2026

Regulatory barriers to the use of biological by-products in European feed production

BELLONA REPORT

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Co-funded by the European Union
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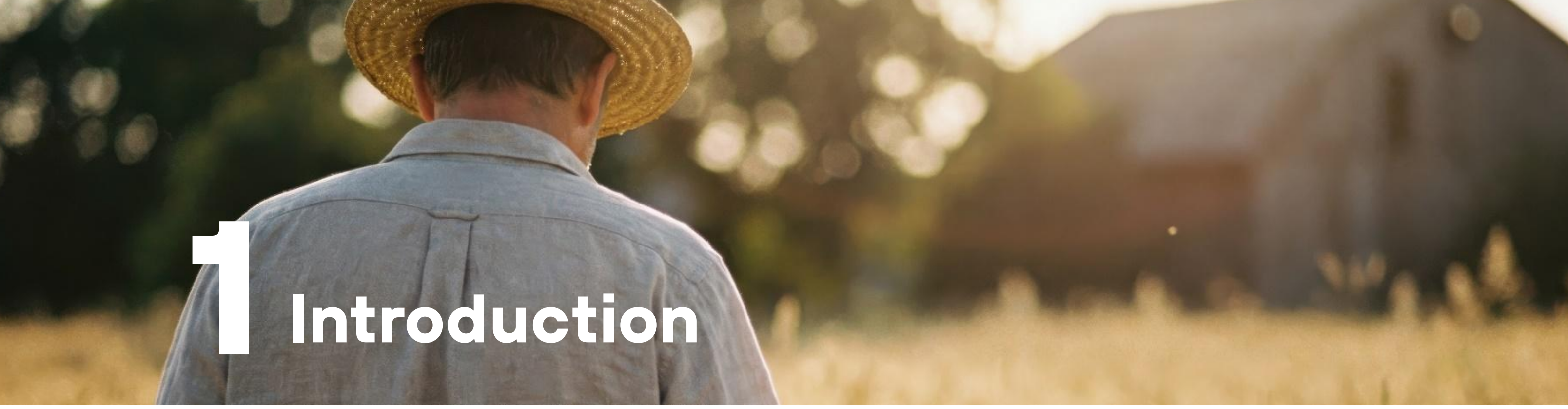
Executive summary

This report examines the potential of biological by-products and underutilised bioresources for sustainable feed production, with a focus on supporting circularity, climate objectives, and strategic autonomy. It assesses feed-relevant biomass volumes, identifies regulatory and market barriers, and highlights pathways to increase the use of domestic resources within EU and Norwegian value chains, while proposing actionable measures to unlock their full potential.

Key findings include:

- Establishing a robust biomass value-based hierarchy is essential, as it provides the framework to allocate biological by-products and residual streams to high-value applications like feed, helping Europe manage limited resources efficiently and sustainably.
- Enhancing domestic feed supply can reduce Europe's dependence on imports, mitigate exposure to global market volatility, and strengthen resilient, climate-friendly, circular food systems.
- Significant volumes of animal by-products, mixed food waste, agricultural residues, and aquatic residual streams remain untapped. Mobilising these could expand feed supply without increasing land use or pressure on primary resources.
- Current EU and national regulations restrict the use of many biological by-products and secondary biomass streams, limiting circular feed opportunities; addressing these barriers is crucial to unlock their full potential.
- Selected European and Norwegian case studies illustrate practical applications, the potential for scaling up, and alignment with feed and biomass hierarchies.

This report demonstrates that substantial volumes domestic biological by-products and underutilised biomass streams across Europe are going largely untapped. Unlocking their potential through targeted regulatory adjustments, safe valorisation pathways, and strategic investment can transform these wasted resources into resilient, circular, and self-reliant feed systems.



1 Introduction

Europe generates substantial volumes of biological by-products and secondary biomass streams across agricultural, food, aquatic (including marine), and terrestrial animal value chains. Many of these resources remain underutilised due to regulatory, market, and practical barriers, despite their potential to contribute to feed production for livestock, aquaculture, and other food-producing animals. Recognising that biomass is a finite resource, it is critical to apply circular economy principles, such as cascading use and a biomass prioritisation hierarchy, to ensure that high-value applications like feed are prioritised before lower-value uses, including energy or disposal.

Increasing the use of domestic feed biomass is critical for multiple interlinked reasons. Circular utilisation of by-products reduces waste, retains nutrients within European systems, and lowers environmental pressures associated with land use and imports. Strengthening domestic feed production also reduces reliance on imported commodities, enhancing the resilience of livestock and aquaculture sectors against global market volatility and geopolitical risks. At the same time, mobilising Europe's bioresources supports industrial and technological sovereignty, reducing dependence on fossil-based and imported feed inputs while contributing to climate and sustainability goals.

Against this backdrop, the purpose of this report is to assess the availability and potential of European biological by-products and underutilised bioresources for feed production, and to identify the regulatory and market barriers that currently constrain their safe and efficient use. For clarity, "feed" in this context refers exclusively to biomass intended for animals entering the human food chain, excluding pet food or non-food applications. "Biological by-products" are defined here as secondary materials of biological origin generated within agricultural, food, aquatic (including marine), and terrestrial animal value chains that may be valorised as feed within the food production system.

The assessment considers a range of streams, including animal by-products from slaughterhouses and food processing, mixed food waste from households and commercial sources, agricultural residues such as straw and crop residues, and aquatic residuals and low-trophic species, including algae. Many of these streams are currently underutilised, yet they are available in sufficient volumes and align with circularity objectives. As such, understanding and addressing the regulatory and practical constraints that limit their use is essential to unlock their potential for feed production.

Illustrative case studies from both European and Norwegian contexts demonstrate how these resources can be mobilised effectively, linking practical applications to the proposed biomass hierarchy and demonstrating scalable solutions. While this report was planned and conducted prior to the publication of the *EU Feed Circularity Catalogue* by FEFAC,[1] it complements and extends their work. By compiling quantitative volumes, identifying regulatory bottlenecks, and suggesting actionable measures, it provides additional evidence and insights to inform policy, industry practices, and governance, supporting the development of more resilient, sustainable, and circular feed systems across Europe.

[1] FEFAC, "EU Feed Circularity Catalogue: Existing legal restrictions to enhanced animal feed circularity", 23 May 2025, https://fefac.eu/wp-content/uploads/2025/07/Circularity-Catalogue_version-1.0-HIGH-RESOLUTION.pdf

2 Biomass hierarchy and regulatory context

This chapter establishes the conceptual and regulatory foundations relevant to the use of biological by-products in European feed production. It introduces the biomass hierarchy as a framework for prioritising limited bioresources, highlighting the importance of directing residual and secondary biomass streams toward high-value applications such as feed. The chapter then outlines key EU regulatory principles shaping biomass allocation, before examining the fuel versus feed dilemma as a central tension influencing the availability and regulatory treatment of by-products for feed use.

2.1. Rationale for a biomass value hierarchy

Bioresources are limited. With the green shift in the economy, transitioning away from fossil fuels, alongside increasing climate-induced stressors, the pressure on these resources will only increase in the future. Population growth, changes in dietary preferences, such as an increase in global meat consumption, and the expected use of bioresources for everything from fuel to medicine, will also have implications on the potential to produce new raw materials for feed.

There are many efficient and inefficient uses for our limited bioresources, which raises the obvious question: which bioresources should be used, and where should they be used to achieve the best possible outcome?

The biomass hierarchy is a framework for answering that question: a suggested categorisation that prioritises the use of bioresources towards the best overall result, with a view to maximising benefits to society while minimising harm to the environment and climate. Where medicines, food and feed (for food producing animals) are ranked above, among others, biomaterials, fertilisers, and bioenergy, while at the bottom of the hierarchy are incineration, waste disposal, and pollution.

Such a framework is intended as a decision-support tool for policymakers and regulators when designing legislation, incentives, and public funding priorities related to biomass use, while also providing guidance for biomass producers, processors, feed and material users, and other actors across the value chain when making investment and sourcing decisions. By evaluating competing biomass uses against consistent criteria, market actors and policymakers will be able to prioritise food, feed, materials, or energy uses, guide incentives, and permits and align decisions with sustainability and climate objectives.

The role of bioresources in the economy depends on two key variables: the source of the biomass and how that biomass is used. An effective biomass hierarchy should therefore consider both, where biomass comes from (its sustainability and renewability), and how it is used (societal value and application efficiency) allowing trade-offs between sourcing impacts and end uses to be assessed with a single decision framework. Additionally, it would remain open to the possibility of not harvesting a particular bioresource in the first place, should the environmental harm overshadow the potential societal benefit that may be generated.

From a climate perspective, it is also important to consider the disruption of the carbon cycle. Whereas the extraction of fossil fuels represents a perturbation of the carbon cycle on the order of hundreds of thousands of years, the harvesting of biomass is likewise a perturbation of the carbon cycle, albeit on a much shorter timeline, on the order of centuries, decades, or less. Therefore, harvesting and using biomass instead of fossil fuels may present a benefit in this regard. However, this distinction also applies amongst biomass sources, whereby harvesting from an ancient rainforest will disrupt the carbon cycle in a much more significant way than harvesting crops grown on marginal land. Broadly speaking, where carbon is needed it should be sourced in such a way as to minimally disrupt the carbon cycle.

Therefore, an extreme negative example would be the deforestation of an old-growth biodiverse-rich forest purely for the combustion of the biomass to generate electricity. The environmental harm of harvesting this biomass is severe and impossible to fully recover within a reasonable timeline. At the same time, the societal benefit of generating electricity in this way is quite limited, especially considering that cheaper, more efficient, and less polluting ways of generating electricity are already commonplace.

On the other extreme, harvesting forest residues which would otherwise pose severe wildfire risks and using them for a combination of high-value applications, such as long-lived wood products, create multiple societal and environmental benefits.

A biomass hierarchy must be able to differentiate and prioritise such contrasting examples and provide general guidance for the many intermediate cases that arise in practice. Rather than prescribing outcomes for every specific biomass pathway, the hierarchy is intended to establish overarching prioritisation principles, helping decision-makers navigate complexity and align biomass use with circularity and climate objectives. It provides a clear orientation in the overall management of what will prove to be a much-needed transition, from a fossil-based and linear economy, towards one which is more circular and respectful of planetary boundaries.

In practice, this concept is illustrated in *Figure 1*, adapted from the BioDigSirk project (2022), commissioned by the Norwegian Ministries of Climate and Environment, Industry and Fisheries, and Agriculture and Food. **The figure presents a *value hierarchy* for bioresources, in which positioning within the pyramid reflects the relative societal value and resource efficiency of different biomass uses rather than the volume of biomass allocated to them. Higher levels of the hierarchy correspond to applications**

that generate greater value per unit of biomass while preserving material quality, enabling cascading use, and limiting irreversible losses of biological resources. Lower levels represent progressively greater degradation of biomass functionality, culminating in energy recovery or disposal pathways where material value is largely lost. The green part of the pyramid therefore indicates preferred uses within a resource-constrained bioeconomy. Note that the value hierarchy presented here serves as a conceptual starting point, which will be further operationalised in subsequent work by Bellona to translate these principles into practical guidance for EU bioresource governance.

In particular, the hierarchy should also encompass emerging sources of biomass, including low-trophic aquaculture, algae, and other marine side-streams, to relieve pressure on land-based resources and support the development of sustainable feed alternatives. By providing explicit guidance on the allocation of limited biomass, a hierarchy would serve as a practical tool to manage competing demands and ensure the EU's bioeconomy develops in a circular, sustainable, and climate-aligned manner. Within this framework, biological by-products and residual streams are especially important, as they allow feed production to expand without increasing pressure on primary biomass resources, while remaining consistent with principles of circularity and resource efficiency.

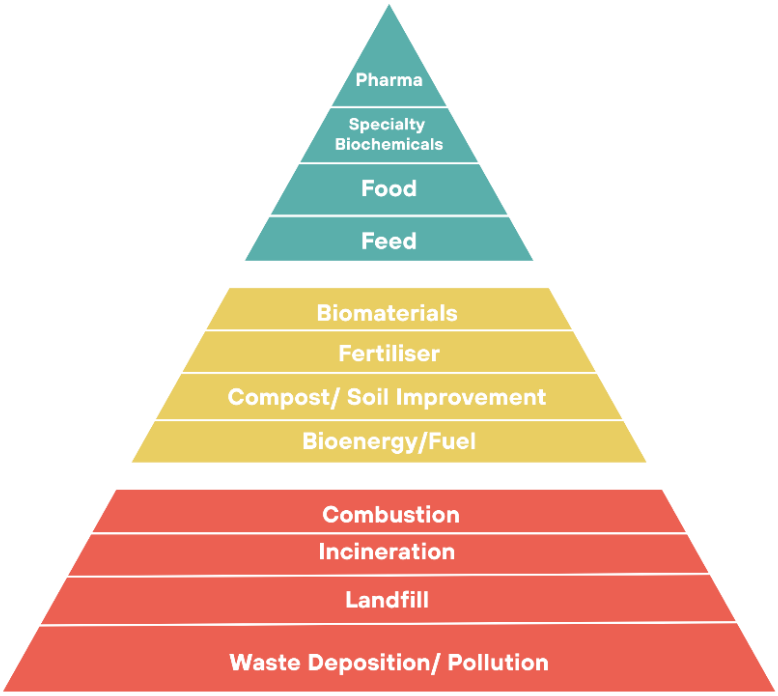


Figure 1 – Politically anchored value hierarchy for bioresources.
Image adapted from BioDigSirk (2022).[2]

[2] Nærings- og fiskeridepartementet, Klima- og miljødepartementet, and Landbruks- og matdepartementet, "BioDigSirk – oppsummering og sluttrapport", [BioDigSirk – Summary and Final Report], 18 January 2023, https://www.regjeringen.no/no/dokumenter/biodigsirk/id2959778/

2.2. Cascading use and current EU regulatory context

The principle of cascading use prioritises the highest-value applications of biomass before energy recovery, ensuring that materials are used efficiently and sustainably. Within EU law, the principle has been explicitly integrated into the Renewable Energy Directive (RED III, 2023/2413/EC), which requires Member States to design support schemes for energy from biofuels, bioliquids, and biomass in a manner that ensures biomass is used according to its highest environmental and economic value. It specifically sets an order of priorities for woody biomass placing wood-based products, lifetime extension, re-use, and recycling above bioenergy and, ultimately, disposal.[3] Although RED III focuses primarily on woody biomass, this principle should be applied more broadly to other forms of biomass, including agricultural and aquatic by-products, by prioritising material uses over energy recovery wherever feasible.

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The cascading principle is also reflected indirectly through broader EU policy frameworks. Article 4 of the Waste Framework Directive[4] (2008/98/EC), establishes a hierarchy for waste management that prioritises prevention, reuse, and recycling before recovery and disposal, embedding a legal logic of prioritisation that guides Member States in the management of bio-based resources.[5]

Beyond binding legislation, the 2025 EU Bioeconomy Strategy (COM(2025)960 final)[6] encourages Member States and stakeholders to maximise the value of biological resources across sectors and to shift towards more circular production models to enhance the EU's strategic autonomy while supporting climate and biodiversity objectives.

