



INNOVATIVE RECOVERY TECHNIQUES
FOR ALTERNATIVE FERTILISERS

D1.4 Gaps and challenges of available recovering and recycling techniques

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FERTITEC Project Synopsis

The EU Horizon CSA project FERTITEC, funded under the *HORIZON-CL6-2024-ZEROPOLLUTION-01-02* call, promotes the circular economy by advancing **alternative fertilizing products** derived from secondary raw materials. By reducing dependence on conventional mineral fertilizers, the project addresses challenges in **waste management and environmental pollution**, contributing to sustainable nutrient recovery. Conventional fertilizer production depletes natural resources and generates pollution, underscoring the need for more **resource-efficient solutions**.

FERTITEC builds on expertise from previous EU-funded initiatives—including Novafert, SUSFERT, FERPLAY, SOILUTIONS, MainstreamBIO, SuMaNu, CiNURGi, and NUTRIMAN—by integrating advanced **waste recycling technologies** into fertilizer production. The goal is to develop **competitive, bio-based alternatives** that enhance both agricultural productivity and environmental sustainability.

Aligned with the **EU's strategic priorities** in sustainable agriculture, waste reduction, and the bioeconomy, FERTITEC also works to harmonise **sustainability certification systems** and improve the marketability of bio-based fertilizers. Through its **Knowledge Exchange Platform (KEP)**, the project fosters collaboration with key agricultural stakeholders to drive innovation in the fertilizer industry.

By **bringing forward Best Available Fertilizing Techniques (BATs) in several EU countries and extrapolating outcomes to the African Union**, FERTITEC supports the broader transition to sustainable fertilizing solutions. With a commitment to both **environmental sustainability and economic viability**, the project integrates learnings from past initiatives, engages industry actors, and applies state-of-the-art fertilizer technologies, helping shape the future of sustainable agriculture in Europe and beyond.

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Executive Summary

The deliverable D1.4 “Gaps and challenges of available recovering and recycling techniques” is the result of the implementation of task T1.5 “Assessing gaps and challenges of techniques for recovering/recycling fertilizing products from secondary raw materials”. The D1.4 report presents the scope of task T1.5 and describes in detail the methodological framework adopted for its implementation, as well as the action plan that guided its execution. It introduces the main issues associated with existing gaps and challenges that limit the large-scale uptake of techniques for the recovery and recycling of fertilizing products from SRMs. The report includes an assessment of the data collected, a set of relevant definitions and abbreviations, and a last chapter with a SWOT analysis of the data and the key outcomes and conclusions. The report is complemented by the annex, with the content of a dedicated online form used for fast and reliable data collection during the Co-creating Workshop with Expert Panel (EP).

The first chapter of the core part of the D1.4 reviews the scientific literature and identifies significant technological, regulatory, economic, and social barriers that hinder the large-scale implementation of nutrient recycling systems in Europe. The second chapter examines a significant and representative sample of EU projects (including B-Ferst, bio-SOLUTIONS, CiNURGi, FER-PLAY, FERTIMANURE, Lex4Bio, MainstreamBIO, Novafert, NUTRI-KNOW, NUTRIMAN, P2GreeN, SEA2LAND, SuMaNu, SYSTEMIC, and WaLNUT), and identifies gaps & challenges that limit the development, scale-up, and implementation of alternative fertilizers (AFs), biobased fertilizers (BBFs), and recycled nutrient fertilizers (RNFs). Across all projects, these limitations form an interconnected system of technical, environmental, economic, regulatory, social, and data-related challenges. The next section summarizes the findings from the FERTITEC project work to date (Task 1.1, Deliverable 1.3, and the 30 case studies from Task 1.3). It identifies the factors shaping the technological development and market uptake of AFs and confirms that progress in this sector is influenced by complex regulatory, technical, economic, agronomic, logistical, and socio-market conditions that act as both enabling and limiting factors. In the next step, data were collected from 24 interview questionnaires conducted in task T1.1, supported by the content of 19 interview questionnaires from the parallel CiNURGi project. The study confirmed the need to intensify efforts to develop technologies for recycling nutrients from secondary raw materials. Alternative fertilizers should be viewed as valuable products, not waste disposal methods. However, further development of the AF market requires strengthening public confidence, harmonizing regulations, and increasing financial support.

Based on the findings presented in Chapters 3.1–3.4, the key positive and negative factors influencing the development of AF technologies and the AF market were identified and incorporated into the SWOT analysis. The analysis revealed that the development of the alternative fertilizers market is significantly hindered by external risks, particularly legal complexities surrounding these products. However, favourable internal conditions, such as the availability of raw materials, and external opportunities, including EU initiatives related to the circular economy, have a positive influence on this market.

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List of Terms and Definitions

Abbreviation	Definition
AF(s)	Alternative Fertilizer(s)
AU	African Union
BAT	Best Available Technologies/Techniques
BBF(s)	Bio-Based Fertilizer(s)
BSR	Baltic Sea Region
Corg	Organic Carbon
CA	Consortium Agreement
CAP	Common Agricultural Policy
CMC	Component Material Categories
DoA	Description of Action
EC	European Commission
EP	Expert Panel
EU	European Union
GA	Grant Agreement
HELCOM	Helsinki Commission
FPR	Fertilizer Products Regulation
K	Potassium
KEP	Knowledge Exchange Platform
LCA	Life Cycle Assessment
Mg	Magnesium
N	Nitrogen
NH₃	Ammonia
NH₄⁺	Ammonium
NH₄-N	Ammoniacal nitrogen
NH₄NO₃	Ammonium nitrate
(NH₄)₂SO₄	Ammonium sulphate
NR	Nutrient Recycling
OM	Organic matter
P	Phosphorous
PP(s)	Project Partner(s)
REACH	Registration, Evaluation, Authorisation and Restriction
RNF(s)	Recycled Nutrient Fertilizer(s)
S	Sulphur
SI	Soil Improver
SME	Small and Medium Enterprise
SRM(s)	Secondary Raw Material(s)
SWOT	Strengths, Weaknesses, Opportunities, Threats analysis
TRL	Technology Readiness Level
WP	Work Package

1. Introduction

Interest in sustainable alternative fertilizers that recycle nutrients back into agricultural systems by processing organic and non-organic waste streams is growing, and this is a cornerstone of the circular bioeconomy. Fertilizers derived from sources such as sewage sludge, animal manure, digestate, and industrial waste are increasingly valued for their potential to support sustainable agriculture. Recognising the advantages, including the positive impact on the environment from nutrient recycling, decreased waste output and financial savings for farmers, is becoming more common. Despite increasing interest and rising policy support, the EU faces persistent gaps and challenges across technological, legal, economic, and social dimensions that hinder large-scale implementation and market uptake of alternative fertilizers (AFs).

FERTITEC is working on developing the market for AF products to reduce agriculture's dependence on mineral fertilizers produced using fossil fuels and limited mineral resources, as well as high energy consumption. The project consortium started its search by analysing and collecting more than 150 state-of-the-art available technologies, techniques, and practices. FERTITEC focused here on the most efficient recovery of nutrients while maintaining the principles of a sustainable circular economy and mitigating the environmental impact of fertilizer production. After that, 30 case studies of existing installations in the EU and the African Union (AU) recovering nutrients from more than 6 secondary source streams were selected from the established database. They will be subjected to a technical, environmental, and socio-economic assessment to identify the 12 best available technologies (BAT) in terms of functionality, emission reduction, and environmental impact. To make this choice as justified as possible, FERTITEC identified and analyzed the main gaps, challenges and barriers that limit the development of technologies and their dissemination in order to develop the fertilizer products market. The knowledge acquired will be made available to a wide range of stakeholders and actors at the EU and international level, decision-makers and users in the economic and agricultural fields and will be available on the FERTITEC knowledge exchange platform and the EcoFerti tool, an innovative tool supported by artificial intelligence, developed by the consortium.

1.1 Description of Task 1.5 in Grant Agreement

Task 1.5 focuses on identifying and analysing the main gaps and challenges that limit the implementation and market uptake of techniques for nutrient recovery and recycling, and consequently of fertilizing products obtained from secondary raw materials (SRMs). The task adopts a context-based approach in the project's case regions, taking into account regional socio-economic conditions and the availability of SRMs. Building on the findings of Tasks 1.3 and 1.4, the results are systematised and analysed with respect to regional specificities, in order to better understand the barriers and drivers affecting the development and adoption of technologies and practices for nutrient recovery and recycling.

To support this analysis, a virtual co-creation workshop, organised by IUNG, was held to ensure the active participation of experts from the Expert Panel (EP) and other relevant stakeholders (more than 20 participants). During the workshop, preliminary findings were presented, and participants were engaged in co-creative sessions to identify technical, regulatory, economic and social gaps and challenges, as well as potential solutions and enabling measures that could support the wider uptake of AF value chains.

Although the deliverable table in Annex 1 of the Grant Agreement refers to D1.4 as reporting “only findings from Task 1.4”, the detailed description of Task 1.5 specifies that D1.4 consolidates results from Tasks

1.3 and 1.4 together with additional stakeholder inputs gathered through the Expert Panel and co-creation workshop. This deliverable follows the Task 1.5 description and therefore integrates all these sources into a single analysis of gaps and challenges.

The outcomes of Task 1.5 provide essential input for understanding current limitations and future opportunities in nutrient recovery and recycling systems. All findings and stakeholder inputs are consolidated and reported in this deliverable (D1.4).

2. Approach and Methodology

The overall responsibility for implementing Task 1.5 was borne by IUNG, which planned the direction of individual activities, determined their time frames, supervised the implementation of individual stages of the task, and coordinated the storage of results.

2.1 Action plan

The action plan presented in Table 1 was first discussed at a project meeting in Thessaloniki and then slightly modified during the implementation of Task 1.5

Table 1. Action plan for Task 1.5

No.	Action point	Who	By When
1	Gaps and challenges in scientific literature review	IUNG	31 Jul 2025 (M7)
2	Analysis of gaps and challenges in finished and ongoing projects	IUNG	31 Aug 2025 (M8)
3	Evaluation of selected results from T1.1 Interview questionnaire	IUNG	31 Aug 2025 (M8)
4	Virtual co-creation workshop with 20+ experts from EP organised by IUNG with support by PP	IUNG, LUKE, CET	30 Oct 2025 (M10)
5	Co-creation workshop feedback evaluation and SWOT analysis	IUNG	10 Nov 2025 (M11)
6	Analysis of findings from T1.1, T1.3 and T1.4	IUNG	14 Nov 2025 (M11)
7	D1.4 is prepared in a pre-review version	IUNG	14 Nov 2025 (M11)
8	Submit D1.4 to the quality reviewer (RISE)	IUNG	14 Nov 2025 (M11)
9	Receive comments from the quality reviewer	RISE	21 Nov 2025 (M11)
10	D1.4 second submission	IUNG	26 Nov 2025 (M11)
11	Gaps and challenges of available recovery and recycling techniques is delivered as D1.4	IUNG	30 Nov 2025 (M11)

2.2 Methodology

2.2.1 Analyze the main gaps and challenges that hinder the implementation of techniques for nutrient recycling

The research was conducted in four phases, combining the analysis of existing data, a SWOT analysis, and expert evaluation to assess the current state and development potential of technologies for nutrient recovery/recycling from secondary raw materials, as well as the growth of the alternative fertilizer (AF)

product market. The methodological approach aimed to identify key gaps, barriers, challenges, and driving forces for implementing circular economy principles in this area, as presented in the following chapters of this document.

In the first phase of the study, existing data were analyzed using the desk research method to diagnose the current state of development of nutrient recovery/recycling technologies from secondary raw materials, identify gaps and challenges limiting their further development, and propose potential solutions that could contribute to the growth of this sector. A review of the scientific literature was conducted using publicly available databases and the previous achievements of the project consortium.

In the second phase, publicly available reports from completed and ongoing EU projects were analyzed, with particular attention given to projects involving and/or collaborating with consortium participants. At the same time, interview questionnaires carried out under FERTITEC Task T1.1 with specialists in technologies, techniques, and practices for producing alternative fertilizer products were analyzed in terms of gaps, challenges, and potential solutions. The feedback obtained from these interviews also enabled the identification of relevant aspects based on expert and societal opinions. In total, 43 opinions collected within the FERTITEC and CiNURGi projects were analyzed. The outcomes of the CiNURGi project supported the research, as its data were useful for identifying factors limiting the acceptance of AFs and hindering the development of production technologies.

In the next phase, virtual co-creative workshops were organized with FERTITEC EP experts. To moderate discussions and obtain maximum feedback within a relatively limited timeframe, a dedicated online form was created.

The fourth phase of the research included a review of previous work and deliverables developed within the FERTITEC project. In particular, technological, environmental, and economic constraints identified in Task 1.1 were analyzed, along with the findings and analyses presented in the final report of Task 1.4 on the market status and legislation related to AFs, as well as 30 selected case studies examined under Task 1.3.

As data from various sources were progressively collected, a parallel SWOT analysis was carried out, focusing on determining the current and prospective position of AF technology development and market growth. The SWOT analysis was chosen due to its usefulness for conducting early, expert-based strategic assessments in areas undergoing complex systemic changes. It enabled the evaluation of four key groups of factors influencing the development of the alternative fertilizer sector: strengths, weaknesses, opportunities, and threats. To minimize the typical limitations of this method, including subjectivity and the absence of factor weighting, a structured scoring system was applied, followed by the use of an expert panel to validate and prioritize the identified factors. The EP consisted of a 29-member international group of specialists in circular technologies.

The summary of the research presents a forecast of the best course of action resulting from the SWOT analysis, along with proposed measures for the further development of alternative fertilizer technologies and the AF market.

2.2.2 Online form

IUNG developed a dedicated online form to enable fast and reliable data collection during the Co-creating Workshop with EP. To facilitate the T1.5 co-creation session, which involved experts with substantial knowledge and experience in technologies, techniques, and practices for producing

alternative fertilizing products, IUNG employed the online form presented in Annex 1. The form was designed to collect feedback aimed at systematizing the identified gaps, challenges, and potential solutions as strengths, weaknesses, opportunities, and threats for the broader introduction of alternative fertilizer technologies to the market. The above activity was one of the stages of the SWOT procedure/analysis for the studied project. EP experts were invited to contribute their expertise by evaluating both positive and negative factors, assessing their significance (weight) and impact on the development and market integration of AF technologies. In addition, IUNG launched a supplementary outreach campaign targeting independent experts through its network of contacts established via current and past projects, as well as national and international collaborations. All responses were collected anonymously to protect sensitive information and ensure that experts could share their views freely.

2.2.3 Characteristics of SWOT Analysis

SWOT analysis is a popular technique for organizing, analyzing, and verifying information, and it is also a recommended method of strategic management. The name SWOT is an acronym derived from the English words *Strengths* (strong points), *Weaknesses* (weak points), *Opportunities* (opportunities in the environment), and *Threats* (threats in the environment).

The simplicity and universality of the SWOT method make it applicable both for assessing the environment and surroundings of an organization/company, as well as for analyzing a project, undertaking, or business plan. It is often used as the first stage of planning more or less complex activities. It is particularly important at the stage of situational analysis and project goal formulation, as well as in evaluating options and selecting a project variant. It can also serve as a useful tool for assessing the innovativeness of various business ventures, initiatives, and products, as well as for early strategic assessments in areas undergoing complex systemic changes.

SWOT analysis is a comprehensive method that allows the identification and examination of strengths and weaknesses, as well as existing and potential opportunities and threats arising from the external environment of a specific project, to understand its potential and evaluate the chances of success and achievement of the desired outcome (planned objectives). In other words, SWOT is a way of organizing and presenting facts, enabling the understanding of data and recognition of their consequences. Moreover, it makes it possible to determine the current position of a company and its future actions. SWOT analysis can be treated as a specific reasoning algorithm and the first step in the process of identifying areas that form the basis for initiating organizational changes, which—regardless of market conditions—allows a company to grow in a sustainable way.

The main objective of SWOT analysis as a research method is to determine the current and prospective position of the subject under analysis and to forecast the best strategy of action.

In this analysis, all factors influencing the current and future position of an organization are divided into external factors in relation to the organization and internal conditions, as well as those exerting a negative influence on the organization and those having a positive impact. From the intersection of these two divisions, four categories of factors emerge:

- **Internal positive – strengths**
- **Internal negative – weaknesses**
- **External positive – opportunities**
- **External negative – threats**

Strengths are considered to be all elements that constitute an asset, advantage, or benefit—resources, skills, and specific features that foster the development of a project and allow building a favorable market position. These are elements that contribute to gaining a competitive edge. They should be maintained and nurtured to ensure their persistence in the future.

Weaknesses are all elements that represent a limitation, barrier, or flaw, which reduce operational efficiency or hinder further development and require improvement. These negative features contribute to an unfavourable competitive situation for the organization. Efforts should focus on eliminating them so they do not undermine strengths.

Opportunities are all existing or anticipated processes, phenomena, and trends occurring in the organization’s environment, which, if identified in time and properly utilized, may positively influence its functioning and development, as well as help mitigate the impact of emerging threats. They may also offset the weaknesses of the enterprise. The focus should be on maximizing their use.

Threats are all processes, phenomena, and trends occurring in the environment of the analyzed subject that pose the risk of negative changes. These are factors that hinder maintaining a position and may constitute barriers to the development of the project, obstruct its functioning, and increase operating costs. Efforts should concentrate on finding countermeasures so that threats do not affect the project’s activities, as they could ultimately lead to its failure.

The SWOT procedure includes the following stages:

1. Identification of all factors relevant from the perspective of the subject under analysis.
2. Grouping the identified factors into the four categories described above. Information that cannot be correctly classified into any of the mentioned groups is omitted in further analysis as strategically irrelevant.
3. Creation of a four-part SWOT matrix, in which the left half contains the two categories of positive factors, and the right half contains the two categories of negative factors (see Fig. 1).

	positive factors	negative factor
internal factors	Strengths	Weaknesses
external factors	Opportunities	Threats

Figure 1. Elements of the SWOT matrix

4. Examination of the relationships between the distinguished pairs of factors to detect possible synergies. The grouped factors form a set of interacting elements. It is necessary to identify the dependencies between opportunities–threats and strengths–weaknesses, and to confront strengths with opportunities, weaknesses with opportunities, strengths with threats, and weaknesses with threats, while also observing how the identified factors mutually reinforce or

neutralize each other. Weaknesses and threats should not outnumber strengths and opportunities, and the analysis should be conducted with common-sense objectivity.

