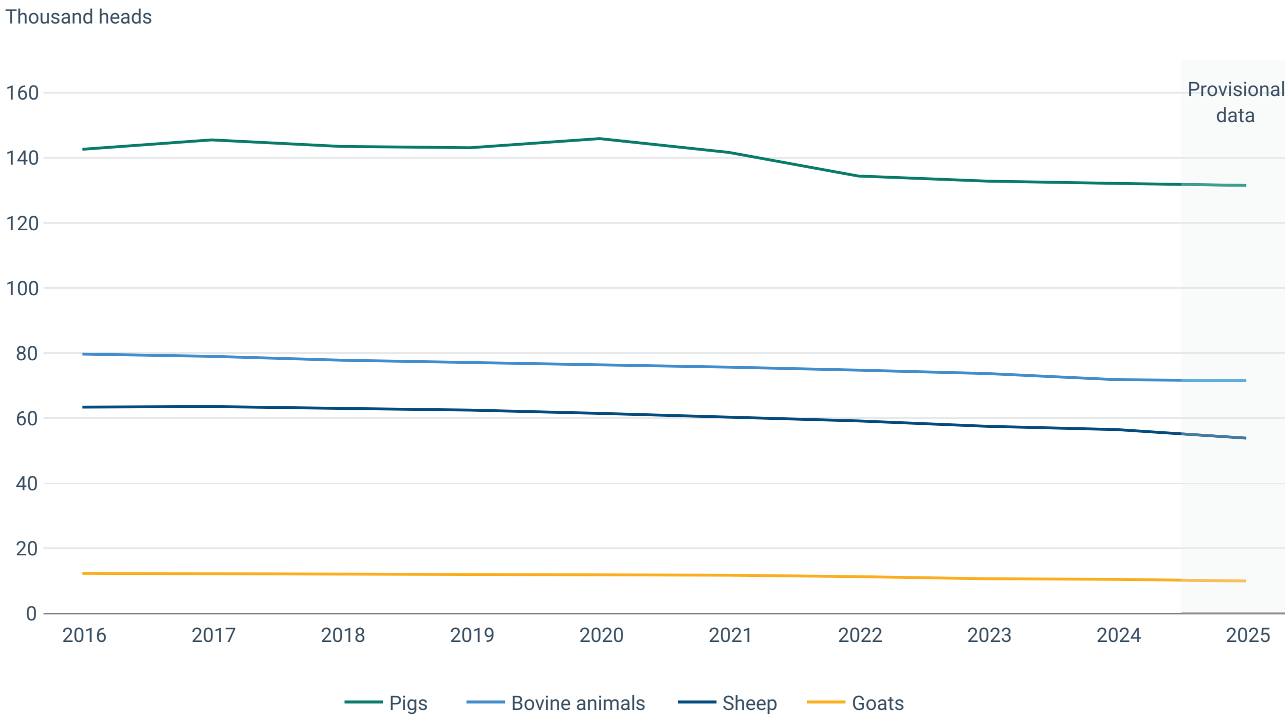
Source: EEA.

(2) The 65% estimate refers to emissions from enteric fermentation and manure management reported in sector 3 (Agriculture) of the EU greenhouse gas inventory (EEA, 2026). It excludes emissions from managed soils and other livestock-related sources reported elsewhere in the inventory (e.g. feed production in other sectors) and should therefore be interpreted as a partial estimate of livestock-related greenhouse gas emissions.

Livestock production can also generate environmental and public-health pressures linked to antimicrobial use. Veterinary antimicrobials are often only partially metabolised, with a substantial share excreted into soils and water through manure application or aquaculture discharges (EEA, 2024c). More broadly, antimicrobial residues originate from multiple sources, including human and veterinary use, pharmaceutical manufacturing, healthcare effluents and sanitation systems (UNEP, 2022). From a One Health perspective, which recognises the interconnections between human, animal and ecosystem health, these residues can persist in environmental systems and exert selective pressure on microbial communities, contributing to the emergence and spread of antimicrobial resistance. Reducing antimicrobial use through improved animal health, husbandry practices and more resource-efficient livestock systems can therefore contribute to both environmental and public health objectives.

EU livestock systems remain large and contracted only gradually over recent years (Figure 2.3), reflecting shifting demand, tighter environmental and animal welfare regulations, rising production costs and broader structural change across agriculture. In 2024, the EU counted approximately 132 million pigs, 72 million bovine animals and 67 million sheep and goats (Eurostat, 2025a). Livestock production is geographically concentrated, with a limited number of Member States and regions accounting for a large share of output. This concentration is particularly pronounced in intensive livestock systems, where production often clusters around feed imports, processing infrastructure and export-oriented value chains. Pig production illustrates this pattern clearly (Map 2.1). In Spain, Aragón and Cataluña together accounted for more than half of the national pig population. Across the EU, just 10 regions

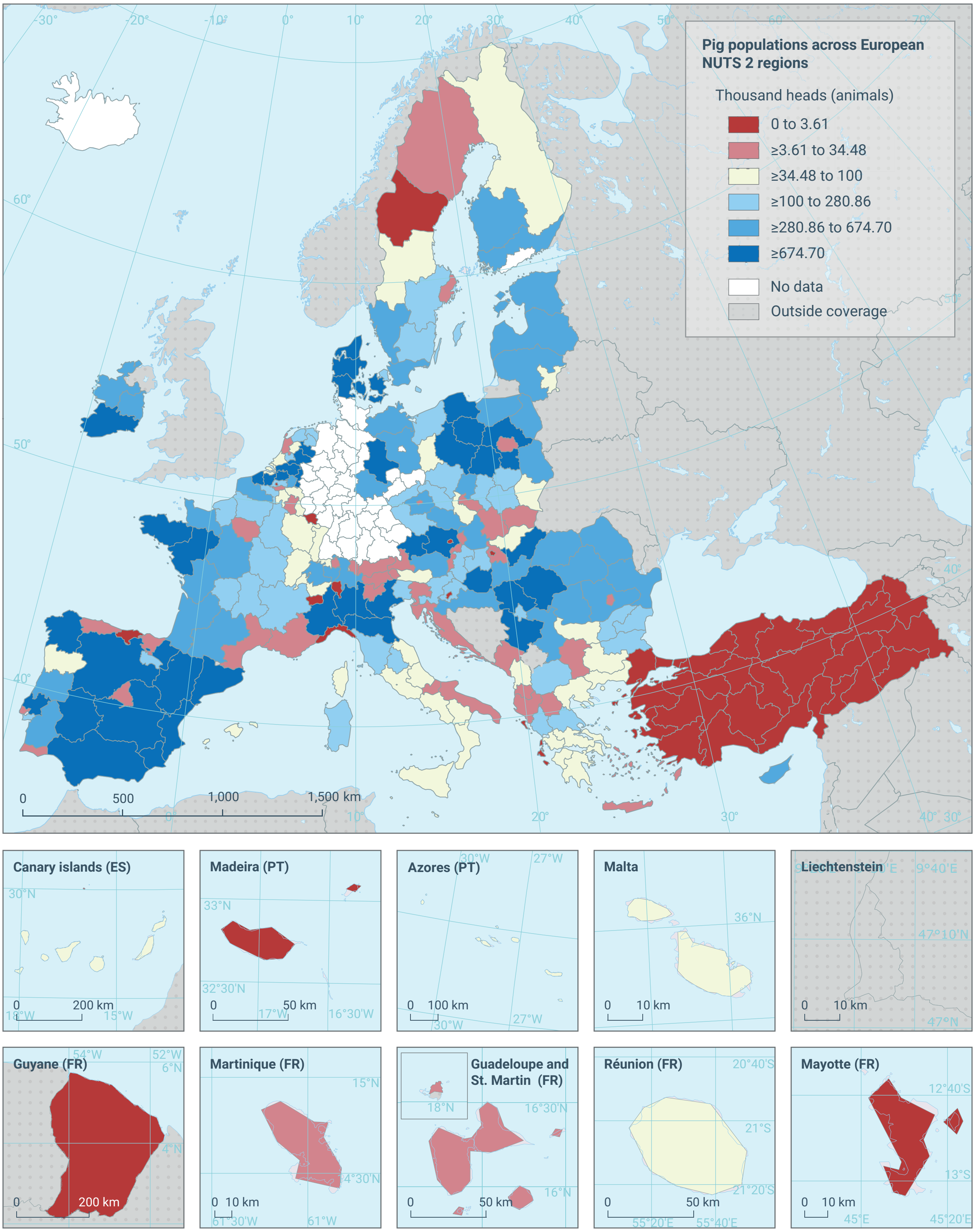
Figure 2.3 Developments in selected EU livestock populations, 2016-2025