Despite these frameworks, **no binding EU regulation currently establishes a clear hierarchy for competing biomass uses.** In practice, this can result in suboptimal outcomes as described in the previous section. Finite bioresources, combined with pressures from

[3] European Commission, "Directive (EU) 2023/2413 of the European Parliament and of the Council of 19 October 2023 on the Promotion of the Use of Energy from Renewable Sources (RED III)", 19 October 2023, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32023L2413
[4] European Parliament & Council, "Directive 2008/98/EC on Waste (Waste Framework Directive)", 12 November 2008, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32008L0098
[5] SBP, "The Cascading Principle: Considerations on Guidance and Options for Applying the Cascading Principle through SBP Standards", Working Paper, 2025, https://sbp-cert.org/wp-content/uploads/2025/03/SBP_Cascading_Principle_v3.0_Final_25March25.pdf
[6] European Commission, "Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: A Strategic Framework for a Competitive and Sustainable EU Bioeconomy", COM(2025) 960 final, SWD(2025) 895 final, Brussels, 27 November 2025. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52025DC0960

population growth, dietary changes, and the green transition, make clear guidance particularly important to avoid inefficient uses and to ensure climate, biodiversity, and societal benefits.

Bellona has therefore highlighted[7] the need for a robust EU biomass hierarchy rooted in the cascading principle, which would explicitly guide the allocation of bioresources to the highest value uses.

In addition, Bellona recommends that the European Commission evaluates Article 3(3) of RED III to refine and strengthen the cascading principle based on the latest scientific evidence, explicitly recognising biomass resource scarcity and adopting a holistic approach that accounts for carbon and energy efficiency.

Finally, the Commission should disincentivise inefficient biomass combustion and promote substitution with other renewable energy sources, freeing up additional biomass for higher-value material uses within the bioeconomy, including sustainable feed and biobased products, while improving overall system efficiency.

2.3. The fuel and feed dilemma

With a growing population, climate change that challenges food production, and limited arable land, it is widely acknowledged that food and feed production should take priority over crops grown for energy to ensure food security. At the same time, as Europe transitions towards a fossil-free future, biofuels play an important role in replacing fossil fuels, particularly in non-electrifiable sectors such as maritime and air transport, and high-temperature industrial processes.[8]

Today, about 60% of EU renewable energy originates from biomass[9], mainly from forestry but also from agricultural crops. The EU Renewable Energy Directive (RED III) sets a binding target to achieve at least 42.5% of its total energy use from renewables by 2030[10], with sectoral measures promoting renewable fuels and advanced biofuels. While these targets are crucial for the energy transition, biomass remains a finite resource, and as introduced by the biomass hierarchy in section 2.1 *(Figure 1)* high-value applications, such as food, feed, and cascading uses, should be prioritised over lower-value ones like energy and fuel.

[7] Bellona EU, "Press Release – EU Bioeconomy Strategy Must Establish a Robust Biomass Hierarchy," 27 November 2025, https://eu.bellona.org/2025/11/27/press-release-eu-bioeconomy-strategy/
[8] ECCO, "Biomass and the Transition of the Plastics Industry: Towards Strategic and Efficient Use of Bio-based Resources", Technical Report, November 2025, https://eccoclimate.org/wp-content/uploads/2025/11/EN_Report_Biomass-and-transition-1.pdf
[9] European Commission, "Bioenergy – Research and Innovation", accessed February 2026, European Commission, https://research-and-innovation.ec.europa.eu/research-area/energy/bioenergy_en
[10] European Commission, "Directive (EU) 2023/2413 of the European Parliament and of the Council of 19 October 2023 on the Promotion of the Use of Energy from Renewable Sources (RED III)", 19 October 2023, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32023L2413

The fuel and feed dilemma encompasses not only resource allocation but also food safety, climate, and market considerations. The European Bioeconomy Alliance[11] highlights that using primary biomass for non-food applications often yields co-products suitable for feed.
Diversifying biomass use in this way can strengthen food security, maintain overall feedstock availability, and increase system resilience, enabling rapid responses to fluctuations in demand for food production during emergencies.

Biofuels can contribute to de-fossilising the European industry and transport sector, and at the same time provide valuable protein-rich by-products for food and feed. Processing cereal crops and oilseeds for biofuel applications generates large quantities of proteins and fibres that would otherwise not enter the feed supply. From a circular bioeconomy perspective, these co-products are important, as they allow energy production and feed production to coexist without increasing pressure on primary biomass resources. They also offer additional benefits to farmers by diversifying income streams and strengthening economic security. In this sense, biofuel and other non-food biomass applications can support rather than compete with food and feed production, provided that the overall allocation of biomass follows a clear hierarchy that prioritises high-value uses first and that the use of land to grow energy crops does not lead to deforestation.

This interplay between feed, food, and energy underscores the importance of a robust biomass hierarchy that optimises the use of limited bioresources, alongside a coherent regulatory framework that safeguards access to biological by-products for feed, prioritises cascading use, and ensures that bioenergy policies complement, rather than undermine, circularity, resource efficiency, and food and feed security.

[11] C. vom Berg, M. Carus, and K. Seeger, "Benefits of Using First-Generation Biomass for Food, Fuels, Chemicals and Derived Materials in Europe", ed. Renewable Carbon Initiative, 2025, https://doi.org/10.52548/GCJC4981

3 Key biomass streams and associated regulatory barriers

Photo: Magnus Stoud Myhre/ SINTEF

The biomass streams covered in this section are considered *key* in the context of European feed production due to their high existing and projected volumes, their significant untapped circularity potential, and their relevance for reducing reliance on imported feed materials. Aquatic biomass and by-products, terrestrial animal by-products (ABPs), food waste, and agricultural residues represent some of the largest and most readily available sources of secondary biological resources in the EU. At the same time, their use in feed is currently constrained by a range of regulatory, administrative, and practical barriers. Focusing on these streams therefore allows this report to assess where regulatory frameworks most strongly influence the feasibility of increased circularity in feed production, and where targeted interventions could unlock the greatest impact.

3.1. Aquatic resources

There is significant potential for the feed industry in underutilised residual raw materials and by-products from the fisheries and aquaculture sector. Norway is the world's largest producer of Atlantic salmon and the largest seafood exporter within the EEA. As such, this chapter illustrates some potential aquatic biomass streams using examples from the Norwegian seafood industry:

- Residual raw material and by-products from wild-catch fisheries
- Sludge from aquaculture farms, primarily from salmon farming

3.1.1. Residual raw materials and by-products

When considering residual raw materials and by-products, it is useful to provide some general explanations of the different categories:

The terms "residual raw material" and "by-product" are often used interchangeably, but there are important differences between the two, particularly when the materials originate from animals:

- *Marine residual raw material* is defined as the non-primary product remaining after gutting and processing of fish and shellfish. It includes what remains of the fish, such as liver, roe, skin, and heads. If this material is treated as food and is not contaminated with any undesirable substances, it can be used for human consumption.
- Residual raw material that is not suitable for human consumption and is not considered food waste is defined as an *animal by-product*. Once a raw material is classified as a by-product, it cannot be upgraded back to be used for human consumption.

By-products from the seafood industry can be processed into fish oil, fishmeal, protein concentrate, and protein hydrolysate through various processes.

3.1.1.1. Regulatory framework for using by-products in feed

Various regulations apply to the use of residual raw materials and by-products in feed for food-producing animals. The Animal By-Products Regulation[12] ensures the safe use of ABPs not intended for human consumption. Under this regulation, by-products are categorised according to their health risk to humans and animals:

- **Category 1 material:** Mostly related to prion diseases, such as BSE (Bovine Spongiform Encephalopathy, "mad cow disease") and other TSEs (Transmissible Spongiform Encephalopathies: a group of fatal neurodegenerative prion diseases affecting animals and humans), or with toxic contaminants. This category presents the highest risk and must be destroyed or incinerated.
- **Category 2 material:** Mainly associated with infectious diseases or farm hygiene (e.g., manure). It cannot be used in feed for food-producing animals or pets in the EU and is in most cases used for energy production or as fertiliser.
- **Category 3 material:** Material that was fit for human consumption at the point of slaughter. It presents a low risk and can be repurposed into animal feed or pet food after appropriate processing.

In the fisheries sector, mainly Category 3 material is produced, while aquaculture produces both Category 3 and Category 2 materials (primarily dead fish).

The use of proteins derived from the same species in feed for food-producing animals is prohibited in the EU. Salmon oil, however, may be used in salmon feed, and hydrolysed marine protein that meets current regulatory requirements may be used in feed for the same species without restrictions.

Do we need an additional category of by-products?

Dead farmed fish as a by-product are normally classified as a Cat 2 material and are mainly used for energy production. However, the regulatory framework governing this classification was originally developed for terrestrial animals and not for fish farming.

Salmon production differs from land-based animal production in several important ways, for instance, mortality rates of salmon often increase due to routine handling procedures, including delousing and other treatments.

[12] European Union, *Regulation (EC) No 1069/2009 of the European Parliament and of the Council laying down health rules as regards animal by-products and derived products not intended for human consumption and repealing Regulation (EC) No 1774/2002*, Official Journal of the European Union, consolidated version, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009R1069

The primary priority should be to implement measures that reduce high mortality in farmed fish. Secondary to that is the question of the best possible use of this raw material. When handled correctly, this type of dead salmon is likely to pose limited biological risk.

An amendment to EU regulations allowing the use of low-risk dead salmon for feed (Cat 3) would depend sufficient scientific documentation demonstrating that fish diseases are not transmitted through the products, as well as strategic engagement at the EU level.

In 2024, 123,800 tonnes, corresponding to 23 % of all by-products from the Norwegian seafood sector, consisted of dead fish generated in the aquaculture sector.[13]

3.1.2. Marine by-products

Various marine by-products are already used as fish feed. For instance, by-products from whitefish and pelagic fish are mainly used in salmon feed, whereas by-products from salmon aquaculture can also be used, as mentioned above, but they face barriers related to market-acceptance, even though their use is allowed.

Fishmeal and fish oil from wild-caught fish can be used directly in salmon feed and are currently produced from both whole fish and by-products. In these factories, raw material is heated before being pressed, ground, and dried. The outputs of this processing are fishmeal, fish oil, and water.

Fresh by-products can also be used to produce protein hydrolysates. Enzymes are added to break down proteins, which allows amino acids and peptides to be extracted. This method is suitable for producing pure products for, for example, dietary supplements that are neutral in taste and smell.

Discards of by-catch in fisheries are prohibited under the EU Landing obligation[14] implemented in 2019, as part of the Common Fisheries Policy (Regulation (EU) No 1380/2013). While this is an important measure, it should also cover the landing of all parts of the fish and other harvested bio-resources, including residual material in addition to by-catch.

In 2024, 89% of the total residual raw material from the Norwegian seafood industry was utilised. This figure includes residual raw materials from both aquaculture and wild-catch

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[13] Magnus Myhre, Roger Richardsen, Gunn Strandheim, and Ragnar Nystøyl, Analyse marint restråstoff 2024: Tilgjengelighet og anvendelse av marint restråstoff fra norsk fiskeri- og havbruksnæring, SINTEF Ocean AS Report 2025:00517 (Trondheim: SINTEF Ocean AS, 2 June 2025), https://www.fhf.no/prosjekter/prosjektbasen/901844/

[14] European Commission, "Discarding in Fisheries – Landing Obligation," Oceans and Fisheries, accessed February 2026, https://oceans-and-fisheries.ec.europa.eu/fisheries/rules/discarding-fisheries_en

fisheries. However, the greatest potential in the Norwegian industry lies in whitefish fisheries, where 72% of residual raw materials are currently utilised. [15]

The main barrier to fully utilising residual raw materials from wild-catch fisheries in Norway is that they are not landed; in other words, not all residual raw materials are brought ashore, and an extensive amount is still simply discarded at sea. Most of these unused bioresources originate from larger fishing vessels with onboard filleting facilities. As a result, in 2024 an estimated 118,000 tonnes of marine residual raw materials and by-products were not utilised, mainly from whitefish fisheries. [12] While a formal cost-benefit analysis of landing these residuals was not found, authorities already recognise that leaving these materials at sea represents a loss of valuable resources. From a circularity perspective, it is clear that maximising the use of these bioresources is the priority, even if the value chains to process them are not yet fully established.

There is no regulatory requirement (other than the market itself) encouraging fishing vessels to land all parts of the fish.

Currently, there is no regulatory requirement (other than the market itself) encouraging fishing vessels to land all parts of the fish. The main barriers to landing all residual raw materials are:[16]

1. The market value of residual raw material is too low.
2. Fishing vessels are not designed with sufficient storage capacity to land all raw materials.

A publication from the Norwegian government's *Social Mission on Feed* (December 2025) lists its top 20 recommendations for achieving the mission's goals[17]. Among these, one recommendation specifically proposes introducing regulation that requires all marine residual raw materials to be landed.

[15] Magnus Myhre, Roger Richardsen, Gunn Strandheim, and Ragnar Nystøyl, Analyse marint restråstoff 2024: Tilgjengelighet og anvendelse av marint restråstoff fra norsk fiskeri- og havbruksnæring, SINTEF Ocean AS Report 2025:00517 (Trondheim: SINTEF Ocean AS, 2 June 2025), https://www.fhf.no/prosjekter/prosjektbasen/901844/?utm_source=chatgpt.com
[16] Bellona Foundation, "Råvareløftet: Hva skal laksen spise/ what should the salmon eat", November 2022, https://bellona.no/publication/hva-skal-laksen-spise-ravareloftets-veikart-og-barrierestudier-for-nye-forravarer?utm_source=chatgpt.com
[17] The Research Council of Norway (Norges forskningsråd), "På vei mot bærekraftig fôr – 20 grep for 2026: Rapport fra samfunnsoppdraget om bærekraftig fôr" Norway social mission on sustainable feed- 20 recommendations for 2026 (Oslo: The Research Council of Norway, 2025), https://www.forskningsradet.no/siteassets/publikasjoner/2025/pa-vei-mot-barekraftig-for--20-grep-for-2026.pdf

3.1.2.1. Sludge from the aquaculture industry as a potential feed biomass stream

The fish farming sector generates an underutilised side stream in the form of fish sludge, also known as aquaculture sludge. This sludge consists of feed residues (excess feed) and faeces and is rich in nutrients such as nitrogen, phosphorus, and carbon.

From Bellona's perspective, sludge from the aquaculture industry is a valuable bioresource that is currently lost from the value chain, as it is mostly discharged into the sea rather than collected and utilised.

<u>The main challenges connected to fish sludge are:</u>

1. Collection of the sludge: Most sludge from salmon aquaculture in open pens at sea is not collected today. Therefore, regulatory changes to encourage collection of this valuable bioresource are required, alongside further technological development to improve sludge collection, and the establishment of good practices for storing or drying sludge with reasonable energy consumption.
2. Application of the sludge: Some potential uses are currently not allowed due to regulatory barriers.

Politically, the collection and use of fish sludge has not been high on the EU agenda. Fish/aquaculture sludge is mentioned in European initiatives such as Farm-to-Fork and the EU Integrated Nutrient Management Plan, but it is not included in legally binding documents. In particular, neither the Waste Framework Directive (WFD), the Industrial Emissions Directive (IED), the Fertilising Products Regulation (FPR), nor the Animal By-Products Regulation (ABPR) specifically mention aquaculture sludge.

This means that no European criteria determine when sludge ceases to be a waste product (End-of-Waste status, EoW). As a result, these criteria and the granting of formal EoW status are defined at national level.

3.1.2.2. Fish sludge as substrate for insects, bristle worms and algae

Bellona's report *"What should the salmon eat?"* (2022)[18] investigated the potential for developing insects (black soldier flies) as a new raw material for feed.

Black soldier flies can feed on a variety of substrates, but the main barrier to scaling up insect production is finding an affordable and sustainable substrate for them to consume. For optimal

[18] Bellona Foundation, "Råvareløftet: Hva skal laksen spise/ what should the salmon eat", November 2022, https://network.bellona.org/content/uploads/sites/2/2022/11/R%C3%A5varel%C3%B8ftet-veikart.pdf

production, the process should have a low carbon footprint, and the substrate should be a residual raw material that is widely available and produced in sufficient volumes. Fish sludge could therefore be an excellent candidate as a substrate for both insects and bristle worms (polychaete), provided the regulatory hurdles for such applications are removed.

