

Circular Nutrients for a Sustainable Baltic Sea Region (CiNURGi)

Case Study: RNF Fertiliser Production Facilities in Baltic Sea Countries

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Organisations from the following countries cooperate together to make that happen: Sweden (LP), Denmark, Estonia, Finland, Germany, Latvia, Lithuania and Poland.

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RNF Fertilizer Production Facilities in Baltic Sea Countries

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Foreword

CiNURGi (Circular Nutrients for a Sustainable Baltic Sea Region) is an Interreg BSR Core Project dedicated to advancing circular economy for nutrients within the Baltic Sea Region. By enhancing infrastructure, technology, and policy the project seeks to improve nutrient recovery from biomass and resource streams originating from agricultural, municipal, and industrial sources. This endeavor aligns with several regional and European strategies, including the HELCOM Baltic Sea Regional Nutrient Recycling Strategy, the EU's Circular Economy Action Plan under the Green Deal, and the Integrated Nutrient Management Action Plan of the Farm to Fork Strategy. The CiNURGi is ongoing from November 2023 to October 2027.

This report pertains to Task 2.1 (Piloting NR with knowledge and processing support centers to produce recycled nutrient fertilizers) within WP2 – Piloting and evaluating solutions. Task 2.1 focuses on identifying and evaluating ongoing nutrient-recycling (NR) initiatives across the Baltic Sea Region, placing particular emphasis on case studies that demonstrate the technical feasibility and maturity of recycled nutrient fertilizer (RNF) production. These case studies investigate various agricultural, municipal and industrial biomass streams and assess their potential to support the redistribution of nutrients from surplus regions to areas experiencing nutrient deficits.

The findings and activities detailed herein contribute directly to CiNURGi's overarching goals by providing insight into existing processing pathways and business models and by highlighting opportunities for cross-sectoral cooperation that can strengthen circular nutrient flows. Through the systematic documentation of regional NR initiatives, Task 2.1 supports the development and promotion of safe and sustainable nutrient-recycling practices in line with the EU Green Deal, the HELCOM Regional Nutrient Recycling Strategy, the Baltic Sea Action Plan and other relevant policy frameworks. The knowledge generated in this report enables evidence-based discussion and policy dialogue, encourages new symbioses between biomass resource streams, and ultimately facilitates the transition toward a circular bioeconomy and "circular agronomics" in the Baltic Sea Region.

We acknowledge the collaborative efforts of our consortium, comprising 24 partners and 13 associated organizations from Denmark, Estonia, Finland, Germany, Poland, Latvia, Lithuania, and Sweden. Their dedication and expertise are instrumental in driving the project's success.

For more information about CiNURGi and its initiatives, please visit our project homepage <https://interreg-baltic.eu/project/cinurgi/>

May 2026

Erik Sindhøj & Cheryl Cordeiro, CiNURGi Project Coordinators

RISE – Research Institutes of Sweden

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Executive Summary

This report presents an overview of Recycled Nutrient Fertiliser (RNF) production facilities across the Baltic Sea Region, compiled within the CiNURGi project to support the development of circular nutrient management. The analysis focuses on selected case studies representing agricultural, industrial and municipal waste streams, demonstrating how nutrient-rich materials can be transformed into valuable fertiliser products. These solutions contribute to key regional goals, such as reducing nutrient leakage into the Baltic Sea, improving resource efficiency, and decreasing dependence on mineral fertilisers.

A total of fifteen RNF technologies were reviewed, including pelletisation and other mechanical treatment, composting, anaerobic digestion, struvite precipitation, urine dehydration, and innovative nutrient-capture systems. The diversity of raw materials—ranging from livestock manure, meat and bone meal, and biowaste to mineral industrial residues and wastewater rejects—illustrates the wide potential for nutrient recovery. Final products vary in nutrient composition and form, including pellets, granules, digestate, and crystalline mineral fertilisers. Several solutions already comply with EU regulatory frameworks and are approved for use in organic farming.

Comparison of the technologies indicates that product characteristics depend largely on feedstock origin and process type. Struvite-based products show high phosphorus bioavailability, whereas composted and digestate-based fertilisers provide additional soil-improving benefits due to their organic matter content. Many technologies demonstrate added environmental value through reduced sludge volumes, biogas production, or improved nutrient logistics. However, scalability remains dependent on regulatory acceptance, market demand, and investment feasibility.

Overall, the case studies highlight promising pathways for nutrient circularity in the Baltic Sea Region. Successful implementation relies on mature technologies, improved handling and logistics, supportive policy frameworks, and collaboration among producers, regulators, and farmers. Further development should prioritise solutions offering both high nutrient efficiency and resilience within local agri-food systems.

Keywords: recycled nutrient fertilisers (RNF); nutrient recovery; circular economy; waste-based fertilisers; Baltic Sea Region

1. Introduction

The CiNURGi project aims at supporting the development towards a circular economy for nutrients in the Baltic Sea Region, by promoting the conversion of nutrient-rich organic waste from agriculture, municipals and industries into bio-based fertilisers (BBFs) / RNFs. This initiative supports sustainable nutrient management while reducing environmental impacts of nutrient loss, particularly eutrophication.

1.1. Purpose of the report

Task 2.1 builds directly upon the results of Task 1.3, which compiled a longlist of promising RNF (Recycled Nutrient Fertilizer) value chains across the Baltic Sea region. These cases have demonstrated either a degree of market maturity (higher TRL levels) or relevance to the CiNURGi project objectives, particularly concerning circular economy principles and climate neutrality.

While Task 1.3 provided a broad overview of the selected cases focusing on the market potential, Task 2.1 aims to conduct a more in-depth analysis of these and new initiatives, exploring their technical, environmental, regulatory, and economic dimensions and beyond. Emphasis will be placed on showcasing the most promising solutions and promoting practices that can be replicated or scaled up in other regions, especially broken down for industrial, agricultural and municipal sectors.

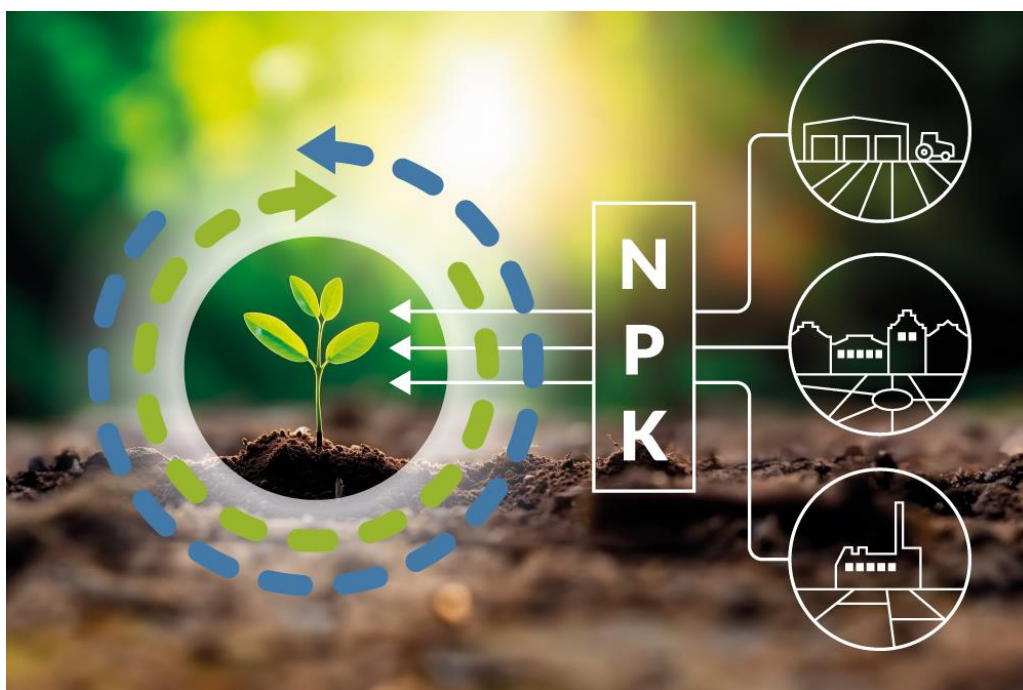


Figure 1. This CiNURGi profile illustration is clearly visualising the project focus on the plant macro nutrients N, P and K, the circularity and the scope being agricultural, municipal and industrial waste streams.

Figure credits: Adobe Stock -Nongkran - Modified by Sari Kaija

CiNURGi focuses on the key nutrients nitrogen (N), phosphorus (P) and potassium (K) (see Figure 1), with an emphasis on N and P due to their contribution to eutrophication of waters, including

the Baltic Sea. By addressing these nutrient flows, the project seeks to create a more sustainable and resource-efficient system for nutrient management in the region.

1.2. Definition of RNF Fertilisers and their role in the Circular Economy

Recycled Nutrient Fertilizers (RNFs) are fertilizers produced from recycled materials, such as animal manure, organic household or industrial waste, sewage sludge, or other nutrient-rich byproducts.

As outlined in the CiNURGi project and aligned with the HELCOM Regional Nutrient Recycling Strategy (HELCOM, 2021b), RNFs are part of a broader Nutrient Recycling (NR) process—reusing organic or inorganic nutrients to support plant growth and soil fertility. These fertilizers may also fall under the category of Bio-Based Fertilizers (BBFs), provided that a significant share of their nutrients (typically over 80–90%) originates from organic sources.

RNFs exemplify the principles of the circular economy by transforming waste streams into valuable agricultural inputs. This reduces dependency on finite mineral fertilizers, closes nutrient loops, and helps limit environmental degradation.

The use of RNFs is regulated by several EU legal frameworks, including Regulation (EU) 2019/1009, which introduces classification through Component Material Categories (CMCs) and Product Function Categories (PFCs) (THE EUROPEAN PARLIAMENT AND OF THE COUNCIL, n.d.-c). Other regulations—such as (EC) No 1069/2009 (THE EUROPEAN PARLIAMENT AND OF THE COUNCIL, n.d.-b), (EU) No 142/2011 (The European Commission, 2011), and (EU) 2024/3019 (THE EUROPEAN PARLIAMENT AND OF THE COUNCIL, n.d.-a)—set safety and quality standards, particularly for products containing animal by-products or derived from wastewater. Additionally, Commission Implementing Regulation (EU) 2021/1165 (COMMISSION IMPLEMENTING, n.d.) governs the use of certain fertilising materials, including digestates, in organic farming. By encouraging sustainable waste management and improving soil health, RNFs play a vital role in creating resilient and resource-efficient agri-food systems.

1.3. Characteristics of Waste Rich in Nutrients

Waste streams rich in nutrients constitute the primary resource base for RNFs. Their chemical composition, physical characteristics, and degree of biological stability determine both the choice of processing technology and the agronomic performance of the final product. Within the Baltic Sea Region, these streams originate predominantly from agriculture, municipal wastewater treatment, and industry. Their effective management offers opportunities to reduce greenhouse gas emissions, limit nutrient surpluses being released to the environment, and increase nutrient self-sufficiency—objectives aligned with the principles of the circular economy and European policy frameworks (Buckwell & Nadeu, n.d.; Pociene & Šlinkšiene, 2024).

Agricultural streams are among the most abundant and widely used nutrient-rich resources. Livestock manures (cattle, pig, poultry) and slurries contain relevant levels of key nutrients, alongside valuable organic carbon. Their high organic matter content improves soil structure, water retention, and microbial activity. However, nutrient concentrations vary significantly

depending on animal species, feed composition, and handling. Manure-based streams may include pathogens and require appropriate treatment—such as composting, anaerobic digestion, or drying—to increase stability and safety, reduce odour emissions, and facilitate transport. In some cases, co-substrates such as straw, peat, or woody biomass residues are mixed with manure to adjust physical consistency and enhance nutrient retention, as seen in several RNF products throughout the region (Velthof et al., 2024).

Industrial nutrient-rich streams often originate from the processing of agricultural or mineral raw materials. These include animal by-products—such as meat and bone meal, blood meal—or mineral residues formed during metal and phosphate ore processing. Industrial side streams are typically characterised by higher and more stable nutrient concentrations than untreated agricultural waste. For example, meat and bone meal pellets are valued for their high phosphorus content and relatively rapid nitrogen mineralisation. Meanwhile, mineral phosphorus residues can be incorporated into fertilisers as a partial substitute for phosphate rock. However, these streams must meet strict quality and safety standards (e.g. EU Animal By-Product Regulation, heavy metal limits), requiring appropriate processing and traceability before use as fertilising products.

Municipal sources comprise sewage sludge, digestate from sludge treatment, and source-separated human urine. These streams contain significant amounts of plant nutrients, particularly N and P, making them important targets for recovery. Advanced processes such as struvite precipitation, nitrogen stripping, urine drying, and digestate separation enable recovery of concentrated fertiliser products in mineral or organic-mineral form. Their application reduces the load of nutrients discharged into water bodies, helping to mitigate eutrophication in sensitive basins such as the Baltic Sea. Municipal streams may also contain heavy metals or micropollutants; therefore, hygienisation and compliance with EU standards are crucial to ensure safe agricultural use. The increasing adoption of source-separated systems demonstrates the growing interest in high-purity nutrient recovery compatible with organic farming.

Across all nutrient-rich waste streams, several characteristics are particularly relevant for RNF production. First, nutrient concentrations and forms vary widely: nitrogen may be present in organic or ammonium form, while phosphorus and potassium may occur in organic, inorganic, or mineral forms—each influencing bioavailability and crop uptake. Second, organic matter content plays a dual role: it enhances soil health by contributing to humus formation but may decrease the immediate nutrient availability compared to mineral fertilisers. Third, the physical state of the material (liquid vs. solid) affects transport and handling; while liquid solutions may require costly transport, solid products are easier to store, blend, and distribute. Fourth, safety and quality aspects—including pathogen load, trace metal content, and chemical stability—determine required treatment intensity and legal compliance.

Understanding these characteristics is essential for selecting appropriate processing technologies and for evaluating the environmental and agronomic performance of the resulting RNFs. The diversity of nutrient-rich waste streams within the Baltic Sea Region presents both opportunities and challenges: a wide resource base supports innovation and local circularity, yet variations in composition require tailored technological solutions. The following chapters present concrete examples of how different processing pathways are applied in practice, demonstrating how

nutrient-rich waste can be transformed into valuable fertiliser products compatible with European regulatory requirements and contributing to the protection of the Baltic Sea environment.