5. Assigning weights to each of the listed factors, defining their importance in the development of the project, and ranking the factors within each category according to weight (from highest to lowest). The weight answers the question of how important a given factor is relative to the others in the same category. Weights are recorded as decimal fractions, and their sum within one category should equal 1.
6. Assigning each factor a score on a scale from 1 to 5, defining its strength of influence (impact) on the analyzed project (where 1 means very low influence and 5 means very strong influence). To properly determine the weight and score in the adopted scale, it is best to rely on the knowledge of industry experts or seek external consultations to help establish appropriate ratings for the identified factors.
7. Determining the weighted value for each factor by multiplying the factor's weight by its score, and then calculating the sum of products for each category separately.
8. The combination of factors for which the cumulative sum of products is the highest indicates the adoption of one of the four normative strategies.

Depending on the predominance of positive or negative factors in the environment and within the analyzed subject, four types of strategies are distinguished:

- **Aggressive strategy (maxi-maxi)** – predominance of strengths and opportunities
- **Competitive strategy (mini-maxi)** – predominance of weaknesses and opportunities
- **Conservative strategy (maxi-mini)** – predominance of strengths and threats
- **Defensive strategy (mini-mini)** – predominance of weaknesses and threats

Additionally, SWOT analysis makes it possible to indicate the strategic position of the analyzed subject and to define the directions of this strategy. This position is represented by a point in the Cartesian coordinate system (Fig. 2), which can be calculated according to the following formula:

$$X = | \text{strengths} | - | \text{weaknesses} | \quad (1)$$

$$Y = | \text{opportunities} | - | \text{threats} | \quad (2)$$

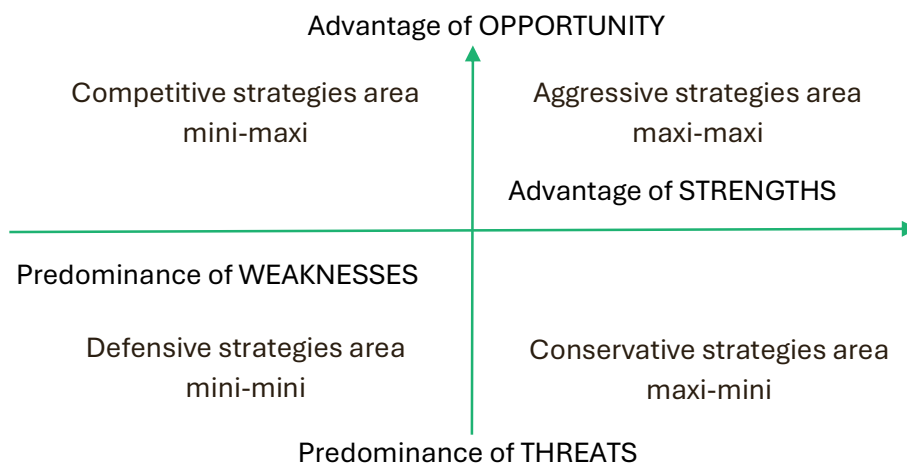


Figure 2. Strategies according to the SWOT analysis

The most general set of strategies—or rather recommendations—resulting from SWOT analysis consists of two actions that should be undertaken in every situation, namely:

- **Reduce threats and exploit opportunities** – threats usually have a rapid and direct impact on the efficiency of an organization’s operations. Protective barriers (financial, human, material) should be built to safeguard the project against their negative effects. It should also be remembered that if all entities operating in the market are exposed to the same threats, this may paradoxically become an opportunity, since competitors lacking such protective barriers will suffer the consequences, which in the long term may lead to their elimination from the market. Opportunities, on the other hand, generally require specific actions to make their positive impact tangible for the organization. A system of continuous monitoring should be implemented, and the inevitable internal resistance to organizational changes necessary to seize these opportunities should be minimized.
- **Eliminate weaknesses and strengthen strengths** – weaknesses that most negatively affect the efficiency of the project should be identified and eliminated. It must be remembered that the process of identifying and monitoring the internal functioning of the organization should be continuous. A weakness that did not exist before may arise for various reasons and require a flexible response.

Conducting a SWOT analysis brings the following benefits for the subject under study:

- **Internal organizational analysis** – enables a thorough understanding of the project’s strengths and identification of weaknesses requiring improvement.
- **Identification of development opportunities** – allows recognition of potential areas of expansion and determination of directions for the organization’s future growth.
- **Minimization of business risk** – enables early identification of potential threats and the development of defensive strategies.
- **Optimization of decision-making processes** – provides managers with essential information for making informed strategic decisions.
- **Improvement of internal communication** – supports the exchange of information between different management levels and organizational departments.
- **Strengthening of competitive position** – allows leveraging strengths to gain an advantage over competitors in the given market.

2.3 Content of the deliverable

Deliverable D1.4 consists of two complementary components: a report and an annex, both published and accessible via Zenodo. The report defines the scope of Task 1.5 and describes in detail the methodological framework adopted for its implementation, as well as the action plan that guided its execution. It introduces the main issues associated with existing gaps and challenges that limit the large-scale uptake of techniques for the recovery and recycling of fertilizing products from SRMs. The report includes an assessment of the data collected, a set of relevant definitions and abbreviations, and a last chapter with a SWOT analysis of the data and the key outcomes and conclusions.

The annex complements the report by providing the digital online form specifically developed to collect data supporting the SWOT analysis presented in Chapter 3.6. This form was introduced during a co-creation workshop held with EP and subsequently disseminated among EP experts and other relevant stakeholders. The collected input contributes to a deeper understanding of the strengths, weaknesses, opportunities, and threats related to the recovery and recycling of fertilizing products from SRMs, and forms an essential part of the evidence base for the analysis conducted under Task 1.5

3. Gaps and challenges of available recovering and recycling techniques

3.1 Gaps and challenges based on the scientific literature

3.1.1 Definitions

According to formal definitions, a **gap** is a missing element or shortfall between the current state and the desired or ideal state. It shows where improvement or further work is needed. In research, a gap is an area where little or no existing research has been conducted, leaving room for new studies. It could be a pure knowledge deficit, a shortcoming in the scholarship, often due to methodological tendencies and oversights, or a pervasive and unproven assumption [Lorelei 2017]. A **challenge** is a difficulty or problem that requires effort and skill to overcome. It doesn't necessarily stop progress but makes it more difficult. A **barrier** is something that blocks or prevents progress completely or partially. It is more restrictive than a challenge — often a cause of inaction or failure if not removed [Cinar et al. 2019]. A **driver** is a key factor that initiates, supports, and directs actions leading to change, development, or innovation within a given sector [Strand et al., 2014].

In research and practice, several terms are defined in the area of recovering and recycling nutrients. **Nutrient Recycling (NR)** refers to returning nutrients derived from biomass to plants, consistent with HELCOM's definition. **Alternative Fertilizers (AFs)** appear in EU Horizon programs like FERTITEC and FERTICOVERY to describe fertilizers derived from secondary raw materials. **Recycled Nutrient Fertilizers (RNFs)** describe fertilizers produced from secondary sources such as manure, organic waste, sewage sludge, or industrial by-products, as defined by the CiNURGi (INTERREG BSR) project. **Bio-Based Fertilizers (BBFs)** are fertilizers originating from organic biomass—plant, animal, or microbial. Industry guidelines recommend that products containing less than 80–90% bio-based nutrient content should be classified as Partly Bio-Based [ESPP, 2023]. According to Regulation (EU) 2019/1009, Annex I, **Inorganic Fertilizers (mineral, synthetic)**, consisting of nutrients in mineral form, obtained by extraction or by physical and/or chemical industrial processes. In **Organic Fertilizers**, nutrients are solely derived from organic materials of plant, animal, or microbial origin. **Organo-Mineral Fertilizers** contain both organic and mineral nutrient sources, combined in a single product.

3.1.2 Resource streams and nutrient recycling

The fertilizer sector is confronted with challenges such as regulatory barriers, competition from mineral fertilizers, and the potential health risks posed by pollutants in organic waste streams. One of the most significant challenges is encouraging or incentivising fertilizer producers to transition from non-renewable to renewable resources. The major producers of fertilizers still base their production on non-renewable resources and have been using well-known technologies for decades. Each technology requires research and development studies to be conducted first. Shifting to renewable resources poses many technological challenges. Addressing these challenges requires coordinated action across sectors and borders. Regulatory reform, economic incentives, and inclusive communication strategies must match technological innovation. Only then can nutrient recovery from secondary raw materials become a mainstream solution for sustainable agriculture in Europe. In light of the pressing ecological challenges we face, the exploration of biomass waste as a potential source of fertilizer components holds significant promise for enhancing our global environment.

There is also a significant need to focus on positive messaging and marketing. Sustainable development is contingent on the recovery of materials and energy. This should be achieved in accordance with a strategy for growth and optimisation of separate municipal collection systems. Additionally, it is crucial to reduce non-renewable resource consumption and waste generation. Existing barriers show that nutrient prices in waste-based products are higher than mineral fertilizers. Moreover, waste materials require additional post-treatment to increase the concentration of nutrients and their availability [Xu Fo, et al., 2018].

Delivering clear information to the end users is crucial. The first step should be labelling the product with information about the share of recovered nutrients per kilogram of product. Instructions for proper application are also needed. In order to optimise management and take into account regional differences, farmers require access to additional policy tools. Regulations should be more compact and interconnected, especially the EU Fertilizers Regulation with the Water Framework Directive and the Common Agricultural Policy (CAP) proposal or the EU Water Reuse Regulation (draft) [Huygens, 2018].

3.1.3 Issues related to phosphorus recycling

Renewable secondary raw materials could be a valuable source of a fertilizer for plants. Suspension bio-based fertilizers, for example, have been produced from sewage sludge ash and animal bones, and enriched with *Bacillus megaterium* bacteria [Jastrzębska et al., 2016]. The use of bones for fertilizing purposes is currently the only way to recycle this burdensome waste, given the EU ban on the use of meat and bone meal in livestock feed [European Union, 1991].

Unprocessed phosphorus raw materials are characterised by the low solubility of phosphorus compounds they contain [Saeid et al., 2012]. The transition of phosphorus from an insoluble to a soluble form is the key to both the production of efficient fertilizers and the improved bioavailability of its compounds from the soil's nutrient pool. As access to phosphate rock reserves diminishes, both economically and geographically, the risk to global food production also increases. These challenges highlight the need to develop strategies for phosphorus recovery and recycling.

Livestock manure is the largest secondary P resource (15–20 Mt P yr⁻¹), accounting for more than 50% of the annual secondary P generated worldwide. However, a substantial portion of manure is difficult to recover because grazing animals deposit it directly onto grasslands. The water content and volume of manure can be reduced using non-thermal methods, such as flocculation, settling, screw pressing, belt filtration, centrifugation, and dissolved air flotation after anaerobic digestion, but technical, logistic and financial challenges remain [Reitzel et.al., 2025; Hjorth et al., 2010; Hjorth & Jørgensen, 2012]. The production of biogas from manure is common in developed countries, yielding a digestate containing approximately 2% phosphorus (P). To concentrate phosphorus further in fresh manure and its digestate, solid–liquid separation techniques have proven effective. Around 70–75% of phosphorus can be recovered in the solid fraction without flocculation, whereas flocculation increases this figure to 80–90% [Möller & Müller, 2012; Kabeyi & Olanrewaju, 2022].

Recycling potential from farming, food manufacturing, biorefining, and consumer waste and by-products could reach 1.2 Mt P on an annual basis. The heterogeneity of resources complicates the recycling process for food product waste. Recovery techniques such as composting, anaerobic digestion and fermentation are the most common strategies for nutrient recovery from food waste. Whilst other methods, such as incineration, show great promise, they are not without their own drawbacks, including increased pollution. Meat and bone meal (a slaughterhouse byproduct) has high P content (3–5%) and is already used as a P fertilizer in some countries, but concerns about pathogen risk

and public perception still limit its use in other countries [Garcia-Garcia et al., 2012; Otles et al., 2015]. Biorefinery residuals, such as waste from bioethanol production or breweries, are also rich in phosphorus. However, the spatial disconnect between production and consumption sites requires complex transport logistics and high costs. This frequently leads to sub-optimal P recovery [Otles et al., 2015].

Post-consumer food waste, which mainly comes from households and the food service industry, is the largest source of global food waste, totalling approximately 570 million tons each year. This type of waste is often mixed with various materials and is frequently contaminated with plastics or packaging residues. This contamination creates significant logistical and regulatory challenges for safe reuse. Resolution is critical for sustainable practices and environmental health. Despite its potential, phosphorus recovery from food waste remains underdeveloped, partly due to severe logistical, environmental, and behavioural challenges, low economic incentives, and weak regulatory enforcement [Haldar et al., 2022].

Recovering P directly from sludge typically results in lower-quality struvite, which contains reduced phosphorus levels and higher concentrations of impurities. In contrast, recovering phosphorus from the liquid separated from sludge generally yields a higher-quality product and increases the overall recovery rate [Cieślak & Konieczka, 2017]. However, when these methods are combined, they only capture about 10% to 40% of the phosphorus present in the influent. Higher recovery rates, ranging from 60% to 70%, can be achieved through processes like vivianite precipitation or sludge acidification, followed by solid-liquid separation and precipitation. Nonetheless, these methods are energy-intensive, contributing to global warming, and they require significant amounts of acid. While the phosphorus recovery efficiency is higher than that of struvite-based technologies, these processes have not progressed beyond pilot-scale demonstrations. Achieving high phosphorus recovery rates from secondary resources is essential, but it is equally important to produce clean, safe, and highly efficient fertilizers. Optimizing these factors together is crucial for sustainable agricultural practices [ESPP, 2023].

There is currently no standardised method for P speciation (the chemical forms in which P exists) in recovered products, although X-ray diffraction is often used. Although effective for identifying mineral P forms, this method is unsuitable for detecting organic P. This method is qualitative and fails to provide accurate results when mineral phases are poorly crystalline or amorphous. The varied and complex chemical nature of secondary phosphorus resources complicates their assessment as fertilizer substitutes. The lack of knowledge regarding phosphorus (P) availability and speciation hinders model developers in improving phosphorus management, as well as regulators who need these data to make informed decisions [Sichler et al, 2022]. Recycled products often exhibit lower water solubility and slower phosphorus (P) dissolution dynamics compared to conventional mineral P fertilizers. However, they can release similar amounts of P over longer periods and achieve comparable agronomic efficiency. Despite this, the long-term effects of continuous use of recycled fertilizers remain largely unknown. The characteristics, production processes, application methods, and environmental risks associated with various recycled P sources are not well understood. This lack of understanding makes it challenging to predict how these fertilizers will perform and their long-term environmental impact. Therefore, it is crucial to study the dissolution kinetics and overall behaviour of recycled fertilizers in different environments to model their transport in fields and watersheds effectively [Duboc et al,2022].

Research on aluminium phosphorus forms, which are also widely used for phosphorus precipitation in wastewater treatment plants, remains insufficiently researched. This gap significantly obstructs the advancement of phosphorus recovery processes from waste streams rich in aluminium, making it more challenging to evaluate the potential and limitations of different recycled phosphorus sources

comprehensively and comparatively. To reduce the contamination of waste streams, it is necessary to reduce and replace harmful substances at their source. Addressing this issue is essential for optimizing recycling efforts and maximizing resource efficiency. Logistical barriers are obstacles that hinder the collection, handling, processing, and redistribution of waste streams and recycled P. A significant logistical challenge is the distance between the sources of recycled P and the arable land where it is needed. Regional generation and distribution imbalances present significant challenges. The substantial volume and high moisture content (85–95%) of manure complicate its handling, storage, and long-distance transport, making efficient management essential for sustainable agricultural practices.

The adoption of recycled P fertilizers, while promising, faces significant challenges that need to be addressed. These fertilizers often come in bulky or dusty forms, which complicates handling and requires specialised equipment for application. For instance, food waste-based compost and digestate can greatly improve soil structure and enhance organic carbon content, yet they contain only about 0.4% phosphorus on a dry-matter basis. Given the availability of more concentrated phosphorus fertilizers, many farmers are understandably reluctant to invest in the specialized gear needed to utilise these bulkier recycled options. Moreover, recycled fertilizers may exhibit variability in nitrogen, potassium, and micronutrient levels, adding another layer of complexity. This inconsistency, combined with diverse nutrient-release rates and logistical constraints, often deters farmers from exploring recycled products. By addressing these hurdles, we can create a more inviting environment for the integration of recycled fertilizers into agricultural practices, ultimately benefiting soil health and sustainability [Case et al., 2017].

In the near future, the challenge will be to combine two techniques, acidification and thermal hydrolysis for manure with P recovery on an industrial scale. This dual-processing approach is seen as a bridge technology: it leverages existing wastewater and manure treatment infrastructure while solving the phosphorus recovery challenge. By combining acidification and thermal hydrolysis, the food and agriculture sectors can move toward industrial-scale circular nutrient management, reducing dependence on finite phosphate rock and mitigating environmental risks [Lee et al., 2023; Su et al., 2025; Xie et al., 2022].

Applying pre-treatment to manures before anaerobic digestion has the potential to enhance phosphate recovery efficiency by 13% to 50%. This could lead to an additional annual recovery of 131,000 tonnes of phosphate. In order to enhance the fertilizing potential, consideration should be given to the combination of processes. Another challenge is to reduce taxation if renewable nutrients are used or if fertilizers are based on fossil materials. Measures of this kind have already been implemented in Denmark, where the taxation of supplemental inorganic mineral feed phosphate has been shown to stimulate more efficient use of plant phosphorus in livestock production [Circular Economy Package].

Strubias materials - struvite, biochar, and ashes are nutrient-rich byproducts from waste streams. They are considered Component Material Categories (CMCs) under the EU Fertilizing Products Regulation. These materials are highly concentrated sources of nutrients, particularly phosphorus, nitrogen, and potassium. Despite their benefits, several challenges exist. They are regulatory hurdles ensuring compliance with the EU Fertilizer Regulation and REACH standards for safety and environmental impact. They can also face hurdles with respect to public perception and acceptance.