Some small-scale trials have demonstrated that black soldier flies can grow on substrates derived from fish sludge, and there are also trials and pilot projects raising bristle worms on fish sludge-based substrates. A recent research project, SecureFeed,[19] aimed at generating knowledge and documenting biosafety aspects of using sludge from salmon farming to produce safe feed ingredients for terrestrial and marine organisms. The project conducted controlled inoculation experiments for selected viruses, bacteria, and prions, using the black soldier fly *(Hermetia illucens)* and the polychaete worm *(Hediste diversicolor)* as model organisms. Although the SecureFeed project provided useful insights, further research is still needed.

Today, feed legislation states that faeces, urine, and stomach and intestinal contents are prohibited for use as feed (EU Regulation 767/2009 Article 6 and Annex III).[20] This restriction reflects a precautionary approach to feed safety, but it also limits the potential for circular use of these resources if they can be shown to be safe.

To overcome regulatory barriers for using fish sludge as a substrate, the following is needed:

1) More research and scientific documentation on food safety if fish sludge is to be used as substrate for insects and polychaete bristle worms.
2) Clarification of what type and level of scientific evidence would be sufficient for, for example, the European Food Safety Authority (EFSA) to recommend changes to current regulations, so the issue can be raised with the relevant authorities.
3) Interest and willingness across the EU, not only in Norway, to support regulatory change. Currently, these resources from farmed aquaculture are mainly of interest to a few European countries, most of which are not EU members: Norway, UK (Scotland), the Faroe Islands, and Iceland. While these countries partly follow EU regulations, they are not formally part of the EU, which limits coordinated action at the European level.

Considering that more food and bioresources will need to come from the ocean in the future, improving knowledge and the use of resources across the entire fish farming value chain is fundamental to support upscaled aquaculture in Europe. This aligns with EU policy, which explicitly promotes the growth and valorisation of aquaculture through instruments such as the EU Aquaculture Guidelines and will further support sustainable marine bioeconomy development through the planned EU blue bioeconomy innovation initiative under the Ocean Pact. By optimising resource use, including underutilised side streams such as fish trimmings

[19] Fiskeri- og havbruksnæringens forskningsfinansiering (FHF), "Securefeed (Project 901732)," accessed 17 February 2026, https://www.fhf.no/prosjekter/prosjektbasen/901732/
[20] European Union, "Regulation (EC) No 767/2009 of the European Parliament and of the Council on the placing on the market and use of feed, including marketing and labelling requirements," consolidated as of 1 January 2018, Official Journal of the European Union, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02009R0767-20180101

and shells, these policies aim to close nutrient loops and make the best use of available aquatic bioresources.

3.2. Terrestrial animal by-products

According to the European Food Safety Authority (EFSA) Animal by-products (ABPs) are materials obtained from animals which are not intended for human consumption. ABPs include slaughterhouse waste (skin, bones, horn and hooves, blood, fat, and offal), catering waste, fallen stock, dead pets, and materials produced by animals such as manure, eggshells, feathers, wool and beeswax. Also, former foodstuff of animal origin such as milk, eggs, meat that is no longer suitable for human consumption (commercial reasons, quality, production failures etc.) falls into this category.[21]

ABPs provide significant value due to their rich nutrient profile. This makes them essential raw materials for various industries, including the production of fertilisers, animal feed, biofuels, and cosmetics. Animal fat, as an example, can be used to produce biodiesel.

To distinguish among various forms of ABPs, three categories are defined in the Animals By-Products Regulation (EC) No 1069/2009[22] A short summary is provided in section 3.1, while a more detailed table is provided in *Appendix 1*.

3.2.1. Circularity potential

The EU Bioeconomy Strategy[23] and the forthcoming 2026 EU Circular Economy Act both underline the strategic importance of keeping materials, nutrients, and biomass resources in productive use for as long as possible and points towards the establishment of a functional single market for secondary raw materials. For the agriculture, food and feed sectors, this translates into increased attention to the circular use of biological by-products, including animal by-products, to reduce dependencies on imported inputs, enhance resource efficiency, and strengthen the resilience of European value chains.

ABPs are valuable not only as a source of protein for animal feed but also because they contain essential nutrients, such as phosphorus, which can be recovered and reused. Expanding the use of ABPs and other secondary raw materials is therefore essential for a robust circular economy. This shift supports food sovereignty and farm resilience by reducing reliance on

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[21] European Food Safety Authority, "Animal by-products," accessed 17 February 2026,
[22] European Union, "Regulation (EC) No 1069/2009 of the European Parliament and of the Council laying down health rules as regards animal by-products and derived products not intended for human consumption and repealing Regulation (EC) No 1774/2002", Official Journal of the European Union, consolidated version, https://eurnt/EN/TXT/PDF/?uri=CELEX:32009R1069
[23] European Commission, "Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: A Strategic Framework for a Competitive and Sustainable EU Bioeconomy", COM(2025) 960 final, SWD(2025) 895 final, Brussels, 27 November 2025. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52025DC0960

imported feed proteins and mineral phosphates, the latter being designated by the EU as a Critical Raw Material due to limited domestic availability and high supply risk.

To formalise these efforts, the development of an EU Feed Circularity Roadmap, based on existing research as the one conducted by the European Feed Manufacturers' Federation (FEFAC),[24] should be a priority. This FEFAC report states that "at this point, there is no methodology to measure feed circularity, which is a clear limitation for those operators willing to engage in more circular practices." Consequently, it identifies the development of such methodology as a key action going forward. One body that could play a leading role in this work is the Joint Research Centre (JRC). Establishing a methodology to measure feed circularity is crucial to ensure equality, transparency, and traceability across the feed chain. Nevertheless, the absence of such a framework should not be used as a justification to delay progress toward more circular feed practices.

Establishing a methodology to measure feed circularity is crucial to ensure equality, transparency, and traceability across the feed chain. Nevertheless, the absence of such a framework should not be used as a justification to delay progress toward more circular feed practices.

FEFAC's report on circularity, along with the paper by Jedrejek et al.,[25] highlight the regulatory barriers affecting ABPs. The FEFAC report lists a total of eleven barriers and cases related to ABPs (p.10), including proposed regulatory actions, estimated timelines, and the potential impact if each barrier were addressed. [26] Of these eleven, five are classified as having very high potential and two as high potential, indicating a strong demand for regulatory revision to enable more by-products to remain in the food chain. However, the FEFAC catalogue does not provide information on the volumes affected by these barriers. To address this gap, the following sections will illustrate selected value streams and their potential volumes.

3.2.2. Overall feed volumes

The total European feed production reached 267.8 million tonnes in 2024. Of this, approximately 233.4 million tonnes were directed to food-producing animals, primarily cattle, pigs, and poultry, which ultimately enter the human food chain. In the European Union, the amount of compound feed for food-producing animals is approximately 147 million tonnes.[27] Additionally,

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[24] FEFAC, "EU Feed Circularity Catalogue: Existing legal restrictions to enhanced animal feed circularity", 23 May 2025, https://fefac.eu/wp-content/uploads/2025/07/Circularity-Catalogue_version-1.0-HIGH-RESOLUTION.pdf
[25] D. Jędrejek et al., "Animal by-products for feed: characteristics, European regulatory framework, and potential impacts on human and animal health and the environment," Journal of Animal and Feed Sciences 25 (2016), https://www.jafs.com.pl/pdf-65548-5325?filename=Animal%20by-products%20for.pdf
[26] There are in total 13 cases, from which case 7 and 11 are related to fish/fish meal and not terrestrial animals.
[27] FEFAC, The Feed & Food Report 2024, April 2025, https://fefac.eu/wp-content/uploads/2025/04/FF_2024_FINAL.pdf

4.8 million tonnes were used in aquaculture, 11.7 million tonnes were used for pet food[28] and therefore did not enter the human food chain, and around 2 million tonnes were fed to equine animals.[29] Although equine feed could theoretically enter the human food chain, horse meat consumption in the EU/EEA is very limited, and some horses are ineligible as food due to medical treatments.

It is important to note that, under the current regulatory framework, the same requirements apply to feed intended for food-producing animals, that enter the human food chain, and to feed for pets. This means that feed raw materials suitable for food animals are not prioritised over feed used for other purposes. Such a lack of differentiation represents a regulatory barrier to improving food system sustainability because it limits the ability to divert alternative or underutilised resources to pet food or other non-food applications without meeting the more stringent standards for food-producing animals. In other words, even resources that pose minimal risk must meet high food-chain standards, reducing flexibility and efficiency in the overall food system.

Under the current regulatory framework, the same requirements apply to feed intended for food-producing animals, that enter the human food chain, and to feed for pets.

3.2.3. Animal by-product volumes by category (1, 2 and 3)

Approximately 18 million tonnes of ABPs are processed annually in the EU[30]. For processing purposes and value optimisation, ABP value streams are usually, but not always, divided into two main fractions: animal fats and processed animal proteins (PAPs). For regulatory classification, Category 3 material (fit for human consumption) represents the largest share of these volumes, amounting to approximately 11.5–12.5 million tonnes per year. Owing to its classification, this stream has significant potential for use in feed. In contrast, Categories 1 and 2 together account for an estimated 5-6 million tonnes.

Notably, Category 1 material is not considered in this report, as it is associated with high risks (e.g., TSEs or toxic contaminants) and is destroyed or incinerated as it would pose unacceptable risks if introduced into the feed or food chain.

[28] According to FEDIAF (the European Pet Food Industry Federation), pet food production in the EU Member States amounts to approximately 10.5 million tonnes. While a detailed breakdown by species is not provided here, dog and cat food account for roughly 58% and 35% of pet food production, respectively.
[29] Alltech Inc., Agri-Food Outlook 2025 https://www.alltech.com/agri-food-outlook
[30] EFPRA, Rendering in numbers (Factsheet, 2022), https://efpra.eu/wp-content/uploads/2023/12/EFPRA-Infographic-23.3-A4-PRINT.pdf

Of the approximately 18 million tonnes of ABPs processed annually, 2.75 million tonnes consist of fallen stock, classified as Category 2 material, which is predominantly directed to the production of fuels and fertilisers. Where collection and processing occur within existing time limits (currently 24 hours), part of this stream could technically be suitable as feed raw materials for applications not entering the human food chain, such as pet food. The fact that this does not currently occur indicates the presence of regulatory and market barriers.

Where collection and processing occur within existing time limits (currently 24 hours), part of this stream could technically be suitable as feed raw materials for applications not entering the human food chain, such as pet food.

In *Table 1*, the volumes associated with the above-mentioned aspects are listed. Based on EFPRA's factsheet[31] and Meijer et al. (2023)[32], the *table* presents estimated volumes for fallen stock and Category 2 material downgraded due to physical impurities, together with suggested reallocation options. It also illustrates how policy objectives such as reducing fossil CO_2 emissions in the transport sector through increased use of biofuels under the Renewable Energy Directive (RED III), have a clear impact on the sourcing of bioresources. Additionally, *Table 1* suggests potential alternative uses of these bioresources that could deliver higher overall sustainability outcomes, than current uses.

Table 1 – Estimated volumes and current versus proposed uses of selected Category 2 animal by-product streams. [31][32]

Type of resource	**Volume (tonnes)**	**Current uses**	**Proposed higher value applications**
Fallen stocks	2,750,000	Bioenergy /fuel and fertiliser	Pet food (proteins and animal fat)
Cat. 2 due to foreign bodies*	1,100,000 – 1,500,000	Bioenergy / fuel and waste/incineration	Pet food (proteins and animal fat)
SUM	**3,850,000 – 4,250,000**		

**Products of animal origin which have been declared unfit for human consumption due to the presence of foreign bodies, as stated in Regulation (EC) No 1069/2009, Article 9(d). A calculation showing the background for this estimate is shown in Appendix 2.*

[31] EFPRA, Rendering in numbers (Factsheet, 2022), https://efpra.eu/wp-content/uploads/2023/12/EFPRA-Infographic-23.3-A4df
[32] K. Meijer et al., "The use of animal by-products in a circular bioeconomy: Time for a TSE road map 3?," *Heliyon* 9, no. 3 (2023), https://doi.org/10.1016/j.heliyon.2023.e14021

In addition, the so called "clean Category 2" material (ABPs not associated with hazardous residues) generally represents the smallest share in the ABP processing sector, as significant quantities, such as manure-based fertilisers, are used directly in agriculture or biogas production outside large processing plants. Regulations that support the direct use of bioresources for biogas production should therefore be examined to ensure that higher-value and more resource-efficient uses are not unintentionally discouraged.

Regulations that support the direct use of bioresources for biogas production should therefore be examined to ensure that higher-value and more resource-efficient uses are not unintentionally discouraged.

An assessment of Category 2 volumes and value streams indicates that the potential for reallocating resources from biogas towards pet food is 1.1-1.5 million tonnes *(Table 1).* This is based on the fraction(s) ending up under Regulation (EC) No 1069/2009, Article 9(d): "products of animal origin which have been declared unfit for human consumption due to the presence of foreign bodies".

A potential regulatory approach could thus involve restricting the disposal of "products unfit for human consumption due to the presence of foreign bodies", followed by a stepwise implementation. Retaining this volume within the feed chain could improve resource efficiency, but doing so would require technological development and/or technical adjustments, as well as the possible introduction of new sub-categories. The overall environmental and resource implications, including energy use associated with removing foreign bodies and processing the material safely, should be carefully assessed before such changes are introduced. As a first step, Bellona suggests dividing these materials into two subcategories: one suitable for biogas and one suitable for pet food, combined with a gradual increase in the share directed to pet food. This stepwise approach would allow time for industrial adaptation while progressively improving circularity.

3.2.4. Regulatory pathways to increase circularity

Moving the use of bioresources higher up in the bioresource hierarchy requires, among other things, changes to existing regulations. Regulatory adjustments that involve bringing raw materials into the food chain are generally more complex than other types of regulatory amendments. The previously mentioned FEFAC report[33] does not address the issue of defining a specific feed class for pet food; however, it outlines the legal steps needed to enable greater circularity.

[33] FEFAC, "EU Feed Circularity Catalogue: Existing legal restrictions to enhanced animal feed circularity", 23 May 2025, https://fefac.eu/wp-content/uploads/2025/07/Circularity-Catalogue_version-1.0-HIGH-RESOLUTION.pdf

Bellona suggests targeted regulatory amendments to ensure animal feed for food-producing animals is subject to different requirements than pet food, in the same way that feed for fur animals is already treated under separate rules than feed entering the food chain. This differentiation would need to be carefully designed, as it would allow feed for different purposes to be treated appropriately, increasing circularity in the feed sector and making it easier to introduce targeted incentives.

For illustrative purposes, this report classifies regulatory barriers as either more or less complex; these distinctions are indicated in the *Tables* below using green or yellow, respectively.

The potential resulting from the above-mentioned actions is shown in *Tables 2 and 3*, for animal fat and PAPs, respectively. *Table 2* shows volumes of the fat fraction of rendered meat, mainly from Category 3. *Table 3* shows volumes of the PAP fraction of rendered meat, also mainly from Category 3. Although the volumes of animal fat and PAPs that could realistically be re-allocated from fertiliser to pet food are small in an EU-wide perspective, the amount is still eight times the volume of pet food consumed, for instance, in Norway[34].