Note: See the interactive version of the chart.

Source: Eurostat, 2025.

Map 2.1 **Regional concentration of pig populations in Europe, 2024**



Reference data: © EuroGeographics, © FAO (UN), © TurkStat Source: European Commission – Eurostat/GISCO

Notes: This map illustrates the regional concentration of pig populations across European NUTS 2 regions in 2024, based on Eurostat livestock statistics. Values are expressed as the number of pigs (thousand heads) per region and highlight the strong spatial concentration of pig populations within a relatively limited number of intensive livestock regions.

Source: Eurostat, 2025.

accounted for at least 2.5% of the total pig population in 2024, together representing 43.9% of all pigs in the EU (Eurostat, 2025a). These spatial patterns influence the distribution of environmental pressures, including nutrient surpluses, ammonia emissions and water pollution, and underline the importance of protein diversification pathways that are adapted to regional production systems and territorial contexts.

These findings align with those of the 2025 EAT-Lancet Commission, which concluded that current food systems globally exceed planetary boundaries related to climate change, biodiversity loss, biogeochemical flows (phosphorus and nitrogen), freshwater use, land-system change and novel entities, including pesticides and antimicrobial use, with livestock-centred protein supply identified as a major driver (Rockström et al., 2025). In practice, achieving climate and environmental objectives is likely to require not only more diversified protein sources, but also a gradual rebalancing of livestock production and consumption patterns, particularly within highly feed-intensive livestock systems. At the same time, however, modelling studies indicate that dietary shifts can have complex effects on soil greenhouse gas balances, partly offsetting mitigation gains depending on land-use change and management (Michailidis et al., 2025). Nevertheless, the broader evidence base suggests that aligning food systems with environmental limits will require a more diversified protein supply and a shift towards lower-impact pathways (Sala et al., 2020).

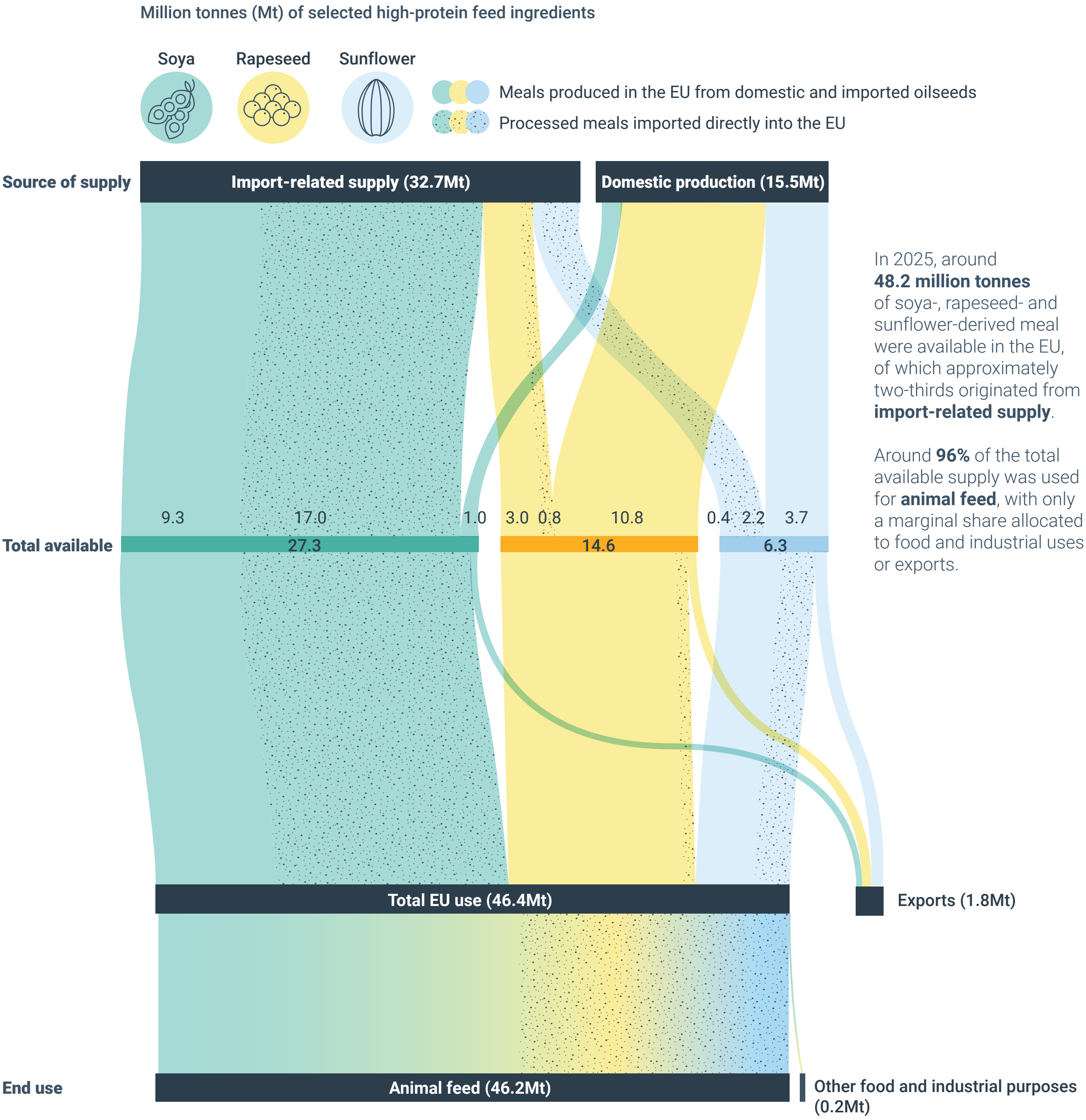
2.2 Resilience and strategic autonomy

Protein diversification can also contribute to resilience and strategic autonomy in food production, thereby strengthening food security (EC, 2022a). Recent shocks, including energy and fertiliser price spikes, Russia's war against Ukraine, global supply-chain disruptions and extreme weather events, have exposed structural vulnerabilities associated with imported feed dependency, market concentration and external shocks across European agriculture (SCAR, 2026). While feed markets have remained relatively stable overall, the EU's reliance on imported high-protein feed can increase exposure to climate-, market- and geopolitically driven disruptions where supply chains are highly concentrated or global trade conditions deteriorate (EC, 2024a). This is particularly relevant in specialised livestock systems dependent on a limited number of suppliers (Ercin, Veldkamp and Hunink, 2021). Climate change is expected to further increase production variability, shift agricultural production patterns and contribute to greater volatility in agricultural commodity markets, reinforcing the importance of diversified and resilient food systems (EEA, 2021).