Fertilizers from waste streams may face scepticism, despite being chemically safe and effective. Moreover, they can have source variability. Materials derived from manure, municipal wastewater, slaughterhouse waste, and food industry residues can vary in composition and contamination risk. The biomass of sewage sludge may contain organic matter, contaminants, as well as harmful pathogens

[Severin et al., 2014]. However, the direct application of ash from sludge incineration as a fertilizer is associated with the presence of toxic metals [Bierman et al., 1995]. The higher cost of recycled P fertilizers is related to the physicochemical characteristics of the secondary materials, smaller operation sizes (due to economies of scale) and the increased complexity of most recovery processes. For instance, advanced phosphorus recovery from manure results in a final product that is too costly for most farmers compared to raw manure. Similarly, fertilizers produced using struvite precipitation technologies can cost 2–14 times more than those derived from phosphate rock. Most attempts at struvite precipitation have been motivated by an interest in reducing maintenance costs rather than in producing fertilizers, due to clogged pipes resulting from uncontrolled struvite crystallisation [Mudragada et al., 2014].

There is also an economic aspect to consider, including the costs of the process. Converting raw waste into usable phosphate salts requires advanced treatment technologies, which can be costly. The challenge lies in developing transdisciplinary strategies and research to accelerate phosphorus recycling and the development of a sustainable, closed-loop phosphorus economy. Including the perspectives of different stakeholders will help achieve increasingly sustainable phosphorus management. The following key challenges need to be addressed: the low competitiveness of phosphorus recycling products, complex waste management procedures, limited phosphorus recovery, and fragmented cooperation among stakeholders. A key barrier to developing and implementing effective strategies for sustainable phosphorus use is conflicting objectives among stakeholders' strategies for the sustainable use of phosphorus. Improved communication, interdisciplinary research and transdisciplinary processes that incorporate the needs of all stakeholders are required for successful strategies for circular management of phosphorus [Reitzel et al., 2025].

Barriers related to geopolitical dependence on primary phosphorus imports underscore the challenges posed to recycled phosphorus. Recent supply chain disruptions include the impact of the pandemic, the conflict in Ukraine and Russia, China and Russia reducing P fertilizer exports, and trade wars between key stakeholders, such as China and the USA. These events have had a disproportionate negative impact on countries in Africa. The asymmetric risks associated with primary P dependence highlight the importance of diversified P sources and more resilient supply chains. Although quantifying global P flows and stocks is crucial, it is challenging due to major regional differences in P resource availability, prices, and the efficiency with which it is used. Economic, political, and environmental factors shape these differences. Improving the circularity of P is indispensable to overcoming the geopolitical and agricultural challenges associated with its mismanagement environmental challenges associated with P mismanagement. This can be achieved by enhancing P recycling from P-rich secondary sources, including waste from the mining and fertilizer industries, livestock manure, wastewater, sewage sludge, and food waste.

3.1.4 Issues related to nitrogen recycling

Another important macronutrient in the recovery process is nitrogen (N). In most liquid waste streams, reduced N is present, either as ammoniacal nitrogen and/or as organic nitrogenous compounds. Nitrogen is essential for fertilizers, yet its production demands high energy and resources [Pajura et al., 2023]. Using ammonia from biogas slurry offers a sustainable alternative that benefits both the circular economy and social sustainability [Spiller et al., 2022]. Recovering nitrogen from concentrated waste streams, such as urine or anaerobic digestate, can be accomplished using various techniques, including ammonia stripping, struvite precipitation, and cation exchange. Among these methods, ammonia stripping combined with acid-based absorption is the most extensively researched. This process

recovers nitrogen in the form of ammonium salts, which can be used as fertilizers. However, despite its high potential for ammonia nitrogen removal, this method is challenging to implement on a large scale due to its high operating costs and specific requirements for pH and temperature [Lee et al., 2021].

Van der Hoek et al. (2018) demonstrate that recovering nitrogen from wastewater using the existing treatment system only achieves limited sustainability improvements. Furthermore, substantial improvements in sustainability require radical changes to wastewater treatment and the application of several nitrogen recovery technologies in parallel. While the separate collection and treatment of urine is an attractive option, it necessitates the development of entirely new wastewater collection and treatment infrastructure. Using adaptation pathway maps to compare and evaluate several combinations of nitrogen recovery technologies is an attractive method, especially when different strategies have to be analysed and technological and market developments are uncertain.

The recovery of nitrogen (NH_4^+ or NO_3^-) from wastewater using adsorption-based processes is not currently a common practice. However, there are no insurmountable technical reasons to prevent it, and recent economic and environmental assessments indicate indisputable benefits compared to the conventional activated sludge process. Technical challenges associated with nitrogen recovery might be, for example, that wastewater contains competing ions, organic matter and suspended solids, which hinder the recovery of NH_4^+ or NO_3^- . Furthermore, variations in nitrogen concentration over time or between different types of wastewater may also complicate recovery [Yao et al., 2022].

It is imperative to propose sustainable and cost-effective engineering technologies that will effectively remove excess nitrate and phosphate ions from wastewater streams before their reuse or discharge into receiving waters. The selection of proper adsorbent material is the key challenge [Alagha et al., 2020]. Another disadvantage of processes other than adsorption is that they are not suitable for nitrogen recovery from wastewater. Membrane separation has several drawbacks, including the use of chemicals, a higher selectivity for salts other than ammonium ions (NH_4^+), and issues with membrane fouling. Struvite precipitation also comes with disadvantages, such as the need for a high pH, the cost of chemicals, and the requirement to add magnesium ions (Mg^{2+}) and phosphate ions (PO_4^{3-}).

Microbial assimilation techniques face challenges like operational complexity, long processing times, and the production of harmful intermediate compounds. Meanwhile, air stripping technology can lead to air pollution, requires an elevated pH, and can cause fouling of the stripping tower. The major bottlenecks preventing the widespread adoption of nitrogen recovery are also related to non-technical barriers, such as a lack of incentives or value chains. In the context of nitrogen recovery through adsorption, the challenge for wastewater treatment plants is post-tertiary, where conventional unit operations and processes, such as coagulation/flocculation, sedimentation, activated sludge process (without nitrogen removal), and sand filtration, have effectively eliminated solids and organic matter [Yu et al., 2025]. To further reduce the footprint, it is essential to explore alternative reagents and energy-efficient technologies that minimise chemical dependency and operational costs [Gong et al., 2024].

3.1.5 Issues related to the potassium recycling

Potassium recovery from secondary raw materials such as biomass ash, food processing residues, and municipal waste is gaining attention as a strategic pathway toward circular nutrient management. However, despite its agronomic importance and environmental potential, the deployment of potassium recovery technologies faces significant barriers across technological, social, legal, and economic dimensions. These challenges are particularly pronounced in key sectors such as agriculture, the food industry, and waste management. Technologically, potassium recovery remains less mature than

nitrogen or phosphorus recovery. Existing methods—including selective electro dialysis, acid leaching, adsorption, and bioleaching—often require complex setups, high energy input, or chemical reagents that limit scalability and sustainability. Feedstock variability poses a major challenge: the potassium content and contaminant load in biomass ash, digestate, or food waste can fluctuate widely, requiring tailored pre-treatment and monitoring systems. In the food industry, where process residues may contain valuable potassium, recovery technologies must meet stringent hygiene and purity standards, adding to technical complexity. Moreover, integration into existing waste treatment infrastructure is often limited, especially in small and medium-sized facilities [Chauhan et al., 2022].

Socially, awareness and acceptance of potassium recovery remain low. In agriculture, farmers are generally familiar with potassium as a key macronutrient, but few are aware of its potential recovery from waste streams. Scepticism persists regarding the safety, consistency, and agronomic performance of recovered potassium products, particularly when derived from unconventional sources. In the food industry, concerns about reputational risk and consumer perception may discourage the use of recovered nutrients, even in non-food applications. Public understanding of circular nutrient flows is still limited, and outreach efforts are fragmented across regions and sectors.

Legally, potassium recovery is constrained by regulatory ambiguity and fragmentation. In many EU Member States, recovered potassium compounds are still classified as waste, subjecting them to restrictive transport and handling rules. The lack of harmonized end-of-waste criteria and product standards for potassium-based fertilizers delays market entry and creates uncertainty for producers. In the waste management sector, operators face complex permitting procedures and unclear responsibilities when implementing nutrient recovery systems. Furthermore, potassium recovery is not consistently recognized or incentivized under EU agricultural or environmental policy frameworks, such as the Common Agricultural Policy (CAP) or the Fertilizing Products Regulation (FPR) [ESPP, 2024].

Economically, the viability of potassium recovery technologies is often undermined by high operational costs and weak market signals. Conventional potassium fertilizers such as potassium chloride are widely available and relatively inexpensive, making it difficult for recovered alternatives to compete without subsidies or premium positioning. In agriculture, farmers are price-sensitive and may be reluctant to adopt new inputs unless clear cost-benefit evidence is provided. In the food industry, the economic case for potassium recovery depends on the scale of operations and the ability to valorise by-products. Waste management operators, meanwhile, face limited financial incentives to invest in nutrient recovery unless supported by policy instruments or circular economy mandates [UNEP, 2024].

In conclusion, unlocking the potential of potassium recovery requires coordinated efforts across sectors and governance levels. Technological innovation must be matched by regulatory reform, economic incentives, and targeted communication strategies. Agriculture, the food industry, and waste management each offer unique opportunities for potassium recovery, but only through integrated approaches can these be transformed into scalable, sustainable solutions for nutrient circularity.

3.1.6 Conclusions

From a technological perspective, nutrient recovery systems are advancing but remain constrained by complexity, energy intensity, and scalability. Techniques such as electro dialysis combined with nitrate reduction (EDNR), dissimilatory nitrate reduction to ammonium (DNRA), and adsorption-based recovery methods show potential for extracting ammonium compounds from dilute waste streams. However, these processes often require precise environmental conditions, advanced control systems, and high operational costs. Feedstock variability, especially in municipal and agricultural waste, further complicates process optimisation and product consistency. Moreover, contamination risks and the

need for post-treatment limit the direct use of recovered nutrients in agriculture without additional safeguards [Guo et al., 2024; Phan et al., 2025].

Legally, the classification of recovered nutrients as “waste” in many EU Member States creates significant regulatory friction. Transporting, storing, and marketing these materials often involves complex documentation and compliance with waste legislation, even when the final product meets fertilizer standards. The lack of harmonised end-of-waste criteria and certification frameworks for compounds like ammonium nitrate or ammonium sulphate delays market entry and discourages investment. Furthermore, nutrient recovery is not consistently recognised or incentivised under the Common Agricultural Policy (CAP), leaving producers without clear policy support.

Economically, the sector struggles with uncertain return on investment. High capital and operational costs, coupled with slow adoption and limited financial incentives, make nutrient recovery a risky proposition for producers. The low market price of conventional mineral fertilizers—especially phosphate rock and synthetic nitrogen—distorts competition and undermines the business case for recovered alternatives. Without targeted subsidies, tax relief, or performance-based payments, many technologies remain economically unviable [Gahane and Mandavgane, 2024].

Socially, farmer scepticism and weak outreach remain major barriers. Many farmers are unaware of the agronomic and environmental benefits of recyclates, or perceive them as inferior and risky. Advisory services often lack training and resources to promote AFs effectively, while communication strategies tend to focus on technical or policy aspects rather than practical, field-level benefits. Cultural attitudes toward waste-derived inputs vary widely across Member States, requiring tailored engagement and education efforts. With the growing importance of social factors in sustainability assessments, the fertilizer sector should embrace Social Life Cycle Assessment (S-LCA). By adopting S-LCA, we can thoroughly evaluate the social impacts and public acceptance of alternative fertilizers, ultimately leading to more responsible and widely supported agricultural practices.

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3.2 Gaps and challenges based on previous and ongoing EU projects

The following projects — B-Ferst, bio-SOILUTION, CiNURGi, FER-PLAY, FERTIMANURE, Lex4Bio, MainstreamBio, Novafert, NUTRI-KNOW, NUTRIMAN, P2GreeN, SEA2LAND, SuMaNu, SYSTEMIC, and WalNUT — were selected for examination to identify gaps and challenges.

Work carried out within the **B-Ferst** project provided a detailed assessment of the challenges and opportunities associated with the production and use of AFs. The project grouped its findings into several categories that reflect the complexity of building a sustainable and economically viable nutrient recycling system. Feedstock and biomass-related issues remain one of the most significant barriers. Biomass sources are seasonal, geographically dispersed, and often variable in quality, making it difficult to ensure a reliable year-round supply. Waste streams such as agricultural residues, food waste,

manure, and sewage sludge differ widely in nutrient content, contamination, and moisture. Moreover, different industries, including bioenergy, animal feed, and chemical production, compete for the same materials, further limiting availability. Technological barriers include the need for recovery methods such as composting, anaerobic digestion, struvite precipitation, and thermal or membrane processes to handle diverse raw materials with varying properties. Many technologies are still at the pilot stage, and scaling them up to industrial levels is both technically and economically demanding. Integrating new recovery processes into existing fertilizer production systems based on fossil inputs often requires substantial modernization and investment. Product quality and consistency also remain problematic. Due to the heterogeneity of feedstocks and process variability, AF products frequently show inconsistent nutrient content, which undermines farmer trust and complicates regulatory approval. Risks of contamination with heavy metals, microplastics, or pathogens persist, particularly when materials originate from sewage or manure. Some liquid or fermentation-based products have short shelf lives, are difficult to store and transport, and lose quality over time. Logistics and supply chain challenges arise from the high costs of collecting, transporting, and pre-treating dispersed waste streams. Maintaining suitable storage conditions and ensuring product stability during seasonal changes in supply and demand adds further complexity. Environmental and health risks include delayed nutrient release, leading to leaching, eutrophication, or acidification, as well as difficulties in consistently meeting strict limits for contaminants. These factors restrict market access for many AF products. Economic and market barriers are linked to the capital- and energy-intensive nature of recovery technologies, especially those for phosphorus recovery. Without stable markets and supportive policy frameworks, production costs remain higher than for conventional fertilizers. Lengthy registration and certification processes, along with varying regulations between regions, further slow down market entry. Adoption and social barriers persist due to limited awareness, uncertain performance, and negative perceptions of waste-derived products. Farmers often remain hesitant to replace mineral fertilizers without clear evidence of comparable results. The lack of demonstration trials and technical guidance contributes to this cautious approach. Research and human resource gaps also play a role. Continued innovation is needed to improve efficiency, safety, and adaptability to new materials. There is a shortage of skilled personnel to operate advanced systems and to provide user training. Cooperation between the agricultural, waste management, research, and policy sectors remains limited. Finally, regulatory and policy inconsistencies across Europe create uncertainty. Unclear definitions and lengthy licensing procedures delay product approval, while few economic incentives exist to encourage either waste recovery or the substitution of mineral fertilizers with organic ones.

According to the B-Ferst project report *“Towards sustainable business models in the circular bioeconomy: The case of bio-based fertilizers”*, AF can deliver substantial economic, environmental, and social benefits, including stable or improved crop yields, local job creation, and safer, sanitized fertilizer products. However, their full-scale adoption requires consistent product quality, effective risk management, and strong communication with end users. Market development depends on certification, consumer education, and validated field trials demonstrating reliability and safety. Achieving competitive pricing, optimized logistics, and sustained investment in research and innovation are key to ensuring the long-term financial and environmental sustainability of the AF sector.

The **bio-SOLUTIONS** project team explored the key challenges that limit the development and wider adoption of innovative AF. The findings point to several interconnected gaps that need to be addressed to advance the sector toward practical implementation and market maturity. A major constraint identified by the project relates to the regulatory environment. Existing EU legislation, including Regulation (EC) No 1069/2009 and the Industrial Emissions Directive 2010/75/EU, places restrictions on the use of certain feedstocks and technologies such as biochar production and biowaste pyrolysis.

These regulations, while essential for safety and environmental protection, currently limit the deployment of innovative fertilizer products. The absence of clear and harmonized criteria for determining when biowaste-derived materials cease to be classified as waste—the so-called “end-of-waste” status—adds to this uncertainty. Simplified and coordinated procedures are needed to reduce administrative burdens and encourage investment in circular fertilizer production. Quality assurance was also identified as an area for improvement. The establishment of consistent product and process quality standards across EU Member States would help to ensure safety, reliability, and market confidence. Strengthening innovation and investment through targeted financial support, public procurement mechanisms, and greater regulatory flexibility would further promote the uptake of advanced, high-performing technologies. The quality and availability of biowaste and other feedstocks can vary greatly depending on local collection systems and processing methods. To ensure reliable production, these factors must be carefully assessed in advance, taking into account potential contamination risks and seasonal variability. The project also emphasized the importance of user involvement and co-creation. Farmers' needs and practical fertilization requirements should be taken into account in the design and development process through transparent communication, demonstration activities, and regular consultation. This participatory approach helps build trust, increase product relevance, and accelerate its acceptance in the agricultural community. Technical knowledge and joint development were also identified as factors that directly influence progress. Developing fertilizers in collaboration with end users and providing access to products on a pilot scale for testing purposes can help demonstrate their performance in real-world conditions. Such co-creation not only strengthens stakeholder confidence but also supports the transition from research to market-ready solutions within the circular bioeconomy.

Research conducted within the **CiNURGi** and **NUTRIMAN** projects explored how nutrient recovery and recycling could become more practical, safe, and scalable across European agriculture. Both initiatives involved close collaboration between researchers, industry actors, and farmers to understand what still limits the wider use of AF and related technologies. Stakeholders noted that information about successful nutrient recovery practices remains fragmented and that large-scale demonstrations proving the practical value of these solutions are still rare. Without such evidence from real conditions, confidence among farmers, regulators, and investors remains limited. Participants also pointed to a series of recurring challenges. Regulatory hurdles related to animal by-products and sewage sludge, inconsistent quality control, and insufficient engagement of farmers were all identified as major issues that slow down adoption. Across these and other related projects, several categories of barriers can be distinguished. Regulatory barriers arise from the need to comply with the EU Fertilizing Products Regulation, the Animal By-products Regulation, the Nitrates Directive, and local rules that limit which waste streams can be used. Social resistance persists due to safety and environmental concerns. Market competition remains difficult because AFs are often more expensive and perceived as less reliable than mineral ones. Quality consistency is another problem, as products must be free from pollutants and pathogens and meet agronomic standards. Knowledge gaps exist, with many users lacking access to clear guidelines, best practices, and replicable models. Economic incentives are still weak, as current policy frameworks do not strongly encourage the reduction of mineral fertilizer use or the uptake of circular alternatives. Finally, although many nutrient recovery technologies are technically advanced, most have not yet been tested at a large scale under real farming conditions. It can be said that, as a result of the work carried out in the CiNURGi and NUTRIMAN projects, it has been proven that stronger policy alignment, clear quality standards, and active farmer involvement are extremely important elements for wider acceptance. Building trust through transparent communication, practical demonstrations, and evidence gathered in the field is essential for integrating nutrient recovery solutions into mainstream agricultural practices.