Table 2 – Current and proposed uses of animal fat, including volumes [35][36]

Current application	**Volume (tonnes)**	**Further details**	**Proposed higher value applications**
Biofuel	1,400,000	It is a high demand for animal biproducts for biofuel due to climate requirements (RED III directive).	Pet food
Oleochemicals	365,000	Used in soap, cosmetics, candle wax, rubber industry etc. The market is estimated to increase when fossil-based inputs are excluded.	Already used for high value applications like speciality chemicals and cosmetics.
Pet food	865,000	Used as fat source (energy) and flavour enhancer in feed.	Feed to food producing animals
Energy (incineration)	~100,000	Direct use as fuel in industry (less common for Category 3, as its value is higher elsewhere).	The part coming from Category 3: to pet food (relatively small volumes)
SUM	**2,730,000**		

[34] Anne Lise Stranden, "Så stort er katter og hunders poteavtrykk på klimaet," Forskning.no, December 14, 2020, https://www.forskning.no/dyreverden-hunder-klima/sa-stort-er-katter-og-hunders-poteavtrykk-pa-klimaet/1783947
[35] EFPRA, Rendering in numbers (Factsheet, 2022), https://efpra.eu/wp-content/uploads/2023/12/EFPRA-Infographic-23.3-T.pdf
[36] K. Meijer et al., "The use of animal by-products in a circular bioeconomy: Time for a TSE road map 3?," *Heliyon* 9, no. 3 (2023), https://doi.org/10.1016/j.heliyon.2023.e14021

Table 3 – Current and proposed uses of processed animal proteins (PAPs), including volumes [37][38]

Current uses	Volume (tonnes)	Proposed higher value applications
Fish feed	215,000	Already used in feed
Pet food	1,670,000	Feed to food producing animals
Fertiliser	~500,000	Pet food
SUM	**2,385,000**	

In general, it is positive that the fraction of potential feed materials leaving the food chain is low. However, the absolute volume of raw material that could be retained in the food chain and thereby increase circularity and contribute to decarbonising the feed sector, is sufficient to make a substantial impact.

INSECTS NEED SUBSTRATE

Current EU frameworks restrict the use of meat- and fish-based former foodstuffs in insect production. However, research indicates that species such as **black soldier flies** and **yellow mealworms** can effectively and safely process these materials. A case study evaluates the safety protocols required to support legislative amendments that would permit the controlled inclusion of such feedstocks. By revising these regulations, the EU could:

- **Enhance circularity:** Divert high-value food waste back into the production cycle.
- **Strengthen the viability** of sustainable alternative protein sources.
- **Reduce environmental impact:** Minimise the footprint of traditional waste management.

Regulatory barriers and possible solutions (Solution developed by FEFAC)

- **Current regulation:** Annex X, Chapter II, Section 10 of Regulation (EU) No 142/2011 restricts the use of foodstuffs containing products of animal origin for farmed animals to non-meat and non-fish containing materials.
- **Proposed revision:** Amend the aforementioned Regulation (e.g. Annex X, chapter II, section 10) to allow the controlled use of these materials as feed for farmed insects, under specified processing conditions that ensure pathogen inactivation and traceability.

FEFAC, "EU Feed Circularity Catalogue: Existing legal restrictions to enhanced animal feed circularity", 23 May 2025, Case 2 https://fefac.eu/wp-content/uploads/2025/07/Circularity-Catalogue_version-1.0-HIGH-RESOLUTION.pdf

[37] EFPRA, Rendering in numbers (Factsheet, 2022)https://efpra.eu/wp-content/uploads/2023/12/EFPRA-Infographic-23.3-NT.pdf
[38] K. Meijer et al., "The use of animal by-products in a circular bioeconomy: Time for a TSE road map 3?," *Heliyon* 9, no. 3 (2023), https://doi.org/10.1016/j.heliyon.2023.e14021

Strategic evaluation: The rise and fall of Ÿnsect

Founded in 2011, Ÿnsect was positioned as a flagship of the insect protein industry. The company specialised in the yellow mealworm (*Tenebrio molitor*), aiming to produce high-quality protein for pet food, aquaculture, and organic fertilisers. Its operational model was defined by extreme industrialisation; Ÿnsect pioneered "vertical farming" at an unprecedented scale. By 2024, the company had secured over $600 million in funding, reflecting investor confidence in its ability to decarbonise the food chain.

Hypotheses for the 2025 collapse

Despite its technological prowess, Ÿnsect entered safeguard proceedings and eventually filed for bankruptcy in 2025. Several core factors likely contributed to this failure:

1. Capital intensity and the "scale-up gap": Ÿnsect's model was heavily reliant on "Gigafactories." *TechCrunch* highlights that the transition from pilot projects to industrial-scale production proved more difficult and expensive than anticipated. Delays in reaching full capacity at the Amiens site created a "cash burn" that surpassed the company's ability to secure fresh capital in a tightening venture market.

2. Biological volatility vs. **automated precision**: While Ÿnsect treated insect farming like a software-driven manufacturing process, biological systems are inherently unpredictable. Maintaining consistent yields in a vertical, high-density environment poses significant sanitary and environmental control risks that automation alone could not fully mitigate.

3. Commodity price competition: As noted in the *Journal of Insects as Food and Feed*, insect producers struggle to compete with established, low-cost proteins like soy and even also more costly fishmeal. Ÿnsect's "premium" positioning was challenged by the reality that the feed industry is driven by price-per-ton, making it difficult to achieve the margins necessary to service massive infrastructure debt.

Sources:

Anna Heim, "How reality crushed Ÿnsect, the French startup that had raised over $600M for insect farming," *TechCrunch*, December 26, 2025, https://techcrunch.com/2025/12/26/how-reality-crushed-ynsect-the-french-startup-that-had-raised-over-600m-for-insect-farming/.

"Ÿnsect's collapse raises big questions: Is feed and fertiliser the future of insect farming?," *AgTech Navigator*, December 8, 2025, https://www.agtechnavigator.com/Article/2025/12/08/ynsects-collapse-raises-big-questions-is-feed-and-fertiliser-the-future-of-insect-farming/.

H. H. Niyonsaba-van den Hoorn, J. Höhler, B. A. Rumpold, H. J. van der Fels, and M. P. M. Meuwissen, "Robustness of business models for insect production for feed and food in Europe," *Journal of Insects as Food & Feed* 11, no. 17 (2025), https://brill.com/view/journals/jiff/11/17/article-p211_16.xml.

European Commission, *Flagship demonstration of industrial-scale production of nutrient resources from mealworms to develop a bioeconomy new generation* (FARMYNG project fact sheet), 2020, https://www.europeandissemination.eu/wp-content/uploads/2025/01/PRj22-Farmyng_FINAL.pdf.

3.3. Food waste

Food waste is commonly differentiated between **industrial food waste**, which is not considered waste and, in most cases, already utilised as by-products or feed; and **household and catering waste** (mixed food waste) which is prohibited from being used as feed in the EU.[39] Household waste consists of a combination of plant- and animal-derived products. The use of mixed food waste for feed, known as swill feeding, has been banned in the EU since 2002 following the Foot-and-Mouth Disease epidemic.

At EU level, total food waste in 2023 was estimated to exceed 58 million tonnes of fresh mass. Of this amount, 29% was generated during primary production, processing, and manufacturing, and is therefore considered suitable for animal feed. The remaining share consisted of mixed food waste from households, restaurant and food services, retail, and other food distribution activities.[40] This implies that a total of more than 40 million tonnes of mixed food waste generated annually is not suitable for animal feed.

Currently, most food waste is directed to landfills or used to produce biofuel or energy. Preventing food waste from ending up at the lower levels of the hierarchy is the first priority, as outlined in the EU food use and waste hierarchy *(Figure 2)*. Circular use of household food waste for animal feed should therefore be prioritised above biogas end energy production.

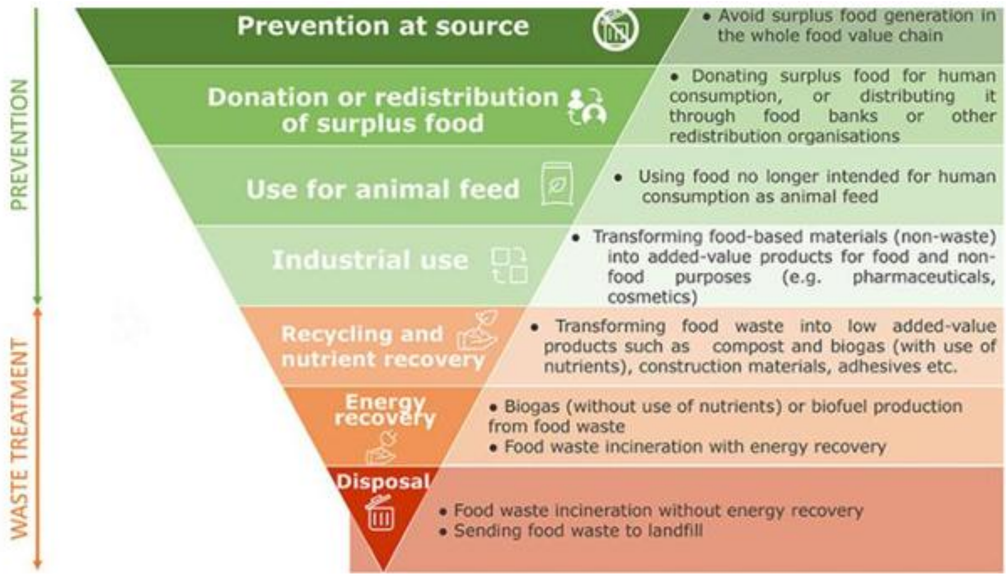

Figure 2 - The food use and waste hierarchy.[41]

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[39] European Commission, "Commission Regulation (EU) 2022/1104 of 1 July 2022 amending Regulation (EU) No 68/2013 on the Catalogue of Feed Materials", OJ L 175, 2 July 2022, https://eur-lex.europa.eu/eli/reg/2022/1104/oj/eng

[40] Eurostat, "Food waste and food waste prevention by NACE Rev. 2 activity – tonnes of fresh mass" (dataset), accessed February 2026, https://ec.europa.eu/eurostat/databrowser/view/env_wasfw/default/table?lang=en

[41] European Commission, "Food use and waste hierarchy", EU Food Waste Relevant Legislation, accessed February 2026, https://food.ec.europa.eu/food-safety/food-waste/eu-food-waste-relevant-legislation/food-use-and-waste-hierarchy_en

3.3.1. Potential for use as feed

Several challenges are associated with using mixed food waste, which contains a combination of plant and animal materials from different species, as feed. In addition to the regulatory hurdles, contamination with non-food waste content (such as plastics) and spoilage of the food due to variability in storage conditions and collection frequency are key issues. Mixed food waste is therefore not considered a suitable direct source of animal feed today.

However, processing technologies and various de-risking strategies exist that could enable the indirect use of mixed food waste for animal feed in the future. These approaches can help manage contamination risks, stabilise feed quality, and comply with EU feed regulations, thereby allowing mixed food waste to contribute to a more circular and sustainable feed sector over time.

3.3.2. Mixed food waste as substrate for insects

Mixed food waste could potentially be used as a substrate for insects. In this context, insects have been suggested as a promising contribution to the circular economy, as they can revalorise large quantities of organic waste. Insects are valuable both as animal feed and, where culturally accepted, for human consumption, as they are rich in proteins, amino acids, lipids, energy, and micronutrients. Several studies have demonstrated the potential of rearing different types of insects on mixed food waste.[42][43] Commercially produced insects, mostly used for animal feed and successfully reared on food waste, include black soldier fly, housefly, mealworm, beetles, locusts and crickets.[44]

However, mixed food waste is currently prohibited as a substrate for insects. Meijer et al.[45] summarise this regulatory landscape for insect substrates: in 2017, when the rearing of insects to produce PAPs for aquaculture was authorised, Commission Regulation (EU) 2017/893[46] clarified their status under Article 3(6) of the Animal By-Products Regulation (EC) No 1069/2009, by classifying insects as "farmed animals" for PAP production. As a result, insects may only be reared on feed materials that are also permitted as feed for conventional livestock, meaning that substrates are generally vegetable- and cereal-based.

[42] Corentin Biteau, Tom Bry-Chevalier, Dustin Crummett, Ren Ryba, and Michael St. Jules, "Is Turning Food Waste into Insect Feed an Uphill Climb? A Review of Persistent Challenges", Sustainable Production and Consumption (advance online publication July 4, 2024), https://doi.org/10.1016/j.spc.2024.06.031
[43] Vassileios Varelas, "Food Wastes as a Potential New Source for Edible Insect Mass Production for Food and Feed: A Review", Fermentation 5, no. 3 (2019): 81, https://doi.org/10.3390/fermentation5030081
[44] Harinder P. S. Makkar, Gilles Tran, Valérie Heuzé, and Philippe Ankers, "State-of-the-Art on Use of Insects as Animal Feed", Animal Feed Science and Technology 197 (2014): 1–33, https://doi.org/10.1016/j.anifeedsci.2014.07.008
[45] N. Meijer, "European Union Legislation and Regulatory Framework for Edible Insect Production – Safety Issues," Animal (2025), https://doi.org/10.1016/j.animal.2025.101468
[46] European Union, "Commission Regulation (EU) 2017/893 of 24 May 2017 amending Annexes I and IV to Regulation (EC) No 999/2001 of the European Parliament and of the Council and Annexes X, XIV and XV to Commission Regulation (EU) No 142/2011 as regards the provisions on processed animal protein," Official Journal of the European Union, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32017R0893

Further restrictions come from the Regulation amending the Catalogue of feed materials (EU 2022/1104)[47] which explicitly forbids the use of food waste that might contain animal products as feed. Consumer food waste, slaughterhouse products, manure, and human wastewater or household waste are prohibited, while the only allowed waste products and by-products are processing waste and former foodstuffs consisting solely of vegetal, dairy, egg, and/or honey origins.

One of the main reasons for these prohibitions is the high risk of contamination in untreated food waste, which is a source of pathogenic microorganisms. These include bacteria such as *Salmonella spp., Listeria monocytogenes, Escherichia coli, Clostridium spp.*, and *Campylobacter spp.,* as well as viruses, endoparasites (e.g., *Trichinella spiralis, Toxoplasma gondii,* etc.), prions (causing TSEs, in cattle) and other viral agents (e.g., swine fever virus, foot-and -mouth disease virus, etc.).[48][49] Toxins, heavy metals, and microplastics are additional contaminants of concern. These must therefore be addressed to be able to use food waste safely as feed in the future.

Additional challenges for using mixed food waste as substrate for insects, beyond regulatory and safety hurdles, include the variability in composition and quality of mixed food waste, which may not always be optimal for insect rearing, as well as competition for this biomass from biogas and energy production.

3.3.3. Overcoming regulatory challenges: de-risking strategies

The main concern of using mixed food waste as substrate for insects is contamination risk. Nonetheless, various pre-treatment methods are available to eliminate the risk of pathogenic agents:[50]

- Heat treatment is an effective and universal requirement, although temperature and duration requirements vary by country.
- Wet-based methods typically include a simple heating step for sterilisation, whereas dry-based treatment combines heating with drying to extend shelf life of the feed.
- Chemical treatments, combined with thermal treatment, may also reduce pathogen risks of feed and feed ingredients. Organic acids such as propionic, formic, acetic and lactic acids may be applied.