1.4. Importance of Nutrient Recycling for the Protection of the Baltic Sea

Nutrient recycling plays a crucial role in protecting the Baltic Sea from eutrophication, one of the region's most pressing environmental challenges. Excessive nutrient loads—particularly nitrogen and phosphorus—enter the sea from agriculture, wastewater, and industrial sources, causing algal blooms, oxygen depletion, and damage to marine biodiversity. By reusing nutrients from organic waste streams such as manure, sewage sludge, and food waste, nutrient recycling helps close nutrient loops and reduce the need for mineral fertilizers, which are a major source of nutrient runoff.

The HELCOM Regional Nutrient Recycling Strategy (HELCOM, 2021b) emphasizes nutrient reuse as a key measure for achieving the goals of the Baltic Sea Action Plan (HELCOM, 2021a). RNFs help divert nutrient-rich materials from polluting the sea and instead return them to the soil in a controlled, sustainable manner. This contributes to improved water quality, reduced greenhouse gas emissions, and better resource efficiency across the agri-food system. Promoting nutrient recycling supports a transition toward circular and sustainable agriculture in the Baltic Sea region, ensuring long-term environmental protection while maintaining agricultural productivity. Effective regulation, innovation, and cross-border cooperation are essential to scale nutrient recycling practices and safeguard the Baltic Sea for future generations.

2. Case Studies of RNF production facilities in Baltic Sea Region

RNFs are derived from a wide range of nutrient-rich waste streams, each with distinct characteristics and processing requirements. This chapter presents case studies of RNF production facilities across the Baltic Sea Region, grouped by the origin of their input materials: agricultural, industrial, and municipal. Wastes and by-products from agricultural activities typically includes manure, slaughterhouse by-products, and crop residues, offering high organic content and essential nutrients like nitrogen and phosphorus. Wastes and by-products from industrial sources often stems from food processing, mining, or chemical production, and may require advanced treatment to ensure safety and nutrient recovery. Waste from municipalities, such as sewage sludge, biowaste and source-separated urine, presents both challenges and opportunities for nutrient recycling, especially when integrated with sanitation and wastewater systems. By examining these diverse sources and the technologies used to transform them into RNFs, this chapter highlights the practical pathways toward circular nutrient management and showcases scalable solutions for sustainable agriculture and environmental protection in the Baltic Sea Region.

2.1. Agriculture Origin

2.1.1. Gyllebo Gødning (Malmö, Sweden)

Location

Gyllebo Gødning has a processing factory in Malmö, Sweden (Figure 2), where animal by-products, such as meat and bone meal, blood meal is used to produce various composition fertilizer pellets "Biofer" (Gyllebo Gødning Aktiebolag, 2026).

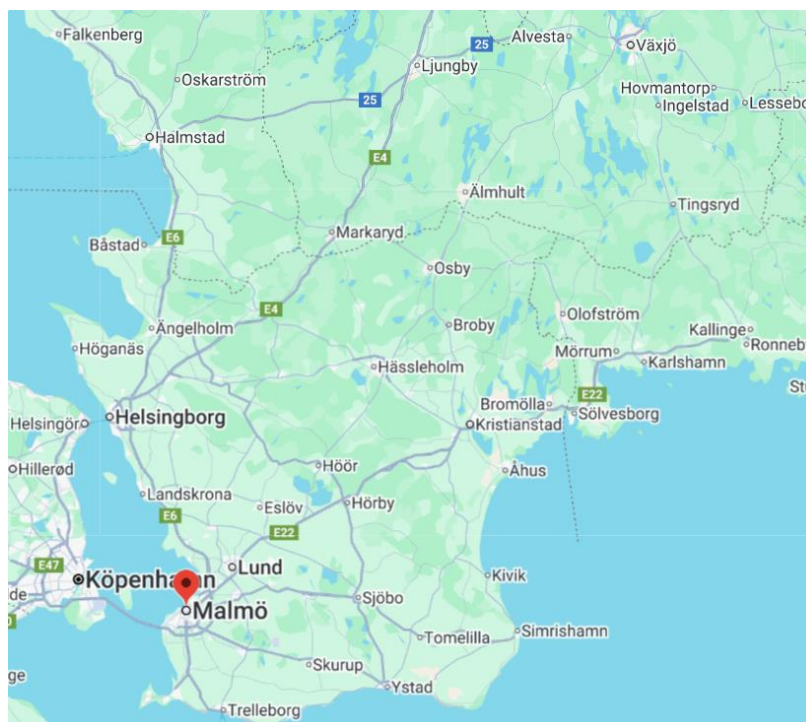


Figure 2. Location of the company in Sweden, Malmö.

Technology

The processing technology involves mixing of substrates, pelletizing, and finally packaging recycled nutrient fertilizer in various size bags. The material is collected from DAKA A/S, Dronninglund, Denmark and brought to Malmö factory (470 km). Animal and vegetable residual products as well as naturally occurring minerals and mineral fertilizers. Used chosen raw materials with very low levels of heavy metals.

Final Product

The company distributes its fertiliser products throughout nearly every country bordering the Baltic Sea, with adaptations made to suit the specific regulatory requirements of each locality. As illustrated in Figure 3, the products—such as Biofer 6-3-12+7 and Biofer 7-9-0—are presented in distinct pellet forms, which are packaged for retail in various bag sizes. Although the prices remain comparable to those in 2019, they are regarded as relatively high by customers. The end products are eligible for CE marking and approved for use in organic agriculture, offering a balanced supply of nitrogen (N), phosphorus (P), and a range of supplementary nutrients to support sustainable farming.



Figure 3. Examples of the products. Biofer 6-3-12+7 (left side) and Biofer 7-9-0 (right side).

Malmö plant consumes 1,219,000 kWh, or 0.14 kWh per kg. Its processing energy is comparable to a feed factory at 0.04–0.175 kg CO₂-eq per kg. In 2009, approximately 15,000 tons of Biofer were utilized in organic agriculture, while annual production in Malmö amounted to 8,711.68 tons.

Table 1 provides a detailed breakdown of the nutrient content and origins for the main fertiliser products manufactured at the Malmö facility. Boiler SUPER offers a nutrient ratio of 11:2:1, indicating a high nitrogen content complemented by phosphorus and potassium, and is derived from meat and bone meal as well as bristle meal and blood meal. These components are sourced from category 2 and 3 animal by-products, with KRAV approval ensuring their suitability for organic farming. Biofer, another key product, features a nutrient composition of 10:3:1 and is similarly produced from category 2 animal by-products, also carrying KRAV certification. This composition supplies essential nutrients to crops, supporting soil fertility and sustainable agricultural practices.

Table 1. Description of the products with the nutrient content and origin.

Product	Nutrient Content	Origin
Boiler SUPER	11:2:1	Meat & bone meal, bristle meal/blood meal (category 2&3, KRAV-approved)
Biofer	10:3:1	Animal by-products (category 2, KRAV-approved)
Biofer	7:9:0	Animal by-products (category 3) from the conventional food industry
Biofer	6:3:12	Animal by-products from the conventional slaughterhouse and food industry (category 2)

2.1.2. Jepua Biogas (Uusikaarlepyy, Finland)

Location

Jepua Biogas is a biogas plant located in Uusikaarlepyy, Western Finland (Figure 4). The plant was first started in 2013 as a wet digestion process. Later a solid digestion process was added.

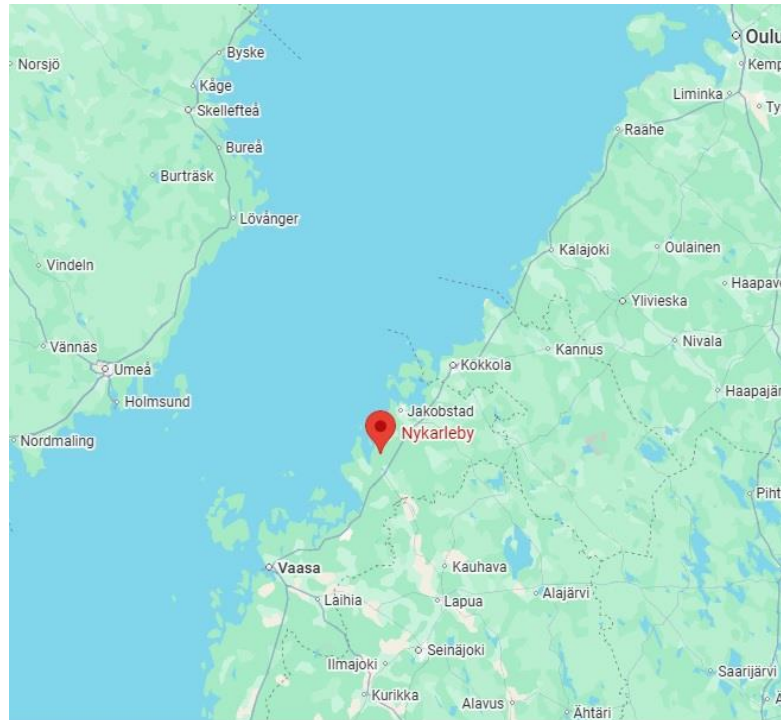


Figure 4. Location of the Jepua Biogas Plant.

Technology

The biogas plant digests mainly livestock manure due to being located in a region of dense livestock production. Additional feed materials are agricultural plant biomasses and food industry side streams. The annual capacity of the plant is currently 150 000 tons. Most of the manure digested is pig slurry, part of which is pumped to the plant directly from neighbouring farms. The other manure types received are cattle manures and poultry manure.

The annual energy production of the plant is approximately 40 GWh. All produced biogas is upgraded to biomethane and sold as a vehicle fuel or to industrial use to replace natural gas.

Final Product

The digestate is currently mechanically separated using a screw press. The liquid and the solid fractions are sold as fertilizing products (Table 2).

Table 2. Current fertilising products of Jepua Biogas Ltd.

Fertilising Product	Volume weight (kg/m ³)	Dry matter (%)	Organic Carbon (%)	Total Nitrogen	Soluble Nitrogen	Total Phosphorus
Jepuan Kasvuvoima	1020	5.5	2.3	4.4 kg/t	3.3. kg/t	1.6 kg/t
Jepuan Ravinnevoima	303	30	14	1.28 kg/m ³	0.46 kg/m ³	0.83 kg/m ³

Jepua Biogas Ltd is developing their nutrient recycling system with many measures. They are improving pre-storage of feeds on the plant to receive more and higher quality grass biomasses to the process, and post-storage of digestate and/or its separated fractions to facilitate enhanced logistics. They are an advocate for e.g. farm-co-owned storages to be built in chosen locations to improve application possibilities of the fertilizing products produced. This is seen important to improve logistics especially to farms specializing in plant production. Overall, the possibility to transport the products closer to the fields in-between spreading seasons improves the logistics significantly.

Furthermore, Jepua Biogas Ltd is planning an investment in membrane filtration of the separated liquid fraction. This is seen important due to the need to reduce the cost and environmental impact of transporting large liquid volumes especially when the customer is further away. Several technologies have been screened, and membrane filtration seems best suited for the plant. A concentrated nutrient solution is seen as the preferred end-product.

In CiNURGi, Jepua Biogas Ltd and Natural Resources Institute Finland (Luke) are cooperating to develop membrane filtration of the digestate liquid fraction. Experimental work is ongoing with a vibrational shear-enhanced system (VSEP). Following pretreatment and the addition of a tannin-based biopolymer, a process was employed to enhance the efficiency of membrane filtration processes, such as ultrafiltration and concentration by reverse osmosis.

The main challenges of developing the nutrient recycling activities of Jepua Biogas Ltd are related to the economy. There are new centralized biogas plants being built relatively close-by. This means more competition for both feed materials and end-users for the products. For example, the prospect of losing tenders for industrial side streams bringing in gate fees may affect the plant economy negatively. Still, the company sees this also as a possibility, provided the new biogas plants are ready for cooperation.

Furthermore, investments in enhancing nutrient recycling solutions require public support. Jepua Biogas Ltd receives operational grant for nutrient cycles, a novel subsidy available for manure-based biogas plants in Finland. The grant is awarded by a competitive tendering, and the support is paid for the amount of phosphorus in manure digested. Jepua Biogas Ltd is also set to receive investment support for the processing of the digestate liquid fraction from the Finnish Ministry of the Environment. These subsidies are, however, available for only a limited time, making the future unpredictable for further development activities.

2.1.3. Scandagra Lietuva (Kaunas, Lithuania)

Location

The holding company Scandagra Group was founded in 2006 with the goal of enhancing the use of synergies, expertise, and competencies across both geographical regions and ownership structures within the Baltic area. With its five subsidiary companies, including Scandagra Lietuva (Figure 5), Scandagra Group serves as a reliable partner for both established large-scale farmers and newcomers to the industry and provides a comprehensive range of agricultural solutions (Scandagra, 2026a, 2026b).

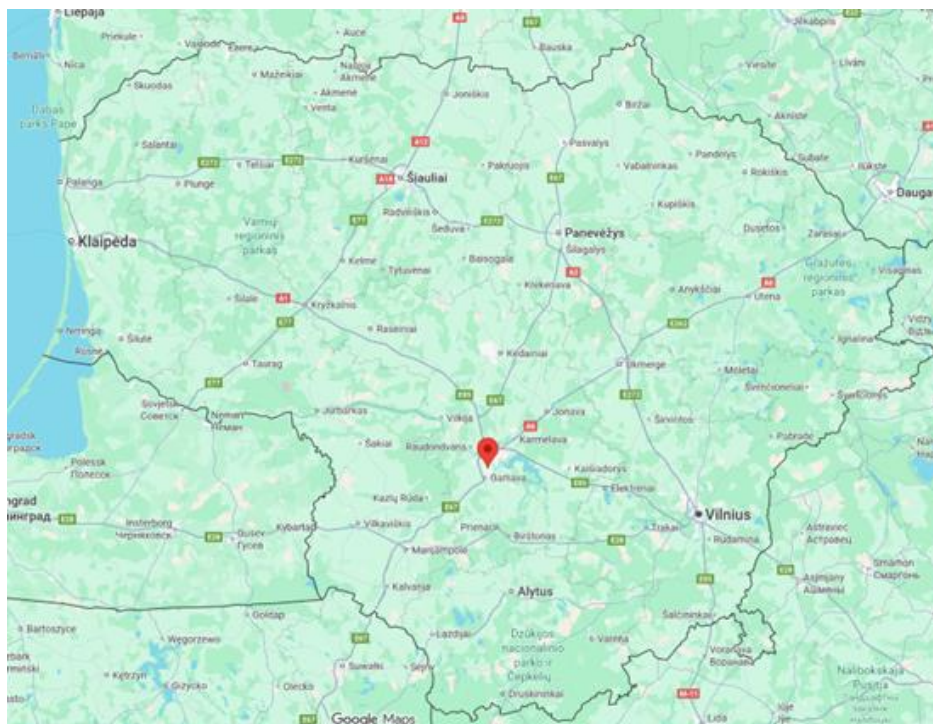


Figure 5. Location of Scandagra Group company.