Research carried out within the **FER-PLAY** project examined how alternative and AF can be more effectively developed and introduced to the market. The team reviewed best practices, regulatory frameworks, and market strategies to identify barriers to practical implementation. The study showed that although many initiatives generate promising innovations, their outcomes are often not fully applied in policy or practice. This results mainly from limited coordination, inconsistent data collection, and weak communication between research, industry, and public authorities. The FER-PLAY consortium members pointed out that an unstable and fragmented regulatory environment remains a major obstacle. Variations in legislation across countries, combined with limited awareness and acceptance among stakeholders, contribute to the slow and uneven introduction of new products. The team also noted that systematic data on technology readiness, environmental trade-offs, and socio-economic conditions are still lacking, particularly at the regional and local levels. Finally, the work under FER-PLAY emphasized that broad collaboration among projects and stakeholder groups requires time and resources that are often insufficient. To achieve lasting progress, the team recommends stronger coordination, improved data harmonization, and sustained support to ensure that innovative solutions reach both markets and policy frameworks.

The **Lex4Bio** project addresses the transition from minerals to AFs by examining the scientific, environmental, and socioeconomic conditions required for their safe and efficient use in European agriculture. The Project identified several significant challenges for AF. The main issue is the variability in the quality and composition of alternative fertilizers. Alternative fertilizers vary significantly in terms of nutrient content, contamination levels, and nutrient release rates, which complicates their use on different soils, crops, and in different climatic regions. This heterogeneity makes it difficult to predict agronomic performance and undermines market confidence. Reliable quality control and standardization are therefore essential to ensure that AFs can match the performance and safety of conventional mineral fertilizers. Agronomic performance and food safety are also major concerns. Demonstrating that AFs can deliver comparable yields while remaining safe for human health requires extensive field trials under a variety of environmental and management conditions. Currently, such evidence remains limited, slowing down the policy approval process and adoption by farmers. Socioeconomic barriers further hinder market uptake. Farmers and industry stakeholders often lack adequate knowledge, technical support and financial incentives to switch to circular fertilizer solutions. Regional nutrient imbalances add to these difficulties, as some areas experience nutrient surpluses while others face shortages. Efficiently redistributing and adapting fertilizer products to local needs remains a technical and logistical challenge. Environmental protection is another priority. Many waste-derived fertilizers contain trace contaminants such as heavy metals or organic pollutants, and current purification technologies are not yet sufficiently advanced or widely adopted. Ensuring that AFs meet strict standards for food safety, human health, and environmental protection is vital for building trust and regulatory acceptance. Policy and standards development are progressing but remain fragmented. Coherent European-level legislation and harmonized quality standards are needed to guide sustainable AF production, certification and use. Such frameworks take time to design and implement, especially given the diversity of agricultural systems across Europe. Equally important is stakeholder engagement and knowledge transfer, which are crucial for long-term success. Widespread adoption of this technology depends on transparent communication of scientific evidence, practical demonstrations, and a participatory approach that involves farmers, industry, and policymakers. The Lex4Bio project concluded that the transition from mineral fertilizers to alternative fertilizers is not only a technical change, but also a systemic one, requiring a balance between environmental protection, food safety, socio-economic viability, and regulatory consistency. Building trust through evidence-based research, harmonized standards, and targeted policy support will be crucial for the safe and widespread use of sustainable fertilizers in Europe.

Research carried out within the **MainstreamBIO** and **SuMaNu** projects focused on how nutrient recycling and the use of AF can be effectively scaled up and integrated into regional and national agricultural systems. Both projects gathered extensive feedback from stakeholders and practitioners to understand why the transition toward circular fertilization remains slow. The analyses carried out in these projects have shown that nutrient recycling techniques, although technically mature and cost-effective, are still poorly known and underused. The lack of harmonized guidelines and standards continues to cause uncertainty in the sector. Stakeholders have pointed to significant political, social, and regulatory differences between countries, which hinder implementation and reduce stakeholder confidence. Concerns about the safety of waste-derived fertilizers and varying levels of public acceptance, particularly among farmers and consumers, remain major barriers to their wider use. According to analyses carried out by MainstreamBIO, the market for waste-derived fertilizers and recovered fertilizer substitutes is underdeveloped. Value chains are weak and fragmented, and producers find it difficult to reach distribution networks and end users. The awareness and technical knowledge of farmers and rural entrepreneurs are still limited, and many of them are still unaware of the potential benefits of these products. Financial barriers and limited access to investment make it difficult for small and rural operators to enter or expand their activities in the market.

MainstreamBIO's findings underline the need for a better understanding of bioeconomy and nutrient recovery concepts among rural stakeholders. Practical demonstrations, hands-on training, and targeted capacity-building are essential to bridge the gap between innovation and adoption. The project team also highlighted that cooperation, knowledge exchange, and continuous feedback loops are crucial for improving technology transfer and building trust. However, discrepancies between market dynamics and policy frameworks slow down large-scale implementation, and fragmented local supply chains make it difficult to achieve economies of scale. Country-specific analyses reinforced these findings. In Denmark, initiatives based on wetland biomass face challenges related to logistics, landowner cooperation, and insufficiently tailored subsidies. In Sweden, entrepreneurs developing recovered nutrient fertilizer systems encounter barriers such as high market entry costs, limited financial support, a lack of infrastructure, and difficulties applying circular economy principles in practice.

In the SuMaNu project team analyzed why many initiatives for recycling manure and nutrients fail to meet political and environmental goals. Researchers pointed to persistent nutrient surpluses in areas of intensive livestock farming, limited nutrient recovery from wastewater, and a lack of clear and measurable (SMART) targets. Furthermore, project recommendations often fail to influence actual behaviour or policy, mainly due to poor communication, limited stakeholder involvement, and weak integration with existing management structures.

Both projects concluded that stronger cooperation, targeted training, and improved monitoring mechanisms are essential to fill the current gaps. A more supportive regulatory and financial framework is needed to maintain innovation and facilitate market access. Ultimately, effective and sustainable implementation will depend on building local relevance, stakeholder capacity, and consistent alignment of policy and practice at all levels of the AF value chain.

The **Novafert** project provides a critical and comprehensive analysis of how Life Cycle Assessment (LCA) and sustainability frameworks are currently applied to alternative fertilizers (AFs). Its central aim was to identify inconsistencies and propose a harmonized approach that would enable fair comparison between AFs and conventional mineral fertilizers. Novafert's findings reveal a landscape characterized by fragmentation and methodological divergence. The project identified a lack of standardized LCA models, which prevents the consistent evaluation of environmental performance across different fertilizer types. Moreover, discrepancies in functional units, system boundaries, and performance

indicators make direct comparison between products nearly impossible. This methodological inconsistency is further amplified by diverse and sometimes conflicting regulatory frameworks and datasets across regions, which hinder a coherent and unified approach to environmental and agronomic assessment. Another important insight from Novafert is that current LCA practices often overlook key sustainability dimensions, such as soil health, biodiversity, carbon sequestration, and pollution control (including contaminants like heavy metals and microplastics). These indicators are essential for understanding the real environmental value of AF but are rarely included in assessments due to insufficient location-specific models and methodological limitations. In addition, the project observed that most existing studies remain focused on technological process optimization rather than on measuring the actual agronomic performance and long-term field impacts of AF products. This gap limits the ability to verify claims about environmental benefits and crop performance under real conditions. From a governance and market perspective, Novafert highlighted inconsistent technology performance, fragmented local governance structures, and weak economic incentives as barriers to the safe and economically viable scaling of bio-based alternatives. Although nutrient recovery technologies already exist, they are often not fully adapted to local contexts or integrated into existing value chains. Stakeholders also emphasized the need for better coordination and clearer regulatory guidance to enable uptake. Finally, the project underscored two systemic challenges: delays in environmental impact assessments and the persistent difficulty of keeping nitrogen and phosphorus flows within ecological limits. The lack of a coordinated regional approach, coupled with scattered and unsystematic best practices, further hampers progress. To address these issues, Novafert is developing policy briefs and action plans aimed at improving regulatory alignment, promoting harmonized methodologies, and encouraging more effective market integration of AF. Overall, Novafert makes a compelling case for standardization, collaboration, and systemic policy support as prerequisites for scaling circular and sustainable fertilizer solutions in Europe.

The **NUTRI-KNOW** project provides an in-depth analysis of the current state of recovery and recycling techniques for bio-based products (BBs), recovered nutrients (RNs), and related materials. Its findings reveal a series of interconnected challenges that hinder the effective scaling, adoption, and long-term sustainability of these innovative solutions within nutrient management and the broader bioeconomy. One of the most prominent issues identified is the persistence of communication and knowledge gaps. Training opportunities and capacity-building initiatives for practitioners, farmers and other end users remain limited, resulting in a lack of technical expertise and confidence in applying advanced recovery or recycling processes. Gaps in data on the performance, safety, and practical benefits of available technologies further undermine confidence and interest in them. Technology transfer is often slow, and successful pilot projects are rarely replicated on a larger scale due to differences in local conditions and a lack of structured knowledge-sharing mechanisms. Furthermore, public awareness of the environmental and economic benefits of such innovations is generally low, and monitoring and evaluation systems for tracking the performance of new technologies remain underdeveloped. Economic challenges also play a significant role. Many recovery and recycling systems require substantial investments in infrastructure, technology adaptation, and operation, yet financial support remains insufficient. Market demand for recovered products is often weak, partly due to uncertainty about their quality and reliability. Furthermore, the lack of transparent data on costs and profitability makes it difficult for investors and manufacturers to assess the long-term viability of these processes. Without clear business models and financial support mechanisms, the financial risks associated with implementing these technologies remain high. Environmental challenges relate mainly to the unknown or variable impacts of new recovery methods. Techniques that perform well under specific climatic or soil conditions may not be suitable elsewhere, raising concerns about regional adaptability and ecological compatibility. Furthermore, while these technologies are designed to reduce environmental

harm, some may introduce unforeseen risks to ecosystems or contribute to new forms of pollution if not properly managed. Long-term sustainability assessments are therefore essential to ensure that solutions align with broader environmental protection goals. Legal and regulatory barriers further hinder implementation. Current recycling and recovery regulations are often unclear or restrictive, making it difficult for operators to obtain permits and comply with standards. Trade barriers, fragmented policies, and a lack of harmonization between regions create additional obstacles to market access. Intellectual property and licensing issues can also limit the adaptation or modification of existing technologies, reducing flexibility and innovation potential. Social and behavioural factors represent another layer of complexity. Adoption is often limited by resistance to change, cultural preferences, and skepticism toward new products or practices. In some cases, technologies are incompatible with local farming traditions or perceived as risky or unproven. Social acceptance and equity issues - such as unequal access to resources, technologies, or benefits—further constrain widespread implementation. Demonstration projects and successful case studies remain limited, reducing opportunities for learning and trust-building. As solutions to the aforementioned gaps and challenges, the project emphasized the importance of coordinated stakeholder engagement. Effective cooperation between farmers, scientists, policymakers, industry representatives, NGOs, and the media is essential, but currently fragmented. A lack of mutual trust and insufficient communication between sectors undermines knowledge exchange and slows down the implementation of innovative recovery solutions. In conclusion, NUTRI-KNOW emphasizes that although the technological potential for nutrient recovery and recycling is significant, systemic barriers remain in the areas of knowledge, economics, the environment, regulation, and society. Overcoming these challenges will require targeted actions to strengthen training and communication, harmonize policies, provide financial incentives, and build collaborative networks linking science, policy, and practice.

The **P2GreeN** guidance report highlights several significant technical, environmental, economic, and data-related gaps that affect the implementation and evaluation of AF. The findings underscore the complexity of managing diverse regional contexts, ensuring data quality, and achieving harmonized methodologies across all pilot regions. From a technical point of view, one of the most important challenges is the diversity of value chains. Each pilot region operates under different local conditions, including different sanitary waste management systems, fertilizer production technologies, crop structures, and environmental conditions. This diversity makes it difficult to standardize data collection methods and compare results between locations. Another important issue is monitoring requirements — ensuring pollution control; fertilizers derived from human waste streams must be thoroughly tested for pathogens, pharmaceutical residues, and heavy metals. From an environmental assessment perspective, gaps have been identified in the assessment of the life cycle and impact of AFs. Reliable life cycle assessments (LCAs) rely on detailed process data, including inputs, emissions, and energy consumption, but this data is often incomplete or replaced by general literature values, which undermines the accuracy of the results. Furthermore, direct monitoring of emissions—especially greenhouse gases and nutrient leaching—cannot always be implemented, leading to uncertainty in environmental impact estimates. Challenges related to ensuring compliance with FAIR principles (findability, accessibility, interoperability, and reusability) were identified. Data templates and digital tools used in different pilot projects are not always compatible, which hinders integration, analysis, and broader knowledge sharing.

The **SEA2LAND** project analyzed the main gaps and challenges related to the use of nutrients recovered from agricultural and aquaculture by-products for the production of bio-based fertilizers. The following barriers limiting the wider use of bio-based fertilizers were identified. Environmental gaps relate to limited knowledge about greenhouse gas emissions associated with bio-based fertilizers. Regulations

and business models are a challenge. Standards and approval rules vary from country to country, causing uncertainty among producers and users. Farmers are cautious about using these fertilizers without clear evidence of benefits or a stable supply. Production and distribution systems also need improvement to make bio-based fertilizers more competitive with mineral fertilizers in terms of cost and ease of use.

The **SYSTEMIC** Policy Brief identifies the following gaps and challenges for AFs. At the regulatory level, one of the most difficult challenges is the classification of recovered nitrogen fertilizers. Differences between countries in the definitions of bio-based waste and certification procedures further fragment the market, preventing the establishment of a coherent EU framework. From an economic and market perspective, the lack of targeted incentives remains a major obstacle. Manufacturers and farmers face significant financial and operational risks when considering switching from conventional synthetic fertilizers to recovered fertilizers. It has been noted that there is no harmonized European certification system that recognizes the climate and environmental benefits of using AF, which limits their visibility in the context of sustainable development and hinders their competitiveness in the agricultural inputs market.

The **WalNUT** project reports D1.4 “Barriers to BBF Development” and D1.3 “EU27 matrix for bio-based input streams and NR technologies” describe a wide range of technical, regulatory, economic, social, and policy issues that currently limit the large-scale use of AFs. The gaps include fragmented and sometimes conflicting national, regional, and EU regulations. These inconsistencies hinder the development of a single European market for recovered fertilizers. Concerns about contamination, such as the presence of heavy metals, micropollutants, or pathogens, also remain a serious issue. Farmers are often concerned about soil safety, crop contamination, and consumer perception, which reduces their willingness to use fertilizers derived from waste or sewage sludge. Because of these concerns, frequent and costly testing is often necessary, slowing down market development. The challenge is end-user acceptance. Many farmers are hesitant to use waste-based fertilizers due to uncertainty about their quality and a lack of reliable information. Economically, nutrient recovery systems involve high investment and operating costs, and business models remain underdeveloped. The lack of harmonized product definitions and standards across Europe makes it difficult for producers to certify and market their products. Furthermore, communication between scientists, policymakers, and practitioners is often limited, preventing effective knowledge exchange and dissemination of good practices. Policy gaps—particularly the lack of financial incentives or dedicated support programs—remain one of the main barriers to wider adoption of these fertilizers. The WalNUT D1.3 report adds a broader perspective at the EU level, focusing on differences between Member States in terms of operational, technical, and regulatory barriers. It identifies missing data collections, differences in technological readiness, and limited experience in large-scale operation as the main obstacles. Challenges related to pollution, compliance with the EU Fertilizer Regulation, and complex approval procedures under end-of-life waste and REACH regulations are also slowing down commercialization. A key technical issue is the lack of standardized analytical and monitoring protocols. There is a strong need for harmonized EU definitions, certification systems, and risk assessment protocols for recovered fertilizers. Monitoring and data collection must be strengthened to make information more comparable and transparent. Finally, stronger policy coordination and targeted incentives are required to encourage investment, improve user confidence, and align national approaches with the EU’s circular economy goals. WalNUT shows that the barriers to nutrient recovery and bio-based fertilizer development are not only technical but also institutional and behavioral. Addressing them will require collaboration among policymakers, researchers, industry, and end users to build a trusted, safe, and economically viable circular nutrient system in Europe.

Across all analyzed projects, recurring patterns emerge that regulatory fragmentation and lack of harmonized certification are universal barriers. Economic and infrastructural limits hinder scaling, especially for smaller producers. Social acceptance, communication, and data management issues reduce trust and adoption. Technical variability and contamination control remain key research priorities. The main overarching solutions proposed include harmonizing EU and national regulations on recovered products, creating stable financial and policy incentives, establishing common data, testing, and certification frameworks, strengthening stakeholder engagement through co-creation and training and promoting awareness and transparent communication to boost acceptance.

Table 2. Technical, environmental, economic, and data gaps and challenges in AF development.