The EU imports nearly two-thirds of the high-protein feed ingredients used in livestock production, with supply concentrated in a relatively small number of exporting countries, notably Brazil, Argentina and the United States. Figure 2.4 illustrates the supply and use of selected soya-, rapeseed- and sunflower-derived meals in the EU. In 2025, around 48.2 million tonnes were available for use, of which approximately 32.7 million tonnes originated from imports, either as processed meal imported directly into the EU or as imported oilseeds processed within the EU. Around 96% of the total available supply was used for animal feed, with only a marginal share allocated to food and industrial uses. Soya accounted for the largest share of imported feed proteins. The land embodied in EU soya imports is estimated to correspond to an area roughly equivalent to the land area of Ireland, illustrating the scale of external land use associated with European livestock feed demand (Eurostat, 2026) [3].

(3) The estimate is based on JRC land-use footprint modelling, which quantifies the agricultural land area required globally to produce goods consumed in the EU, including land embodied in imported soya and other agricultural commodities (De Laurentiis et al., 2024).

Figure 2.4 EU supply and use of selected high-protein feed ingredients in 2025



In 2025, around **48.2 million tonnes** of soya-, rapeseed- and sunflower-derived meal were available in the EU, of which approximately two-thirds originated from **import-related supply**.

Around **96%** of the total available supply was used for **animal feed**, with only a marginal share allocated to food and industrial uses or exports.

Notes: This figure illustrates the supply, processing and use of selected high-protein feed ingredients derived from soya, rapeseed and sunflower in the EU in 2025. It distinguishes between meals produced in the EU from domestic and imported oilseeds and processed meals imported directly into the EU. The figure highlights both the EU's continued reliance on imported high-protein feed ingredients and the important role of domestic crushing and processing capacity, particularly for rapeseed and sunflower, in supporting feed supply. Numbers may not add exactly due to rounding.

Source: Directorate-General for Agriculture and Rural Development.

These patterns reflect not only strong demand for livestock-derived products, but also structural constraints within the EU, including agro-climatic conditions, relative production costs, limited domestic protein-crop production and path dependencies in feed supply chains that constrain uptake of EU-grown protein crops. While domestic crushing and processing capacity plays an important role in supporting EU feed supply, reducing import dependency would also require increased domestic protein crop production, more diversified feed sources and shifts in demand. Addressing these dependencies therefore requires action on both supply and demand sides to strengthen the long-term resilience and adaptability of European food systems.

Joint Research Centre (JRC) modelling suggests that a coordinated protein transition, combining increased support for EU protein crop production with changes in livestock systems and demand-side shifts, could reduce reliance on imported feed while also lowering EU agricultural greenhouse gas emissions by around 5% by 2035 (Hristov et al., 2024). However, lower EU demand for imported feed may partly redirect exports towards other global markets. This could potentially limit overall emission reductions in production and associated environmental pressures in exporting regions. The scale of these effects remains uncertain and will depend on broader global demand trends, trade dynamics and future dietary patterns.

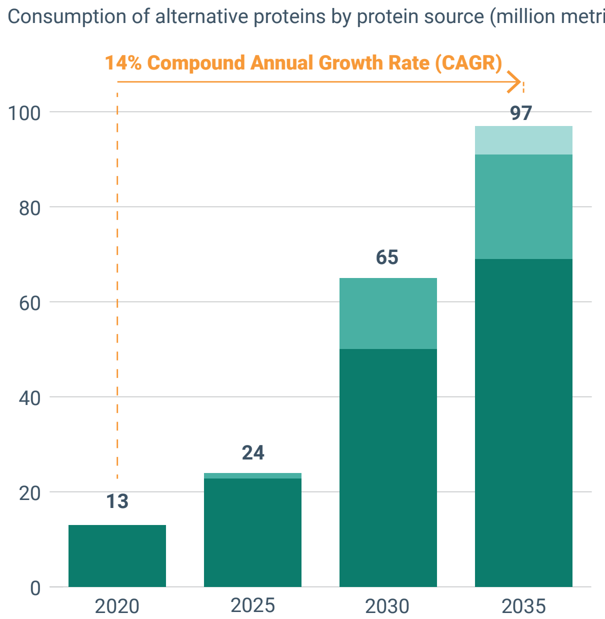
2.3 Competitiveness and economic opportunity

Global demand for protein is projected to continue rising, driven by population growth, rising incomes and changing diets, particularly in middle-income economies (OECD-FAO, 2025). Conventional protein consumption is expected to increase substantially before 2050, especially for meat and dairy products in these economies. However, climate impacts on food production may alter these trajectories. Meanwhile, alternative proteins are projected to expand rapidly from a relatively small base. Total alternative protein consumption, including plant-based products, was estimated at around 13 million tonnes globally in 2020, roughly 2% of the conventional animal protein market (BCG, 2021). This market could increase more than sevenfold to around 97 million tonnes annually by 2035, which would account for an estimated 11% of the global protein market [4]. Plant-based proteins are expected to remain the dominant source of alternative protein consumption through 2035, while fermentation-derived proteins are projected to expand particularly rapidly from a low starting point and cultivated meat is expected to remain a relatively small contributor despite high projected growth rates (Figure 2.5).

These projected consumption trends are also reflected in growing market opportunities. The global plant-based protein market is projected to grow from USD 23.89 billion in 2025 to USD 34.97 billion by 2030 (M&M, 2025). The global market for alternative proteins in animal feed is also projected to expand from USD 5.2 billion in 2026 to USD 9.7 billion by 2035. Although these markets remain relatively small relative to established food and feed markets, they indicate growing economic opportunities linked to more diversified protein value chains. These trends create opportunities for Europe to generate value through innovation, processing and exports. The EU is well positioned to compete in emerging and higher-value segments, including plant-based foods, fermentation-derived proteins and sustainable feed ingredients. Success will depend on whether market access, infrastructure and regulatory constraints are addressed effectively (EC, 2024b).

(4) These projections should be interpreted as scenario estimates rather than forecasts, as future market developments will depend on technological progress, production costs, regulatory frameworks, consumer acceptance and broader economic conditions.

Figure 2.5 **Projected global consumption of alternative proteins by source, 2020-2035**



Projected CAGR (%)

	2020-2025	2025-2030	2030-2035
Total alternative protein consumption (CAGR)	13%	22%	8%
Cultivated meat	52%	66%	120%
Fermentation-derived proteins	45%	111%	8%
Plant-based proteins	12%	16%	7%

Notes: The figure presents a scenario-based projection of global alternative protein consumption developed by Blue Horizon and BCG. Growth trajectories are uncertain and depend on technological progress, regulatory developments, energy availability, production costs and consumer acceptance. For consistency with the terminology used in this report, 'fermentation-derived proteins' and 'cultivated meat' are used in place of the original source's 'microorganism-based proteins' and 'animal-cell-based proteins'. CAGR (compound annual growth rate) refers to the average annual rate of growth over a given period, assuming growth occurs at a steady compounded rate each year. The percentages shown in the coloured rows indicate projected compound annual growth rates (CAGR) during the respective period. The orange row refers to total alternative protein consumption, while the remaining rows refer to individual protein sources.