Technology

Scandagra Lietuva markets granulated organic fertilisers, including a meat-and-bone-meal-based granular product (“Organic 10-3-1+10% CaCO₃”). The product is positioned as a long-term soil fertility solution: it supports gradual nutrient release, adds organic matter, and helps improve soil structure and microbial activity. The company highlights agronomic effects in acidic, low-humus soils, including reduced soil acidity and increased humus (organic carbon) as well as increases in mobile phosphorus and potassium and total nitrogen (Scandagra, 2026c, 2026d).

- Fertiliser type and form: granulated organic fertiliser based on meat and bone meal, with added calcium carbonate (CaCO₃); intended for sustainable soil fertility management.
- Claimed functional benefits: high organic matter content, gradual nutrient release over time, and reduced risk of nutrient leaching and crop burn compared with fast-release mineral fertilisers.

- Reported trial outcomes (VDU): in pot tests with winter wheat, green biomass increased by 27.68% and dry biomass by 50.10%; in very acidic, low-humus sandy soils, the fertiliser reduced soil acidity and increased humus/organic carbon, mobile P and K, and total N.
- Packaging listed on the product page: 1200 kg.

Final Product

The 10-3-1 + 10% CaCO₃ fertilizer is a granular product made from meat and bone meal. The nutrient content of the fertilizer is presented in Table 3 (Scandagra, 2026c). The product is characterized by the following properties:

- Reduces soil acidity more effectively than chicken manure,
- Increases the content of humus, plant-available phosphorus, and total nitrogen in the soil,
- Balances nitrogen uptake during the vegetation period,
- Ensures effective fertilization both when broadcast and when incorporated during sowing,
- Animal proteins are converted into plant-available nitrogen significantly faster than from other natural sources,
- Can be evenly spread over a wide area,
- Granule diameter of 4–5 mm.

Table 3. Product nutrient analysis.

Element	Percentage (%)
Total Nitrogen	7.5 – 8.5
Phosphorus (P₂O₅)	7.0
Potassium (K₂O)	1.0
Magnesium	0.6
Calcium	8.0
Sodium	0.7

2.1.4. Biodinamika (Vilnius, Lithuania)

Location

Biodinamika is located in Vilnius, Lithuania, as depicted in Figure 6. The company is strategically situated to serve farmers and agricultural enterprises across the region, providing convenient access to its range of organic fertiliser products. Its position in Vilnius allows for efficient distribution and engagement with the local agricultural community.

Since 2014, the company has utilized fertilizer production technology and expertise from UAB “Agrolinija,” a beef cattle farm, to continue manufacturing organic fertilizers using bedded beef cattle manure compost provided by that farm.

UAB “Biodinamika” aims to support sustainable agriculture in Lithuania by offering farmers and agricultural businesses high-quality organic fertilizers made from processed cattle manure, organic sapropel, and other biological materials (Biodinamika, 2025).

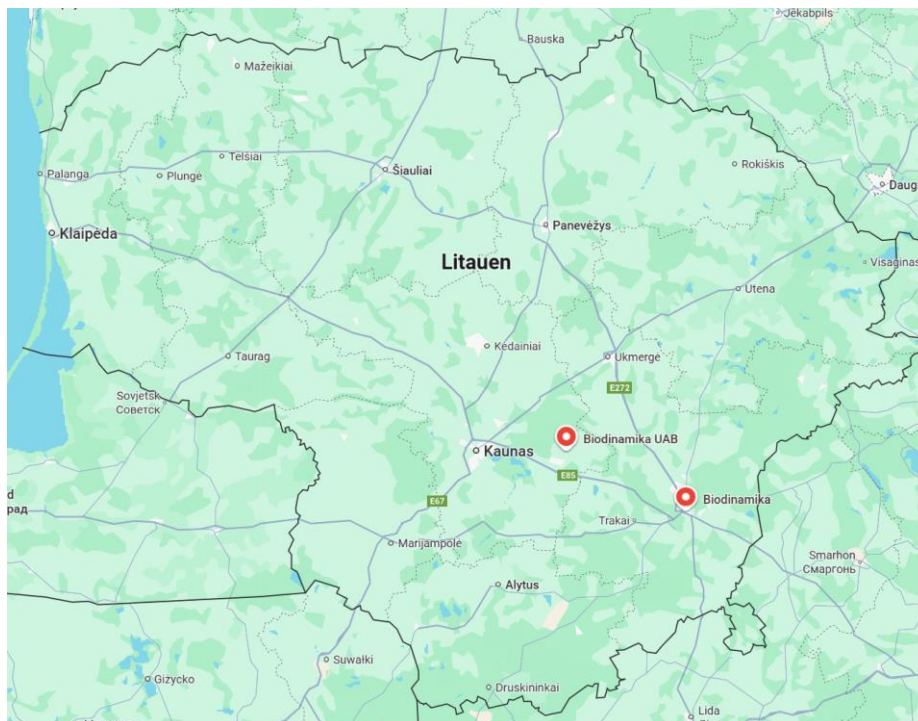


Figure 6. Location of Biodinamika.

Technology

Fertilizer is made while using advanced composting technology. Fully composted manure is further processed by drying and grinding to the appropriate fraction for the granulation process.

Final Product

AGROLINIJA-GRAN is a high-quality organic fertilizer produced from composted beef cattle manure (Figure 7). Its granulated form ensures convenient application and uniform distribution in the field. The fertilizer is valued for its beneficial composition and granulometric characteristics.

Application of AGROLINIJA-GRAN to soil increases the content of available phosphorus, potassium, total nitrogen, organic carbon, and humus, while not influencing soil acidity. The product is suitable for all plant species and is permitted for use in organic farming.



Figure 7. Packaged AGROLINIJA-GRAN fertilizer.

Properties:

AGROLINIJA-GRAN is a long-lasting, granulated organic fertiliser of 100% natural origin, designed to increase crop yields and enhance the quality of harvested produce. Its formulation, NPK: 3-1.5-7, provides essential nutrients for plant growth and is entirely free of pathogens and weed seeds, ensuring safe use in agricultural settings. This fertiliser plays a crucial role in restoring depleted soils, improving both their physical and agrochemical properties. Rich in organic matter, AGROLINIJA-GRAN also contains macro- and microelements, including ultra-microelements such as selenium and iodine, which are vital for healthy crops. Developed using a technology that supports the local application of organic granulated fertilisers, it is most effective when applied directly where crops are grown. Importantly, no GMOs are used in its production. In addition, Table 4 presents the product's nutrient analysis: AGROLINIJA-GRAN has a pH value of 9%, dry matter content of 85%, organic matter at 72%, and organic carbon at 29%, highlighting its beneficial composition for soil enrichment and plant nutrition.

Table 4. Product nutrient analysis.

Element	Value
pH	9
Dry matter	85%
Organic matter	72%
Organic carbon	29%
Total nitrogen (N)	3%
Total phosphorus (P ₂ O ₅)	1.5%
Total potassium (K ₂ O)	7%
(S, Ca, Mg, Fe)	>4%
(B, Mo, Mn, Cu, Zn, I, Se, Co)	<400 mg/kg

Source: (Biodinamika, 2023)<http://www.biodinamika.lt/wp-content/uploads/2024/06/Agrolinija-Granskrajute-dvipuse-A4-LT-Korekcija-2023-08-03.pdf>.

2.1.5. TURPS Organic OÜ (Poaka, Estonia)

Location

TURPS Organic OÜ, based in Poaka village, Estonia (Figure 8), began developing its product in 2016 and launched pilot production in 2022. By 2025, the company stabilized its product, validated by field trials across various crops. Their patented Estonian process uses local organic fen peat (H > 8), fresh chicken manure, and wood ash to create a multifunctional soil improver and organic fertilizer suitable for certified organic agriculture (TURPS, 2026).

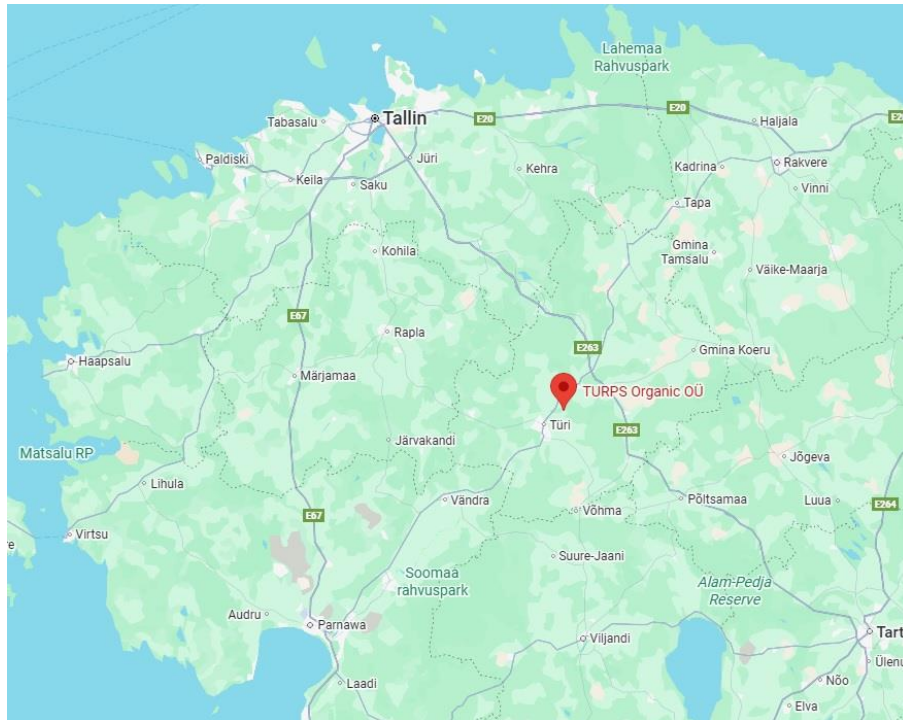


Figure 8. Location of TURPS Organic OÜ in Estonia.

Technology

TURPS is produced in three stages:

1. Activation of Humic Acids

Peat and manure are mixed and held in an oxygen-free environment at 35-70 °C for 2-5 days. During this stage, ammonia released from the manure displaces metal ions (Ca, Mg, etc.) bound to the peat's humic acids, making humic substances more available to plants.

2. pH Elevation and Solubilization

Fresh wood ash is added to the mixture. The potassium oxide in the ash reacts with water, raising the pH to about 12-12.5 and converting humic acids into their soluble form.

3. Granulation and Stabilization

The peat-manure-ash compound is granulated, dried and packaged in airtight form. Airtight packaging prevents hydroxides from reacting with atmospheric CO₂, preserving long shelf life.

Final Product

TURPS is a soil conditioner made entirely from natural ingredients. Every strong plant starts with healthy, vital soil. TURPS has been developed to restore and revitalize the natural balance of agricultural soils. It is not just a fertilizer – it is a soil health booster that helps nature take better care of itself.

As illustrated in Figure 9, TURPS is available in both granulated and packaged forms. The granulated product appears as compact, uniform particles, while the packaged variant is securely sealed to maintain quality and prolong shelf life.



Figure 9. Granulated (right) and packaged TURPS (left) (Meelis Malk).



Figure 10. Product logo.

TURPS is composed of three key components:

- Black peat – naturally rich in humic substances, improves soil structure and water retention capacity.
- Poultry manure – a balanced organic fertilizer that enriches the soil with nitrogen, phosphorus, and potassium.
- Wood ash – supplies minerals and neutralizes soil acidity.

This unique combination creates a synergy that brings soil back to life, making it fertile and resilient again.

The impact of TURPS goes far beyond nutrient supply. It is a complex soil improver that supports ecological balance in the soil and triggers biological processes that benefit both plants and the entire soil microbiome.

Main mechanisms of action:

- Stimulating root development: TURPS enhances oxygen supply to plant roots, encouraging new root formation, and strengthening the entire plant structure.
- Improving nutrient availability: Humic and fulvic acids bind nutrients and make them more accessible to plants.
- Boosting soil microbiota: TURPS provides food for beneficial microorganisms, which in turn help produce essential compounds for plants and suppress pathogens.
- Balancing soil structure: TURPS reduces problems caused by soil compaction, improving both water retention and aeration.

Additional benefits:

- Acts both as a soil conditioner and a balanced organic fertilizer (approx. NPK 2:2:2), with additional Ca, Mg, and micronutrients.
- Restores humus content, improves cation exchange capacity, and enhances water retention.
- Remains effective for years, reducing the frequency of re-fertilization.
- High pH yields a natural liming effect, useful for acidic soils.
- Completely derived from natural materials, suitable for organic farming under EC Regulations 834/2007 and 889/2008.

TURPS can be applied across a wide range of uses. It is suitable for field crops such as cereals, legumes, and root vegetables. In horticulture, it supports the growth of fruit trees, berries, and greenhouse crops. TURPS is also highly effective in gardening and landscaping, improving the health and vitality of lawns, flowers, and ornamental plants (Figure 11).



Figure 11. TURPS container ready for application

Source: (TURPS, 2026).

2.1.6. Biocover – SyreN (Denmark)

Location

BioCover has two products that use this technology The SyreN / in-field acidification case (FCL) is implemented in Denmark (as shown in Figure 12)— operated at farm level (e.g., by contractors such as Rostgård Maskinstation) in real field trials.