Category	Gaps and Challenges	Projects Highlighting the Issue	Potential or Proposed Solutions
Technical Performance	Limited technology readiness, inconsistent performance of AF systems across regions and feedstocks	WalNUT, SEA2LAND, P2Green, NUTRI-KNOW	Harmonized testing protocols, pilot-to-field scale transition programs, and technology standardization
Feedstock Variability	Composition and contamination (heavy metals, pathogens, micropollutants) vary by source, complex treatment	WalNUT, P2Green, bio-SOLUTIONS	Establish quality schemes and contaminant thresholds; promote pre-treatment and source separation
Process Monitoring	Lack of continuous process and emission monitoring (especially N ₂ O, CO ₂ , and leachate)	P2Green, SEA2LAND, NUTRI-KNOW	Implement site-specific sensors, harmonies LCA protocols, invest in digital monitoring
Product Safety and Quality	Uncertainty around the safety of waste-derived fertilizers and insufficient analytical standards	WalNUT, P2Green, SYSTEMIC	EU-wide certification scheme for recovered products, updated analytical guidelines
Environmental Impact	Unknown long-term soil, crop, and emission impacts; inconsistent field results	SEA2LAND, NUTRI-KNOW, bio-SOLUTIONS	Long-term multi-site trials, integrated LCA and risk assessment frameworks
Climate Sensitivity	AF performance and quality often depend on local conditions, which makes them difficult to standardize.	SEA2LAND, NUTRI-KNOW	Regional adaptation strategies, climate-resilient nutrient models
Data Gaps	Missing or inconsistent process and impact data across pilots and countries	P2Green, WalNUT	Centralized open databases, adherence to FAIR data principles
Economic Viability	High costs of installation, operation, logistics, and certification	NUTRI-KNOW, SEA2LAND, SYSTEMIC, WalNUT	Financial incentives, shared infrastructure, and carbon credit schemes
Market Competitiveness	Conventional fertilizers are cheaper and more convenient to use	SYSTEMIC, SEA2LAND, NUTRI-KNOW	Policy incentives, carbon pricing, and public procurement of AFs
Infrastructure Constraints	Solutions are difficult to implement in existing systems and are typically viable only for new facilities.	P2Green	Design modular systems adaptable to existing infrastructure
Investment Barriers	There are no stable or lasting financial programs, grants, or investments that could support the project or technology over time.	SYSTEMIC, WalNUT, NUTRI-KNOW	Dedicated EU and national investment schemes, risk-sharing models

Table 3. Social, communication, policy, and regulatory gaps and challenges in AF development

Category	Gaps and Challenges	Projects Highlighting the Issue	Potential or Proposed Solutions
Regulatory Ambiguity	Overlapping or inconsistent EU/national rules; unclear end-of-waste criteria	WalNUT, SYSTEMIC, bio-SOLUTIONS, NUTRI-KNOW	Harmonized EU definitions; update of Regulation (EC) 1069/2009; clearer guidance for additives and inputs
RENURE Restrictions	Recovered nitrogen treated as manure under the Nitrates Directive	SYSTEMIC	Implement RENURE criteria and pilot exemptions for recovered N products
Fragmented Standards	Different national certification and safety schemes	WalNUT, SYSTEMIC	Create a unified EU certification and quality assurance framework
Permitting Delays	Complex and slow permitting for new nutrient recycling installations	NUTRI-KNOW, WalNUT	Streamlined administrative procedures, clear national guidelines
Lack of Policy Alignment	Disconnection between circular economy, water, and agriculture policies	bio-SOLUTIONS, SYSTEMIC, WalNUT	Integrated nutrient management strategies across sectors
Missing Incentives	No carbon credits, subsidies, or tax reliefs for AF producers/users	SYSTEMIC, NUTRI-KNOW	Include nutrient recycling in the EU ETS, and offer eco-scheme payments
Knowledge Gaps	Lack of technical expertise, training, and information for practitioners	NUTRI-KNOW, WalNUT, bio-SOLUTIONS	Capacity-building programs, advisory networks, extension services
Communication Barriers	Poor transfer of knowledge from research to farmers and industry	NUTRI-KNOW, WalNUT, bio-SOLUTIONS	Multi-actor platforms, farmer-to-farmer learning, media involvement
Social Acceptance	Resistance to using waste-derived products due to perception or stigma	NUTRI-KNOW, WalNUT, P2GreeN	Awareness campaigns, transparency in safety & benefits
User acceptance and practice adjustment	Low willingness to implement unfamiliar technologies	NUTRI-KNOW, WalNUT	Promote learning through peer-to-peer examples
Poor collaboration across sectors	Weak cooperation among farmers, researchers, and policymakers	NUTRI-KNOW, WalNUT, P2GreeN	Co-creation approaches, regional innovation clusters
Data Management	Partners not following FAIR principles, database incompatibility	P2GreeN	Enforce FAIR data standards, interoperable EU data platforms
Transparency and Trust	Farmers distrust quality claims and policy commitments	WalNUT, NUTRI-KNOW	Certification transparency, demonstration projects, and local partnerships
Market Awareness	Limited understanding of AF advantages among users and buyers	SYSTEMIC, NUTRI-KNOW	Marketing campaigns, eco-labels for recovered fertilizers

3.2.1 Conclusions

The development and deployment of bio-based fertilizers (BBFs) and recovered nutrient (RN) solutions in Europe have shown significant potential for creating a sustainable, circular nutrient economy. Multiple Horizon 2020 and EU-funded projects, including Novafert, FER-PLAY, MainstreamBIO, SuMaNu, B-Ferst, bio-SOLUTIONS, Lex4Bio, NUTRI-KNOW, P2GreeN, SEA2LAND, SYSTEMIC, and WalNUT, have systematically explored the technological, environmental, economic, regulatory, and social barriers that currently limit the uptake of these solutions. All of these studies together show that the development of bio-based fertilizers and nutrient recovery solutions is shaped by a highly interconnected system, where advances in technology, consistent regulations, market growth, and effective stakeholder involvement influence each other and must progress in coordination.

A recurrent technical challenge identified across projects is the variability and heterogeneity of bio-based and recovered nutrient products. AFs are derived from diverse feedstocks, including agricultural residues, food waste, manure, sewage sludge, wetland biomass, and aquaculture by-products, which vary seasonally, geographically and in chemical composition. These variations affect nutrient content, mineralization rates, moisture retention, and the presence of contaminants such as heavy metals, micropollutants, microplastics, pathogens, and organic residues. Recovery technologies, ranging from composting, anaerobic digestion, and struvite precipitation to thermal methods, membrane filtration, and biorefinery processes, must accommodate these diverse inputs while remaining scalable and economically feasible. Pilot-scale demonstrations often highlight limitations in handling multiple feedstocks or integrating recovered nutrients into existing fertilizer production lines. Slow or uneven nutrient release from AFs can reduce agronomic reliability, requiring supplemental mineral fertilizers in some cases, and field trials show site- and season-specific variability in yield performance.

Environmental and sustainability gaps are also important. Current tools for assessing fertilizers, like DSSAT, DNDC, and DayCent, often cannot fully capture how bio-based fertilizers behave. Many models rely on incomplete or literature-based datasets, reducing reliability in predicting greenhouse gas emissions, nutrient leaching, or ecosystem impacts. Climate variability introduces additional uncertainty, with droughts, excess moisture, or extreme weather events influencing both product performance and environmental risk. Monitoring for emissions, leachate, pharmaceuticals, pathogens, and other contaminants is not consistent across locations, making it harder to evaluate environmental risks and trust safety claims.

Nutrient recovery technologies often require large investments and high energy use, and without stable markets or coordinated supply chains, recovering these costs is hard. High expenses for production, transport, storage, and quality control make it difficult for farmers and small operators to adopt these products. Conventional fertilizers are usually cheaper and more familiar, so bio-based and recovered nutrient fertilizers face competition. Financial and policy support is often limited, making investment risky, especially for small-scale or rural producers.

Divergent national and EU regulations, unclear definitions of biowaste, variable end-of-waste criteria, and inconsistent application of the Fertilizing Products Regulation create uncertainty and hinder harmonization. Regulations often do not recognize that some recovered nitrogen fertilizers work as well as conventional mineral fertilizers, which limits their use under rules like the Nitrates Directive. Approval processes are complex and slow, and responsibilities are divided among different authorities, creating extra administrative burdens and delaying market access. Certification for environmental benefits, nutrient content, and safety is often inconsistent or missing, which reduces trust among farmers and consumers.

Farmers remain cautious because AF quality can vary, the agronomic benefits are uncertain, and there are perceived risks from contaminants. Limited knowledge of product advantages, few demonstration trials, and a lack of local pilot projects make it harder to trust new solutions. Consumers also show resistance, especially to fertilizers made from human or animal waste. Knowledge sharing and communication are often inconsistent, relying on intermediaries like cooperatives, advisors, or NGOs. Differences between generations, varying digital skills, and local cultural practices also affect how widely these products are adopted.

Many innovative techniques and technologies, although developed and tested, are not effectively disseminated or scaled due to inadequate monitoring, evaluation, and reporting systems. Data fragmentation prevents benchmarking, replication, and comparative analysis across regions and feedstocks. Projects report on the need for standardized methodologies for monitoring product quality, environmental impact, nutrient flows and social acceptance. Collaboration and coordinated action between academia, industry, public authorities, and end users are often limited, hindering mutual learning and alignment of research outputs with practical needs.

Addressing these multi-dimensional barriers requires coordinated action on several fronts. Technically, investments in research and development are essential to optimize nutrient recovery, improve process scalability and ensure consistent product quality. Enhanced field trials and site-specific calibration of agronomic models will strengthen confidence in AF performance. Environmentally, robust and harmonized monitoring systems are required to assess emissions, nutrient losses, and long-term soil health impacts. Economically, supportive policies, financial instruments, and market incentives can lower entry barriers and promote investment in innovative solutions. Regulatory alignment and simplification, including consistent certification, harmonized standards, and clearer end-of-waste criteria, will reduce administrative burdens and improve cross-border adoption. Socially, targeted education, hands-on demonstrations, stakeholder engagement, and transparent communication are needed to increase awareness, acceptance, and trust among farmers, consumers, and local communities.

In conclusion, the transition to a circular nutrient economy in Europe is constrained by mutually dependent technical, environmental, economic, regulatory and social challenges. While individual projects have developed innovative technologies, identified best practices and demonstrated potential environmental and agronomic benefits, widespread uptake is limited by heterogeneity in products and technologies, fragmented policy frameworks, market uncertainties and social resistance. Achieving scalable, safe and economically viable bio-based and recovered nutrient solutions requires integrated strategies that combine technology optimization, harmonized regulation, stakeholder engagement and coordinated knowledge sharing. Only through such systemic action can the full potential of nutrient recovery, bio-based fertilizers and circular nutrient management be realized across diverse European contexts.

List of investigated projects

B-Ferst Towards sustainable business models in the circular bioeconomy: The case of bio-based fertilizers (https://bferst.eu/wp-content/uploads/2025/04/16752_2.pdf)

bio-SOLUTIONS <https://www.soilutions-project.eu/resources/>

FER-PLAY D2.3. Clustering with sister projects: outcomes and lessons learnt (https://fer-play.eu/wp-content/uploads/2024/09/FER-PLAY-D2.3_clustering_projects_outcomes_lessons_website.pdf)

FER-PLAY D1.1. Comprehensive overview on alternative fertilizer value chains (https://fer-play.eu/wp-content/uploads/2024/07/FER-PLAY-D1.1_Comprehensive-overview-on-alternative-fertiliser-value-chains_website.pdf)

Lex4Bio <https://lex4bio.eu/expected-results/>

Mainstream Bio D1.3 Mapping of regional bio-based value chains (https://mainstreambio-project.eu/wp-content/uploads/2025/09/D1.3_MTU.pdf)

Mainstream Bio D2.1 Catalogues of technologies, business models and social innovations for small-scale biobased solutions (https://mainstreambio-project.eu/wp-content/uploads/2025/09/D1.3_MTU.pdf)

Mainstream Bio D2.4 MainstreamBIO methodology for matching available biomass and waste streams with market and technology information (https://mainstreambio-project.eu/wp-content/uploads/2025/09/D2.4_WR.pdf)

Mainstream Bio D3.1 Report on engagement of multi-actor partnerships, capacity building, networking and innovation support - final version (https://mainstreambio-project.eu/wp-content/uploads/2025/09/D3.3_INNV.pdf)

Mainstream Bio D3.2 Report on awareness raising and education activities - initial version (https://mainstreambio-project.eu/wp-content/uploads/2025/09/D3.2_MTU.pdf)

Mainstream Bio D3.4 Report on awareness raising and education activities – final version (https://mainstreambio-project.eu/wp-content/uploads/2025/09/D3.4_MTU.pdf)

Mainstream Bio D4.3 Replication guide and toolkit (https://mainstreambio-project.eu/wp-content/uploads/2025/09/D4.3_IUNG.pdf)

Mainstream Bio D4.8 Joint policy recommendations and briefs (https://mainstreambio-project.eu/wp-content/uploads/2025/09/D4.8_IUNG.pdf)

Novafert D2.1 – Sustainability Mapping Report (<https://www.novafert.eu/wp-content/uploads/2025/03/D2.1-%E2%80%93-Sustainability-Mapping-Report-1.pdf>)

NUTRI-KNOW Report on needs and barriers for user acceptance (https://www.nutri-know.eu/wp-content/uploads/2024/12/Attachment_0-2.pdf)

NUTRI-KNOW D2.3 Report on needs and barriers for user acceptance (https://www.nutri-know.eu/wp-content/uploads/2024/12/Attachment_0-2.pdf)

P2Green D5.5 Report on results of actions for knowledge exchange and capacity building (4 focus groups), providing focus groups' results. Closing the gap between fork and farm for circular nutrient flows (<https://p2green.eu/wp-content/uploads/2024/03/D5.5-Report-on-results-of-actions-for-knowledge-exchange-and-capacity-building-4-focus-groups-providing-focus-group-results.pdf>)

Sea2Land D9.9 Practice Abstracts M54

Sea2Land D5.3 Future evolution of the produced fertilizers effectiveness (<https://sea2landproject.eu/wp-content/uploads/2025/07/D5.3.pdf>)

SuMaNu Typical pitfalls leading to gaps between envisaged and realized impacts of manure and nutrient-related projects - a gap analysis (https://www.organe.dk/docs/SuMaNu_Report_2-3_Gap_analysis_Organe_Report.pdf)

SuMaNu The SuMaNu International events report 2021 (<https://balticsumanu.eu/wp-content/uploads/2021/06/SuMaNu-International-events-report-2021.pdf>)

SYSTEMIC D4.10 Cover delivery report: Policy sound message on the produced products, including information on regulatory obstacles and barriers on national and EU level (https://systemicproject.eu/wp-content/uploads/D4.10_SYSTEMIC_Policy_Brief.pdf)

WalNUT D1.4 Barriers on BBF development (https://walnutproject.eu/wp-content/uploads/2023/11/Attachment_0-6.pdf)

WalNUT D1.3 – EU27 matrix for bio-based input streams and NR technologies (https://walnutproject.eu/wp-content/uploads/2023/11/Attachment_0-8.pdf)

WalNUT D2.2 Characterization of wastewater streams with different origins (https://walnutproject.eu/wp-content/uploads/2023/11/Attachment_0-2.pdf)

3.3 Gaps and challenges based on FERTITEC project findings

The main source of information for this part of the study was previous work and final products developed within the project. In particular, the detailed technology descriptions developed within Task 1.1 were used, with particular emphasis on the identified technological constraints and development conditions. Additionally, the findings and analyses presented in Deliverable 1.3 were considered, as well as the 30 selected case studies examined within Task 1.3. These materials served as a basis for identifying and categorizing the main factors influencing the development of technologies and the market of alternative fertilizers.

According to the main findings from Task 1.1, the development of technologies for recovering and processing fertilizer nutrients from organic waste in the European Union faces numerous administrative, legal, technical, and economic challenges.

3.3.1 Regulatory and administrative aspects

Across the European Union, there remains considerable divergence in the interpretation of regulations regarding the classification of fertilizer products. In many countries, recovered nitrogen products, despite a high degree of purification, are still treated as manures under the Nitrates Directive. Another problem is the diversity of interpretations regarding obtaining the appropriate environmental permit for the construction and operation of installations. In most EU countries, such installations are subject to environmental protection regulations, which require obtaining an administrative decision issued by the relevant authority. The differences in national procedures and interpretations create formal obstacles to the implementation of the same installation or technology across different EU countries. The lack of a uniform approach to product classification under Regulation (EU) 2019/1009 remains a problem. Some materials, such as human excreta compost or separated urine, are not yet recognized as permitted ingredients (CMCs), meaning products containing them cannot be placed on the market.

3.3.2 Technical and operational conditions

Many of the technologies discussed are still in the pilot phase, with a technology readiness level (TRL) of 6–8. This means that while these solutions are technically feasible, full commercial validation and long-term operational data are still lacking. Implementing them on a larger scale requires further testing, reliability assessment, and analysis of environmental impact and economic viability. Some of the available solutions are patent-protected or require the purchase of licenses. This applies to stripping and scrubbing technologies and phosphorus recovery systems, for example. This requires a thorough licensing analysis before planning any investment and may impact further commercialization. The technical aspects of operation also pose challenges. The efficiency of ammonia removal processes

varies seasonally and is reduced during extreme winter and summer temperatures. In some cases, excessive water content in the product arises, requiring additional maintenance methods.

3.3.3 Economic and investment challenges

One of the key factors limiting the widespread adoption of these technologies is their high investment cost. Depending on the type of installation, capital expenditures range from several hundred thousand to several million euros. Such costs make stationary installations profitable only at sufficiently large production scales. In addition, operating expenses are considerable, including energy, chemicals, and equipment maintenance, which, depending on the technology, may reach tens of thousands of euros per year.

3.3.4 Agronomic and Logistical Aspects

From an agronomic perspective, key limitations concern the chemical composition and quality of fertilizers. The variability of organic raw materials affects product heterogeneity, which complicates precise fertilization planning. The presence of sulfur can limit the use of some fertilizers, particularly on grasslands. Furthermore, liquid products are characterized by low nutrient concentrations, which increases transportation costs and limits their economic distribution range to approximately 30 kilometres from the processing plant. In the case of nitrogen-potassium concentrates, this range can be up to 200 kilometres, but exceeding this distance often makes transportation uneconomical.

Task 1.3 identified the 30 most promising alternative fertilizer production technologies from among those already in use and described in Task 1.1 (over 180 cases). The evaluation considered techno-economic parameters, the degree of innovation, circularity along the entire value chain, environmental impacts, scalability, market performance of the resulting products, as well as regulatory, standardization, and social acceptance aspects. The technologies selected on this basis were most frequently represented by processes based on anaerobic digestion and composting, utilizing agricultural biomass and urban wastewater. Similar patterns were observed in Task 1.1, where the largest group comprised technologies relying on composting, anaerobic digestion, ammonia recovery, and struvite precipitation. This indicates that these technologies are currently the most mature, well-adapted to market conditions, and least constrained by the limiting factors described above.

Report D1.3, based on information gathered among project partners and an assessment of the alternative fertilizer (AF) market and regulatory environment, this section presents the main drivers and barriers affecting their implementation and use. These factors are crucial for identifying the main challenges and potential opportunities for further market development. It is important to emphasize that some of them – such as policies and regulations – can simultaneously act as both drivers and barriers.