Source: Adapted from BCG, 2021.

Competitiveness gains are not limited to digital or technology-intensive pathways. Evidence from the EU CAP Network indicates that regional protein value chains linking crop production, processing and food manufacturing can strengthen connections between farmers, processors and downstream markets while improving value chain coordination. However, farm-level uptake depends on relative profitability, agronomic suitability and access to stable markets. Evidence from European farm-level case studies suggests that reducing dependence on external inputs and strengthening ecological functions can improve economic resilience by lowering exposure to climate and market shocks while supporting more stable farm performance under changing climatic conditions (EEA, 2026a). Taken together, these findings suggest that diversification is likely to develop gradually and complement rather than rapidly replace livestock production in many regions. This gradual pace of change can provide time for adaptation and help reduce transition risks for livestock-dependent regions. Where enabling conditions are in place, such integration can support SMEs, strengthen locally embedded business models and increase regional value retention, thereby contributing to more resilient and inclusive rural economies (Schulp et al., 2024).

2.4 Health and societal benefits

Diversification of protein sources can deliver a range of public health benefits (Willett et al., 2019). Diets with a higher share of plant-based foods and lower consumption of red and processed meat are consistently associated with reduced risks of major non-communicable diseases, including cardiovascular disease and certain cancers (Clark et al., 2019). Replacing some animal-source foods with plant-based alternatives or minimally processed plant foods can substantially reduce environmental pressures while remaining broadly consistent with nutritional recommendations, provided that diets are appropriately balanced and diverse (Bunge et al., 2024). However, animal-source foods also provide important micronutrients, including vitamin B12, iron, zinc and selenium, and poorly managed dietary substitution may affect nutrient adequacy for some population groups (Fabricius et al., 2021). Well-planned dietary diversification can therefore support both environmental sustainability and improved health outcomes while maintaining nutritional adequacy (WHO, 2023).

Assessments against European Food Safety Authority dietary reference values show that total protein intake is generally sufficient across Europe and, in many cases, exceeds requirements for most adult populations (EFSA, 2012). The primary nutritional challenge therefore relates less to overall protein quantity than to the composition and quality of diets, including the balance between animal- and plant-based protein sources and their nutrient profiles. Available evidence indicates that shifts towards more diversified protein patterns are broadly consistent with existing dietary guidelines. When diets are appropriately balanced, they can be achieved without compromising nutritional adequacy (Springmann et al., 2018). Such shifts may also contribute to broader public health objectives linked to healthier dietary patterns and reduced environmental pressures.

3 Protein diversification pathways

Protein diversification in Europe is already underway, driven by technological innovation, evolving consumer preferences, food security concerns and targeted policy support (EASAC, 2025). It includes a growing range of protein sources being commercialised or developed for food, feed and functional ingredients. These range from established plant-based foods to insect-, microbial-, fermentation- and cell-based pathways. While these pathways vary considerably in technological maturity, environmental performance, economic viability and social acceptance (see Figure 3.1), together they reflect broader efforts to diversify Europe's protein supply, reduce strategic dependencies and respond to environmental and market pressures.

Plant-based proteins currently perform relatively strongly across these dimensions. This is due to established production systems, mature markets and relatively high consumer familiarity. Emerging pathways, including insect-, microbial-, fermentation- and cell-based proteins, may nevertheless offer strategic advantages in specific applications, including improved resource efficiency, ingredient functionality, feed diversification and reduced land dependence. Many nevertheless continue to face barriers related to production costs, infrastructure requirements, regulatory complexity and uncertain consumer uptake. Continued innovation and market development may make some pathways more viable and scalable over time.

Importantly, these pathways do not all serve the same function within food systems. Some provide direct alternatives to meat or dairy products, while others supply ingredients that enhance taste, texture or nutritional properties. Other pathways are primarily relevant for livestock feed diversification and reducing dependence on imported feed. Their contribution to more sustainable and resilient food systems therefore depends not only on production impacts, but also on how effectively they are integrated into diets, value chains, livestock systems, consumer practices and wider food environments. As a result, the relevance and potential contribution of different pathways are likely to vary across sectors, regions and time horizons.

Overall, the available evidence suggests that protein diversification should be understood as a portfolio of complementary pathways rather than a single technological transition (EIT Food, 2023). Different pathways are likely to become more relevant across specific applications, sustainability objectives and stages of market development and transition. This supports a pathway-neutral but sustainability-oriented approach that evaluates pathways according to their real-world contribution to environmental performance, resilience, competitiveness, health and social acceptance. In turn, this reinforces the need for adaptive governance and continued monitoring of environmental and socio-economic outcomes.

Figure 3.1 Overview of selected protein diversification pathways in Europe

Indicative assessment based on current evidence, relative to conventional livestock systems.

	Technological maturity	Potential environmental performance	Current economic viability	Social acceptance
Plant-based proteins	High	Strong	Competitive	Moderate/high
Insects	Low–intermediate	Moderate	Constrained	Low–moderate
Biomass fermentation	Intermediate	Conditional/moderate	Constrained	Moderate
Precision fermentation	Low–intermediate	Uncertain/conditional	Low currently	Low–moderate
Cultivated meat	Low	Uncertain/conditional	Low currently	Low/uncertain

Notes: The table provides a qualitative comparative synthesis of major protein diversification pathways, based on expert judgement and drawing primarily on scientific evidence synthesised by the European Academies Science Advisory Council (EASAC, 2025) and related peer-reviewed literature. Assessments reflect indicative relative performance compared with conventional livestock systems, particularly beef production, and should not be interpreted as exhaustive or definitive. Outcomes vary considerably depending on factors such as energy sources, feedstocks, production scale, regulatory conditions and consumer behaviour. Emerging pathways are associated with greater uncertainty due to limited commercial-scale evidence and evolving market and regulatory conditions and should therefore be interpreted with caution. The table is intended to support strategic comparison and policy discussion rather than rank technologies or prescribe specific pathways.

See the interactive version of the chart.

Source: Based on EASAC, 2025.

3.1 Plant-based proteins (pulses, legumes and plant-based alternatives)

Plant-based proteins are the most mature and widely deployed diversification pathway across Europe. They include minimally processed foods such as pulses, tofu and tempeh, alongside more processed meat and dairy alternatives based on extracted and texturised plant proteins. Future developments may be supported by improved breeding and new genomic techniques that enhance protein quality, yield stability and lower-input production systems, while expanding the range and performance of protein crops grown in Europe (Asiamah et al., 2025).

Environmental assessments consistently show that greater use of plant-based proteins can substantially reduce greenhouse gas emissions and land-use requirements compared with many animal-based proteins, particularly when substituting beef and other ruminant products (Poore and Nemecek, 2018). As a result, shifting protein consumption towards plant-based sources is widely recognised as one of the most effective options for reducing greenhouse gas emissions, land-use pressures and other environmental impacts associated with food production (Rockström et al., 2025). Plant-based proteins can also contribute to feed diversification and support more diverse crop rotations, particularly where legumes reduce reliance on synthetic fertilisers and improve soil health (The Protein Project, 2026).