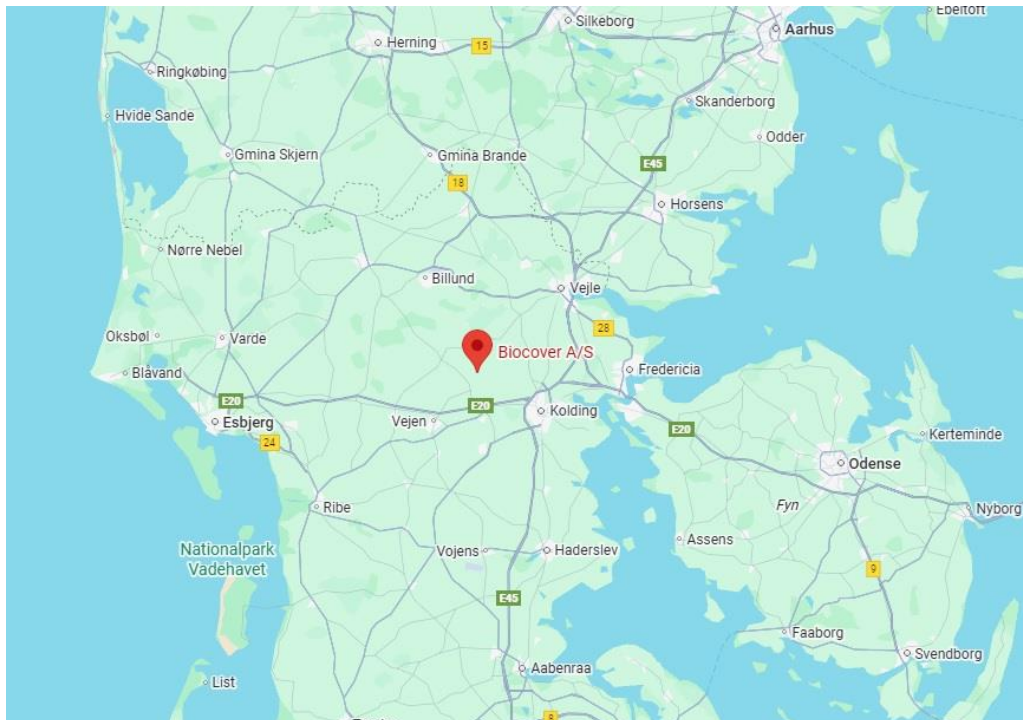


Figure 12. Location of Biocover company.



Figure 13. BioCover logo.

Technological Process

The Danish company BioCover has developed an acidification technology that reduces methane emissions by 80% and ammonia emissions by up to 70% by converting ammonia into ammonium. BioCover has two products that use this technology: SyreN and SyreN+.

SyreN represents an in-field slurry acidification technology, the process works as follows:

- Raw livestock slurry is applied directly to fields using a spreading system equipped with the SyreN unit.
- During spreading, sulphuric acid (H_2SO_4) is injected and mixed with the slurry in real time, lowering its pH. This reduces ammonia (NH_3) volatilisation and retains nitrogen in the fertiliser (Figure 14).
- The process is mobile and automatic – the system continuously monitors pH and flow rate to adjust acid dosage.
- It integrates directly with existing manure spreading equipment, meaning no separate waste treatment plant is required.

- This technology is considered a mechanical-chemical process improving nutrient efficiency and lowering emissions at source.



Figure 14. Acidification of the slurry.

Source: (Global Methane Initiative, 2026)

Final Product

The acidified slurry produced has several key features:

- It increases fertiliser efficiency by preserving nitrogen, making it available for crops.
- Ammonia and greenhouse gas emissions are reduced both during and after application.
- Nutrient recycling is improved, with more nitrogen retained within the agricultural system.
- This slurry can be used directly as a bio-based fertiliser on fields.

2.2. Industrial Origin

2.2.1. AVEMA (Bolesławiec, Poland and Göppingen, Germany)

Location

AVEMA, based in Göppingen, Germany, is responsible for sales and distribution of the produced material across Germany, Switzerland and Austria, while production and logistics are located in Bolesławiec, Poland (Figure 15).

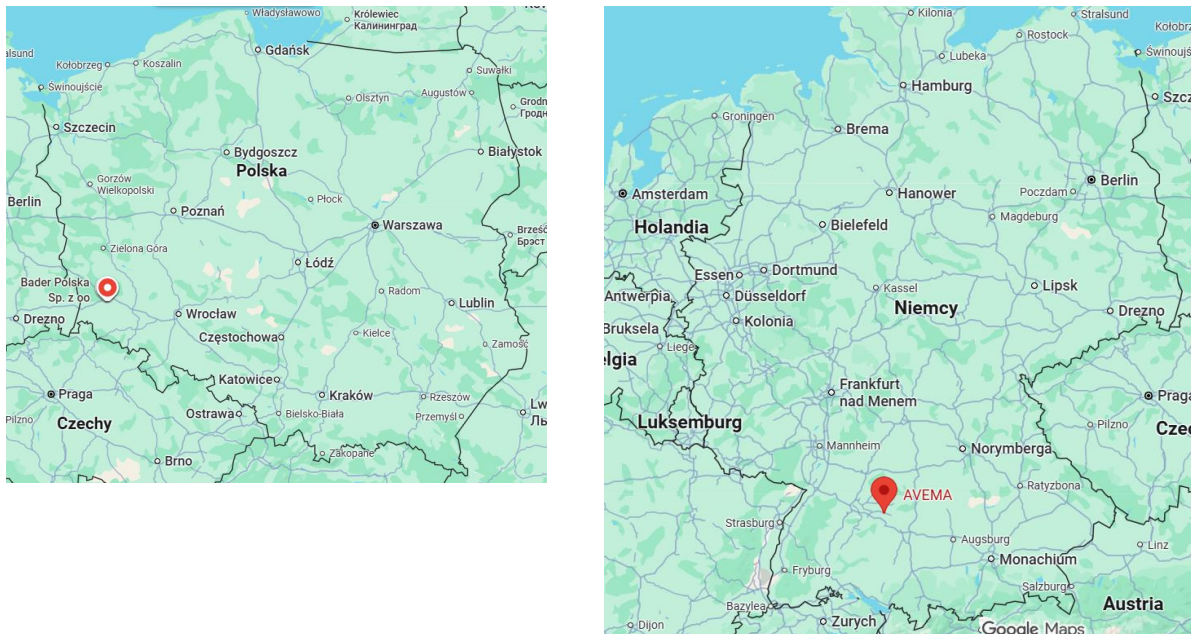


Figure 115. Location of BADER Polska Ltd. (left) and AVEMA (right).

Technological Process

Feedstock source – bovine shavings from the car upholstery plant from the pre-processing stage (free of chromium). The process details constitute a property of BADER Polska Ltd (Figure 16).



Figure 16 View of the bovine shavings before mechanical grinding.

Table 4. Chemical composition of selected waste fractions and processed waste fractions for fertilisers

Element	Shavings
Macronutrients (%)	
N	8,86 ± 1,31
P	0,02 ± 0,002
K	0,03 ± 0,005
S	0,59 ± 0,09
Ca	0,40 ± 0,06
Mg	0,03 ± 0,005
Na	1,24 ± 0,19
Micronutrients (mg/ kg)	
Cu	3,41 ± 0,511
Fe	233 ± 34,4
Mn	1,01 ± 0,150
Mo	<LOD (<0,055)
Zn	15,5 ± 2,30
Heavy metals (mg/ kg)	
As	<LOD (<4,98)
Ba	<LOD (<0,02)
Cd	<LOD (<0,09)
Cr (III)	22,1 ± 3,30
Cr (VI)	1,12 ± 0,17
Hg	<LOD (<0,001)
Ni	<LOD (<0,56)

Pb	<LOD (<0,36)
Others (mg/ kg)	
Al.	10300 ±1550
Co	<LOD (0,27)
Se	<LOD (0,49)

Kuligowski et al. (2023) investigated raw materials to enhance fertilizer efficiency, focusing on the application of leather waste fractions and their biochars as organic fertilizers for ryegrass growth. Their research examined agri-environmental aspects and modelled plant responses. The method used for producing organic nitrogen-based fertilizers, which relies solely on mechanical grinding, is protected by BADER Polska Ltd (Kuligowski et al., 2023).

Final Product (Organic fertilizer)

The produced organic fertilisers regulate moisture, are fully biodegradable and promote healthy microbial activity. Made from upcycled collagen fibres, they not only support a more sustainable approach to the environment but are also ideally suited for organic farming. Versatile and effective, organic fertilisers enhance plant growth in beds, pots, lawns and beyond.

AVEMA Dura-N

AVEMA Dura-N is a premium organic slow-release nitrogen fertilizer designed for long cultivation periods, viticulture, tree nurseries, and depot fertilization. Made from 100% collagen-based natural fibers, it promotes healthy soil biology while steadily supplying nitrogen over time. Its pellets have exceptional moisture-regulating properties, enabling them to retain many times their own weight in water, improving soil structure and aeration. Dura-N is particularly suitable for growers seeking controlled nitrogen availability and enhanced soil conditioning in professional horticulture and agriculture.

AVEMA Plena NPK+Mg

AVEMA Plena NPK+Mg is a balanced wholefood organic fertilizer developed for vegetables, berries, shrubs, hedges, and general horticultural use. With a nutrient composition of 8-3-10, it provides nitrogen for growth, phosphorus for root development, and high potassium levels for flowering and fruit quality. The product also supports long-term soil fertility through its high organic matter content and moisture-retention capabilities. Its pellet structure allows for easy manual spreading and continuous nutrient release, making it ideal for diverse crop applications where balanced nutrition is required.

AVEMA Rapid-N

AVEMA Rapid-N is an organic nitrogen fertilizer pellet engineered for efficient nutrient availability during extended cultivation periods. Produced from natural organic fibers, it enhances soil life while delivering a continuous nitrogen supply. Compared with Dura-N, Rapid-N emphasizes quicker nitrogen availability while still maintaining long-lasting fertilization effects. The pellets improve soil loosening and water retention, helping plants maintain stable growth under varying moisture conditions. Its polymer-free production process makes it a sustainable option for professional growers focused on organic farming systems.

AVEMA Dura-N



AVEMA Plena NPK+Mg



AVEMA Rapid-N



Table 5. Comparative analysis between fertilizer products (Avema, 2026b)

Characteristic	AVEMA Dura-N	AVEMA Plena NPK+Mg	AVEMA Rapid-N
Fertilizer Type	Organic N Fertilizer	Organic NPK Fertilizer	Organic N Fertilizer
NPK Ratio	13-0-0	8-3-10	13-0-0
Main Purpose	Slow-release nitrogen supply	Balanced crop nutrition	Faster nitrogen availability
Organic Matter	86.23%	50%	84.83%
Key Benefit	Long-term depot fertilization	Complete nutrient support	Continuous nitrogen release
Recommended Crops	Viticulture, nurseries, long-term crops	Vegetables, berries, hedges, shrubs	Plant, vegetable, and fruit growing
Moisture Regulation	Excellent water retention	Excellent water retention	Excellent water retention
Soil Improvement	Improves structure and aeration	Improves structure and aeration	Loosens soil and improves structure
Pellet Characteristics	Suitable for manual application	Suitable for manual application	Suitable for manual application
Production Process	Polymer-free	Polymer-free	Polymer-free
Organic Farming Approval	Approved for organic production in Germany	Approved for organic production in Germany	Approved for organic production in Germany

Legislation and Final market

Products are distributed in the German, Austrian and Swiss markets: FiBL-listed according to audit standards: Bioland & Naturland Germany, Gaa, Ecovin Germany, Betriebsmittelliste Germany, EU organic legislation

Final Product (Others)

AVEMA's innovation strategy is built around transforming industrial by-products from leather manufacturing into high-value, sustainable solutions for multiple industries. By applying circular economy principles and advanced material engineering, the company develops biodegradable, recyclable, and resource-efficient products that replace conventional petroleum-based or

disposable alternatives. The company's portfolio demonstrates how upcycled collagen and natural fibre technologies can be successfully integrated into the Garden & Leisure, Construction, and Industrial sectors, creating products that combine sustainability with high technical performance.

In the Garden & Leisure sector, AVEMA focuses on biodegradable and environmentally responsible products designed for both hobby users and professional applications. *The Plantpot GRETA pro* is a fully biodegradable cultivation pot made from miscanthus fibres, stabilised collagen fibres, natural waxes, and vegetable succinates. Unlike conventional plastic pots, GRETA pro decomposes directly in the soil within a few weeks, eliminating transplant waste while simultaneously releasing nitrogen that supports root growth and humus formation. The product is also compatible with commercial potting machinery, making it suitable for industrial horticulture as well as home gardening.

The *GRETA pro plant set* expands this concept into a complete sustainable growing solution. The set combines biodegradable GRETA pro pots with high-quality seeds and peat-free coconut swelling substrate, creating an eco-friendly planting system that simplifies cultivation from sowing to harvesting. The sets are designed for seasonal gardening, promotional gifts, and retail applications while reducing plastic waste and protecting peatlands through the use of renewable materials.

AVEMA also developed the *TEEO golf tee* as a sustainable alternative to conventional plastic golf tees. Produced from natural and biodegradable materials, the product addresses the growing demand for environmentally friendly accessories in sports and leisure while maintaining the durability and functionality required for practical use.

In the Construction sector, AVEMA introduced *CALOR* sound and thermal insulation, an insulation solution based on recycled leather fibres and natural materials. CALOR combines acoustic and thermal insulation properties with moisture-regulating performance, contributing to healthier indoor climates and energy-efficient buildings. The material is particularly suitable for prefabricated housing and sustainable construction projects, where low-energy and water-free manufacturing processes support reduced environmental impact.

For industrial applications, *KOLLAMAT*[®] compound represents a sustainable alternative to crude oil-based plastics. Manufactured from recycled leather fibres and bio-based polymers, the compound offers moisture regulation, shock absorption, impact resistance, UV stability, and a warm natural surface feel. *KOLLAMAT*[®] can be processed through injection moulding, extrusion, or pressing, enabling applications such as tool handles, ski and hiking poles, floorboards, profiles, and technical surfaces. Its flexible processing characteristics and energy-efficient production make it a versatile material for modern industrial manufacturing.