[47] European Commission, "Commission Regulation (EU) 2022/1104 of 1 July 2022 amending Regulation (EU) No 68/2013 on the Catalogue of Feed Materials", OJ L 175, 2 July 2022, https://eur-lex.europa.eu/eli/reg/2022/1104/oj/eng
[48] Gerald C. Shurson, Ellen S. Dierenfeld, and Zhengxia Dou, "Rules Are Meant to Be Broken – Rethinking the Regulations on the Use of Food Waste as Animal Feed", Resources, Conservation and Recycling 196 (2023), https://doi.org/10.1016/j.resconrec.2023.107273
[49] Gerald C. Shurson, Pablo E. Urriola, and J. L. G. van de Ligt, "Can We Effectively Manage Parasites, Prions, and Pathogens in the Global Feed Industry to Achieve One Health", Transboundary and Emerging Diseases 69 (2022): 4–30. https://onlinelibrary.wiley.com/doi/epdf/10.1111/tbed.14205
[50] Zhengxia Dou, John D. Toth, and Michael L. Westendorf, "Food Waste for Livestock Feeding: Feasibility, Safety, and Sustainability Implications", Global Food Security 17 (2018), https://doi.org/10.1016/j.gfs.2017.12.003

The reduction in pathogen levels after treatment is typically expressed as a "log reduction." In simple terms, a 1-log reduction means 90% of pathogens are eliminated, a 2-log reduction means 99% are eliminated, and a 3-log reduction means 99.9% are eliminated. The final safety of the feed depends on both the initial contamination level and the effectiveness of the treatment. It is important to notice that thermal treatment and irradiation reduce pathogen concentration only at a single point in time; in some cases, storage of the feedstock for some time is therefore recommended to ensure effective treatment. Even though bacteria and viruses are present in feed, understanding the concept of the minimum infectious dose is also crucial, as the number of viable and infectious pathogens present are determining the risk of infection.[51]

To ensure safe use of mixed food waste as insect feed, the EU should establish clear standards and certification schemes that define which treatment techniques are required and which waste types are suitable. This would provide legal clarity, enable industry adoption, and reduce risks from contaminants such as heavy metals, microplastics, toxins, and prions.

3.3.4. Enabling policies

In Europe, the use of food waste for animal feed has been banned since 2002 following the foot-and-mouth disease outbreak in the UK linked to the feeding of untreated food waste to pigs. However, this ban has begun to soften. An amendment to Annex IV of the TSE Regulation (EC) No 999/2001, now permits the use of PAPs derived from pigs to be fed to poultry and vice versa.[52]

Several countries outside Europe have successfully recycled a high proportion of food waste into animal feed. Japan and South Korea have implemented regulations and oversight to ensure adequate thermal treatment, storage and transport of food waste to minimise biosafety risks. Landfilling of food waste was banned in South Korea in 2005.[53] In Japan, about 40% of pre-consumer food waste (e.g., from food manufacturing) is thermally processed, recycled into animal feed, and trademarked as EcoFeed.[54] Frequent collection and cold storage followed by thermal treatment, along with proper regulations, government subsidies, and certification systems, have enabled safe use of food waste for feed in countries like Japan.[55]

[51] G. C. Shurson, P. E. Urriola, and J. L. G. van de Ligt, "Can We Effectively Manage Parasites, Prions, and Pathogens in the Global Feed Industry to Achieve One Health?," Transboundary and Emerging Diseases 69 (2022): 4–30, https://doi.org/10.1111/tbed.14205
[52] European Fat Processors and Renderers Association (EFPRA), "White Paper – Amendments to Legislation for PAPs", June 2024, https://efpra.eu/wp-content/uploads/2024/05/White-Paper-Legislation-June-2024.pdf
[53] Zhengxia Dou, John D. Toth, and Michael L. Westendorf, "Food Waste for Livestock Feeding: Feasibility, Safety, and Sustainability Implications", Global Food Security 17 (2018), https://doi.org/10.1016/j.gfs.2017.12.003
[54] K. Sugiura, S. Yamatani, M. Watahara, and T. Onodera, "Ecofeed, Animal Feed Produced from Recycled Food Waste," Veterinaria Italiana 45, no. 3, 2009: 397–404, https://pubmed.ncbi.nlm.nih.gov/20391403/
[55] Gerald C. Shurson, Ellen S. Dierenfeld, and Zhengxia Dou, "Rules Are Meant to Be Broken – Rethinking the Regulations on the Use of Food Waste as Animal Feed", Resources, Conservation and Recycling 196 (2023), https://doi.org/10.1016/j.resconrec.2023.107273

Implementation of preventative measures to avoid contamination is another de-risking strategy. In the USA, the Food Safety Modernisation Act requires the application of Hazard Analysis and Risk-based Preventative Controls (HARPC).[56] The HARPC regulation identifies the controls required to prevent food safety hazards in the supply chain. HARPC plans address prevention of physical, chemical and biological food safety hazards, but not yet viral contaminants. Besides these controls, traceability of feed ingredients and feed throughout the supply chain is also fundamental for maintaining biosecurity.

Overall, Europe has a great potential to increase the use of food waste for feed ingredients and feed. Numerous lessons can be drawn from countries that already successfully implement preventative measures, appropriate regulations, well-developed infrastructure for collection and storage, pre-treatment and certification systems.

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3.4. Agricultural residues

Agricultural residues are leftover materials from crop production and can be divided into field residues and post-harvest residues. **Field residues** include stalks, leaves and seed pods left on the field after harvest of the crops. **Post-harvest residues** are byproducts generated during crop processing, such as husks, seeds, and bagasse.

Handling practices for field residues vary. In many cases, they are left in the field to return nutrients and organic matter to the soil and prevent erosion. A common practice in many countries outside the EU is to burn field residues. Alternatively, residues may be collected for use as animal bedding, bioenergy production, bio-based materials or for feed products.

Approximately 46% (442 million tonnes) of the total agricultural biomass produced annually in the EU consists of residues from primary crops.[57] Cereals represent 74% of the total agricultural residue production, while oil-bearing crops (e.g., rapeseed, soybean, sunflower, etc.) contribute to 17% of the residue production. Wheat is the crop that generates the highest residue volumes (149 million tonnes/year), followed by maize (80 million tonnes/year), rapeseed (54 million tonnes/year), and barley (50 million tonnes/year).

[56] U.S. Food and Drug Administration, Center for Veterinary Medicine, "Hazard Analysis and Risk-Based Preventive Controls for Food for Animals: Guidance for Industry," July 2022, https://www.fda.gov/

[57] Alessandro Camia et al., Biomass Production, Supply, Uses and Flows in the European Union: First Results from an Integrated Assessment, EUR 28993 EN, JRC109869 (Luxembourg: Publications Office of the European Union, 2018), /doi.org/10.2760/539520

Only a fraction of agricultural residues is currently collected: 25% of residues from cereals, and only 10% for the oil-bearing crops. Of collected residues, 33% is used for animal feed and bedding. According to Scarlat et al. (2010),[58] 15–60% of total cereal residues could be sustainably removed depending on soil type, crop, and management practices, indicating a significant potential for upscaling collection. Taking this into account ~140 million tonnes/year of agricultural residues could potentially be mobilised for feed use (See calculation in *Appendix 3*).

3.4.1. Agricultural residues for feed

Post-harvest residues (also called agro-industrial food waste) are generated from post-harvest losses and processing/packaging losses. Residual streams not suitable for human consumption can be recycled as animal feed, composted, used as fertiliser or to produce bioenergy. Examples include biofuel co-products (e.g., distiller grains, sugarcane bagasse), agro-industrial processing wastes (e.g., oilseed meal, soybean hulls, sugar beet pulp), crop residues (e.g., wheat straw, corn stover) and fruit and vegetables discards.

Most agro-industrial by-products are rich in energy and nutrients and can be upcycled into animal feed materials, thereby also reintroduced into the human food supply chain. However, for some residues, nutrients may not be suitable for direct use as feed due to suboptimal nutrition profiles or digestibility.[59] In such cases, bioprocessing by fermentation and single-cell protein production are approaches for upgrading agricultural residues into feed ingredients.

3.4.2. Bioprocessing by fermentation

Agricultural residues and agro-industrial food waste may contain high levels of dietary fibre and lignin, suboptimal amino acid profiles, indigestible phosphorous, and anti-nutritional factors. Bioprocessing with feed-grade fungi, yeast, bacteria and enzymes can improve the suitability for feed ingredients.

Biorefineries generate valuable products from biomass and waste through different techniques. Biorefining processes may be simple: using a single raw material and a fixed process to produce a single product; or complex: with different types of raw materials and producing multiple products. Fermentation bioprocessing (the use of microorganisms to convert biomass into higher-value products) may modify the chemical composition of the

[58] N. Scarlat, M. Martinov, and J.-F. Dallemand, "Assessment of the Availability of Agricultural Crop Residues in the European Union: Potential and Limitations for Bioenergy Use," Waste Management 30, no. 10 (2010): 1889–1897, https://doi.org/10.1016/j.wasman.2010.04.016
[59] Xiao Sun, Zhengxia Dou, Gerald C. Shurson, and Bo Hu, "Bioprocessing to Upcycle Agro-Industrial and Food Wastes into High-Nutritional Value Animal Feed for Sustainable Food and Agriculture Systems", Resources, Conservation and Recycling 201, 2024: 107325, https://doi.org/10.1016/j.resconrec.2023.107325

feedstock, reducing fibre content, improving protein/amino acid profiles, minerals, and degrading anti-nutritional factors and mycotoxins.[60]

Fermentation processes can be performed as submerged fermentation (substrate in liquid phase) or solid-state fermentation (substrate as moist solid). Solid-state fermentation typically requires less energy for sterilisation of the substrate, and product recovery is simplified due to low water content. However, maintaining parameters like pH, temperature, and humidity in the solid sample may be more challenging.

The starter culture for fermentation is critical in determining the process and the product. Yeast and some fungi are often suitable for degrading lignin, whereas specific fungi and bacteria are more efficient in removing anti-nutritional factors. Exogeneous chemical supplements (e.g., copper, manganese, ammonia) may enhance process efficiency or improve feed ingredient quality.[60] Such fermentation processes can also efficiently degrade mycotoxins[61] which is crucial for biosecurity.

3.4.3. Single-cell protein production

Single-cell protein (SCP) production is the cultivation of microorganisms such as microalgae, yeast, fungi and bacteria, to generate protein-rich biomass that can be used as feed or feed ingredients.[62][63] Unlike conventional fermentation, where microorganisms primarily transform a substrate, in SCP production the microbial biomass itself is the product.

In the fermentation processes, microorganisms degrade the substrates, making it more suitable and accessible for use as feed or feed ingredients. In SCP production, the aim is to produce microorganisms with a high protein content for various applications, including animal feed ingredients.

Advantages of SCP production include the ability to use a wide variety of substrates, low requirement for land use, rapid microbial growth, high protein content, and easy protein recovery.

Industrial food waste is a desirable substrate for SCP production due to its high content of starch, cellulose, proteins and lipids. Field residues, on the other hand, are available in large quantities but harder to convert into food and feed ingredients because of their high lignin

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[60] Xiao Sun, Zhengxia Dou, Gerald C. Shurson, and Bo Hu, "Bioprocessing to Upcycle Agro-Industrial and Food Wastes into High-Nutritional Value Animal Feed for Sustainable Food and Agriculture Systems", Resources, Conservation and Recycling 201, 2024: 107325, https://doi.org/10.1016/j.resconrec.2023.107325
[61] Cheng Ji, Yu Fan, and Lihong Zhao, "Review on Biological Degradation of Mycotoxins," Animal Nutrition 2, no. 3 (2016): 127–133,
[62] Bojana Bajić, Damjan Vučurović, Đurdina Vasić, Rada Jevtić-Mučibabić, and Siniša Dodić, "Biotechnological Production of Sustainable Microbial Proteins from Agro-Industrial Residues and By-Products", Foods 12, no. 1 (2023): 107,https://doi.org/10.3390/foods12010107
[63] Patrick T. Sekoai, Yrielle Roets-Dlamini, Frances O'Brien, Santosh Ramchuran, and Viren Chunilall, "Valorization of Food Waste into Single-Cell Protein: An Innovative Technological Strategy for Sustainable Protein Production", Microorganisms 12, no. 1 (2024): 166, https://doi.org/10.3390/microorganisms12010166

content. Pre-treatment can improve their biodegradability, although it increases processing costs.

Basidiomycetes, a group of fungal species, can directly convert lignocellulosic substrates into protein-rich fungal biomass. Mushroom-forming fungi grow on lignocellulosic substrates, forming a mycelial network which degrades the substrate and absorb released nutrients.[64] Field residues could therefore serve as a suitable substrate for producing fungal biomass for feed ingredients. Both the mushroom and the mycelium formed can be used as feed or feed ingredients.

Overall, SCP offers a sustainable and innovative approach to upgrading field residues and other organic waste streams into high-value feed ingredients.

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Insect proteins produced from food waste for use in animal feed

Waste2Protein, a successful project under the EU Life programme which ran between 2019-2023. During this period 300 tonnes of Black Soldier Fly larvae were fed on 20 tonnes of daily biowaste, mainly from local supermarkets. The insect proteins produced can replace fish meal and soybean meal in animal feed, significantly reducing the carbon footprint.

Sources:
LIFE Waste2Protein, Pilot plant for insect protein production from biowaste as sustainable alternative to fish and soy meal for animal feed
LIFE Waste2Protein - LIFE Awards 2025

Animal feed from industrial food waste - FeedValid

FeedValid is a Dutch company producing animal feed ingredients from residual flows from the food processing industry in Europe. Raw materials range from potato, rice, soy, and wheat to bread, biscuits, chocolate, and many more. Collection and transport infrastructure from suppliers has been developed and is operational. FeedValid offers ingredients to a wide range of sectors from ruminants, pigs, poultry, pet food and aquaculture.

Source:
Home | FeedValid

[64] Karin Scholtmeijer, Lambertus A. M. van den Broek, Arnout R. H. Fischer, and Arend van Peer, "Potential Protein Production from Lignocellulosic Materials Using Edible Mushroom Forming Fungi", Journal of Agricultural and Food Chemistry 71 (2023): 4450–4457, https://doi.org/10.1021/acs.jafc.2c08828

Food-industry by-products for animal feed

Eco-feed has been defined as the use of co-products for animal feeding. Co-products include by-products generated from food industries, as well as surplus and waste from distribution, retail and food consumption. Eco-feed companies are present in many countries like Tunisia, Japan, and the United States, and distribute their products globally.

Sources:
Eco-Feeds in Japan | FFTC Agricultural Policy Platform (FFTC-AP)
EcoFeed - Nutrition for Growth
The Company | EccoFeed

Agricultural residues as insect substrate for production of animal feed

NUTRIFEEDS is an EU-funded project that started in 2025 and will run until 2029. The project promotes a circular, sustainable food system by converting previously underutilised plants and by-products of food processing into high-quality, protein-rich animal feed. This will be achieved through innovative processes, such as black soldier fly larvae utilisation and targeted fermentation, to improve nutrient content and reduce anti-nutritional factors.

Sources:
Nourishing Europe's Future through Regenerative Livestock Feed | NUTRIFEEDS | Project | Factsheet | HORIZON | CORDIS | European Commission
NUTRIFEEDS project successfully launched

4 Geopolitical and strategic considerations

This chapter examines how geopolitical pressures, global market dynamics, and strategic dependencies shape the European bioeconomy, with a particular focus on feed production. It highlights risks arising from reliance on imported raw materials, volatile supply chains, and regulatory gaps, and explores how domestic bioresources, including by-products, waste streams, and underutilised sources, can strengthen industrial capacity, enhance resilience, and support sustainable, circular feed systems.