Economic performance is relatively strong across several market segments, particularly for minimally processed foods and established plant-based products. However, profitability remains sensitive to scale, processing costs, raw material availability and input prices, especially in more highly processed categories. Market growth has accelerated in recent decades. Advances in processing technologies, expanding retail availability and rising consumer interest in health-oriented and lower-impact diets all lie behind this trend (Mylan, Andrews and Maye, 2023).

Social acceptance is generally highest for familiar foods such as pulses, legumes and traditional plant-based products. More processed plant-based meat and dairy alternatives nevertheless continue to face scrutiny regarding nutritional quality, processing levels, affordability and labelling. While whole plant foods are generally associated with positive health outcomes, the nutritional profile of plant-based alternatives varies considerably depending on ingredient composition and processing methods. Some highly processed products may contain higher levels of salt or saturated fats than minimally processed plant foods, while anti-nutritional factors can affect the bioavailability of certain micronutrients (Mayer Labba et al., 2022). As a result, health impacts should be assessed in the context of overall dietary patterns rather than individual products in isolation (Scarborough et al., 2023).

3.2 Insects (food and animal feed)

Insects present an emerging protein diversification pathway in Europe. They currently show the strongest potential in animal feed applications and selected food markets. Technological maturity remains early to intermediate, with production concentrated in small- and medium-scale facilities and a limited number of authorised species for food and feed use. In addition, current regulatory restrictions on feed substrates, including the prohibition of catering and household food waste, limit opportunities to utilise low-value organic streams, thereby constraining cost competitiveness and circularity potential.

Using more insects for protein diversification could bring a range of environmental benefits. Insect farming can offer high feed-conversion efficiency, relatively low land requirements and opportunities for integration into vertical production systems, for example (Elleby et al., 2021). The overall environmental performance of insects as a protein source depends on energy use, substrate choice and whether insect protein replaces higher-impact feed or food sources. Where insects are used as feed, overall resource efficiency may depend on substrate choice, production systems and the extent to which higher-impact feed sources are displaced under current conditions (Smetana, 2023).

Economic viability remains uncertain under current production conditions due to high production and processing costs, limited economies of scale and fragmented value chains (Niyonsaba et al., 2021). Additional challenges include investment requirements for specialised facilities, regulatory compliance costs and limited consumer demand in many markets. Current production is largely oriented towards feed markets and niche food uses, with limited penetration into mainstream human consumption. This reflects a position at the early stage of market, infrastructure and value-chain development (Smith, Etienne and Montanari, 2024).

Social acceptance for direct human consumption remains relatively limited in many Member States. Acceptance is generally higher when insects are used indirectly, such as in animal feed or as processed ingredients in familiar food products (Kozak and Jupowicz-Kozak, 2025). Nutritionally, insects can provide high-quality protein, beneficial fats and micronutrients. However, allergenicity, food safety, hygiene and animal welfare considerations require careful management and clear regulatory oversight (Cappelli et al., 2020).

3.3 Single cell proteins produced from biomass fermentation

Single-cell proteins (SCP) produced through biomass fermentation represent an intermediate-maturity pathway. Commercial products are already available and rapid innovation is underway. Production systems use microorganisms such as yeast, fungi, bacteria or algae to convert feedstocks into protein-rich biomass. Current approaches include systems based on agro-industrial side streams or industrial gases. The technology benefits from controlled production environments, relatively predictable yields and limited dependence on agricultural land or climatic conditions (Smith, Etienne and Montanari, 2024).

Environmentally, SCP can substantially reduce land-use requirements and greenhouse gas emissions compared with ruminant livestock. This is particularly true when production displaces more resource-intensive animal proteins. However, performance varies significantly depending on energy sources, feedstocks, water use, nutrient inputs and overall process efficiency (Smetana et al., 2023). Energy demand can nevertheless be considerable, particularly for hydrogen-based systems, making access to abundant low-carbon electricity a critical condition for favourable sustainability outcomes and large-scale deployment (Järviö, Maljanen, et al., 2021).

Economic viability remains uncertain under current market conditions, as production costs are generally higher than for conventional protein sources. However, SCP production systems offer several potential advantages. These include scalability, predictable yields, year-round production and opportunities to integrate with existing industrial fermentation and food-processing infrastructure where capacity is available (Kobayashi et al., 2023). Further production growth in Europe is currently constrained by limited access to food-grade fermentation capacity, downstream processing infrastructure and related scale-up capabilities.

Social acceptance is moderate and generally higher when SCP are incorporated into familiar food formats rather than marketed as a novel or standalone protein source. Acceptance may also depend on product taste, texture, price, labelling and perceptions of naturalness and sustainability. Fermented proteins can provide high-quality amino acid profiles and valuable micronutrients, but product-specific safety, allergenicity, nucleic acid content, digestibility and processing requirements require continued assessment and appropriate regulatory oversight (Coelho et al., 2020).

3.4 Functional proteins and ingredients produced from precision fermentation

Precision fermentation uses engineered microorganisms as cell factories to produce functional ingredients, including dairy and egg proteins, enzymes, vitamins and flavour compounds. Rather than supplying bulk protein replacement, precision fermentation is primarily used to produce specialised functional ingredients that can replace or complement animal-derived compounds and improve food functionality. The technology is currently at an early to intermediate stage, with pilot-scale production and limited commercial applications. Development in the EU is shaped by regulatory frameworks that may include novel food authorisation, genetically modified organism (GMO) legislation and broader food ingredient and safety rules (Verma et al., 2025).

Environmental performance is highly context-dependent. Precision-fermented ingredients can substantially reduce land use and, in some cases, greenhouse gas emissions compared with conventional animal-derived equivalents (Järviö, Parviainen, et al., 2021). However, overall outcomes depend strongly on access to low-carbon energy, sustainable feedstocks, efficient downstream purification, water use and responsible waste management. Benefits may therefore vary considerably across production systems, locations and product applications.

Economic performance remains highly context-dependent and uncertain at commercial scale. High capital investment, significant energy demand, costly purification processes and regulatory compliance costs continue to constrain large-scale deployment. Yields may also be lower than conventional agriculture or biomass fermentation, which affects cost competitiveness. Future viability is likely to depend on economies of scale, declining input costs, expanded fermentation capacity and an initial focus on high-value applications where functional ingredients can command price premiums.

Social acceptance is mixed and closely linked to perceptions of genetic engineering, transparency, labelling and trust in regulatory oversight (Kühl et al., 2024). Acceptance may also vary across products and use cases, with ingredients incorporated into familiar foods potentially facing lower resistance than more visible novel applications. From a health perspective, products can be nutritionally equivalent to animal-derived ingredients (Tzachor et al., 2022), although allergenicity, residual by-products and product-specific safety considerations require robust regulatory oversight (Graham and Ledesma-Amaro, 2023).

3.5 Cultivated meat

Cultivated meat remains at an early stage of technological and commercial development. Only limited approvals have been granted globally, with no authorisations to date in the EU. There remain significant scientific, engineering, safety and regulatory challenges. Specific obstacles include the development of scalable bioreactor systems, cost reduction, product safety assurance and the ability to deliver consistent texture, taste and nutritional quality at a commercially viable scale. Further challenges relate to the formulation of growth media, process efficiency and compliance with evolving regulatory requirements (Smith, Etienne and Montanari, 2024).