Table 6. Comparative analysis between other upcycled products (Avema, 2026a)

Product / Solution	Sector*	Main Material Basis	Key Features	Sustainability Benefits	Typical Applications
Plantpot GRETA pro	G & L	Miscanthus fibres, stabilised collagen fibres, natural waxes, vegetable succinates	Fully biodegradable, self-fertilising, root-growth support, machine compatible	Eliminates plastic pot waste, contributes to humus formation, releases nitrogen naturally	Professional horticulture, nurseries, home gardening
GRETA pro Plant Set	G & L	GRETA pro biodegradable pots, peat-free coconut substrate	Complete cultivation kit, biodegradable, promotes healthy growth	Plastic-free packaging, peat reduction, natural fertilisation	Hobby gardening, retail plant kits, promotional gifts
TEEO Golf Tee		Natural biodegradable materials	Durable and eco-friendly golf accessory	Reduces plastic waste in sports and leisure	Golf courses, sports accessories
CALOR Insulation	C	Recycled leather fibres and natural materials	Thermal and acoustic insulation, moisture regulation	Low-energy production, recycled content, improved indoor climate	Sustainable buildings, prefabricated houses
KOLLAMAT® Compound	I	Recycled leather fibres and bio-based polymers	Impact-resistant, shock-absorbing, moisture-regulating, UV-stable	Replaces petroleum-based plastics, energy-efficient processing	Tool handles, floorboards, technical components, profiles

* G & L – Garden and Leisure, C – Construction, I - Industry

2.2.2. LKAB (Luleå, Sweden)

Location

LKAB (Luossavaara-Kiirunavaara AB) is headquartered in Luleå, northern Sweden (Figure 17), with its main mining operations located in Kiruna and Malmberget near Gällivare. These sites lie within the Arctic region of Norrbotten County and are home to some of Europe’s largest underground iron ore mines. LKAB’s strategic location allows efficient transport of iron ore via rail to export ports in Luleå and Narvik (Norway), connecting Swedish raw materials to global markets.

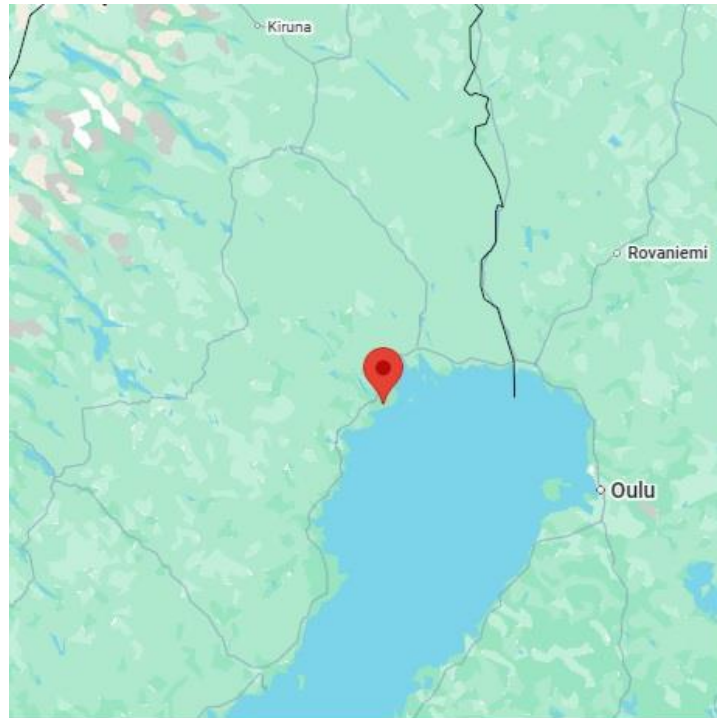


Figure 17. LKAB's location in Sweden.

Technological Process

LKAB is Sweden's leading iron ore producer, operating large-scale underground mines in Kiruna and Malmberget, where high-grade magnetite is extracted and processed into iron ore pellets. These pellets are shipped globally via ports in Luleå and Narvik. In addition to its core mining operations, LKAB is pioneering circular waste processing technologies to recover valuable materials from mine tailings. Through flotation and chemical extraction, LKAB transforms waste sand into apatite concentrate, which is further refined to produce phosphorus, rare earth elements, and gypsum, supporting both resource efficiency and the EU's green transition.

LKAB's waste-processing workflow, shown in Figure 188, starts with recovering tailings sand from their iron ore plants in Kiruna and Malmberget, using flotation in mobile pilot plants to produce a high-purity apatite concentrate. This concentrate is then transported, most often to a Circular Industrial Park in Luleå, where it undergoes chemical processing: it's dissolved in hydrochloric acid to extract phosphorus and rare earth elements (REEs), while regenerating hydrochloric acid (HCl) using sulphuric acid to yield gypsum as a by-product. Part of this innovation includes the KMAP (CleanMAP) technology, an energy-efficient method that effectively separates phosphates from contaminants like fluoride and arsenic. Additionally, LKAB collaborates with Boliden to generate fossil-free sulfuric acid from mine waste pyrite, used in these processes, retrieving heat and iron oxide by-products in the process. Through these integrated steps (shown in Figure 188), flotation, chemical extraction, acid regeneration, and side-stream valorisation, LKAB converts historic tailings into critical raw materials, minimizes waste deposition, and bolsters Europe's transition to a circular, sustainable mining model (LKAB, n.d., 2021, 2025).

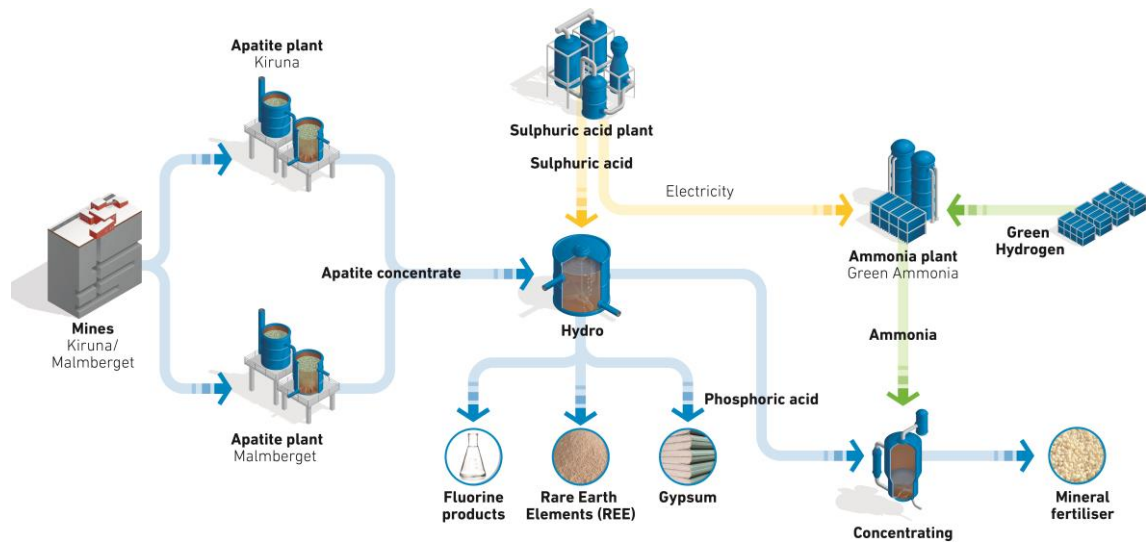


Figure 18. Process flow for recycling mine waste into critical minerals at LKAB.

Source: (LKAB, 2020).

Final Product

LKAB's primary output remains high-quality iron ore pellets (Figure 199), produced from magnetite extracted at the Kiruna and Malmberget mines. In 2024, LKAB mined approximately 22.7 million tonnes of ore and supplied 21.9 million tonnes of pellets to international steel producers, accounting for nearly 87 % of the company's total product sales.



Figure 19. LKAB iron ore pellets, each with ~67 % iron concentration.

Source: (LKAB, 2026).

Alongside traditional products, LKAB is advancing its circular economy strategy by repurposing mine waste. Their ReeMAP process enables extraction of apatite concentrate from tailings, with pilot production running in Malmberget and Kiruna. Once scaled, the process is expected to yield around 400,000 t/year of apatite concentrate (Figure 2020).



Figure 20. Apatite concentrate produced from mine tailings during ReeMAP pilot phase.

Source: (LKAB, 2025).

This concentrate is further processed into phosphorus-based mineral fertilizer, rare earth elements (REEs), and gypsum. The projected annual REE output, given apatite tailings contain 1,200–1,500 ppm, could range from 10,000 to 15,000 t, potentially addressing up to 30 % of EU’s REE demand.

Finally, gypsum, formed as a by-product of acid regeneration in the processing stage, is a valuable secondary resource typically used in construction materials.

2.2.3. Ekoväx (Hova, Sweden)

Location

Ekoväx i Norden AB operates mainly from Slätte Gård, a rural farmstead near Töreboda, and also maintains presence at Storkila Gård near Hova. Both sites are located in southern Västra Götaland County (Figure 21), showing their strong regional footprint in eco-agricultural and organic fertiliser activities.



Figure 21. Location of the operations of Ekoväx in Sweden.

Technological Process

Ekoväx produces organic fertilizers through a carefully controlled process that combines sustainable sourcing with modern agricultural technology. At their facility in Storkila Gård, raw materials such as meat-and-bone meal, vinasse, and dolomite lime are received and blended according to tailored recipes developed through field trials at Slätte Gård, the company's demo farm. The blended mixture is then pelletized using advanced equipment that ensures consistent granule size and low dust levels, resulting in high-quality AgroPellets suitable for organic farming. In parallel, Ekoväx manufactures liquid fertilizers, which are prepared and stored in bulk tanks for efficient delivery. Throughout the process, quality assurance is maintained through regular testing and feedback from on-farm applications, ensuring that the final products meet both ecological standards and practical agronomic needs. This integrated approach allows Ekoväx to deliver over 10,000 tonnes of organic fertilizer annually, supporting sustainable agriculture across Sweden (EKOVÄX, 2026a, 2026b).

Final Product

Ekoväx offers a diverse range of KRAV-certified organic fertilizers, primarily in the form of AgroPellets and complementary liquid fertilizers, all produced at their Storkila Gård facility. Their AgroPellets line includes nutrient-balanced pellet blends suitable for various crops: AgroPellets 8-3-5-3 (NPKS blend with animal- and vinasse-based inputs), AgroPellets N-14 (high-nitrogen, blood-meal-based), 10-3-1, 6-3-8-4, 6-5-2-1, and 4.4-1.5-2 (for established forage), all tailored for organic arable and horticultural use and designed for precise placement by seeding or fertiliser drills. These low-dust, pelletized formulations deliver nutrients directly to moist soil zones to optimize uptake and support sustainable cropping practices. Production operates for about 10

months annually, and over 16,000 tonnes of AgroPellets have been delivered, while current production capacity exceeds 10,000 tonnes per year.

Additionally, Ekoväx produces liquid fertilizers derived from the same ecological raw materials, meat-and-bone meal blended with vinasse, configured for bulk-tanker dispensing to facilitate efficient and flexible nutrient application. Beyond fertilizers, their product portfolio also includes regional offerings like organic seeds, forage seeds, and various granulated agricultural limes (dolomite, calcite, magprill), all aligned with their mission to support certified organic agriculture in Sweden.

2.3. Municipal Origin

2.3.1. Ostara Nutrient Recovery System (Cielcza, Poland)

Location

The wastewater treatment plant in Cielcza, near Jarocin (Figure 22), is successfully operating a pioneering system for recovering phosphorus from sewage sludge and wastewater. This innovative installation is the first of its kind in Poland and one of only a few in Europe. It marks a significant step toward a circular economy by enabling the reuse of valuable nutrients that would otherwise be lost in the treatment process.

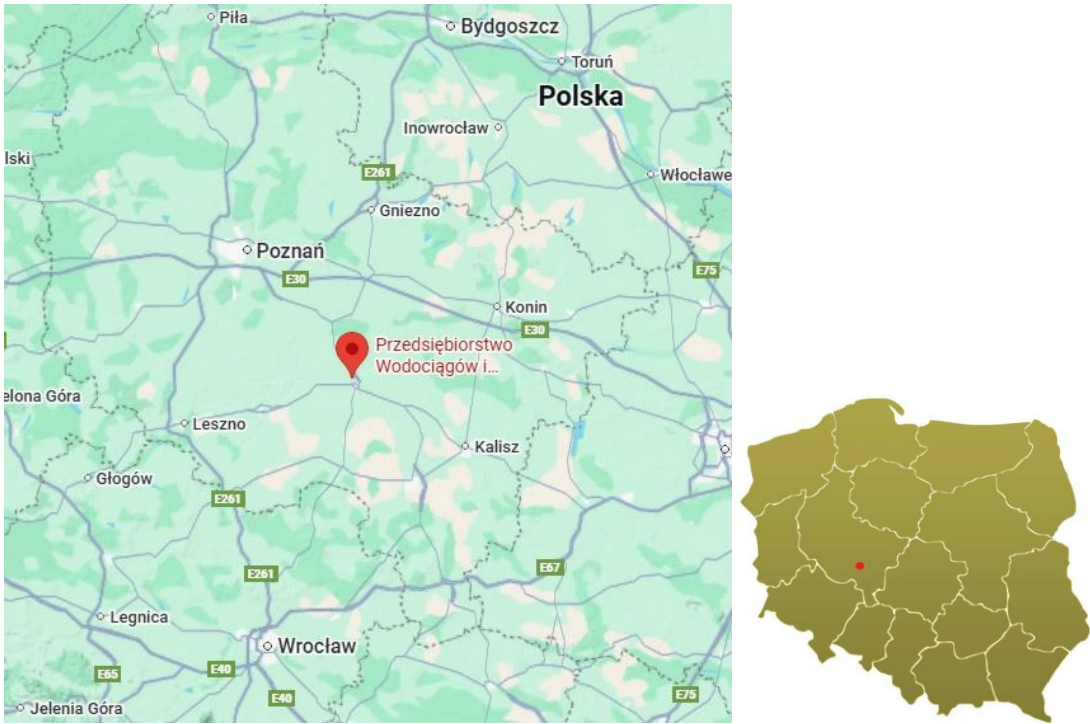


Figure 22. Ostara system location.