4.1. EU strategic framing of the bioeconomy

Over the last decade, the European Commission has progressively strengthened its emphasis on sustainability, resource efficiency, and circularity as core principles of EU economic transformation and food system policy. In the context of increasing geopolitical instability, global competition for critical raw materials, and supply chain disruptions, the 2024–2029 Commission mandate places renewed emphasis on competitiveness, security, and strategic autonomy. Reform, investment, and regulatory simplification have been identified as key levers to support these objectives, as highlighted in the Draghi report (2024).[65]

Within this evolving policy landscape, initiatives such as the Competitiveness Compass (COM(2025)30 final),[66] the Clean Industrial Deal (COM(2025)85 final)[67] and the upcoming Circular Economy Act (2026) seek to integrate economic strength with ecological goals. The Competitiveness Compass is structured around three central priorities: (1) closing the innovation gap with the EU's main global competitors; (2) linking decarbonisation with industrial competitiveness; and (3) reducing external dependencies while increasing economic and strategic security. Together, these initiatives signal a shift towards a more explicitly strategic framing of sustainability, where resilience and industrial capacity take precedence.

The EU bioeconomy has thus been positioned as both a contributor to climate goals and a driver of economic sovereignty and resilience, with the transition from fossil-based to bio-based systems presented as a pathway to reduce strategic dependencies on fossil-based and

[65] European Commission, "The Future of European Competitiveness (Draghi Report)", 2024, https://commission.europa.eu/topics/competitiveness/draghi-report_en
[66] European Commission, "Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions: A Competitiveness Compass for the EU", COM(2025) 30 final, Brussels, 29 January 2025, https://commission.europ18105a34_en?filename=Communication_1.pdf
[67] European Commission, "Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: The Clean Industrial Deal – A Joint Roadmap for Competitiveness and Decarbonisation", COM(2025) 85 final, Brussels, 26 February 2025, httent/EN/TXT/PDF/?uri=CELEX:52025DC0085

imported raw materials, diversify supply chains, strengthen technological leadership, and support economic renewal in an increasingly uncertain geopolitical environment.[68]

The EU bioeconomy has thus been positioned as both a contributor to climate goals and a driver of economic sovereignty and resilience, with the transition from fossil-based to bio-based systems presented as a pathway to reduce strategic dependencies on fossil-based and imported raw materials, diversify supply chains, strengthen technological leadership, and support economic renewal in an increasingly uncertain geopolitical environment.

Fossil-based production systems are widely characterised as environmentally unsustainable and geopolitically problematic due to their concentration in specific regions, reliance on volatile global energy markets, and exposure to supply disruptions. In contrast, the bioeconomy is framed as a strategic opportunity for the EU to decarbonise and renew its industrial base by building on Europe's biological resources, scientific excellence, and industrial capacity. The updated EU Bioeconomy Strategy[69] emphasises that this transition can strengthen competitiveness, innovation, and regional development, particularly in rural and coastal areas, while enhancing strategic autonomy by reducing dependence on imported fossil-based products and supporting climate and circularity objectives.

4.2. EU biomass supply and biocapacity constraints

While the EU is often described as largely self-sufficient in biomass supply, estimated at around 90% by the JRC (2025) and the European Biomass Puzzle (2023),[70] this figure refers to current physical supply and depends on assumptions about efficient use, sustainable management, and the continued availability of diverse biomass sources. A large-scale transition away from fossil-based systems would significantly increase demand for biomass across sectors, potentially exposing underlying limitations in domestic resources.

Evidence from the European Environment Agency (EEA)[71] indicates that EU and EEA countries generate only about half of the biocapacity needed to sustain current levels of consumption. Biocapacity reflects the ability of ecosystems to regenerate renewable resources and absorb wastes such as CO_2. Even if biomass is physically available, this regenerative capacity is insufficient.

[68] European Commission, Joint Research Centre, "EU Biomass Supply, Uses, Governance and Regenerative Actions – 10-Year Anniversary Edition", 2025, JRC140117, https://data.europa.eu/doi/10.2760/6511190
[69] European Commission, "Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: A Strategic Framework for a Competitive and Sustainable EU Bioeconomy", COM(2025) 960 final, SWD(2025) 895 final, 27 November 2025, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52025DC0960
[70] European Environment Agency, "The European Biomass Puzzle: Challenges, Opportunities and Trade-offs around Biomass Production and Use in the EU", EEA Report No 08/2023, 2023, https://www.eea.europa.eu/en/analysis/publications/the-european-biomass-puzzle
[71] European Environment Agency, "Opportunities for Innovation in the Bioeconomy", EEA Briefing 11/2025, 3 July 2025, https://www.eea.europa.eu/en/analysis/publications/bioeconomy-unlocking-opportunities-for-innovation-in-the-bioeconomy

Currently the gap between available biocapacity and total resource demand is effectively externalised through imports, generating environmental impacts beyond Europe's borders and exposing the EU to risks linked to land use, agricultural practices, and geopolitical instability.

4.3. Global food and feed supply chain risk

These dynamics intersect directly with global food and feed supply chain risk. Feed raw materials such as soy, cereals, and critical micronutrient inputs are traded globally, and Europe's agricultural and livestock sectors rely heavily on these imports, making them vulnerable to supply disruptions and price volatility linked to geopolitical tensions, droughts in major producing regions, trade policy discontinuities, and shifting export controls. Such volatility is not only a commercial risk, but a food security risk with knock-on effects throughout livestock, aquaculture, and dairy value chains.

A 2026 industry analysis notes that the EU relies on a small number of non-EU producers for vital feed additives, including vitamins and amino acids, with some nutrients sourced almost entirely from outside the bloc, underlining the fragility of these supply chains. Countries exporting high-protein ingredients such as soybean meal also dominate global markets, exposing EU producers to international market swings and logistical risks.[72]

Stakeholders across these value chains operate under deep uncertainty. Farmers, foresters, processors, industry actors, local communities, and environmental organisations frequently hold divergent but equally legitimate perspectives on priorities and trade-offs. Engaging this diversity at the science–policy interface is essential for developing strategies that are robust, adaptive, and capable of navigating the complexities of technological change, volatile markets, ecological limits, and geopolitical risk.[73]

4.4. Trade policy and strategic diversification

Recent developments in trade policy illustrate the challenges of balancing market access, resilience, and sustainability. For instance, the EU–Mercosur free trade agreement, now progressing toward final approval, exemplifies the tension between strategic diversification of trade relations and concerns related to agriculture, sustainability, and domestic resilience. Negotiated in part as a response to mounting global trade pressures, tariff barriers, and shifts in US trade policy,[74] the agreement is presented by the Commission as a way to secure market access and diversify economic partnerships. At the same time, opposition from agricultural stakeholders, including farmers and industry groups in France and other Member States,[75] reflects fears that increased competition in agricultural and feed commodity markets could heighten dependency on imports, potentially undermining domestic resilience and generating

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[72] FEFAC, "EU Vulnerability for the Sourcing of Essential Feed Additives", 2025, https://fefac.eu/wp-content/uploa925.pdf
[73] European Commission, Joint Research Centre, "EU Biomass Supply, Uses, Governance and Regenerative Actions – 10-Year Anniversary Edition", 2025, JRC140117, https://data.europa.eu/doi/10.2760/6511190
[74] Atlantic Council, "EU and Mercosur Are Creating One of the World's Largest Free Trade Areas," 9 January 2026, https://www.atlanticcouncil.org/dispatches/eu-and-mercosur-are-creating-one-of-the-worlds-largest-free-trade-areas/
[75] Al Jazeera, "Why Are French Farmers Objecting to EU-Mercosur Trade Deal?" 16 December 2025.https://www.aljazeera.com/economy/2025/12/16/why-are-french-farmers-objecting-to-eu-mercosur-trade-deal

environmental pressures abroad. Safeguard mechanisms have been agreed to mitigate potential negative impacts on sensitive sectors such as poultry, beef, and sugar, highlighting official recognition of these strategic risks.[76]

4.5. Case study: Norway's aquaculture sector

Concrete examples from outside the EU further show how geopolitical developments can expose vulnerabilities in biomass-dependent feed value chains. Norway's aquaculture sector, the world's largest producer of Atlantic salmon, is broadly comparable in scale to the entire EU aquaculture industry but is concentrated primarily around a single species, making it particularly sensitive to supply disruptions.

For Norwegian fish farmers, feed represents the largest cost. This sector depends heavily on imported raw materials, with the vast majority of ingredients sourced from global markets rather than domestically produced sources. In recent years, the imported share of salmon feed ingredients was estimated at about 92%,[77] with plant-based materials such as soy from Brazil, cereals from Ukraine and Russia, and critical micro-ingredients from China forming a substantial share of the fish diet.

Following the Russian invasion of Ukraine, feed markets experienced pronounced disruption and price increases, prompting the Norwegian feed and aquaculture actors to reassess their exposure to global supply risk.[78] Climate-related shocks, such as droughts in major producing regions, have compounded these pressures, highlighting the sector's vulnerability to both geopolitical and environmental instability.

Political uncertainty in producing regions is exemplified by the long-running Soy Moratorium[79] in Brazil, which was originally designed to limit soy sourced from newly deforested Amazon land. Its effective rollback in early 2026, following the decision by the Brazilian Association of Vegetable Oil Industries (ABIOVE) and several major trading companies to withdraw from the pact, further underscores the fragility of international feed commodity markets.

In response, Norwegian policy and industry leaders have increasingly emphasised the importance of strengthening self-sufficiency and resilience in the feed sector. For instance, the Social Mission on sustainable feed[80] includes goals to expand the use of domestic raw

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[76] Council of the European Union, "EU–Mercosur: Council and Parliament Agree on Rules to Safeguard the EU Agri-Food Sector", 17 December 2025, https://www.consilium.europa.eu/en/press/press-rel -rules-to-safeguard-the-eu-agri-food-sector/
[77] We Are Aquaculture, "Norway aims for 25% homegrown raw materials in its aquaculture feed by 2034," 10 May 2024
[78] Megan Howell, "Was 2020 the Last 'Business as Usual' Year for Salmon Feed Manufacturers?", The Fish Site, 30 December 2022, https://thefishsite.com/articles/was-2020-the-last-business-as-usual-year-for-salmon-feed-manufacturers
[79] Gabriela Sá Pessoa, "Brazil soy industry's exit from moratorium on using Amazon land could spur deforestation", 10 January 2026, https://www.greenwichtime.com/news/world/article/brazil-soy-industry-s-exit-from-moratorium-on-21287395.php
[80] The Research Council of Norway, "Sustainable feed" (n.d.), accessed February 2026,

materials, develop new sustainable feed ingredients, and increase the share of homegrown feed components.[81]

4.6. Strategic value of domestic bioresources

These examples highlight an important strategic point: unlocking domestic bioresources, including by-products, waste streams, and underutilised sources such as low-trophic aquaculture and algae, represents not only an environmental opportunity but a geopolitical one. As discussed throughout this chapter, the EU's biocapacity is insufficient to sustain current consumption patterns, resulting in structural dependence on imported biomass and associated exposure to global market volatility.

The analysis presented in Chapter 3 demonstrates that significant volumes of currently underutilised bioresources already exist within European value chains. These include approximately 18 million tonnes of animal by-products processed annually, more than 40 million tonnes of mixed food waste generated each year, substantial volumes of aquatic residual raw materials, and hundreds of millions of tonnes of agricultural residues, of which only a fraction is currently collected or valorised. While not all of these streams can or should be redirected to feed production, they illustrate that domestic secondary biomass resources are sufficiently large to meaningfully contribute to reducing import dependency when regulatory and market barriers are addressed.

Mobilising these resources more effectively represents an important pathway to improve circularity by retaining nutrients within European systems, reducing exposure to global market volatility, and enhancing feed and food system resilience without exacerbating competition for finite primary biomass or land use.

At the same time, the bioeconomy's strategic value cannot be taken for granted. It depends on clear prioritisation, coherent governance frameworks, and the capacity to manage trade-offs between climate objectives, food and feed security, and economic competitiveness. In this context, European policy must navigate the dual imperatives of strengthening domestic bioresource mobilisation while managing external dependencies, ensuring that strategic autonomy is not pursued at the expense of sustainability, equity, or long-term resilience

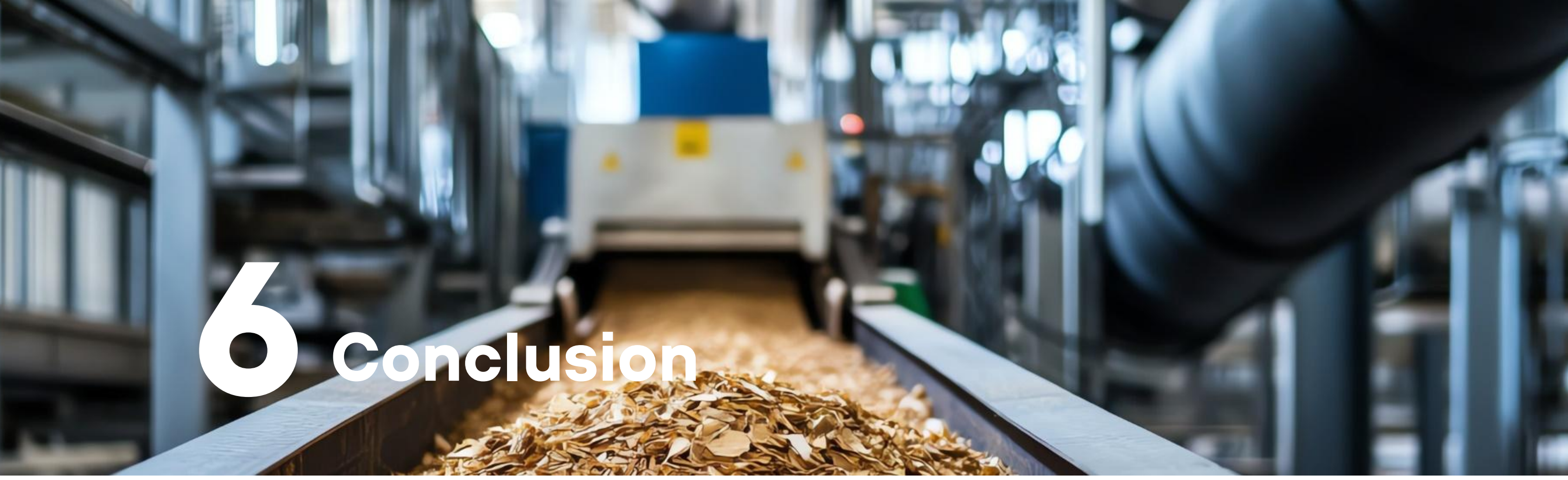
[81] We Are Aquaculture, "Norway aims for 25% homegrown raw materials in its aquaculture feed by 2034", 19 March 2024, https://weareaquaculture.com/news/feed/norway-aims-for-25-homegrown-raw-materials-in-its-aquaculture-feed-by-2034

5 Summary table of barriers and potential interventions

Biomass stream	Volumes	Economic value / cost considerations	Regulatory barrier	Suggested intervention	Policy level
Marine residual raw materials	~118,000 t/year currently not utilised in Norway (mainly whitefish fisheries); EU potential likely higher but not quantified	Low–moderate value; landing and storage costs limit utilisation	No regulatory requirement to land residual biomass; limited onboard storage capacity	Incentivise or require landing of residual biomass; support processing infrastructure	EU & National
Aquatic by-products (Category 2 ABP)	~123,800 t/year in Norwegian aquaculture (2024); currently used mainly for energy and fertiliser	Moderate value if reclassified; processing already exists	Category 2 classification prevents feed use despite potentially low biological risk	Assess risk-based reclassification pathway; develop criteria for safe feed or pet food use	EU
Aquaculture sludge (feed residues & faeces)	Not quantified in this report; significant but largely uncollected resource[82]	Currently low value due to collection costs; potential as substrate or nutrient resource	Lack of EU end-of-waste criteria; feed ban on faecal material	Develop EU guidance on collection, end-of-waste status, and safe downstream applications	EU & National
Animal by-products (Category 3 – Fit for human consumption)	~11.5–12.5 Mt/year total Category 3 stream; larger share should be allocated for feed	High potential value for feed, but handling and processing costs can be significant	EU ABP regulations (e.g., restrictions on category 1–3 material for feed use)	Clarify permitted uses, streamline approval for feed-grade processing	EU