3.3.5 Drivers

Policy and regulations constitute one of the most effective enabling factors at both the European and national levels. They support the development of the biobased market directly (e.g., through eco-design, bio-waste valorization, product standardization, and incentive systems) and indirectly (through shared goals such as the circular economy, soil protection, sustainable agriculture, and climate targets). In countries like Kenya and Greece, the relatively limited number of regulations governing biobased products can facilitate their introduction and accelerate market adoption. However, in Kenya, the transition to biobased products requires comprehensive policy reform, based on multi-stakeholder collaboration and the implementation of evidence-based measures. The growing demand for nutrients from secondary sources, observed in countries such as Poland and Spain, further supports the

development of the AF market. Improving access to data and advanced tools for assessing the availability and quality of raw materials, both at the national and EU levels, would enable producers to optimally select plant locations and best available techniques (BAT) for specific production types. The expansion of organic farming is another key supporting factor. Countries such as Sweden, Finland, and Greece have the highest share of organic farming in total agricultural area, which directly translates into increased demand for AF products. In the industrial sector, numerous voluntary certifications provide additional incentives, promoting the development of new, cost-effective products and strengthening consumer confidence. At the market level, these certifications also enable better positioning of sustainable products in various segments of the traditional fertilizer market. Additionally, geopolitical factors and international tensions are driving research into alternative feedstocks suitable for AF production. A significant development opportunity in Kenya is better segmenting consumer profiles (e.g., organically certified farmers implementing climate-smart practices, low-income farmers, and export-oriented farmers), which would enable more targeted product design, distribution, and educational initiatives. Rising synthetic fertilizer prices and limited government subsidy options could further accelerate the transition to biobased products, especially if they are linked to a quality verification and certification system.

3.3.6 Barriers

Despite numerous enabling factors, a number of barriers remain that limit the widespread use of AF. Complex, overlapping, or inconsistent legal and regulatory frameworks often delay the introduction of new products to the market. For example, differences in the definitions of waste categories or "end-of-waste" status create uncertainty. Furthermore, legislation develops significantly more slowly than the market and technologies. Data from Spain, Poland, and, to some extent, Sweden and Finland indicate that AF products are subject to regulations across multiple sectors, complicating the licensing process and increasing administrative burdens. The analysis also indicates a lack of clearly defined policy goals supporting the development of AF – for example, minimum levels of AF adoption nationwide within a specific timeframe or limits on intensive farming. Incorporating a system of subsidies or incentives for sustainable AF production or for farmers to produce appropriate raw materials into the regulatory framework could significantly improve the situation. The analysis also indicates a lack of clearly defined policy goals supporting the development of AF – for example, minimum levels of AF adoption nationwide within a specific timeframe or limits on intensive farming. Incorporating a system of subsidies or incentives for sustainable AF production or for farmers to produce appropriate raw materials into the regulatory framework could significantly improve the situation. An equally significant barrier is the low level of awareness of the benefits of using AF. While these products provide nutrients in a more environmentally sustainable manner, they also improve the physicochemical and biological properties of soil – benefits that are often underestimated by end users. In Kenya, AF implementation is further hampered by low farmer confidence in the products' effectiveness, a lack of clear labelling and certification, and a poorly developed distribution network. The situation is exacerbated by an insufficiently effective agricultural advisory system, although growing interest among young agricultural enterprises, organic producers, and climate-smart agriculture initiatives indicates growing market potential. There is significant global interest in the development of alternative fertilizers (AF) made from secondary raw materials. Growing demand for these products, combined with the need for more efficient management of secondary raw materials, translates into promising prospects for the AF sector. However, several significant challenges remain, including mapping the quality and availability of raw materials, the level of readiness of available technologies, product logistics, end-user awareness, and the development and adaptation of regulatory frameworks.

3.3.7 Conclusions

The development of technologies for recovering and processing nutrients from organic waste in the EU faces significant regulatory, technical, and economic challenges. Differences in national interpretations of fertilizer regulations, environmental permits, and product classification under EU law create formal barriers to their implementation. High investment and operating costs, combined with variability in raw material quality and product composition, further limit their widespread adoption. Despite these challenges, the growing demand for sustainable and bio-based fertilizers, the development of organic farming, and supportive EU policies are strong drivers for market development. Overall, the alternative fertilizer sector holds promising potential, but further progress depends on regulatory harmonization, improved technological readiness, and increased awareness and trust among stakeholders.

Table 4. Drivers and barriers to AF technology and market development (FERTITEC project findings)

Area	Drivers	Barriers
Political and regulatory	<ul style="list-style-type: none"> - EU and national policies supporting the circular economy, soil protection, and sustainable agriculture. - Eco-design, bio-waste valorization, and incentive and certification systems supporting the bio-based product market. - In some countries (e.g., Greece, Kenya), fewer regulations may accelerate the introduction of bio-based products. - Potential opportunities for introducing subsidy and tax relief systems for sustainable bio-based production. 	<ul style="list-style-type: none"> - Lack of regulatory consistency across the EU (different interpretations of regulations, end-of-waste status, and waste definitions). - Legal adaptation slows down compared to technological and market development. - Complex administrative procedures and varying requirements for environmental permits. - Lack of clear national goals and strategies for developing the AF market. - Failure to recognize certain raw materials (e.g., human faecal compost, urine) as permitted fertilizer ingredients (CMCs).
Technical and operational	<ul style="list-style-type: none"> - Technological advances in nutrient recovery (e.g., composting, anaerobic digestion, struvite, ammonia recovery). - High level of technology maturity (TRL 6–8) for selected solutions. - Adaptability of the technology to various types of biomass (agricultural and urban). - Development of digital tools and databases supporting raw material assessment and plant location planning. 	<ul style="list-style-type: none"> - Many technologies are still in the pilot phase, with no long-term operational data. - High licensing costs (patented technologies, e.g., stripping/scrubbing, phosphorus recovery). - The variability of raw material quality complicates the production process, product standardization and fertilization planning
Economic and investment	<ul style="list-style-type: none"> - Rising prices of synthetic fertilizers as a result of geopolitical turmoil and access to non-renewable raw materials - The possibility of creating local value chains (short supply chains, lower transport costs). - The development of business models based on the bioeconomy and the circular economy. - Financial support under EU policies (e.g., green investments, environmental innovations). 	<ul style="list-style-type: none"> - Very high investment costs (from several hundred thousand to several million €). - High operating costs (energy, chemicals, service) - Economically viable only at large production scales. - Lack of direct support mechanisms (subsidies, investment incentives) for AF producers.

<p>Agricultural and logistics</p>	<ul style="list-style-type: none"> - The increase in organic farming areas increases demand for AF products (e.g., Sweden, Finland, Greece). - The potential for improving soil quality and ecosystem services. - The possibility of using local organic raw materials (agricultural, municipal). 	<ul style="list-style-type: none"> - Low nutrient concentration in liquid products - high transportation costs. - Limited economic distribution range (approx. 30–200 km). - Chemical variability of products complicates fertilizer application planning.
<p>Market and social</p>	<ul style="list-style-type: none"> - Growing demand for fertilizers promoting AF market development (e.g., Poland, Spain). - Voluntary certifications increase consumer confidence and position sustainable products. - Increased environmental awareness among farmers and consumers. 	<ul style="list-style-type: none"> - Low awareness of the benefits of using AF (lack of understanding of the impact on soil and the environment). - Lack of effective agricultural advisory systems. - Poorly developed distribution networks, lack of confidence in product quality (especially in Kenya). - Insufficient labeling and lack of transparent quality certificates.

3.4 Gaps and challenges based on interviews

As part of Task T1.1 of the FERTITEC project, 24 interview questionnaires were conducted with specialists in the fields of technology, agriculture, the environment, and economics, who have extensive knowledge of the technologies, techniques and practices for producing alternative fertilizer products. The survey involved experts from four European Union countries – Poland, Finland, Spain and Greece – and one African country (UA), Ghana. The respondents represented various stakeholder groups: fertilizer producers, agricultural advisors, members of producer associations and scientists. Feedback from the interviews provided information on gaps and challenges hindering the implementation of nutrient recovery/recycling techniques and proved helpful in identifying potential solutions to facilitate the development of the market for alternative fertilizer products. The full text of the surveys is available in Deliverable D1.1 Current available circular fertilizing practices of 30 June 2025.

The results of a 19-interview questionnaire from the CiNURGi project – Circular nutrients for a sustainable Baltic Sea Region – were also used to assess gaps and challenges in the recovery/recycling of fertilizer products from secondary raw materials. The opinions collected in the CiNURGi interviews questionnaires concerned the following issues: public perception of AF, factors limiting their use, and assessment of the current legal framework and policy instruments at the EU level and in selected countries of the Baltic Sea Region (BSR).

Based on the information gathered from the interviews and questionnaires, this chapter presents the main gaps and challenges, as well as potential solutions in the field of recovery/recycling techniques for fertilizer products from secondary raw materials, divided into technological, legal, economic and market, social, environmental and political aspects. It should be noted that some gaps and challenges in a given aspect affect gaps and challenges in other aspects, as the areas indicated are closely interrelated. Detailed conclusions from the surveys are summarized in Tables 5-10.

3.4.1 Technological aspects

Respondents identified the following as the main gaps and challenges in the technological area of recovery/recycling of fertilizer products from secondary raw materials: insufficient development of certain recovery technologies (low TRL) and difficulties in scaling up the process, difficulties in ensuring continuity of production due to variable (seasonal) availability of raw materials, inconsistent composition and quality of raw materials, unstable nutrient content and the presence of new groups of contaminants (microplastics, pharmaceuticals) in fertilizer products. They also pointed out that producers sometimes fail to provide information on the type of waste used for AF production. According to the respondents, there is also a lack of funding for research and development of new technologies for AF production.

In the opinion of the respondents, the solution in this regard could be the development of universal technologies for processing a wide range of waste, which are easy to use, preferably single-stage, with the possibility of scaling, and to increase their availability. In addition, modernizing technologies to improve process efficiency and product quality, as well as introducing continuity and standardization of production and ensuring a steady supply of raw materials through the development of local distribution and waste management systems. Clear AF labelling and product quality control confirming the safety of fertilizers are also recommended.

3.4.2 Legal aspects

According to the survey participants, the lack of consistency between fertilizer, climate and waste policies is one of the main factors limiting the development of recovery/recycling technologies for alternative fertilizer products. In addition, complex and inconsistent regulations on end-of-waste status and the use of waste for research purposes harm the development of technologies for processing secondary raw materials for fertilizer purposes. According to respondents, there is also a lack of legal regulations for new substrates (insect farming waste, human excreta) and contaminants (microplastics, pharmaceuticals). Furthermore, according to respondents, the requirements for marketing fertilizers are overly restrictive, complex and costly, regardless of production level.

As a solution in this area, respondents point to the harmonisation and consistency of legal regulations in EU countries and their constant updating, adapted to technological progress. They also suggest simplifying registration regulations for small producers.

3.4.3 Economic and market aspects

High investment costs in new processing plants combined with long-term risk and high uncertainty of return on investment, high production, logistics (including transport and storage) and registration costs, as well as low production profitability, unstable market prices and the lack of support programs dedicated to the development of the AF market are, according to respondents, the most important economic and market factors limiting the development of nutrient recovery/recycling technologies from secondary raw materials.

Among the main economic and market challenges for the development of technologies for the production of alternative fertilizers, respondents identified: increasing the profitability of AF production, ensuring a stable market for sales and achieving competitive prices in comparison to mineral fertilizers.

According to the respondents, to overcome the identified barriers, local distribution and waste management systems should be developed, and production plants should be located close to the main sources of waste generation. Such measures may help to keep AF prices low, reduce transport costs and ensure a steady supply of raw materials and product collection. In addition, the introduction of systemic financial support for research and implementation, as well as subsidies and investment incentives for nutrient recycling for producers and farmers, will also support the development of the AF market.

3.4.4 Socio-environmental aspects

According to respondents, there is a lack of information campaigns on the use of AF in agriculture, as well as a lack of knowledge and awareness among farmers and advisors about the agrotechnical effectiveness of AF. In addition, end users have concerns about the safety of using AF due to the presence of contaminants such as microplastic residues, pharmaceuticals and pathogens. Farmers are also sceptical about the use of AF in fertilization, which is produced from potentially hazardous waste such as sewage treatment plant sludge or human faeces and urine. Farmers' distrust of alternative fertilizer products is also due to the lack of information on labels about the composition, use, safety and effectiveness of AF. Furthermore, uncertainty about the composition of AF due to the variety of waste used in its production can lead to over-fertilization and, consequently, to a negative impact on the environment.

Respondents also indicate that, due to unclear communication and concerns about unpleasant odours, local communities are blocking new waste disposal investments. In turn, producers are afraid of the high environmental costs of waste processing.

The solutions proposed by respondents in this area primarily involve raising public and farmer awareness of the environmental benefits of using alternative fertilizers and building their positive image. Launching educational programmes and technical training for farmers and advisors on the use of AF, organising promotional events such as agricultural exhibitions, webinars, field days and agricultural fairs, conferences, as well as presenting the results of scientific research on demonstration fields. According to the respondents, to increase trust in AF products, it is also necessary to have standards, regulations and certificates that will give end users confidence that alternative fertilizer products comply with applicable legal and quality requirements.

3.4.5 Political aspects

Respondents identified the dominant presence of the traditional fertilizer industry in EU political circles and the associated strong lobby for chemical fertilizers as a key political factor limiting the development of the AF market.

According to respondents, a solution could be government initiatives promoting organic farming and supporting the use of certified AF. In addition, ensuring adequate representation at the European Commission level of entities operating directly in the circular economy and bioeconomy sectors. It was also pointed out that the production and use of fertilizers from waste can be particularly important in times of geopolitical crises in Europe, as these lead to restrictions on access to natural resources (natural gas, phosphates) and thus significantly affect the production and prices of mineral fertilizers.

3.4.6 Summary

The survey confirmed that there is a need to intensify efforts to develop technologies for the recovery/recycling of nutrients from secondary raw materials. Alternative fertilizers should be viewed as valuable products, not as waste disposal methods. Their use can significantly reduce nutrient losses, decrease dependence on synthetic fertilizer imports and support the implementation of the EU's circular economy objectives. For the effective development of the alternative fertilizer market, it is necessary to strengthen public trust, harmonize legislation and increase financial support for the development of alternative fertilizer technologies.

Table 5. Detailed results from interview questionnaires on gaps and challenges in AF development - Technological aspects

Gaps	Challenges	Solutions
Technological aspects		
<ul style="list-style-type: none"> • The availability of raw materials (waste materials) depends on many factors • Forecasting trends in biomass availability depends on uncertain forecasts for the development of agricultural and industrial production • The producer has no long-term guarantees for waste collection due to tender procedures • AF can, to a small extent, replace mineral fertilizers from primary production • Gaps in funding for research and development of AF production technologies 	<ul style="list-style-type: none"> • The availability of raw materials (especially local) changes over time • Insufficient raw material for AF production • Variable quality of raw materials, including exposure to contaminants such as plastic • Low or varied utility value of manufactured products (their effectiveness, including nutrient content, composition repeatability, product quality) • High variability of AF batches, composition repeatability difficult to check, and product stability • Low technological maturity (TRL) • Modernization of processing technology • Limited availability of technology for processing various types of waste 	<ul style="list-style-type: none"> • Ensuring a steady supply of raw materials • Developing local sludge/waste distribution and management systems (e.g., selective bio-waste collection at the municipal level + logistics) • Trends in material availability can be forecast by monitoring agricultural production levels, trends in waste generation, and changes in waste management policies • Widespread availability of waste materials - with the increase in the level of economic development and wealth of the inhabitants, the amount of waste increases • Greater transparency and traceability of raw materials • Demonstrated agronomic effectiveness • Safety of use based on rigorous testing and compliance with standards supported by certificates and test reports from a credible research institute • Standardization of AF production • Improving the quality of AF products • Accessible and adaptable technology on a small or large scale • Developing more reliable processing practices

<ul style="list-style-type: none"> • Lack of technical experience or limited technical information • No specific composition for some waste fertilizers • Sometimes producers do not want to inform that a given product is AF and rarely provide information about what waste materials were used in production 	<ul style="list-style-type: none"> • Need for continuous technological innovation to improve process efficiency and reduce manufacturing/production costs, and end prices • Achieving stable repeatability of the elemental composition of the produced fertilizers on a scale larger than that of a laboratory • Recycled fertilizers are characterized by locality and are typically used near the point of production. • The suitability of a given solution for use in different regions depends on the difficulty of replicating the technology and the availability of professional personnel • Product safety is unclear • Farmers are sceptical about products of unclear origin or without certificates 	<ul style="list-style-type: none"> • Easy-to-use technology and maintenance, suitable for a wide range of raw materials • Scaling up production/processes • Production of concentrated AF fertilizers - products with low water content can be economically transported over longer distances, higher nutrient concentration, smaller quantities of product for application, lower costs and better quality of spreading and application • Single-stage technologies for processing waste into AF – those in which all the raw material used is contained in the product (does not lead to the creation of further waste) • Low-tech or modular options (suitable for SMEs and rural areas) • Indication of composition, at least in a simplified form • Quality control of manufactured AF fertilizers, monitoring heavy metals, pathogens, drugs (including antibiotics, microplastics, pesticide residues, hormonal substances, or bacteria), and certification and standardization of final products, quality certification by independent entities • Transparent labeling, clear signage, and compliance with national and EU standards
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Table 6. Detailed results from interview questionnaires on gaps and challenges in AF development - Legal aspects

Gaps	Challenges	Solutions
Legal aspects		
<ul style="list-style-type: none"> • No legal obligation to recover nutrients from waste materials • Lack of an appropriate waste management hierarchy and provisions promoting waste recovery (closed loop of components) • Legal regulations at the EU and national level have a significant impact on the development of technology and the implementation of AF – they can act as a development stimulus or as a barrier if they are too restrictive or not adapted to new solutions • The requirements for placing on the market (especially the conformity assessment procedure) are so high that so far they have been economically unprofitable for fertilizer producers • The need to obtain permits for waste recovery or to remove waste status – a long and expensive process • A difficulty for producers is the requirement to precisely determine the source of the substrates used for the production of AF. In 	<ul style="list-style-type: none"> • There is no clearly defined path/direction that legal regulations will follow • Regulations are neither consistent nor moving in the same direction at the same time as the development of AF technology • Complex registration procedures and legal restrictions - current legal regulations, both national and EU, are the main factor hindering the development of the AF market and often prevent the development of new recovery technologies or significantly prolong them, as well as limit and prevent the storage or disposal of waste • Legal restrictions prevent the scaling up of AF production - technological development remains theoretical or limited to pilot projects • Obtaining required permits (REACH, etc.) • Restrictive regulatory frameworks significantly limit the implementation of technically mature and effective practices 	<ul style="list-style-type: none"> • Good regulation and rationing, which requires full documentation for registration, are essential to building strong trust in AF • Harmonized regulations and more official controls • Clear regulations and effective permits • Easier to market, smaller quantities of product for producers without long, costly and complicated approval processes, provided that all safety standards and legal requirements for the fertilizer are still met • Establishing robust traceability systems for the entire supply and processing chain would ensure the quality and safety of products and