The municipality of Jarocin utilizes the recovered phosphorus to fertilize and maintain green public spaces, reducing reliance on synthetic fertilizers. In addition to phosphorus recovery, the

facility is designed to reduce sewage sludge volumes, lower the concentration of nitrogen and phosphorus in treated wastewater, and recover water for reuse.

Technology

The modernization of the plant has equipped it with the capacity to process up to 12,500 m³ of wastewater daily, serving a population equivalent of 93,285. Each day, the facility handles around 8,000 kg of sewage sludge (dry matter). The total cost of the modernization amounted to €66.2 million, with the upgraded system now fully operational.

A central element of this technology is the Ostara process, which recovers phosphorus in the form of magnesium-ammonium phosphate, or struvite. This process occurs in a fluidized bed reactor and involves several technical steps, demonstrated in Figure 23:

- (1) Sludge preparation – Sewage sludge is separated and treated anaerobically to release nutrients into the liquid phase.
- (2) Energy recovery – Anaerobic digestion thickens and ferments the sludge, generating biogas. The liquid effluents (a, b) are directed to the fluidized bed reactor.
- (3) Struvite crystallization – Magnesium is added, pH is regulated, and flow is controlled to allow struvite crystals to form and grow.
- (4) Struvite drying and pellet formation – Once large enough, the crystals are collected, dried, and formed into fertilizer pellets.

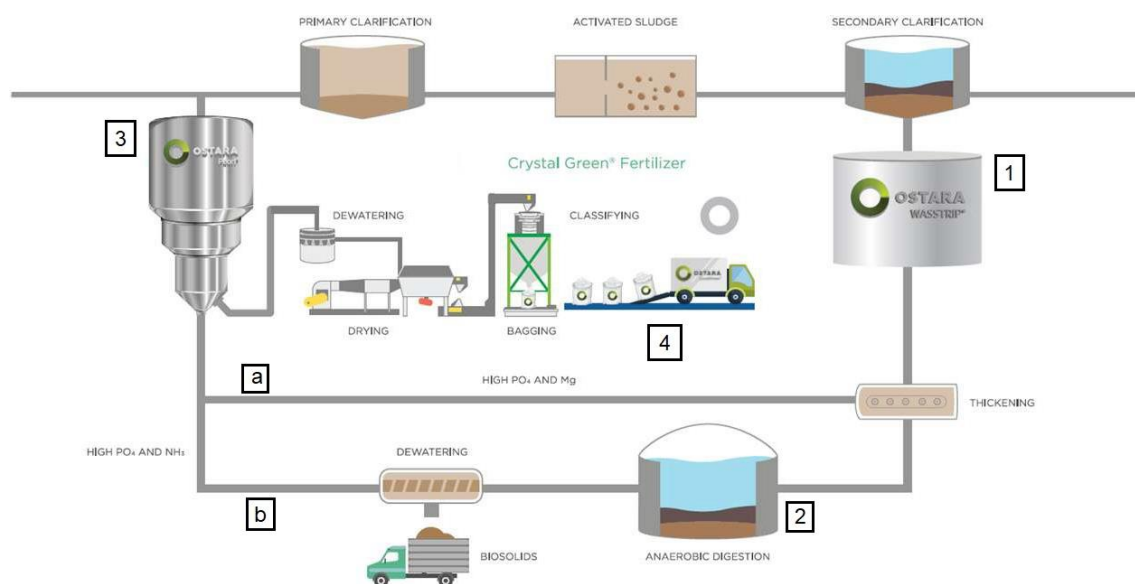


Figure 23. Ostara Technology.

Source: (Ostara, 2026).

Final Product

The resulting mineral fertilizer, shown in Figure 24, contains:

- 5% Nitrogen (NH₄)

- 28% Available Phosphates (P_2O_5)
- 10% Magnesium



Figure 24. Struvite produced using the Ostara Technology.

Annual outcomes of the full-scale implementation include:

- 40–50% reduction in sewage sludge mass
- 80% recovery of phosphate ions (PO_4^{3-})
- 15% recovery of ammonia (NH_3)
- Production of 170 Mg of fertilizer per year
- Recovery of 700,000 m³ of water annually for reuse

This forward-looking project demonstrates how modern wastewater treatment can contribute to resource recovery, climate protection, and sustainable land management.

2.3.2. Sanitation 360 (Visby, Sweden)

Location

Sanitation360 is a Swedish company located on Gotland, an island in the Baltic Sea (Figure 255), where the consequences of nutrient mismanagement are evident in the emergence of harmful algal blooms.



Figure 25. Sanitation360 location in Visby, Sweden.



Figure 26. Sanitation 360 logo.

Source: (Sanitation 360, 2025).

Technology

Sanitation360 has developed a urine recycling technology that captures the nutrients in urine (mainly through urine-diverting toilets and urinals) and produces a fertilizer that works with farmer’s conventional machinery/equipment, as shown in Figure 277. The nitrogen is captured thanks to Sanitation360’s stabilising chemical blend, dosed directly into the collection tank of the urine diverting toilet or urinal, which prevents the formation of ammonia and thereby prevents nitrogen losses. After collection, the urine is dehydrated into a semi-solid mixture that can be granulated into a solid, granular fertilizer. The drying process is mainly run using solar power and waste heat from industries. The process reduces the volume and weight of the urine drastically (x25 times) enabling easier transport, storage and on-farm use.

Conditions:

- Source-separated urine (uncontaminated by flush water or faeces).
- Drying: the urine is heated (ca. 40–60°C) to eliminate pathogens with controlled airflow.
- Best suited for places with either continuous or seasonal but high-volume urine flows, e.g. festivals, public toilets, or buildings with urine-separating systems.



Figure 27. Urine treatment (left), collection and transportation (middle), and use in form of fertiliser (right).

Source: (Sanitation 360, 2025).

Nutrient recovery is known to be high as ~80–90% of nitrogen (N) is retained (depends on drying settings). Moreover, nearly 100% of phosphorus (P) and potassium (K) are preserved.

The process reduces the risk of nitrogen loss and produces a pathogen-safe product that can be stored for long periods and transported safely.

Sanitation360 operates from pilot-scale to small commercial-scale production. Ongoing production supports research and demonstration activities, particularly on Gotland, in Malmö, and in Uppsala, Sweden. The solution can serve a wide range of food producers, such as breweries, restaurants, and demonstration farms.

The product is provided in a dry, granular form that is easy to spread using conventional farming equipment. It is fully hygienized, making it safe to store and transport.

The cost structure is approximate and varies depending on scale. Capital expenditure (CapEx) is low to moderate, with the main costs arising from urine-diverting toilet installations and drying units. Operational expenditure (OpEx) is kept low due to minimal energy requirements, particularly when solar drying is employed, though labour and maintenance are needed for handling and logistics. Transport and storage are more cost-effective than for liquid urine, thanks to the significant reduction in volume.

Sanitation360's goal is to price the urine-based fertilizer competitively with conventional mineral fertilizers, whose prices fluctuate throughout the year based on availability and demand. While the company's current production costs are higher, they are committed to ensuring affordability for farmers. They are actively scaling up production and working to reduce costs, aiming to make urine fertilizer a viable economic alternative.

The pricing model is still under development but is envisioned to be competitive with mineral fertilizers, particularly when:

- accounting for environmental benefits such as reduced emissions and local availability,
- reducing reliance on the volatile import prices of synthetic fertilizers.

Final Product

Nutrient content

Approximate composition (can vary slightly by batch): The dried urine fertiliser is presented as granules, as illustrated in Figure 28. These granules are easy to handle and spread using standard farming equipment, offering a practical and visually recognisable product for agricultural use.

- 10–15% N (mainly as urea)
- 1–2% P
- 3–4% K



Figure 28. Final product: dried urine granules.

Source: Sanitation 360 (2025)

The nutrient profile is similar to NPK mineral fertilizers but based entirely on recycled inputs. In addition, as illustrated in Figure 2929, dried urine fertiliser has already been used successfully by farmers. In 2024, Sanitation360 collected urine and produced 100 kilograms of granulated fertiliser, demonstrating its practical application. If scaled to collect urine from the entire population of Sweden, it is estimated that 25–30% of the mineral fertilisers currently used in Sweden could be replaced, highlighting its potential to support local agriculture and reduce dependency on conventional fertilisers.

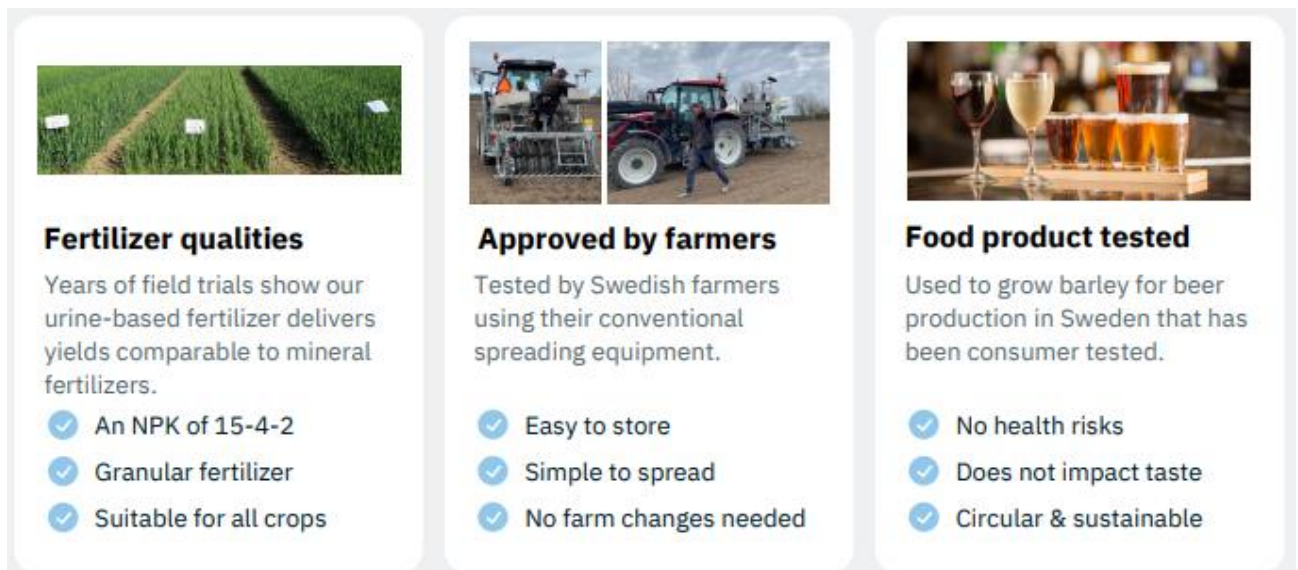


Figure 29. The use of dried urine fertiliser so far.

Source: Sanitation 360 (2025)

The extra benefits of using dried urine fertilizer include reducing the load on wastewater treatment systems and preventing nutrient pollution by eliminating excess nitrogen and phosphorus leaching. It also contributes to greater local nutrient self-sufficiency and strengthens climate resilience and food security, which is particularly important during geopolitical crises or supply chain disruptions.

2.3.3. Ämmässuo Eco-industrial centre, (Espoo, Finland)

Author: Ari-Matti Seppänen, Sari Luostarinen

Location

Biowaste treatment of Finland's capital region has been centralized to Ämmässuo Eco-industrial park in Espoo, 20 km from Helsinki (Figure 3030). Annually 50 000 tons of biowaste, 20 000 tons gardening wastes and 3 000 tons of sewage sludge are treated at this 200 ha facility complex. At the same facility, there is a waste assortment and power plant that processes 170 000 tons of mixed municipal waste yearly.



Figure 30. Location of Ämmässuo Eco-industrial centre, near Helsinki, Finland.

Technology

At the eco-industrial park (Figure 31), incoming biowastes are first crushed and sieved into two types: coarse and fine. Coarse biowaste is composted in windrows along with additional materials, while fine biowaste undergoes anaerobic dry digestion. Gardening waste is also crushed and composted in windrows. After digestion, the resulting digestate is separated by a centrifuge. The wet fraction produced serves as fertiliser for local agriculture, and the solid fraction is added to the windrow composting process.



Figure 31. Ämmässuo Eco-industrial park.

Source: HSY (2025).

HSY is actively attending research projects to try out new solutions to biowaste and sewage sludge recycling. HSY has invested in a pyrolysis pilot to produce biochar from municipal sewage

sludge. Sewage sludge is firstly mixed with sieved compost enhancers such as woodchips, then thermally dried using the pyrolysis heat and finally pyrolyzed in 450-650 °C. The piloting started in 2023 and currently the research is focusing on phosphorus recovery and agricultural use of the produced biochar.

In CiNURGi, HSY and Natural Resources Institute Finland (Luke) are cooperating to develop an alternative processing chain for the digestates solid fraction. A combination of extrusion, infrared drying, milling and pelletizing are studied at Luke's support centre Biopaja. This process chain is estimated to produce a granular fertilizer product that would be suitable to be transported over long distances from the production site.

Final product

Annually, the biowaste processed generates 3.9 million m³ of biogas, with its energy content being utilised to produce 9.3 GWh of electricity and 8 GWh of heat. Each year, 15 000 tons of matured compost are sieved and incorporated as components in landscaping products. Compost from Ämmässuo (Figure 32) is blended with silt soil and peat, then distributed to home gardens and landscaping projects as a growth medium. In addition, the biocompost produced at Ämmässuo has a total solids content of 28%, with organic material making up 9.4%. The nutrient content is 0.4 g/kg for nitrogen, 0.1 g/kg for phosphorus, and 1.7 g/kg for potassium, as detailed in Table 7.

Table 7



Figure 32. Main products of Ämmässuo Eco-industrial parks biowaste line are soil amendments and bioenergy.

Source: HSY (2025).

In July 2025, a new digestate processing plant commenced operations, which will significantly transition the treatment of digestate from traditional composting to the production of organic certified fertiliser for local agriculture.

Table 7. Chemical composition.