[82] Bellona, *Sustainable Aquaculture 2030*, updated 2024, https://bellona.org/publication/sustainable-aquaculture-2030

Animal by-products (Category 2 – Fallen stock and downgraded material)	~3.9–4.3 Mt/year total Category 2 stream; 1.1–1.5 Mt/year relocatable to pet food	Currently low–medium value (bioenergy/fertilizer). Higher value in feed applications not entering the human food chain	ABP rules restricts feed use; no differentiation between pet food and feed for food-producing animals; strong biofuel market pull under RED III	Create differentiated feed category; allow stepwise reallocation from bioenergy to feed	EU & National
Former foodstuff (bakery products)	5 Mt/year already reprocessed as Category 3 feed	Medium value; cost-effective if transport, sorting, and processing logistics are managed	Food safety and feed hygiene rules; inconsistent national interpretation; Category 2 classification due to packaging and contamination	Harmonise feed hygiene standards; enable safe processing to unlock Category 2 material for feed; incentivise industrial collection and sorting	EU & National
Mixed food waste	>40 Mt/year currently excluded from feed use in the EU, represents a significant potential resource if safely processed and allowed by regulation	Low-cost feedstock; costs driven by collection, sorting, contamination control and processing infrastructure	EU ban on use of catering and household waste as feed or insect substrate; strict animal by-product and feed hygiene rules; traceability challenges	Develop standards for safe pre-treatment; enable controlled pilot authorisations, incentivise separate collection and quality assurance systems	EU & National
Agricultural residues (e.g., straw and crop residues from cereals and oilseeds)	~140 Mt/year technical potential; actual volumes depend on collection efficiency, soil sustainability, and competing uses	Low acquisition cost; costs driven by collection logistics, densification, transport and upgrading	Limited recognition of residues as feed input; nutritional limitations for direct feed use; competing with bioenergy uses	Support sustainable residue mobilisation; develop bioprocessing and upgrading pathways; incentivise regional collection systems	EU & National



6 Conclusion

This report demonstrates that **Europe possesses substantial and readily available volumes of biological by-products and underutilised bioresources across agricultural, food, aquatic (including marine), and terrestrial animal value chains**. Yet despite their availability and potential contribution to feed production, significant quantities remain unused or are directed towards low-value applications such as incineration, disposal, or environmental deposition. **This represents a loss of nutrients, economic opportunity, and resource efficiency at a time when biomass must be managed carefully as a finite resource.**

Across all biomass categories assessed, including animal by-products, mixed food waste, agricultural residues, aquatic residual streams, and low-trophic resources such as algae, **the central challenge is not resource availability but the persistence of policy and regulatory barriers, alongside market, logistical, and technical constraints that limit safe and economically viable valorisation.** Unlocking their potential therefore depends primarily on **creating enabling policy conditions supported by appropriate infrastructure, governance alignment, and market development.**

A key barrier identified throughout the report is the fragmentation and misalignment of regulatory frameworks governing feed, waste, animal by-products, and circular economy policy. Divergent classifications and interpretations create uncertainty for operators and discourage investment in circular feed solutions. Precautionary legislation designed to protect animal and public health has played an essential role in safeguarding European food systems; however, in some cases it has also unintentionally restricted access to biological by-products that could be safely utilised under controlled conditions. Economic barriers further compound these challenges, as residue streams often lack sufficient market value to justify collection or processing despite their environmental and strategic importance. In addition, limited infrastructure for collection, storage, and aggregation prevents consistent supply, particularly for food waste and agricultural residues, as well as for aquatic residual streams and low-trophic species. Similarly, complex and precautionary regulations also affect the use of animal by-products, creating uncertainty and limiting safe valorisation, while fragmented value chains hinder scaling of innovative processing technologies.

The main conclusions emerging from this analysis are:

- Significant biological by-products are already available across Europe and can contribute meaningfully to domestic feed production if their use is permitted under appropriate safety conditions, thereby reducing pressure on land and primary resources used for feed production.

- Many currently underutilised biomass streams are discarded not due to technical limitations, but because regulatory uncertainty, insufficient infrastructure, and weak market incentives prevent their effective utilisation.
- Following the cascading use principle and properly prioritising biomass use, as exemplified by the biomass hierarchy, would help retain nutrients within food systems and allocate biological resources to higher-value applications such as feed before lower-value uses.
- Expanding circular feed utilisation can strengthen the resilience of livestock and aquaculture sectors, reduce exposure to global market volatility, and support climate, sustainability, and strategic autonomy objectives in Europe.

Addressing these challenges requires a combination of **targeted regulatory clarification, strategic alignment, and longer-term legislative dialogue.**

Near-term actions could include:

- Clarifying classification boundaries between feed materials and waste.
- Harmonising Member State interpretations of existing rules.
- Providing clearer guidance on safe valorisation pathways for biological by-products.
- Mobilising residues where collection and processing infrastructure exists or can be scaled.
- Investing in collection and storage infrastructure for food waste and agricultural residues, and aquatic residual streams.
- Developing standardised pre-treatment and processing systems to reduce biosafety risks.
- Measures to divert suitable food waste from landfill.
- Allowing safe use of food waste as insect substrate where scientifically justified.
- Enhancing safe valorisation and processing of animal by-products in line with existing hygiene and feed safety regulations.

Longer-term priorities requiring stakeholder engagement or legislative review include:

- Reassessing restrictions on specific food waste streams to enable safe feed and feed-ingredient use, where scientifically justified.
- Updating TSE Regulations and developing risk-based approval frameworks to expand safe valorisation options for animal by-products.
- Strengthening bioprocessing capacity for agricultural residues through fermentation, single-cell protein, or other innovative production pathways.
- Supporting development of innovative processing and bioprocessing pathways for aquatic residual streams, low-trophic species, and underutilised animal by-products.

Improved utilisation of biological by-products ultimately depends on establishing functioning circular value chains. This includes investment in logistics and aggregation systems, expansion of processing industries capable of converting residues into feed ingredients, including animal by-products and aquatic/marine streams, and certification and traceability mechanisms that ensure safety and market confidence. **Where residues currently hold limited economic value, they are frequently discarded despite their resource potential. Creating regulatory certainty and stable market conditions can unlock these streams, transforming them into valuable inputs that reduce waste, lower environmental pressures, and decrease dependence on imported feed materials.**

This report provides evidence on priority biomass streams, regulatory barriers, and practical opportunities for circular feed systems. Building on these findings, the next phase will translate analysis into targeted policy guidance and concise policy briefs to support resilient, circular, and resource-efficient feed systems across Europe.

Overall, the findings underline a central message: Europe's challenge is not a lack of biological resources, but the need to enable their safe, circular, and economically viable use. By removing unnecessary barriers where safety can be assured, strengthening value chains, and aligning policy frameworks, biological by-products and underutilised bioresources can play a central role in reducing waste, alleviating pressure on primary resources and land, and advancing a more circular and resilient European bioeconomy.

7. References and Sources

AgTech Navigator. (2025, December 8). *Ÿnsect's collapse raises big questions: Is feed and fertiliser the future of insect farming?.* https://www.agtechnavigator.com/Article/2025/12/08/ynsects-collapse-raises-big-questions-is-feed-and-fertiliser-the-future-of-insect-farming/

Al Jazeera. (2025, December 16). *Why are French farmers objecting to EU-Mercosur trade deal?* https://www.aljazeera.com/economy/2025/12/16/why-are-french-farmers-objecting-to-eu-mercosur-trade-deal

Alltech Inc. (2025). *Agri-Food Outlook 2025.* https://www.alltech.com/agri-food-outlook

Atlantic Council. (2026, January 9). *EU and Mercosur are creating one of the world's largest free trade areas.* https://www.atlanticcouncil.org/dispatches/eu-and-mercosur-are-creating-one-of-the-worlds-largest-free-trade-areas/

Bajić, B., Vučurović, D., Vasić, Đ., Jevtić-Mučibabić, R., & Dodić, S. (2023). *Biotechnological production of sustainable microbial proteins from agro-industrial residues and by-products. Foods, 12*(1), 107. https://doi.org/10.3390/foods12010107

Bellona. (2024). *Sustainable aquaculture 2030.* https://bellona.org/publication/sustainable-aquaculture-2030

Bellona EU. (2025, November 27). *Press release – EU bioeconomy strategy must establish a robust biomass hierarchy.* https://eu.bellona.org/2025/11/27/press-release-eu-bioeconomy-strategy/

Bellona Foundation. (2022, November). *Råvareløftet: Hva skal laksen spise/ what should the salmon eat.* https://network.bellona.org/content/uploads/sites/2/2022/11/R%C3%A5varel%C3%B8ftet-veikart.pdf

Biteau, C., Bry-Chevalier, T., Crummett, D., Ryba, R., & St. Jules, M. (2024). *Is turning food waste into insect feed an uphill climb? A review of persistent challenges. Sustainable Production and Consumption.* Advance online publication. https://doi.org/10.1016/j.spc.2024.06.031

Camia, A., Robert, N., Jonsson, R., Pilli, R., García-Condado, S., López-Lozano, R., van der Velde, M., Ronzon, T., Gurría, P., M'Barek, R., Tamosiunas, S., Fiore, G., Araujo, R., Hoepffner, N., Marelli, L., & Giuntoli, J. (2018). *Biomass production, supply, uses and flows in the European Union: First results from an integrated assessment* (EUR 28993 EN, JRC109869). Publications Office of the European Union. https://doi.org/10.2760/539520

Council of the European Union. (2025, December 17). EU–Mercosur: Council and Parliament agree on rules to safeguard the EU agri-food sector. https://www.consilium.europa.eu/en/press/press-releases/2025/12/17/eu-mercosur-council-and-parliament-agree-on-rules-to-safeguard-the-eu-agri-food-sector/

Dou, Z., Toth, J. D., & Westendorf, M. L. (2018). Food waste for livestock feeding: Feasibility, safety, and sustainability implications. *Global Food Security, 17,* 1–8. https://doi.org/10.1016/j.gfs.2017.12.003

ECCO. (2025, November). *Biomass and the transition of the plastics industry: Towards strategic and efficient use of bio-based resources* (Technical Report).

https://eccoclimate.org/wp-content/uploads/2025/11/EN_Report_Biomass-and-transition-1.pdf
EFPRA. (2022). *Rendering in numbers* (Factsheet). https://efpra.eu/wp-content/uploads/2023/12/EFPRA-Infographic-23.3-A4-PRINT.pdf
European Commission, Joint Research Centre. (2025). *EU biomass supply, uses, governance and regenerative actions – 10-year anniversary edition* (Mubareka, S. B., & Renner, A., Eds.; JRC140117). Publications Office of the European Union. https://data.europa.eu/doi/10.2760/6511190
European Commission. (2020). *Flagship demonstration of industrial-scale production of nutrient resources from mealworms to develop a bioeconomy new generation* (FARMYNG project fact sheet). https://www.europeandissemination.eu/wp-content/uploads/2025/01/PRj22-Farmyng_FINAL.pdf
European Commission. (2022, July 1). *Commission Regulation (EU) 2022/1104 of 1 July 2022 amending Regulation (EU) No 68/2013 on the catalogue of feed materials.* Official Journal of the European Union, L 175. https://eur-lex.europa.eu/eli/reg/2022/1104/oj/eng
European Commission. (2023, October 19). *Directive (EU) 2023/2413 of the European Parliament and of the Council of 19 October 2023 on the promotion of the use of energy from renewable sources (RED III).* https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32023L2413
European Commission. (2024). *The future of European competitiveness (Draghi report).* https://commission.europa.eu/topics/competitiveness/draghi-report_en
European Commission. (2025, February 26). *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: The clean industrial deal – A joint roadmap for competitiveness and decarbonisation* (COM(2025) 85 final). https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52025DC0085
European Commission. (2025, January 29). *Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions: A competitiveness compass for the EU* (COM(2025) 30 final). https://commission.europa.eu/document/download/10017eb1-4722-4333-add2-e0ed18105a34_en?filename=Communication_1.pdf
European Commission. (2025, November 27). *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: A strategic framework for a competitive and sustainable EU bioeconomy* (COM(2025) 960 final; SWD(2025) 895 final). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52025DC0960
European Commission. (n.d.). *Bioenergy – Research and innovation.* European Commission. Retrieved February 2026, from https://research-and-innovation.ec.europa.eu/research-area/energy/bioenergy_en
European Commission. (n.d.). *Discarding in fisheries.* https://oceans-and-fisheries.ec.europa.eu/fisheries/rules/discarding-fisheries_en
European Commission. (n.d.). *Food use and waste hierarchy.* EU food waste relevant legislation. European Commission, Directorate-General for Health and Food Safety. Retrieved

February 2026, from https://food.ec.europa.eu/food-safety/food-waste/eu-food-waste-relevant-legislation/food-use-and-waste-hierarchy_en

European Environment Agency. (2023). *The European biomass puzzle: Challenges, opportunities and trade-offs around biomass production and use in the EU* (EEA Report No 08/2023). https://www.eea.europa.eu/en/analysis/publications/the-european-biomass-puzzle

European Environment Agency. (2025, July 3). *Opportunities for innovation in the bioeconomy* (EEA Briefing 11/2025). https://www.eea.europa.eu/en/analysis/publications/bioeconomy-unlocking-opportunities-for-innovation-in-the-bioeconomy

European Fat Processors and Renderers Association (EFPRA). (2024, June). *White paper – Amendments to legislation for PAPs.* https://efpra.eu/wp-content/uploads/2024/05/White-Paper-Legislation-June-2024.pdf

European Food Safety Authority. (n.d.). *Animal by-products.* https://www.efsa.europa.eu/en/topics/animal-by-products

European Parliament & Council, *Directive 2008/98/EC on Waste (Waste Framework Directive)*, November 12, 2008, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32008L0098

European Union. (2009). *Regulation (EC) No 1069/2009 of the European Parliament and of the Council laying down health rules as regards animal by-products and derived products not intended for human consumption and repealing Regulation (EC) No 1774/2002* (consolidated version). https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009R1069

European Union. (2009). *Regulation (EC) No 767/2009 of the European Parliament and of the Council on the placing on the market and use of feed* (consolidated version as of January 1 2018). https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02009R0767-20180101

European Union. (2017). *Commission Regulation (EU) 2017/893 of 24 May 2017 amending Annexes I and IV to Regulation (EC) No 999/2001 of the European Parliament and of the Council and Annexes X, XIV and XV to Commission Regulation (EU) No 142/2011 as regards the provisions on processed animal protein.* https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32017R0893

Eurostat. (n.d.). *Food waste and food waste prevention by NACE Rev. 2 activity – tonnes of fresh mass* [Dataset]. Retrieved February 2026, from https://ec.europa.eu/eurostat/databrowser/view/env_wasfw/default/table?lang=en

FEFAC. (2025). *EU Vulnerability for the Sourcing of Essential Feed Additives.* https://fefac.eu/wp-content/uploads/2025/09/COMPRESSED2_FEFAC-Study_EU-vulnerability-for-the-sourcing-of-essential-feed-additives_100925.pdf

FEFAC. (2025, April). *The Feed & Food Report 2024.* https://fefac.eu/wp-content/uploads/2025/04/FF_2024_FINAL.pdf