Environmental assessments suggest cultivated meat could substantially reduce land use and may reduce greenhouse gas emissions relative to production with beef, but impacts may be comparable to or higher than poultry depending on production design, energy sources and process efficiency. High electricity demand means access to low-carbon electricity is likely to be an important condition for favourable sustainability outcomes (Sinke et al., 2023). Current evidence remains uncertain because most assessments rely on modelling or pilot-scale data rather than commercial operations.

Economic viability remains limited under current production conditions, largely due to the high costs of growth media, bioreactors, specialised infrastructure and energy use. Long-term competitiveness remains uncertain and may depend on substantial technological advances that reduce production costs and enable reliable scale-up. Although the EU Novel Food Regulation provides a pathway to market approval, different political and regulatory approaches across Member States may influence future market development (Park et al., 2024).

Social acceptance remains uncertain and varies across countries and consumer groups. Consumer evidence suggests that willingness to try cultivated meat is conditional rather than fixed, depending strongly on regulatory approval, safety assurances, taste, affordability, nutritional value and clear information (Euroconsumers Group, 2025). Potential health benefits may include reduced pathogen risks and the possibility to tailor fat composition or micronutrient profiles. Empirical evidence remains limited, though (Mazac, Järviö and Tuomisto, 2023).

4 Risks and challenges

Protein diversification offers significant opportunities to reduce environmental pressures, strengthen the resilience of food systems and supply chains, and support healthier and more diversified diets. This is particularly the case for greater use of plant-based protein sources. Environmental, economic and social outcomes will depend on how diversification pathways are designed and implemented, however (Nowak, Hansten and Hernandez, 2025). Without appropriate sustainability safeguards, some pathways could shift rather than reduce environmental pressures, create new dependencies or generate uneven social and territorial impacts, particularly in livestock-dependent regions. Nevertheless, the gradual pace of change and diversity of available pathways may provide scope to manage many of these trade-offs through adaptive governance, innovation and targeted policy support.

4.1 Environmental trade-offs and burden shifting

Protein diversification can deliver important environmental benefits, particularly where it supports more diverse cropping systems, improved rotations and lower environmental pressures. Crop diversification is generally associated with positive outcomes for soil health, biodiversity and system resilience. However, some pathways may shift rather than reduce environmental pressures if scaled without safeguards for land use, pesticide use, water demand and biodiversity. In some contexts, rapid crop expansion or intensification without sustainable land management practices may increase pressures on biodiversity and soil health, particularly in intensive arable regions, while potentially shifting environmental impacts to biodiversity-rich regions outside Europe (Zabel et al., 2019). These considerations underline the importance of integrating protein diversification with broader sustainability, biodiversity and land-use objectives, while adopting a global perspective that accounts for trade-related environmental impacts and the risk of burden shifting across regions.

Some novel protein technologies may also create risks of burden shifting if sustainability conditions are not met. Biomass fermentation, precision fermentation and controlled-environment insect farming may be energy- and resource-intensive, particularly during early stages of commercial scale-up. Upstream greenhouse gas emissions may increase where fossil-based electricity is used. This may potentially offset gains from reduced land use or lower methane emissions. Conversely, production based on low-carbon energy and efficient resource use can deliver improved environmental outcomes (EASAC, 2025). This underscores the importance of ensuring that protein diversification does not replace dependence on imported feed proteins with new dependencies linked to energy-intensive production systems or proprietary inputs. For several emerging pathways, access to affordable low-carbon electricity and broader progress towards decarbonised electrification will be critical determinants of long-term sustainability and competitiveness (EEA, 2025c).

4.2 Economic risks and market concentration

Protein diversification requires significant investment in research, infrastructure and processing capacity. This may create opportunities for innovation but also bring economic and governance risks. Several emerging pathways, including fermentation-based and highly processed plant-based proteins, are characterised by high capital intensity and increasing concentration among a limited number of multinational and venture-capital-backed firms (EIT Food, 2024). Increasing market concentration could create new dependencies and weaken the bargaining power of farmers and small processors (Clapp, 2021). Appropriate policy design, competition frameworks and support for regional value chains may help ensure that the economic benefits of diversification are more broadly distributed across the food system.

For primary producers, diversification can entail transition costs and adjustment challenges. Farmers shifting from livestock- or cereal-based systems towards protein crops may face uncertainties related to yields, price stability and reliable market access. Without adequate support, diversification could increase income volatility, particularly in regions highly specialised in livestock production (Van Vugt and Ndeu, 2025). Uncertainty surrounding the longer-term transition may also increase the risk of stranded assets and reduce the viability of investments tied to highly specialised livestock systems. In addition, a disproportionate share of value creation may be concentrated downstream in processing, branding and intellectual property rather than at farm level, potentially limiting the distribution of economic benefits across the value chain (IPES-Food, 2017). However, targeted support, cooperative business models and stronger regional value chains can help improve value retention and reduce transition risks for farmers and rural regions.

4.3 Social acceptance and equity concerns

Societal acceptance is a key determinant of both the pace and durability of protein diversification. While interest in alternative protein sources is growing, particularly among younger consumers, levels of acceptance vary across Member States, population groups and socio-economic contexts (Faber et al., 2020). Surveys consistently show that price, taste and safety remain the main drivers of consumer choice. This is particularly the case for products perceived as highly processed or artificial (Eurobarometer, 2022). If these factors are not addressed, shifts in consumption are likely to remain uneven and confined to niche markets. Growing public awareness of health, sustainability and food security concerns may support broader uptake over time, especially where products are affordable, accessible and aligned with consumer preferences.

Equity considerations further shape the societal feasibility of protein diversification. Some alternative protein products command price premiums relative to conventional animal-based foods. Others such as legumes remain comparatively low-cost options. If diversification leads to higher food costs or unequal access to nutritious protein sources, this could exacerbate existing dietary inequalities and undermine public health objectives (Conti, 2024). Consumer choices are strongly shaped by food environments, meaning the physical, social and economic conditions that influence what people eat. Product availability, pricing, promotion and placement in retail and food service environments can strongly influence dietary choices and the uptake of diversified protein products. Ensuring affordability and broad access while respecting diverse dietary practices and cultural preferences can help support socially inclusive and scalable protein diversification pathways (EEA, 2017).

4.4 Socio-economic implications for livestock-dependent regions

Around 8.4 million people are employed in agriculture across the EU, many in livestock farming. Food and beverage processing employs about 4.6 million people, including a large workforce in meat processing (Eurostat, 2025b). Livestock systems therefore remain economically and socially significant in many regions, particularly in grassland and mountainous areas where alternative land uses are limited. Current evidence suggests that protein diversification is likely to unfold progressively over time, allowing scope for adaptation in production systems, labour markets and regional economies (BCG, 2021). Nevertheless, poorly managed or uneven transitions, especially in the absence of viable alternatives and targeted support, may still contribute to job losses, land abandonment and wider socio-economic pressures in livestock-dependent regions (Kaljonen, Kortetmäki and Tribaldos, 2023).

Protein diversification does not imply abandoning animal agriculture. A more constructive framing is the gradual rebalancing of production and consumption patterns, including reducing livestock numbers in feed-intensive systems alongside improvements in livestock sustainability and animal welfare standards (Herzon et al., 2024). Integrating improved livestock management with diversified feed and protein crops can help sustain farm incomes and employment while reducing environmental pressures (Hristov et al., 2024). This underscores the importance of aligning protein diversification and livestock strategies, with protein crops positioned as a lever for sustainability and resilience rather than as a replacement for livestock production. Targeted support through rural development, training and advisory services can help enable adaptation and avoid disproportionate impacts on livestock-dependent regions.