Product	Total solids (TS%)	Organic material content %	Nutrient content (N:P:K) g/kg TS
Biocompost	28	9,4	0.4:0.1:1.7

2.3.4. EKT Ecobio OU (Maardu, Estonia)

Location

The EKT Ecobio biogas plant is situated in Maardu, a town in northern Estonia just east of the capital city, Tallinn (Figure 33). Maardu is part of Harju County and lies close to major transport routes, making it an ideal location for both receiving bio-waste from Tallinn and the surrounding areas and distributing biogas and fertiliser products. The plant is positioned within an industrial zone, which facilitates efficient logistics and access to infrastructure. Its proximity to urban centres enables the collection of biowaste from households, grocery stores and canteens, supporting the plant's sustainable operations. Additionally, the surrounding agricultural land in northern Estonia provides opportunities for the use of digestate fractions as fertiliser, further promoting circular economy principles.

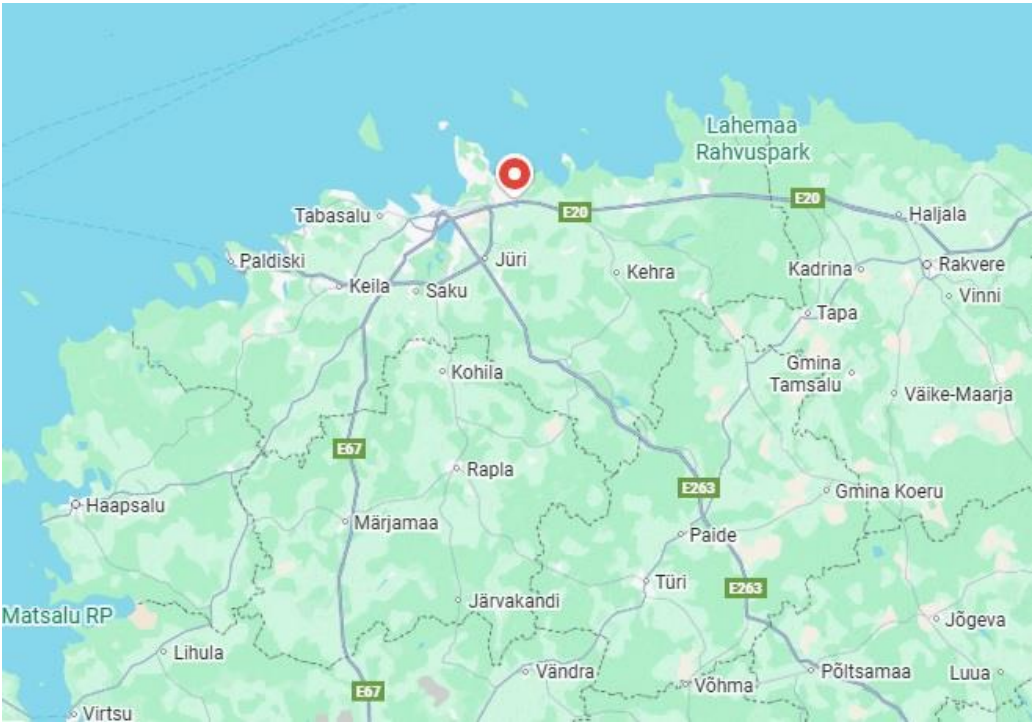


Figure 33. Location of the EKT Ecobio biogas plant in Estonia.



Figure 34. EKT Ecobio logo.

Technology

The EKT Ecobio biogas plant in Maardu (Figure 35) operates according to a sustainable circular system. The plant started operations in spring 2023 and reached full capacity in 2024. It uses separately collected biowaste from households, grocery stores and canteens to produce biogas (used as fuel for buses in Tallinn). The separated digestate fractions are used as fertilizer in northern Estonia.



Figure 35. EKT Ecobio biogas plant in Maardu.

Source: (Hajru Elu, 2023).

The raw materials are bio-waste collected separately across Estonia, mainly from Tallinn and its surrounding areas, as shown in Figure 36. When needed, it also accepts category II and III animal waste.



Figure 36. Separately collected bio-waste being unloaded into the reception bin (left), grocery store waste awaiting pre-treatment at EcoBio before entering the fermenters (right).

Author: Kalvi Tamm (2025)

The stages of the technological process are shown in Figure 37 and described below:

- (1) Shredding and Homogenization – the incoming waste is first shredded and homogenized to ensure uniform particle size and consistency.
- (2) Hygienization – the material is treated for at least one hour at 70 °C to eliminate pathogens and ensure sanitary safety.
- (3) Fermentation – the sanitized feedstock undergoes anaerobic digestion in thermophilic horizontal reactors at 37–40 °C. Two 1,000 m³ reactors operate in parallel, alternately fed at about 2 t/h, with a residence time of around 20 days.
- (4) Post-Digestion Storage – the digestate is transferred to two 2,500 m³ covered tanks, where it remains for at least one month. Retention time depends on feedstock input and ongoing gas production.
- (5) Gas Purification and Utilization – the raw biogas is purified and upgraded to biomethane. Part of the biomethane is supplied to the Maardu industrial park gas network, while another portion is compressed and used directly as fuel for buses.

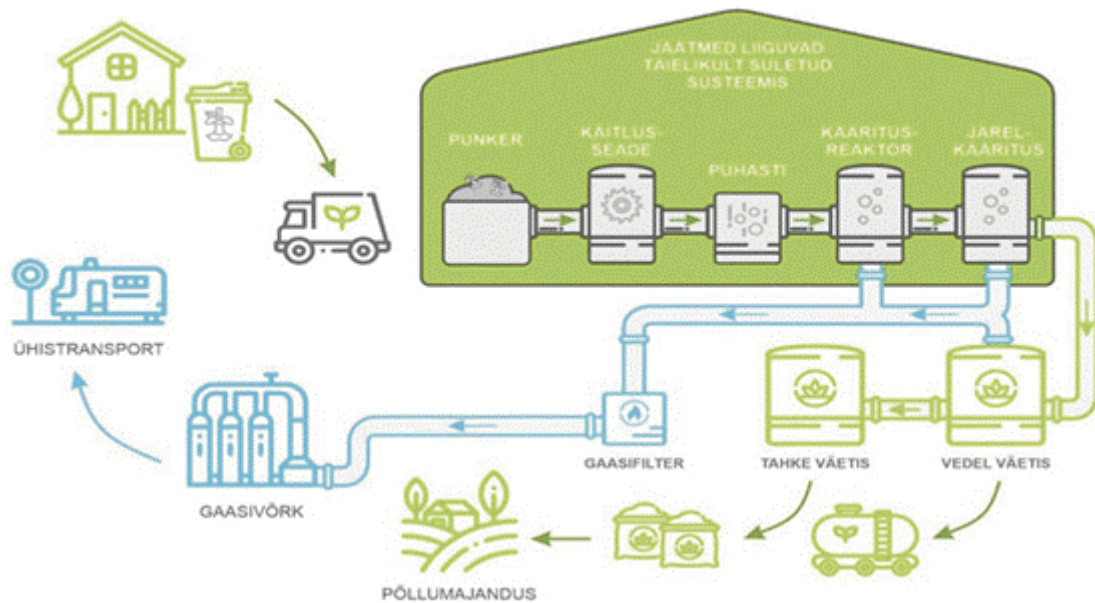


Figure 37. Waste processing process.

Source: (Hajru Elu, 2023).

Final product

The plant processes about 21,000 tons of bio-waste annually, producing:

- Biomethane: over 1.52 million m³ per year. Part of the gas goes to the Maardu industrial park gas network; part is compressed and used as fuel for Tallinn city buses.
- Digestate: about 27,000 t/year, after fermentation, it is separated into solid (approx. 1,000 t/year, Figure 388 - left) and liquid (approx. 26,000 t/year, Figure 388 - right) fractions (from the interview with EcoBio manager, in April 2026).

The liquid fraction is suitable as a liquid fertilizer, while the solid fraction can be used as an organic fertilizer and soil improver.



Figure 38. Separated solid (left) and liquid (right) fractions of digestate

Author: Taavi Võsa (2025)

Table 8 displays the chemical composition of the liquid fraction of digestate, highlighting its suitability as a fertiliser. Nitrogen (N) content is 0.57%, phosphorus (P) is 0.03%, and potassium (K) is 0.23%. The dry matter content is 2.7%, indicating a relatively dilute solution, and the pH-KCl is 8.8, which suggests the liquid fraction is alkaline. These values demonstrate that the digestate contains essential nutrients, making it beneficial for agricultural applications.

Table 8. Chemical compositions of digestate fractions.

Product	Nutrient content [%]			Dry matter content, %	PH-KCl
	N	P	K		
Liquid fraction	0.57	0.03	0.23	2.7	8.8
Solid fraction	1.6	0.37	0.55	62.2	8.4

2.3.5. iPHOS (Hünxe, Germany)

Location

The iPHOS system is a mobile unit, meaning that it does not have a permanent installation site. Instead, it can be deployed flexibly at wastewater treatment plants to process sludge from municipalities of varying sizes. The company’s headquarters are located in Hünxe, Germany (Figure 399), whereas the technology itself is designed for temporary on-site operation.

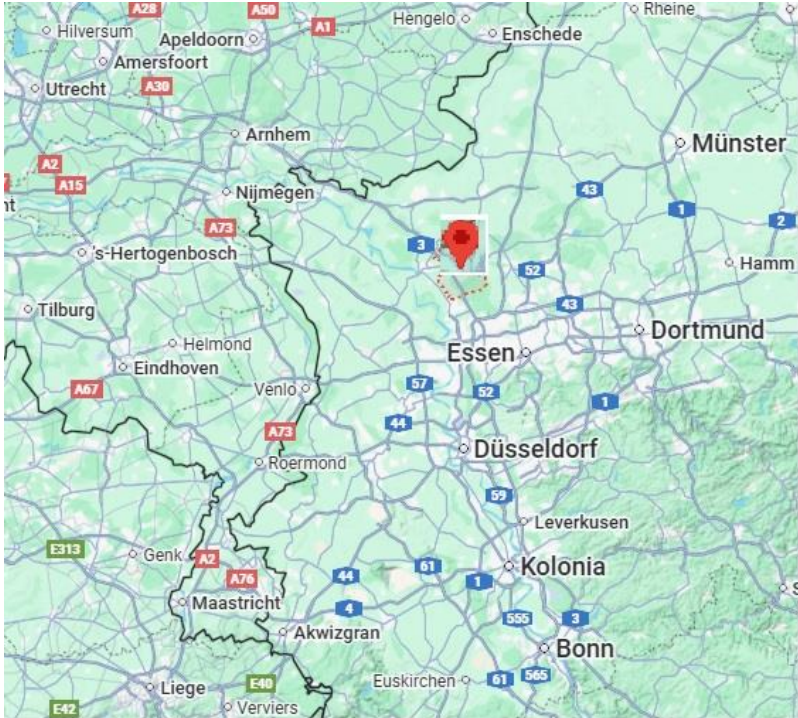


Figure 39. Location of the company headquarters in Hünxe, Germany, from which the mobile iPHOS unit is operated.

Technology

The iPHOS process is designed to recycle phosphorus (P) from wastewater. Implemented as a mobile unit, it can be deployed at wastewater treatment plants to treat sludge from communities of 5,000 to 15,000 inhabitants. The system has been in operation since the summer of 2025.

Figure 40 illustrates the mobile iPHOS unit, showcasing its transportable design which enables flexible deployment at different wastewater treatment sites. The unit is equipped to carry out the complete phosphorus recovery process on location, making it suitable for temporary use wherever needed.



Figure 40. The mobile iPHOS unit.

The iPHOS process mobilizes phosphorus from activated excess sludge (AES) via reductive treatment, after which the recovered phosphorus is precipitated as struvite. It is applicable to both biological phosphorus (bio-P) and iron-bound phosphorus (Fe-P) sludges.

The full recycling scheme consists of five treatment stages (Figure 41):

- (1) Reduction: The sludge is treated with a sulfur-containing reducing agent to convert bound phosphorus into a mobile form. This is the rate-limiting step of the entire process. A residence time between 10 and 24 hours is considered optimal.
- (2) Acidification: A mild acidification is applied, lowering the pH to about 4 to enable further phosphorus release.
- (3) Iron removal: Iron is removed (e.g. by precipitation or separation) to avoid interference with the phosphorus recovery.
- (4) Flocculation & dewatering: The sludge is flocculated and dewatered, so that the remobilized phosphate goes into the liquid phase (the permeate).

(5) Precipitation: The dissolved phosphate is precipitated as magnesium ammonium phosphate (struvite).

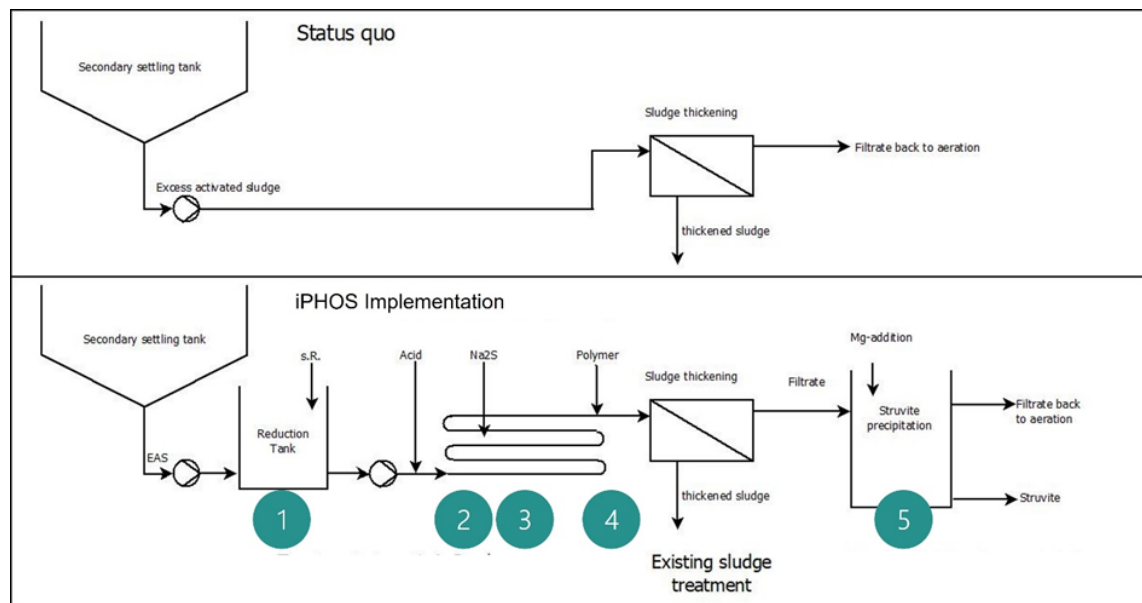


Figure 41. Implementation of iPHOS on a WWTP, numbers indicate the location of the treatment steps of iPHOS.