<p>accordance with the regulations, a change in the source of the raw material generates the need to apply for a new permit to introduce AF into the market</p> <ul style="list-style-type: none"> • Regardless of the type of substances used in production, the assessment of the impact of AF is based on the same parameters (Salmonella, intestinal parasite eggs, heavy metals) – the possibility of other risk factors (antibiotics, carcinogenic substances, microplastics, etc.) is not taken into account • In some cases, regulations are too lenient or unclear, or there is no legal framework, e.g. for digestate, sewage sludge, urine, insect farming • In the case of AF produced from certain substances/wastes that are commonly known and used, e.g. in animal feed (molasses, distiller's grains, mushroom cultivation substrates), the procedure for obtaining a marketing authorization could be simplified 	<ul style="list-style-type: none"> • Regulations should clearly define requirements for waste materials before treatment begins • Establishing realistic thresholds (limits) for contaminants (pathogens, etc.) based on scientific evidence, not preventive prohibitions • Currently, the catalogue of pollutants taken into account when authorizing the marketing of organic fertilizers produced from waste seems insufficient and requires expansion to include standards regarding the content of plastic, radioactivity and other pollutants • Introducing new standards into legislation, e.g. concerning specific pollutants, requires establishing permissible pollutant levels and testing methods for new parameters, which is time-consuming and necessitates completing this work before introducing specific proposals into legislation. Therefore, changing legislation requires proper planning and scientific and financial resources. The system works well for materials that are already well known and fall within existing categories, but getting new materials approved is a long and complicated process. 	<p>raw materials, increasing confidence in the use of AF</p> <ul style="list-style-type: none"> • From the point of view of the specificity of EU and national fertilizer legislation, it requires periodic reviews and adaptation to new challenges and technical progress
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<ul style="list-style-type: none"> • Different EU countries have different limits on heavy metal content (or sanitary requirements) in sewage sludge, which hinders trade in recovered materials and their use in plant production between countries • Discrepancies between national and EU law make it difficult to introduce products to the market due to the multitude of paths and ambiguities in the regulations, and the legislative process is long and costly • The existing regulations, in particular Regulation (EU) 2019/1009, support the development of the AF market by establishing a common legal framework across the European Union that allows the placing on the market of products made from secondary raw materials, however, at the national level, some administrative procedures and formalities remain complicated and time-consuming, which may slow down the entry of new AF products into the market • Currently, there is no obligation in the regulations for the waste processor/fertilizer producers to keep current records of the amount of fertilizer produced from waste and to keep records of the recipients of such fertilizer 	<ul style="list-style-type: none"> • Unification of standards (regulations, certificates) for the production of AF, which would provide credibility that a product of a given category meets common standards regardless of where and what it is produced from and that it complies with the relevant legal and quality requirements • Fragmentation of national legislation, allowing the use of certain materials in one Member State and prohibiting their use in others, distorts competition in the market • AF trading requirements vary across EU countries, which may limit access to distribution channels • Ensuring proper supervision of the production and flow of AF fertilizers between the manufacturer and the farmer requires the establishment of an additional obligation to record the production of fertilizers from waste. Direct sales of such products to farmers should also be recorded so that inspection authorities can check the correct quality of the above-mentioned products and the correct use of such products. Such regulation would also aim to prevent unauthorized trade in waste as fertilizers. 	<ul style="list-style-type: none"> • Transparent labeling with analysis of nutrients and contaminants, including information on the potential harmfulness and retention time of contaminants not covered by the legal system, including microplastics, active substances and heavy metal content tests for each batch of AF, as well as recommendations for proper use (cultivation, variety, application rate, application time), etc. • Simplifying the paths from production to the market, harmonizing them with EU legislation (enabling access to the entire EU market) and clear guidelines for all control services to limit the scope for individual interpretation (clear, simple and consistent guidelines for all market participants) • Further simplification of procedures and unification of technical criteria are necessary to facilitate the development of the AF sector • Introduce additional protective mechanisms • The current national legislation on the marketing and use of organic fertilizers (AF) requires continuous improvement, especially in the context of counteracting risks to human health, animals and the environment
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Table 7. Detailed results from interview questionnaires on gaps and challenges in AF development - Economic and market aspects.

Gaps	Challenges	Solutions
Economic and market aspects		
<ul style="list-style-type: none"> • Emerging new technologies for processing waste materials are too expensive for widespread use in dispersed farms • Risk of long-term investments and collaborations related to the collection and processing of waste raw materials • Uncertainty regarding return on investment • Lack of support programs dedicated to the development of the AF market 	<ul style="list-style-type: none"> • High investment costs associated with the construction or modernization of installations for processing waste materials • The costs associated with REACH registration and research often involve new technology unprofitable • Transport issues • High processing/production and logistics costs – both for sourcing raw materials and distributing products • More economic and market incentives are needed to accelerate the growth of the AF sector 	<ul style="list-style-type: none"> • Reasonable (or low) investment cost and possibility of public or private financing • Efficient logistics, especially in rural areas with good infrastructure • Preferably, installation near the main sources of waste generation • Implementation of logistical solutions (maximum permissible total weight of lorries, loading/unloading systems (hoses/pumps), warehousing, storage, etc.) • The best results are achieved by systems that are well adapted to local conditions and practical realities – combined with appropriate logistics and storage solutions, this approach allows for the redistribution of nutrients and correction of nutrient imbalances at the local level • Financial incentives for farms using AF, subsidies for AF producers for the construction of installations • Regulations (e.g. EU) can force the development and sharing of technologies

<ul style="list-style-type: none"> • Recycled fertilizers do not have a stable market price • Offering products (e.g. post-fermentation) at negative prices suggests waste disposal, which hinders building credibility and market development 	<ul style="list-style-type: none"> • The choice of AF is often determined by the price per pure component and transport costs • Unaffordable AF prices • Current structure of the AF fertilizer market • The fertilizer market directly influences the development of technology. Currently, AF costs limit the development of technology • Product demand and product competitiveness 	<ul style="list-style-type: none"> • Legal regulations that force farmers to make changes, especially the Green Deal regulations and changes in the management of agricultural post-production waste and in area subsidies encouraging (by offering higher subsidies) the use of AF fertilization • Promotion of products manufactured in accordance with the principles of the circular economy • Supporting SMEs and innovators in scaling up production • Government incentives, such as subsidies for certified alternative fertilizers or support for organic farming • Entry into emissions trading for technologically advanced biogas plants with a negative carbon footprint • Achieving competitive prices in relation to mineral fertilizers (along with local availability and proven agronomic effectiveness - product quality and effectiveness) • Attractive AF price per pure component, and the possibility of using the application service for such products • The increase in the prices of mineral fertilizers contributes to the development of AF production technology and increases farmers' interest in cheaper "substitutes" of mineral fertilizers • Good local market with potential for growth and development
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Table 8. Detailed results from interview questionnaires on gaps and challenges in AF development - Social aspects

Gaps	Challenges	Solutions
Social aspects		
<ul style="list-style-type: none"> • Lack of information campaigns regarding the use of AF in agriculture, convincing farmers to use these products • No indication of who would be responsible for information, educational, training campaigns, etc. for farmers, advisors, society (including municipalities, schools, children) on the subject of AF • The problem of proving the effectiveness of AF, especially those with the characteristics of soil improvers (SI) or growth stimulants 	<ul style="list-style-type: none"> • Information confusion in the market among farmers who are faced with mixed messages about the safety and effectiveness of AF undermines confidence in these products • Lack of awareness among farmers about the benefits and effectiveness of AF slows down their implementation • Blocking of new investments, e.g. in biogas plants, by the local population • Mineral fertilizers that are carefully produced and adapted to the needs of plants are more willingly chosen by agricultural producers due to their ease of application, availability on the market, price and long-term proven results 	<ul style="list-style-type: none"> • Safety of use based on rigorous testing and compliance with standards supported by certificates and attestations from reliable research institutes • Raising awareness among the public and farmers about the circular economy and its environmental benefits; building a positive image and ensuring that the fertilizer is safe and fully valuable • Educational programs and technical training for farmers on the use and real benefits of AF, as well as scientific research and presentation of results, experiments and demonstration plots, agricultural exhibitions, conferences and webinars, field days and agricultural fairs • Promotional campaigns organized by institutions supporting agricultural production and enterprises producing and marketing AF • Highlighting the complementarity of AF fertilizers with mineral fertilizers, introducing specific AF products as one fertilization technology, with the technological complementarity of fertilization understood as adaptation to a specific crop, soil and climatic conditions, and not a one-time treatment with a given product

<ul style="list-style-type: none"> • Farmers are unaware of the raw materials used to produce the fertilizers they purchase and use • The greatest concerns relate to the use of sewage sludge for the production of AF and its use in agriculture for food production • Any waste from humans is unacceptable • Lack of an incentive system to promote the use of AF 	<ul style="list-style-type: none"> • Low user confidence - farmers do not trust the data on nutrient content and contamination levels provided by AF producers (especially heavy metal content), and are afraid that AF may be a carrier of plant diseases • Farmers are sceptical of products with unclear origin or without certificates; they want to receive reliable and consistent data - sometimes AF producers are not able to offer this kind of guarantee • One of the main reasons for the lack of acceptance of AF by farmers is the unpleasant odour when applied to the field • Pressure from economic entities to process all waste from industry, municipalities, and households and introduce it into agriculture as fertilizers at low technological and financial costs. This approach does not guarantee that the fertilizer produced is safe enough for its intended use. • Declining interest of people in engaging in agriculture due to economic growth in other sectors unrelated to agriculture 	<ul style="list-style-type: none"> • It is necessary to have standards, regulations and certificates that ensure that agricultural products comply with the relevant legal and quality requirements • Certification of the content of water, heavy metals and pollutants (such as strings and agricultural netting, plastic, etc.) and the composition of macro- and microelements is necessary • Limit the intensity of unpleasant odours and store them away from households • Equip biogas plants with equipment for applying by-products to fields in a manner that is neutral for residents • The legal framework should adequately prevent the introduction of products into agriculture that may pose a risk to the quality of the food produced and cause contamination of the soil environment • Government subsidies for the use of AF/systemic nature of support (e.g. CAP)
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Table 9. Detailed results from interview questionnaires on gaps and challenges in alternative fertilizers AF development - Environmental aspects

Gaps	Challenges	Solutions
Environmental aspects		
<ul style="list-style-type: none"> • Processing waste into AF involves energy inputs, water consumption, etc., including transport and distribution - all of which increase environmental costs • Contaminants such as microplastic residues, medicinal products (drugs, antibiotics) and chemicals (heavy metals) may harm the maintenance of soil quality despite the supply of nutrients 	<ul style="list-style-type: none"> • If the elemental composition is variable in each batch of the AF produced, it is very easy to over-fertilize (an unacceptably high residue of a given substance will remain in the tested food) or an undersupply of a given element in the fertilizer will reduce the crop yields • For many substances, especially organic pollutants, there are no clear limit values. This creates uncertainty about the risks and does not provide sufficient protection for the environment or human health. Some pollutants are technically and economically very difficult, or even impossible, to completely remove from certain raw materials. 	<ul style="list-style-type: none"> • Waste that cannot be used without processing should be processed into AF, and efforts should be made to ensure that the recovery of nutrients takes place primarily through the local use of agricultural by-products • Efficient use of all produced alternative products - energy, heat, organic fertilizer • Information about environmental benefits, such as reducing carbon dioxide emissions • Due to their properties and lack of biodegradability, not all waste is suitable for incorporation into the soil. Therefore, some materials should be excluded from agricultural use as fertilizers • Separation of raw materials into high and low risk, e.g. based on harmful substances or pollutants

<ul style="list-style-type: none"> • There is no verification of what is cultivated on land where products containing sewage sludge have been used • Regulations concerning environmental control and protection for manufacturing facilities are fairly general and do not specify how to achieve sanitisation or pathogen inactivation 	<ul style="list-style-type: none"> • Challenges related to climate and environmental policy – emphasis on environmental safety and reducing toxicological risks • Decreasing area of arable land for agricultural production • Changes in climatic conditions affecting the agricultural sector 	<p>GA 101181513</p> <ul style="list-style-type: none"> • Due to their origin, some fertilizers should be restricted to use only on non-agricultural land or for the reclamation of degraded areas. The use of some fertilizers in vegetable and fruit crops for direct consumption should be limited. • Long-term studies assessing the impact of alternative fertilizers on soil
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Table 10. Detailed results from interview questionnaires on gaps and challenges in AF development - Political aspects

Gaps	Challenges	Solutions
Political aspects		
<ul style="list-style-type: none"> • Dominant presence of the traditional chemical fertilizer industry in the political spaces at the EU level; there is a chemical fertilizer lobby that does not allow the development of the AF market • Care should be taken to ensure that waste disposal by farmers using AF is not treated as another powerful source of income for companies involved in this type of disposal 	<ul style="list-style-type: none"> • National and international policies (including monopolistic conditions) that favour the import of mineral fertilizers instead of developing technologies for local AF production • The use of waste materials as raw materials for AF production depends on regulatory factors specific to each country • Local and international conflicts that affect the peaceful conditions for AF production • Competition for raw materials caused by the geopolitical situation – waste used for energy production or building materials 	<ul style="list-style-type: none"> • Ensuring balanced and credible stakeholder representation at the EU level - so that the European Commission gives more weight to the voices of those directly involved in the circular economy/bioeconomy sectors who are actually driving the transformation towards sustainability • Government initiatives promoting organic farming and supporting the use of certified AF • The production and use of fertilizers from waste (circular economy) may be particularly important in times of geopolitical crises in Europe

3.5 Cross-cutting synthesis of gaps and challenges in AF development

Based on the findings from Chapters 3.1, 3.2, 3.3 and 3.4, including the analysis of scientific literature, completed and implemented EU projects, internal work of FERTITEC, and interview questionnaires, the cross-cutting synthesis of gaps and challenges in AF development was created.

Table 11 shows a cross-synthesis between data sources and categories of gaps and challenges, formulating summary points of the main issues that represent the most significant constraints for the development of AF technology.

Table 11. Cross-cutting synthesis of gaps and challenges by category and evidence source.

Category	Literature	EU projects	FERTITEC tasks (T1.1, T1.3, D1.3)	Interviews / Expert Panel
Technical	<ul style="list-style-type: none"> • Technological challenges when shifting from non-renewable to renewable nutrient sources • Limited maturity of several recovery routes and integration with existing fertilizer systems • Need for coordinated technology development across value chains 	<ul style="list-style-type: none"> • High diversity of value chains and local conditions, hard to standardise solutions • Many technologies are still at pilot scale, with limited long-term operational data • Constraints on integrating new systems into existing infrastructure and treatment plants 	<ul style="list-style-type: none"> • Many options at TRL 6–8, lacking full commercial validation • Variable feedstock quality complicates stable operation and product standardisation • Dependence on patented/licensed technologies for key steps (e.g. stripping/scrubbing, P-recovery) 	<ul style="list-style-type: none"> • Low TRL for some technologies and difficulties in scale-up • Seasonal and inconsistent raw material supply; unstable nutrient content • Presence of new contaminants (microplastics, pharmaceuticals) and lack of R&D funding for robust solutions
Economic	<ul style="list-style-type: none"> • High CAPEX and OPEX for recovery/recycling compared with conventional fertilizers • Economies of scale required to reach competitiveness • Strong price competition from cheap synthetic fertilizers 	<ul style="list-style-type: none"> • Nutrient recovery systems are often costly and financially risky • Underdeveloped business models for AF/BBF/RNF value chains • Lack of stable grants, long-term investment programmes and risk-sharing mechanisms 	<ul style="list-style-type: none"> • Very high investment costs and high operating costs; viable mainly at a large scale • Lack of direct investment incentives or subsidies for AF producers • Low nutrient concentration increases transport costs and limits the distribution radius 	<ul style="list-style-type: none"> • Limited profitability and high investment risk for producers and farmers • Difficult access to finance for small and medium actors • Uncertain payback times make actors hesitant to switch from conventional fertilizers

<p>Regulatory / Policy</p>	<ul style="list-style-type: none"> • Fragmented and sometimes inconsistent regulatory landscape for SRM-based fertilizers • Unclear end-of-waste criteria and risk-based restrictions for pollutants • Need for regulatory reform aligned with technological progress 	<ul style="list-style-type: none"> • Overlapping/inconsistent EU and national rules; unclear end-of-waste definitions • RENEURE restrictions treating recovered N as manure under the Nitrates Directive • Slow and complex permitting; misalignment between circular economy, water and agriculture policies 	<ul style="list-style-type: none"> • Divergent national interpretations of product classification and environmental permits • Recovered N is often still treated as manure; no harmonised approach under FPR • Some substrates (e.g. human excreta compost, urine) are not recognised as CMCs, blocking market access 	<ul style="list-style-type: none"> • Lack of consistency between fertilizer, climate and waste policies • Complex, costly registration and marketing rules, especially for small producers • No clear legal framework for some new substrates and contaminants
<p>Social / Market</p>	<ul style="list-style-type: none"> • Limited social acceptance of waste-derived fertilizers • Risk perception and scepticism toward new products and practices • Need for targeted communication and stakeholder engagement 	<ul style="list-style-type: none"> • User acceptance is a major bottleneck; stigma around waste-based products • Weak knowledge transfer from research to practice; limited training and advisory services • Trust gaps between farmers, industry, researchers and policymakers 	<ul style="list-style-type: none"> • Low awareness of AF benefits and their environmental performance • Poorly developed distribution networks and advisory systems • Lack of clear labelling and transparent quality certificates, especially in AU contexts 	<ul style="list-style-type: none"> • Public perception of AF as risky or low-quality products • Farmers' scepticism and reluctance to change established fertilization practices • Need for demonstration projects, local champions and better advisory support
<p>Environmental</p>	<ul style="list-style-type: none"> • Concerns about pollutants in organic waste streams (heavy metals, micropollutants, pathogens) • Uncertainties about long-term impacts on soils and water bodies • Need for robust, comparable LCAs of AF vs conventional fertilizers 	<ul style="list-style-type: none"> • Limited knowledge on GHG emissions and nutrient losses from AF use • Incomplete or inconsistent LCA data; reliance on generic literature values • Difficulty in directly monitoring emissions and leaching in pilots 	<ul style="list-style-type: none"> • Many technologies lack long-term environmental performance data • Need to better document emissions, soil quality impacts and ecosystem services in case studies • Environmental benefits often assumed rather than fully quantified 	<ul style="list-style-type: none"> • Interviewees concerned about microplastics, pharmaceuticals and other emerging contaminants • Limited evidence on soil and water impacts for some AF products • Demand for clearer environmental standards and monitoring protocols
<p>Data / Knowledge</p>	<ul style="list-style-type: none"> • Identified "research gaps" and knowledge deficits in several areas • Methodological biases and untested assumptions in existing studies 	<ul style="list-style-type: none"> • Incomplete process and emission data for LCAs and performance evaluation • Lack of harmonised, FAIR-compliant datasets; incompatible templates/tools across pilots • Limited transparency and accessibility of project results for practitioners 	<ul style="list-style-type: none"> • Heterogeneous quality and completeness of technology and case-study data • Limited monitoring information hampers robust comparison between AF pathways • Need for shared indicators and reporting formats within FERTITEC and beyond 	<ul style="list-style-type: none"> • Stakeholders lack reliable, comparable information on performance, costs and risks • Absence of easy-to-use decision support tools for farmers and advisors • Demand for clearer, synthesised evidence feeding into the EP SWOT exercise

3.6 SWOT Analysis for the Development of Technology and Market of Alternative Fertilizer Products

The SWOT analysis presented in this chapter for the development of nutrient recovery/recycling technologies from secondary raw materials and the growth of the market for alternative fertilizer products (AF) was carried out in accordance with procedures recommended in the literature.