5 Enabling conditions for protein diversification

Realising the potential of protein diversification depends on forward-looking and adaptive governance frameworks that provide strategic direction across production, trade and consumption. As technologies, markets and dietary patterns evolve, EU policy plays a central role in shaping incentives, managing trade-offs and reducing transition risks. This will help to ensure diversification contributes coherently to sustainability, resilience and competitiveness objectives. Given the diversity of pathways and regional contexts involved, effective governance will also require coordination across agriculture, climate, trade, health and innovation policies, alongside continued engagement with producers, industry and consumers.

5.1 A strategic EU framework for sustainable protein systems

The EU Vision for Agriculture and Food, presented by the European Commission in February 2025, signals a shift towards a more coordinated and holistic approach to protein supply. This builds on the recommendations of the Strategic Dialogue on the Future of EU Agriculture. This emerging policy orientation is structured around three interlinked objectives: expanding sustainable plant protein production; enhancing the sustainability and resilience of livestock systems; and reducing exposure to high-risk imports through more diversified and sustainable protein trade, rather than pursuing full self-sufficiency.

Taken together, these objectives delineate a balanced and pragmatic approach to protein diversification that preserves EU integration into global markets while addressing strategic vulnerabilities, climate and environmental pressures, as well as exposure to external shocks. Recent policy analyses and stakeholder assessments indicate that delivering such an approach requires clear EU-level strategic direction, measurable implementation pathways, dedicated policy targets for protein diversification, and sustained policy coherence across policy domains, rather than relying primarily on fragmented or voluntary initiatives (Van Vugt and Ndeu, 2025; Galli, 2026).

In this context, the regulatory environment plays an important role in shaping the adoption of protein diversification pathways. Lengthy approval processes for novel foods, which can exceed two years, may create uncertainty for innovators and influence investment decisions. At the same time, the EU authorisation framework plays a key role in safeguarding consumer health. This ensures novel foods undergo rigorous scientific risk assessments before they are placed on the market, including by the European Food Safety Authority (EFSA). Ongoing policy developments including the proposed EU Biotech Act aim to improve the efficiency and predictability of procedures. This includes enhanced pre-submission engagement with authorities, while maintaining high safety and consumer protection standards.

5.2 Aligning policies to enable protein diversification

Protein diversification spans multiple policy domains, including agriculture, food, environment, innovation and health (SCAR, 2026). Policy coherence is therefore a critical enabling condition. Without coordination, efforts risk being offset by incentives that continue to favour livestock-intensive or input-heavy systems.

This would slow implementation and increase transition costs. The CAP is a key lever for land-based protein production and farming-system adaptation. Through conditionality, eco-schemes and rural development measures, it can support protein crops, legume-based rotations and more diversified farming systems while also supporting small and medium-sized enterprise (SME) participation and fostering regional innovation ecosystems that anchor value creation in rural areas.

Effectiveness depends on adequate resourcing and alignment with broader climate and environmental objectives. Without clear priorities and safeguards, Member State flexibility risks reinforcing existing production patterns rather than enabling structural change. This is particularly relevant in the CAP 2028-34 negotiations, where the design of eco-schemes and rural development allocations is likely to play a pivotal role. Aligning protein diversification with biodiversity objectives, including those under the EU biodiversity strategy, will help ensure protein crop expansion supports ecosystem integrity and resilient farming systems. Strengthening synergies with Horizon Europe and the EU bioeconomy strategy can further support protein crop development, alternative feed sources and innovation.

Public procurement represents an important demand-side policy lever. By integrating sustainability criteria into food procurement for schools, hospitals and public institutions, governments can help shift consumption patterns, create stable demand for diversified protein sources and support the development of regional value chains. When aligned with nutritional guidelines and sustainability objectives, procurement policies can accelerate the market uptake of plant-based and alternative proteins while improving affordability and access. Alongside public procurement, retailers, supermarkets and food service providers are increasingly important actors in protein diversification, as their sourcing practices, product placement, pricing strategies and sustainability standards can shape consumer behaviour and accelerate the uptake of diversified protein products.

Protein diversification should also be aligned with emerging EU livestock policy. Reducing reliance on imported feed is a shared objective. Greater domestic production of protein crops can strengthen the resilience and competitiveness of livestock systems by reducing exposure to supply-chain disruptions and input price volatility. Competitiveness in this context refers not only to production costs, but also to the capacity of livestock systems to remain productive, innovative and economically viable under tightening environmental constraints and changing market conditions. More diversified feed sources can therefore enhance strategic resilience, stimulate value creation within the EU, support innovation in feed and farming systems and improve the long-term adaptive capacity of the sector.

Trade policy plays a complementary role in this context. Sustainability requirements for imports, including deforestation-free supply chains, greater transparency and enhanced traceability can all help reduce environmental pressures while supporting resilience and strategic autonomy. Such measures can also strengthen market signals for more sustainable production practices in exporting countries, while improving risk management across supply chains. Maintaining open and diversified trade flows remains important to ensure supply stability, buffer regional climate or market shocks and avoid excessive dependence on a narrow set of suppliers or transport corridors. Balancing strategic resilience with continued engagement in international trade will therefore remain an important consideration in the design of future EU protein and food system policies.

5.3 From research to impact: scaling protein innovation

Research and innovation are important enablers of protein diversification, but their impact depends on the effective translation of knowledge into deployment at scale. Recent analysis highlights persistent gaps in commercial uptake, value-chain development, infrastructure, consumer acceptance and market adoption across Europe (SCAR, 2026). At the EU level, the Food 2030 research and innovation framework provides a strategic orientation for food systems transformation, promoting a multi-actor and systemic approach. Within this context, Horizon Europe supports a growing portfolio of projects on alternative proteins and sustainable food systems. For example, Horizon4Protein, a cluster of research projects on alternative proteins funded under Horizon Europe, brings together multidisciplinary research integrating agronomy, food science, technological development and value-chain design. Priority areas include consumer acceptance, safety and regulatory challenges, food applications, and sustainability. This is complemented by the EU life sciences strategy, which aims to strengthen Europe's capacity in biotechnology and bio-based innovation. Living labs and regional innovation ecosystems can further support experimentation under real-world conditions and strengthen feedback between research, implementation and policy (Box 5.1).

Box 5.1

Alternative protein innovation in Europe

Emerging alternative protein sectors across Europe illustrate how diversification can support sustainability, resilience and competitiveness. By reducing reliance on resource-intensive livestock production and imported feed, alternative proteins can help lower environmental pressures and strengthen the resilience of European food systems. Regional innovation ecosystems linking research institutions, start-ups, food manufacturers and public support are increasingly driving technological development and market uptake. In Germany, several federal states have become hubs for alternative protein innovation. Universities and institutes such as the Technical University of Munich, Karlsruhe Institute of Technology and the Fraunhofer institutes are advancing plant-based, fermentation-based and cellular agriculture technologies. Start-up clusters in cities such as Berlin and Hamburg support commercialisation and value-chain development. These developments illustrate how protein diversification can stimulate innovation, strengthen regional value chains and enhance the long-term competitiveness of Europe's farming and food industries.

Source: Systemiq, 2025.