Final product

The final product is a struvite granulate: magnesium ammonium phosphate hexahydrate ($\text{MgNH}_4\text{PO}_4 \cdot 6\text{H}_2\text{O}$).

Composition (approximate dry weight): 5 % Nitrogen (N), 23 % P_2O_5 , 12 % MgO.

It is intended as a fertilizer product, to replace or supplement conventional P fertilizers, by recovering P from sewage sludge.

2.3.6. Aqua2N (Copenhagen, Denmark)

Location

The EasyMining–Aqua2N demonstration (pilot) is located at the Lynetten wastewater treatment plant (WWTP) in Copenhagen, Denmark (Figure 42), and is operated by the Swedish company EasyMining AB (part of the Ragn-Sells Group) (EasyMining, 2023). The pilot focuses on municipal wastewater treatment plants, where reject water from sludge dewatering is treated to recover nitrogen in a usable fertiliser form.

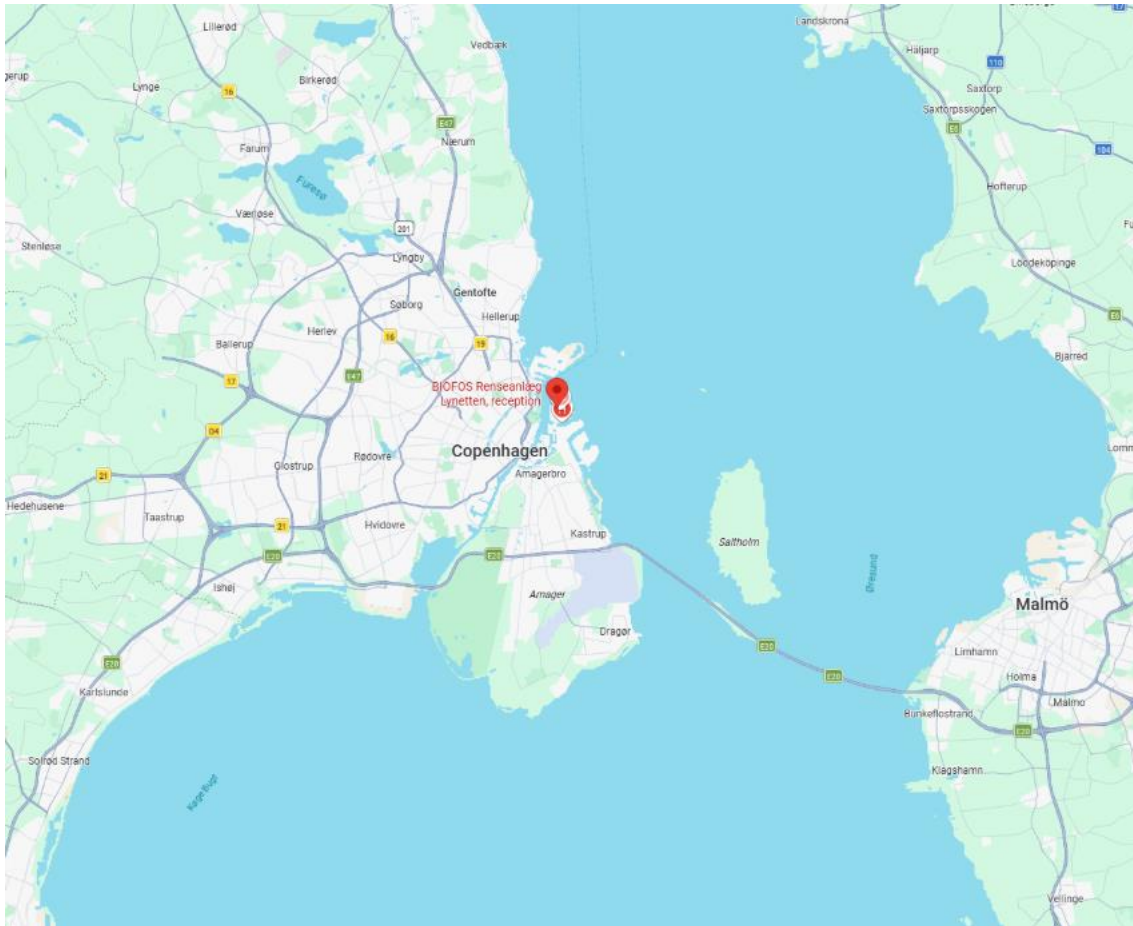


Figure 42. Easy Mining – Aqua2N implementation.

Technological Process

The Aqua2N process treats ammonium-rich reject water (sludge dewatering liquor) from wastewater treatment plants and recovers the nitrogen as an ammonium salt. According to EasyMining, Aqua2N is a two-step chemical process in which ammonium nitrogen is first captured with a precipitation chemical and separated from the wastewater, and then converted to ammonium sulphate while the precipitation chemical is regenerated and reused (EasyMining, 2025; European Sustainable Phosphorus Platform, 2022).

Reject water (sludge dewatering liquor) is routed to the Aqua2N unit, which targets the ammonium nitrogen in this sidestream.

Step 1 – precipitation/capture: ammonium nitrogen is captured using a specific precipitation chemical, forming a separable solid phase.

Solid–liquid separation: the precipitated solids are separated from the treated water (e.g., by mechanical separation such as centrifugation in the pilot setup).

Step 2 – conversion and regeneration: the precipitant is regenerated and returned to the capture step, while an acid step (typically sulphuric acid) converts the recovered nitrogen to ammonium sulphate suitable for direct use in fertilisers or as a feedstock in fertiliser production.

The process operates at ambient or slightly elevated temperature and atmospheric pressure and is designed to be more robust than biological nitrogen removal, avoiding conversion of nitrogen to N₂ gas.

In demonstration operation, the process has been reported to remove and recover around 95% of ammonium nitrogen from sludge liquor, while lowering the nitrogen load on the main biological treatment line and thereby reducing nitrous oxide emissions associated with conventional nitrogen removal (EasyMining, 2023, 2025).

Final product

The recovered product is ammonium sulphate ((NH₄)₂SO₄), marketed by EasyMining as RevoPure. When operated with sulphuric acid, Aqua2N produces a liquid ammonium sulphate solution (reported up to ~20% concentration; higher concentrations can be achieved with an additional evaporation step) (EasyMining, 2025).

- Provides readily plant-available nitrogen (as NH₄⁺) and sulphur.
- Can be applied as a liquid fertiliser (where permitted) or used as an ingredient/feedstock in fertiliser production.
- Replaces part of conventional, fossil-based nitrogen fertiliser production by recovering nitrogen from wastewater side streams.
- Supports reduced nitrogen discharge to water bodies by removing ammonium nitrogen from reject water prior to return flows to the main treatment line.

3. Comparison of technologies and efficiency of different facilities

The following chapter provides a comparative overview of nutrient-recycling technologies implemented in the Baltic Sea Region. The purpose of this comparison is to highlight similarities and differences in applied technological solutions, types of recovered nutrients, compliance with regulatory frameworks, as well as the agronomic value of recovered products. The assessment supports the identification of key strengths and potential limitations of the evaluated technologies, thereby helping to guide future implementation, investment planning, and policy development.

Table 9 summarizes the main characteristics of the analysed RNF technologies. The comparison considers: (a) nutrients recovered (N, P, K), (b) primary feedstock used, (c) resulting fertiliser product form, (d) status of compliance with EU or national legislation, and (e) estimated bioavailability of nutrients.

The table is intended to provide an accessible overview of the functionality and regulatory maturity of each solution and highlight the extent to which nutrient forms are plant-available. This facilitates a clearer understanding of how technical and material choices translate into agronomic performance. It also provides context for evaluating whether these products can be positioned as substitutes for conventional mineral fertilisers or serve more specialised roles.

Table 9. Comparative Analysis of RNF Technologies in the Baltic Sea Region.

Facility / Technology	Nutrient(s) recycled	Substrate / feedstock	Form of RNF	Compliance with national / EU legislation	Estimated bioavailability
Gyllebo Gödning (SE)	N, P, K	Animal by-products	Pellets	CE-marked; organic farming	++
Jepua Biogas (FI)	N, P	Manure, plant residues	Digestate (liq./solid)	Aligned with EU rules	++
Scandagra Lietuva (LT)	N, P, K	Meat & bone meal	Granules	CE-marked; organic	++
Biodinamika (LT)	N, P, K	Composted beef manure	Granules	Organic farming	++
TURPS Organic OÜ (EE)	N, P, K + Ca, Mg	Peat, manure, wood ash	Granules	Compliant with organic rules	+

Facility / Technology	Nutrient(s) recycled	Substrate / feedstock	Form of RNF	Compliance with national / EU legislation	Estimated bioavailability
Biocover – SyreN (DK)	N	Manure (on-field capture)	Liquid ammonium sulphate	National approval	++
AVEMA (PL/ DE)	N, P, K	Bovine shavings from car upholstery plant	Granules	Organic production in Germany	++
LKAB (SE)	P	Industrial mineral streams	Mineral P product	Industrial compliance	+
Ekoväx (SE)	P, K	Ash / biomass residues	Granules	National rules	+
Ostara (PL)	P, N	Municipal sludge liquors	Struvite pellets	EU 2019/1009	+++
Sanitation360 (SE)	N, P, K	Source-separated urine	Granules	Pilot; hygiene compliant	+++
HSY (FI)	N, P, K	Biowaste digestate	Pellets (pilot)	Allowed	++
EKT Ecobio OU (EE)	N, P, K	Bio-waste	Digestate (liq./solid)	EU-compliant	++
iPHOS (DE)	P	Municipal sludge	Recovered P product	Mobile pilot; compliant	++
Aqua2N (DK)	N	Reject water	Liquid N fertilizer	Pilot; compliant	+++

Table 10 provides a qualitative overview of the expected costs and benefits associated with each showcased technology. Cost considerations refer primarily to estimated investment and operational requirements, whereas benefits focus on agronomic effects, contributions to nutrient circularity, reduction of environmental burden, and additional value streams (e.g., biogas recovery, sludge reduction).

This qualitative assessment supports the broader evaluation of the feasibility and scalability of RNF production pathways. By indicating comparative cost levels and identifying key benefits, the table enables a preliminary understanding of economic and environmental trade-offs. While not a full financial analysis, the overview highlights which solutions offer high-value nutrient

products, which deliver multiple resource-recovery functions, and where economic barriers may still limit widespread uptake.

Table 10. Qualitative Cost–Benefit Summary of RNF Technologies.

Facility / Technology	Cost level	Benefits
Gyllebo Gödning (SE)	Medium–High	CE-marked pellets; high quality; organic farming; established market
Jepua Biogas (FI)	Medium	Biogas + digestate utilisation; circular model; transport savings
Scandagra Lietuva (LT)	Medium	Granular product; improves soil; broad applicability
Biodinamika (LT)	Low–Medium	Composted manure; odour reduced; suitable for organic use
TURPS Organic OÜ (EE)	Medium	Soil health improvement; long-term effect; patented technology
Biocover – SyreN (DK)	Medium	Reduced N losses; on-field capture; GHG reduction
AVEMA (PL/ DE)		Slow release N fertilizer, long time supply improving water retention and soil health
LKAB (SE)	High	Industrial-scale P supply; high purity mineral product
Ekoväx (SE)	Medium	Reuses ash; improves nutrient cycling
Ostara (PL)	High	High-value struvite; P recovery; reduces sludge issues
Sanitation 360 (SE)	Medium	High N retention; local nutrient source; scalable
HSY (FI)	Medium–High	Adds value to biowaste; pelletisation; potential scaling
EKT Ecobio OU (EE)	Medium	Efficient biowaste recycling; biomethane co-production
iPHOS (DE)	Medium	Mobile unit; P recovery; decentral flexibility

Facility / Technology	Cost level	Benefits
Aqua2N (DK)	Medium	N recovery; pilot operations; fertiliser-grade product

4. Conclusions

The assessment of nutrient-recycling initiatives across the Baltic Sea Region demonstrates that a wide range of technological solutions exist to convert agricultural, municipal and industrial biomass streams into recycled nutrient fertilizers (RNFs). These solutions vary in maturity, nutrient form, legal status and market readiness; however, together they illustrate a strong technological foundation for advancing circular nutrient management.

Across the examined case studies, several key observations emerge. First, feedstock diversity remains one of the main drivers influencing product quality and processing choice. While manure and digestate-based RNFs offer soil-improving properties due to organic matter content, technologies such as struvite extraction and urine-based fertilizers provide highly plant-available nutrient forms suitable for targeted fertilization. Second, technologies differ in their degree of regulatory compliance and market acceptance. Products based on processed animal by-products or struvite already comply with EU fertilizer rules and can be commercially distributed, whereas solutions involving source-separated human excreta or wastewater-derived products face stricter regulatory pathways.

From an environmental perspective, nutrient recycling contributes to the reduction of nutrient losses into the Baltic Sea, helping to mitigate eutrophication. Many initiatives demonstrate co-benefits such as reduced sludge volumes, emission mitigation, and improved nutrient logistics. Nevertheless, challenges remain, particularly regarding heavy-metal control, hygienisation requirements, and the need for consistent product quality. Technologies that recover concentrated nutrient streams—especially phosphorus—show particular relevance given geopolitical constraints and the EU’s dependency on imported phosphate rock.

The cost–benefit evaluation revealed that while some technologies require substantial investment (e.g., struvite production), they can provide high-value, standardized products and create new business opportunities. Others, particularly composting and digestate-based approaches, offer lower-cost solutions with broader applicability, although their nutrient availability may be lower. A balanced technological portfolio will therefore be essential to achieving both circularity and economic feasibility across diverse regional contexts.

Overall, the findings confirm that nutrient-recycling technologies are increasingly mature and can play a significant role in supporting circular agronomy and regional nutrient balancing. To accelerate their uptake, continued progress is needed in the areas of policy integration, quality standards, certification, and cross-sectoral collaboration. Strengthening knowledge exchange and business models—core goals of CiNURGi—will be essential to scaling these solutions and delivering tangible benefits for agriculture, industry and the environment.

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