FEFAC. (2025, May 23). *EU Feed Circularity Catalogue: Existing legal restrictions to enhanced animal feed circularity.* https://fefac.eu/wp-content/uploads/2025/07/Circularity-Catalogue_version-1.0-HIGH-RESOLUTION.pdf

Fiskeri- og havbruksnæringens forskningsfinansiering (FHF). (n.d.). *Securefeed (Project 901732).* https://www.fhf.no/prosjekter/prosjektbasen/901732/

Heim, A. (2025, December 26). *How reality crushed Ÿnsect, the French startup that had raised over $600M for insect farming*. TechCrunch. https://techcrunch.com/2025/12/26/how-reality-crushed-ynsect-the-french-startup-that-had-raised-over-600m-for-insect-farming/

Howell, M. (2022, December 30). *Was 2020 the last "business as usual" year for salmon feed manufacturers? The Fish Site.* https://thefishsite.com/articles/was-2020-the-last-business-as-usual-year-for-salmon-feed-manufacturers

Jędrejek, D., et al. (2016). Animal by-products for feed: Characteristics, European regulatory framework, and potential impacts on human and animal health and the environment. *Journal of Animal and Feed Sciences, 25.* https://www.jafs.com.pl/pdf-65548-5325?filename=Animal%20by-products%20for.pdf

Ji, C., Fan, Y., & Zhao, L. (2016). *Review on biological degradation of mycotoxins. Animal Nutrition, 2*(3), 127–133. https://doi.org/10.1016/j.aninu.2016.07.003

Makkar, H. P. S., Tran, G., Heuzé, V., & Ankers, P. (2014). *State-of-the-art on use of insects as animal feed. Animal Feed Science and Technology, 197,* 1–33. https://doi.org/10.1016/j.anifeedsci.2014.07.008

Meijer, K., et al. (2023). The use of animal by-products in a circular bioeconomy: Time for a TSE road map 3? *Heliyon, 9*(3). https://doi.org/10.1016/j.heliyon.2023.e14021

Meijer, N. (2025). *European Union legislation and regulatory framework for edible insect production – Safety issues. Animal.* https://doi.org/10.1016/j.animal.2025.101468

Myhre, M., Richardsen, R., Strandheim, G., & Nystøyl, R. (2025). *Analyse marint restråstoff 2024: Tilgjengelighet og anvendelse av marint restråstoff fra norsk fiskeri- og havbruksnæring* (SINTEF Ocean AS Report No. 2025:00517). SINTEF Ocean AS. https://www.fhf.no/prosjekter/prosjektbasen/901844/?fileurl=https://fhfno.sharepoint.com/sites/pdb/Publisertedokumenter/405028Rapport%20-%20Analyse%20marint%20restr%C3%A5stof%202024.PDF

Nærings- og fiskeridepartementet, Klima- og miljødepartementet, & Landbruks- og matdepartementet. (2023, January 18). *BioDigSirk – oppsummering og sluttrapport* [BioDigSirk – Summary and final report]. https://www.regjeringen.no/no/dokumenter/biodigsirk/id2959778/

Niyonsaba-van den Hoorn, H. H., Höhler, J., Rumpold, B. A., van der Fels, H. J., & Meuwissen, M. P. M. (2025). Robustness of business models for insect production for feed and food in Europe. *Journal of Insects as Food & Feed, 11*(17). https://brill.com/view/journals/jiff/11/17/article-p211_16.xml

REFRESH, EU research project. (2019). *Fusions Project ends: Food waste findings taken into EU circular economy strategy.* https://eu-refresh.org/fusions-project-ends-food-waste-findings-taken-eu-circular-economy-strategy.html

Romme, A. (2025, February). Former foodstuffs processing: Circular economy solutions for sustainable food & feed production. *Feed and Additive.* https://www.feedandadditive.com/former-foodstuffs-processing-circular-economy-solutions-for-sustainable-food-feed-production/

Sá Pessoa, G. (2026, January 10). *Brazil soy industry's exit from moratorium on using Amazon land could spur deforestation. Greenwich Time.* https://www.greenwichtime.com/news/world/article/brazil-soy-industry-s-exit-from-moratorium-on-21287395.php

SBP. (2025). *The cascading principle: Considerations on guidance and options for applying the cascading principle through SBP standards* (Working Paper). https://sbp-cert.org/wp-content/uploads/2025/03/SBP_Cascading_Principle_v3.0_Final_25March25.pdf

Scarlat, N., Martinov, M., & Dallemand, J.-F. (2010). *Assessment of the availability of agricultural crop residues in the European Union: Potential and limitations for bioenergy use. Waste Management, 30*(10), 1889–1897. https://doi.org/10.1016/j.wasman.2010.04.016

Scholtmeijer, K., van den Broek, L. A. M., Fischer, A. R. H., & van Peer, A. (2023). *Potential protein production from lignocellulosic materials using edible mushroom forming fungi. Journal of Agricultural and Food Chemistry, 71,* 4450–4457. https://doi.org/10.1021/acs.jafc.2c08828

Sekoai, P. T., Roets-Dlamini, Y., O'Brien, F., Ramchuran, S., & Chunilall, V. (2024). *Valorization of food waste into single-cell protein: An innovative technological strategy for sustainable protein production. Microorganisms, 12*(1), 166. https://doi.org/10.3390/microorganisms12010166

Shurson, G. C., Dierenfeld, E. S., & Dou, Z. (2023). Rules are meant to be broken – Rethinking the regulations on the use of food waste as animal feed. *Resources, Conservation and Recycling, 196,* 107273. https://doi.org/10.1016/j.resconrec.2023.107273

Shurson, G. C., Urriola, P. E., & van de Ligt, J. L. G. (2022). Can we effectively manage parasites, prions, and pathogens in the global feed industry to achieve One Health. *Transboundary and Emerging Diseases, 69,* 4–30 https://doi.org/10.1111/tbed.14205

Stranden, A. L. (2020, December 14). *Så stort er katter og hunders poteavtrykk på klimaet.* Forskning.no. https://www.forskning.no/dyreverden-hunder-klima/sa-stort-er-katter-og-hunders-poteavtrykk-pa-klimaet/1783947

Sugiura, K., Yamatani, S., Watahara, M., & Onodera, T. (2009). *Ecofeed, animal feed produced from recycled food waste. Veterinaria Italiana, 45*(3), 397–404. https://pubmed.ncbi.nlm.nih.gov/20391403/

Sun, X., Dou, Z., Shurson, G. C., & Hu, B. (2024). *Bioprocessing to upcycle agro-industrial and food wastes into high-nutritional value animal feed for sustainable food and agriculture systems. Resources, Conservation and Recycling, 201,* 107325. https://doi.org/10.1016/j.resconrec.2023.107325

The Research Council of Norway (Norges forskningsråd). (2025). *På vei mot bærekraftig fôr – 20 grep for 2026: Rapport fra samfunnsoppdraget om bærekraftig fôr.* https://www.forskningsradet.no/siteassets/publikasjoner/2025/pa-vei-mot-barekraftig-for--20-grep-for-2026.pdf

The Research Council of Norway. (n.d.). *Sustainable feed.* Retrieved February 2026, from https://www.forskningsradet.no/en/research-policy-strategy/ltp/sustainable-feed/

U.S. Food and Drug Administration, Center for Veterinary Medicine. (2022, July). *Hazard analysis and risk-based preventive controls for food for animals: Guidance for industry.* https://www.fda.gov/

Varelas, V. (2019). *Food wastes as a potential new source for edible insect mass production for food and feed: A review. Fermentation,* *5*(3), 81. https://doi.org/10.3390/fermentation5030081

vom Berg, C., Carus, M., & Seeger, K. (2025). *Benefits of using first-generation biomass for food, fuels, chemicals and derived materials in Europe* (Ed. Renewable Carbon Initiative). Hürth. https://doi.org/10.52548/GCJC4981

We Are Aquaculture. (2024, March 19). *Norway aims for 25% homegrown raw materials in its aquaculture feed by 2034.* https://weareaquaculture.com/news/feed/norway-aims-for-25-homegrown-raw-materials-in-its-aquaculture-feed-by-2034

8. Appendices

Appendix 1 - Overview of ABP Categories under Regulation (EC) No 1069/2009

Cat	Risk Level	Key Definitions & Examples	Permitted Disposal & Use
Category 1	**Highest Risk** *(Prions & Contaminants)*	• **Specified Risk Material (SRM):** Brains, spinal cords, eyes of cattle/sheep. • **TSE Suspects:** Animals suspected or confirmed to have Transmissible Spongiform Encephalopathies (e.g., BSE/Mad Cow Disease). • **Pets, Zoo & Circus Animals:** Bodies of dead pets or experimental animals. • **International Catering Waste:** Food waste from international transport (airplanes/ships) entering the EU. • **Illegal Treatments:** Animals treated with prohibited substances (e.g., growth hormones).	• **Incineration** (burning). • **Co-incineration** (used as fuel). • **Pressure Sterilization** followed by permanent marking and landfill. • **Burial** (only in authorised remote areas). *Strictly prohibited from entering the food or feed chain.*
Category 2	**High Risk** *(Infectious Diseases & Chemicals)*	• **Fallen Stock:** Animals that died on the farm (not slaughtered for human consumption) and are not Cat 1. • **Manure & Guano:** Animal excrement and digestive tract content. • **Disease Control:** Animals killed to control disease outbreaks (e.g., Foot and Mouth). • **Residues:** Products containing veterinary drugs or contaminants exceeding permitted levels. • **Dead-in-shell poultry** and foetuses.	• **Incineration** or Co-incineration. • **Pressure Sterilization** followed by landfill or biogas/composting. • **Fertilizers:** Manure and digestive tract content can often be applied to land (sometimes after processing). • **Composting/Biogas:** Allowed after pressure sterilization. *Prohibited for animal feed.*
Category 3	**Low Risk** *(Safe for Consumption but not used)*	• **Fit for Human Consumption:** Parts of animals slaughtered and found fit for humans, but not used for commercial reasons (e.g., fat trimmings, bones). • **Catering Waste:** Household and restaurant food waste (unless from international transport). • **Former Foodstuffs:** Expired meat or dairy products originally meant for humans. • **Animal Parts:** Hides, skins, hooves, horns, pig bristles, feathers, and wool from healthy animals. • **Blood** from non-diseased animals.	• **Pet Food:** Raw material for dog/cat food. • **Animal Feed:** Processed animal protein (for non-ruminants). • **Fertilizer:** Organic fertilisers and soil improvers. • **Cosmetics & Pharmaceuticals.** • **Biogas & Composting.** • **Incineration/Landfill.**

Appendix 2 - Category 2 due to physical impurities, calculations

This appendix presents the breakdown of the calculation and the rationale behind the 1 – 1.4 million tonnes estimate for Category 2 material which is downgraded due to foreign bodies or packaging.

The deduction: A "gap analysis"

The authors could not find a (Eurostat) dataset specifically labelled "Category 2 due to impurities". This figure is derived using a **Gap analysis**, by comparing the *total available volume* of former foodstuffs against the *actual volume processed* into feed. The analysis was assisted by Google Gemini.

1. Total available "former foodstuffs"

These are foodstuffs that are safe but no longer intended for human consumption (due to production errors, formatting, or shelf-life expiry).

- **Data Source:** FUSIONS (EU Food Waste Project, later extended in the REFRESH project).[83]
- **Volume:** Approximately 10–12 million tonnes are generated annually at the industrial and retail levels in the EU.

2. Volume successfully processed into feed (Category 3)

This is the amount that is successfully unwrapped, processed and legally used as animal feed.

- **Data Source:** EFFPA (European Former Foodstuff Processors Association).
- **Volume:** Approximately 5 million tonnes annually.[84]

3. The "lost" volume (The gap)

- **Calculation:** 12 million tonnes (total) – 5 million tonnes (used) = ~7 million tonnes.
- **Status:** This remaining volume of ~7 million tonnes does not enter the feed chain. Instead, it is diverted to biogas, composting, or incineration.
- **Classification:** Under EU regulation, animal-based material diverted to biogas is generally classified as Category 2 (or treated as waste) because it has not undergone the strict separation required to maintain Category 3 status.

4. Isolating the animal-origin fraction

The "Former Foodstuffs" stream includes bakery products (bread, biscuits, etc.) and animal products (meat, dairy, mixed meals). One must estimate the animal (ABPs) portion in this mix.

- **Assumption:** While bakery products constitute the bulk of the volume, animal-based products (dairy, processed meats, pizzas, ready-meals) represent a significant weight.

[83] REFRESH, EU research project, "Fusions Project Ends: Food Waste Findings Taken into EU Circular Economy Strategy," 2019, https://eu-refresh.org/fusions-project-ends-food-waste-findings-taken-eu-circular-economy-strategy.html

[84] A. Romme, "Former Foodstuffs Processing: Circular Economy Solutions for Sustainable Food & Feed Production," *Feed and Additive*, February 2025, https://www.feedandadditive.com/former-foodstuffs-processing-circular-economy-solutions-for-sustainable-food-feed-production/

A conservative estimate is that 20–25% of this waste stream contains animal products. The lower percentage is used for calculations.

- **Calculation:** 7,000,000 tonnes (lost volume) ×20% = 1,400,000 tonnes.
- **Considerations:**
    - For some "former foodstuff" products (e.g., pizzas), it may be more practical to classify the whole product as ABP, rather than separating into animal and vegetable fractions, due to energy and processing constraints. Only material weight is considered here. However, when/if using this for feed, the nutritional composition must be determined.
    - To account for uncertainty in the calculation, a +/-200,000-tonne interval is used, yielding a conservative estimate of 1.1–1.5 million tonnes.

Conclusion:
This estimate suggests that 1.1-1.5 million tonnes of animal-origin material are downgraded to Category 2 (Biogas/Waste) annually, primarily because the cost or technical difficulty of removing packaging (foreign bodies) makes it unviable for feed (Category 3).

Appendix 3 - Calculation of potential agricultural residues for feed use

To estimate the technical potential of agricultural residues for feed in the EU, the following data and assumptions were applied:

1. Total agricultural residues produced in the EU

According to JRC (2018) data, the EU produces approximately 442 million tonnes/year of agricultural residues from primary crops. These residues include field residues (stalks, leaves, seed pods left on the field) and post-harvest processing residues (husks, seeds, bagasse).

2. Residue composition by crop type

- Cereals account for 74% of total agricultural residues (~327 million tonnes/year).
- Oil-bearing crops contribute 17% (~75 million tonnes/year).
- Other crops make up the remaining 9% (~40 million tonnes/year).

3. Sustainable removal fractions

- For cereals, literature estimates that 15–60% of residues could be sustainably removed, depending on soil type, crop type, and management practices (Scarlat et al., 2010).
- For oil-bearing crops, a conservative ~50% removal fraction was assumed to estimate technical potential for feed use.

4. Calculation of potential feed-usable residues

- Cereals: 327 Mt/year × 15–60% → 49–196 Mt/year
- Oil-bearing crops: 75 Mt/year × 50% → ~37 Mt/year
- Combined potential: midpoint estimate → 100 + 37 ≈ ~137 Mt/year

5. Rounding and reporting

For simplicity and reporting purposes, this is rounded to ~140 Mt/year, representing the technical potential of agricultural residues that could be mobilised for feed use in the EU.

6. Constraints and caveats

- Only a fraction of residues can be removed without negatively affecting soil organic matter, nutrient cycling, and erosion control.
- Not all theoretically removable residues can be economically gathered.
- Current residues are used for bioenergy, animal bedding, and other material applications.
- Some residues may require upgrading (e.g., fermentation, single-cell protein production) before being usable as feed.

Conclusion:

The figure of ~140 Mt/year represents residues that could be mobilised for feed under ideal sustainable and logistical conditions, rather than immediately available feedstock.

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