New genomic techniques (NGTs) also enable protein diversification, particularly in plant breeding (Asiamah et al., 2025). NGTs are likely to influence the pace and direction of diversification by enabling crop varieties with improved protein content, greater resilience to drought and pests and more efficient nutrient use. This can support both environmental performance and the economic viability of protein crop production. The policy relevance of NGTs has increased following the provisional agreement between the European Parliament and the Council in December 2025 on a new framework for plants obtained through certain NGTs. This aims to strengthen the competitiveness, resilience and sustainability of the EU agri-food sector. The environmental and socio-economic implications of NGT deployment will depend on how these technologies are governed, adopted and integrated within broader farming systems.

Beyond technology development, the emergence of mission-oriented innovation policy can help align innovation trajectories with sustainability objectives, market demand and consumer expectations (Klerkx and Begemann, 2020). Demand-side measures, including public procurement, can help create lead markets for diversified protein products and support early-stage deployment. Regulatory sandboxes can facilitate controlled, real-world testing of emerging technologies. This allows regulators and innovators to better understand risks, performance and governance needs prior to wider market deployment. Advisory services, skills development and digital decision-support tools are equally important. These can reduce informational and operational uncertainty for farmers and processors, and lower barriers to adoption (EEA, 2022). Together, these measures can help accelerate learning, strengthen market confidence and support the responsible scaling of protein diversification pathways.

5.4 Ensuring a just and territorially balanced protein transition

Effective governance of protein diversification requires attention to social and territorial dimensions. Regions that specialise in livestock face higher adjustment costs and require targeted and predictable support. This includes skills development, advisory services, transition finance and regionally tailored diversification strategies. CAP instruments can contribute by compensating transition risks, rewarding ecosystem services and supporting diversification and investment. This support should be results-oriented and avoid locking in high-impact production systems. Ensuring policy coherence with rural development and cohesion objectives will enable balanced regional transitions and maintain viable rural economies. Given the likely gradual pace of diversification, there is scope to support adaptation over time while reducing the risk of abrupt socio-economic disruption in livestock-dependent regions.

Improved access to finance is also key, notably through de-risking mechanisms, stronger involvement of the European Investment Bank (EIB) and complementary instruments that support long-term structural transitions in agriculture. This may include facilitating access to capital for farmers, SMEs and emerging value chains engaged in protein diversification. Embedding diversification within rural development and cohesion policies can help ensure sustainability transitions are inclusive, socially acceptable and territorially balanced. Support for collaborative and transparent value chains is also needed. Greater coordination between public and private investment will support innovation uptake and reduce barriers to scale for more sustainable protein systems.

Societal feasibility also depends on demand-side conditions. Food choices are shaped by behavioural, informational and economic factors. These all influence the uptake of diversified protein options. Choice architecture interventions, public awareness campaigns and nutrition education can support a shift towards healthier, more plant-rich diets by making sustainable options more visible and accessible (SCAR, 2026). Pricing mechanisms and fiscal measures, where socially and politically appropriate, can also help align price signals with health and environmental objectives while safeguarding affordability for lower-income households. Improved labelling and transparency can further support informed consumer choices. This includes clearer communication on the origin, nutritional characteristics and sustainability of protein products. Addressing persistent misconceptions, for example regarding soy used in European food products, can build public trust and support socially inclusive and equitable uptake of protein diversification pathways.

5.5 Monitoring progress and trade-offs

Protein diversification involves multiple objectives, uncertainties and potential trade-offs. Effective governance therefore requires monitoring systems that track progress, identify unintended effects and support policy adjustment over time. This can help policymakers assess whether diversification pathways are contributing to sustainability, resilience and competitiveness objectives while limiting unintended consequences and uneven territorial impacts.

The disaggregated monitoring of feed protein dependency should be prioritised. Aggregate self-sufficiency metrics can obscure reliance on specific high-protein inputs and associated exposure to global market volatility, climate risks in exporting regions and forest-risk supply chains. Complementary indicators on overall protein self-sufficiency and trade exposure can strengthen the evidence base.

A second priority concerns land use and structural change within agriculture. Particular considerations should be taken regarding the share of utilised agricultural area devoted to livestock feeding systems and the extent to which cropping patterns support diversified rotations and protein crop integration.

A third priority concerns the economic dimensions of protein diversification. This includes value added, employment changes and the development of regional protein value chains. This will support more accurate assessments of competitiveness, resilience and structural change across the food system.

Fourth, monitoring should assess the environmental performance relative to nutritional outcomes. This includes greenhouse gas emissions, reactive nitrogen losses and any pressures on biodiversity, soils and water resources. Established EEA indicators provide robust baselines for evaluating whether diversification pathways contribute to reducing pressures through lower enteric emissions, improved manure management and reduced fertiliser use.

Fifth, consumption-side indicators should track changes in the dietary protein mix, alongside the affordability and accessibility of alternative protein sources. Integrating these environmental, economic and social indicators into existing EU food system monitoring can improve transparency, support evidence-based policymaking and help manage trade-offs across objectives for sustainability, resilience and competitiveness.

6 Strategic priorities for an EU protein strategy

Europe's protein system sits at the intersection of food security, environmental sustainability, competitiveness and strategic autonomy. Continued reliance on livestock-based production and imported feed exposes the EU to environmental pressures and external vulnerabilities that may intensify under climate change and growing geopolitical uncertainty. Protein diversification offers a credible and complementary response, provided it is pursued as a systemic transition rather than a narrow technological or dietary adjustment. In this context, an EU protein strategy, as signalled in the EU Vision for Agriculture and Food and called for by the European Parliament Committee on Agriculture and Rural Development (AGRI), could provide a unifying framework to align policies, manage trade-offs and guide implementation.

Three strategic pillars can guide implementation:

- Sustainability and environmental integrity. This involves embedding sustainability safeguards through CAP instruments, environmental regulation and taxonomy frameworks, including measures to avoid unintended impacts from land-use change, crop intensification and the externalisation of environmental pressures through trade.

- Resilience and strategic autonomy. This focuses on reducing dependence on imported feed by supporting domestic protein crops, diversified value chains and coherent trade policy, while maintaining the benefits of open and resilient trade flows.

- Just transitions. This pillar supports gradual adjustment in livestock-dependent regions through rural development, innovation funding and skills policies, while supporting affordability, territorial equity and societal acceptance.

Such a strategy would need to balance objectives across agriculture, trade, climate, health and territorial development, while managing trade-offs transparently and securing public legitimacy. Through adaptive governance and broad stakeholder engagement, it could help reduce transition risks and support protein diversification as part of the shift towards more resilient, competitive and sustainable European food systems. No single pathway will address all challenges associated with Europe's protein system. Nevertheless, a gradual and well-governed diversification of protein sources has the potential to strengthen food security, reduce environmental pressures and create new opportunities for innovation and value creation across European food systems.

Abbreviations

AGRI	European Parliament Committee on Agriculture and Rural Development
CAP	Common agricultural policy
EASAC	European Academies Science Advisory Council
EC	European Commission
Eionet	European Environment Information and Observation Network
EEA	European Environment Agency
EFSA	European Food Safety Authority
EIB	European Investment Bank
ETC ST	European Topic Centre on Sustainability Transitions
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GMO	Genetically modified organism
JRC	Joint Research Centre
NGT	New genomic techniques
SCP	Single-cell proteins
SME	Small and medium-sized enterprise

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