Due to the nature of the study and the popularity of the method, the focus was placed not so much on obtaining the results of the analysis itself, but on demonstrating how one can move from the obtained results to the selection of a specific strategy derived from them. The strategic options resulting from the SWOT analysis are, in fact, the outcome of assessing the entirety of the undertaking, including the identification of sources and areas of inefficiency that need to be eliminated, as well as highlighting the positive features of the project and the favourable characteristics of its environment.

The strengths and weaknesses of the development of technologies for producing alternative fertilizer products, as well as the opportunities and threats present in this environment, were identified based on information obtained from a review of the literature on AF production technologies, from the analysis of results of other ongoing and completed projects dedicated to alternative fertilizers, from interview questionnaires conducted under Task T1.1, and from the analysis of findings made in Tasks T1.3 and T1.4 (market status and legislation) of the FERTITEC project. Based on these materials, barriers, gaps, and challenges hindering the implementation of nutrient recovery/recycling techniques were first defined, along with potential solutions and drivers of AF market development. These have been described in detail in earlier chapters of this document.

The information obtained in this way was used to build a consolidated overview, taking into account all internal and external factors identified in subsequent steps that affect the current condition and development potential of the project. To increase the effectiveness and usefulness of the analysis, the consolidated overview was used to select (collectively) the most important strengths and weaknesses, as well as opportunities and threats (five factors from each group), which determine the choice of strategy for the development of AF technologies and the market. A weighting system was then established for the selected opportunities, threats, strengths, and weaknesses, indicating the importance/significance of these factors for the future development of the project. The weights were determined by 29 industry specialists, based on the results of anonymous surveys addressed to the EP of the FERTITEC project. The highest weights were assigned to the factors with the greatest level of significance, and the lowest weights to those of least importance for the issue under study. The weights were recorded as decimal fractions, with the sum of all weights within each of the four groups of factors always equal to 1.

In the next step of the analysis, the individual strengths, weaknesses, opportunities, and threats were evaluated by assigning them specific values in the context of their impact on the overall assessment of the situation concerning the development of technologies for producing alternative fertilizer products. For all analyzed elements, a five-point rating scale from 1 to 5 was adopted, where the number of points represented the rating (1 – very low, 2 – low, 3 – medium, 4 – strong, and 5 – very strong) assigned to a given factor. The ratings of the impact of individual factors were also determined based on the results of anonymous surveys addressed to the EP of the FERTITEC project.

Knowing the strengths and weaknesses, opportunities and threats, as well as their assigned weights and ratings, a weighted score (the product of the weight and the numerical rating) was calculated for each

internal factor (strengths and weaknesses) and external factor (opportunities and threats). Summing the scores of all factors comprising opportunities, threats, weaknesses, and strengths yielded an aggregate weighted score for each category: opportunities, threats, weaknesses, and strengths. In this way, numerical values were obtained that indicate whether opportunities or threats predominate in the project's environment, and whether the project has an advantage in terms of strengths or weaknesses. The answer to this question concludes the analysis process, since on this basis one can already select one of the four normative strategies to be implemented in the future for the development of nutrient recovery/recycling technologies from secondary raw materials and the growth of the market for alternative fertilizer products (AF).

The final results of the SWOT analysis for the development of nutrient recovery technologies and the growth of the AF market, including the most important strengths and weaknesses as well as opportunities and threats, their assigned weights, and ratings, are presented in Tables 12 and 13.

Table 12. Aggregate weighted results of the SWOT analysis for the development of technology and the AF market. Strengths and weaknesses.

STRENGTHS	Weight	Rating	Weighted value	WEAKNESSES	Weight	Rating	Weighted value
1. High availability of raw materials (waste biomass) for the production of AF	0,23	3,79	0,87	1. Unstable nutrient composition and the presence of contaminants (microplastics, pharmaceuticals) in fertilizer products	0,23	3,69	0,85
1. The safety of using all fertilizers, including AF, is regulated by law	0,21	3,66	0,77	2. Inconsistent composition and quality of raw materials, as well as their variable and local availability	0,23	3,34	0,77
3. Research and innovation potential in the EU (know-how) for the implementation and development of AF technology and production	0,20	3,00	0,60	3. High investment and production costs and logistical difficulties	0,20	3,72	0,74
4. Existence of standards and regulations enabling the marketing of alternative fertilizers (AF) (EU Regulation 2019/1009)	0,19	3,69	0,70	4. Disrupted production continuity, seasonal availability of some raw materials	0,18	2,93	0,53
5. Possibility of AF production near the main sources of waste biomass (raw materials)	0,17	3,28	0,56	5. Insufficient technological development (low TRL)	0,16	3,07	0,49
Sum	1	---	3,50	Sum	1	---	3,38

Table 13. Aggregate weighted results of the SWOT analysis for the development of technology and the AF market. Opportunities and threats.

OPPORTUNITIES	Weight	Rating	Weighted value	THREATS	Weight	Rating	Weighted value
1. EU actions and incentives to support The circular economy and pressure to reduce greenhouse gas emissions	0,21	3,83	0,80	1. Complex legal regulations regarding various aspects of AF production and marketing (end-of-waste status, complicated and costly registration procedures)	0,23	3,69	0,85
2. Building consumer trust through educational programs and training for farmers and advisors, or additional certification for alternative fertilizers	0,21	3,52	0,74	2. Lack of trust and knowledge, and concerns about the safe use (lack of labelling and certification) of AF among farmers and the public	0,21	3,52	0,74
3. Geopolitical tensions causing increases in mineral fertilizer prices and restrictions on access to natural resources (natural gas, phosphates)	0,21	3,31	0,70	3. Strong dominance of mineral fertilizers in the market	0,19	3,72	0,71
4. Development of local distribution and waste management systems to ensure a steady supply of raw materials and product collection	0,20	3,31	0,66	4. Lack of direct provisions promoting AF production and use in CAP	0,19	3,59	0,68
5. Potential access to EU funds for sustainable agriculture under the CAP	0,17	3,59	0,61	5. Investment uncertainty in AF production and the lack of a stable sales market	0,18	3,86	0,69
Sum	1	---	3,51	Sum	1	---	3,67

Based on Table 5, a point was determined that refers to the strategic position of the analyzed undertaking, which makes it possible to indicate the directions of its future strategic plans (Fig. 3). This point was determined according to formulas (1) and (2) in the following way:

$$X = |\text{strengths}| - |\text{weaknesses}| = 3,50 - 3,38 = 0,12$$

$$Y = |\text{opportunities}| - |\text{threats}| = 3,51 - 3,67 = -0,16$$

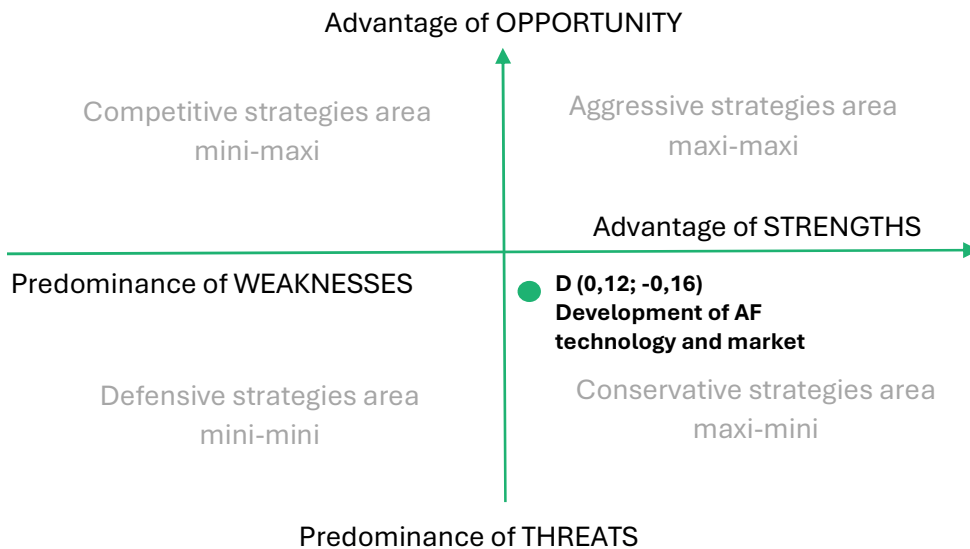


Figure 3. Strategic positioning of AF technology and market development

Analyzing the results of the SWOT analysis, it can be concluded that the subject of the study has more strengths than weaknesses, while its environment contains more threats than opportunities. This means that the analyzed undertaking is located in the fourth quadrant of the Cartesian system, which corresponds to the maxi–mini strategy, i.e., a conservative strategy.

Several factors contributed to this outcome. Among the strengths of the analyzed subject, particular attention should be paid to: the high availability of raw materials for the production of AF fertilizers, the existence of standards and regulations enabling the marketing of AF fertilizers and ensuring their safe use. All these factors had a significant impact on the level of strengths of the analyzed undertaking. Farmers trust products placed on the market in accordance with EU Regulation 2019/1009 or national regulations. They are also willing to use certified AF fertilizer products, for which the nutrient and heavy metal contents are clearly indicated. Moreover, the safety of use is regulated by strict provisions that guarantee these fertilizers meet safety standards and do not pose a threat to soil, crops, or human health.

Among the weaknesses, the most prominent were the variable composition and the presence of new groups of contaminants in fertilizer products, as well as high investment and production costs, along with logistical difficulties. These factors continue to pose a challenge for the development of AF technologies and markets, requiring constant, long-term efforts to mitigate them.

Among the opportunities, the highest-rated were EU actions and incentives supporting the circular economy, as well as geopolitical tensions that increased the prices of mineral fertilizers and restricted access to natural resources. Equally highly rated was the building of consumer trust through educational programs and training for farmers and advisors, or through additional certifications for alternative fertilizers. This represents a particularly important opportunity in the context of overcoming threats in the project’s environment and strengthening its internal strengths.

For the analyzed subject, the highest-rated threats included complex legal regulations concerning various aspects of AF production and market introduction (loss of waste status, complicated and costly registration procedures), as well as a lack of trust, knowledge, and concerns regarding safe use (lack of labeling and certification) of AF fertilizers among farmers and society.

The aggregate results obtained from the SWOT analysis for the development of nutrient recovery/recycling technologies from secondary raw materials and the growth of the alternative fertilizer products market indicate that the undertaking has significant internal potential but must cope with external threats, as the unfavourable environment prevents its intensive development. In this strategy, the undertaking should maximize the use of its strengths to minimize threats arising from its environment.

The outcome of the SWOT analysis shows that the project operates in an unfavourable external environment and is strongly linked to external threats. The set of internal strengths within the undertaking (such as unique resources, skills, and competencies) is therefore capable of decisively responding to threats and competing effectively in the market. In the existing environment, the undertaking is not able to grow intensively, since its strengths do not correspond to the opportunities in the environment. Nevertheless, it can effectively overcome threats while awaiting improvements in external conditions, focusing on strengthening its position and achieving stability (surviving the unfavourable period by drawing on its own resources).

Characteristics of the conservative strategy are actions leading to:

- **Product selection** – focusing on products with the greatest market potential and profitability. Eliminating products that generate losses or have low growth potential.
- **Market segmentation** – precisely defining target groups and concentrating marketing efforts on the most promising market segments. Adapting the offer to the specific needs and preferences of different segments.
- **Cost reduction** – optimizing operational processes to lower production and distribution costs. This may include actions such as automation, renegotiation of supplier contracts, improving energy efficiency, and other measures aimed at increasing efficiency.
- **Improvement of competitive products** – investing in research and development to enhance existing products and create new, more competitive solutions. This may involve introducing technological innovations, improving quality, adding new features, or changing design.
- **Market and product development** – expanding into new geographic or demographic markets and developing new products to meet changing consumer needs. These actions may include entering international markets, adapting products to local requirements, or creating entirely new product categories.
- **Acquisition of new markets** – identifying and entering new markets that offer growth potential. This may include both domestic and foreign markets that have not been previously explored. The strategy may involve actions such as partnerships, strategic alliances, mergers, and acquisitions.

In addition, for the effective development of AF technologies and markets, it is necessary to strengthen public trust, including building strong relationships with key clients, harmonizing regulations, and increasing financial support for circular technologies (investing in the development of key competencies). The development of alternative fertilizers may become one of the key elements in transforming European agriculture toward climate neutrality and resource self-sufficiency.

4. Annex - Online form content

SWOT analysis of technologies for producing alternative fertilising products

Dear Sir/Madame,

We would be very grateful if you would help us evaluate the positive and negative aspects in terms of their significance (weight) and impact on the development of alternative fertilizer (AF) technology and the market.

We cordially invite you to fill out a form dedicated to SWOT analysis (Strengths, Weaknesses, Opportunities, and Threats) concerning key factors in the development of nutrient recovery technologies and the growth of the AF market.

Thank you in advance for your time and valuable contribution.



1. Which of the following stakeholder groups do you represent?

Check all that apply.

- Advisors (e.g.: fertilizer market experts, technology consultants)
- Fertilizer producers (e.g.: SME owners, fertilizer industry managers)
- Fertilizer industry supporters (e.g.: agri-food & bio-based industry experts, tech providers,)
- Financing experts
- Academic/Researcher (e.g.: experts, researchers)
- Government/policymakers
- Fertilizer industry unions & associations
- End users (e.g.: farmers, farm managers)
- Others

Which of the presented **STRENGTHS** are the most important in the development of technology and the market of alternative fertilizers (AF)?

2. Please order from 1 to 5, where 1 the most important, 5 the least important. Use each number **only once** – do not repeat or duplicate rankings.

To proceed to the next question, select **only one rank per column**.

MARK only one oval per row.

	1	2	3	4	5
High availability of raw materials (waste biomass) for the production of AF	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Existence of standards and regulations enabling the marketing of alternative fertilizers (AF) (EU Regulation 2019/1009)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The safety of using all fertilizers, including AF, is regulated by law	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Research and innovation potential in the FI (know-how) for the implementation and development of AF technology and production	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Possibility of AF production near the main sources of waste biomass (raw materials)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Which of the **WEAKNESSES** presented most limit the development of technology and the market for alternative fertilizers?

3. Please order from 1 to 5, where 1 the most restrictive, 5 the least restrictive. Use each number **only once** – do not repeat or duplicate rankings.

To proceed to the next question, select **only one rank per column**.

Mark only one oval per row.

	1	2	3	4	5
Inconsistent composition and quality of raw materials, as well as their variable and local availability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Unstable nutrient composition, and the presence of contaminants (microplastics, pharmaceuticals) in fertiliser products	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
High investment and production costs and logistical difficulties	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Disrupted production continuity, seasonal availability of some raw materials	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Insufficient technological development (low TRL)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Which of the presented **OPPORTUNITIES** stimulate the greatest development of technology and the market for alternative fertilizers?

4. Please order from 1 to 5, where 1 the greatest, 5 the least. Use each number **only once** – do not repeat or duplicate rankings.

To proceed to the next question, select **only one rank per column**.

Mark only one oval per row.

	1	2	3	4	5
EU actions and incentives to support the circular economy and pressure to reduce greenhouse gas emissions	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Geopolitical tensions causing increases in mineral fertilizer prices and restrictions on access to natural resources (natural gas, phosphates)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Building consumer trust through educational programs and training for farmers and advisors, or additional certification for alternative fertilizers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Potential access to EU funds for sustainable agriculture under the CAP	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Development of local distribution and waste management systems to ensure a steady supply of raw materials and product collection	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Which of the presented **THREATS** are the greatest for the development of technology and the market for alternative fertilizers?

5. Please rate from 1 to 5, where 1 – the greatest, 5 – the least. Use each number **only once** – do not repeat or duplicate rankings.

To proceed to the next question, select **only one rank per column**.

Mark only one oval per row.

	1	2	3	4	5
Strong dominance of mineral fertilizers in the market	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Lack of trust and knowledge, and concerns about the safe use (lack of labeling and certification) of AF among farmers and the public	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Complex legal regulations regarding various aspects of AF production and marketing (end-of waste status, complicated and costly registration procedures)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Lack of direct provisions promoting AF production and use in CAP	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Investment uncertainty in AF production and the lack of a stable sales market	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

What is the impact of these **STRENGTHS** on the development of technology and the alternative fertilizer market?

6. Describe the impact of **STRENGTHS** in the scale from 1 to 5, where 1 mean very low, 2- low, 3 - medium, 4 - strong, 5 - very strong. **You may use the same answer more than once.**

Mark only one oval per row.

	very low	low	medium	strong	very strong
High availability of raw materials (waste biomass) for the production of AF	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Existence of standards and regulations enabling the marketing of alternative fertilizers (AF) (EU Regulation 2019/1009)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The safety of using all fertilizers, including AF, is regulated by law	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Research and innovation potential in the EU (know-how) for the implementation and development of AF technology and production	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Possibility of AF production near the main sources of waste biomass (raw materials)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

What is the impact of these **WEAKNESSES** on the development of technology and the alternative fertilizer market?

7. Describe the impact of **WEAKNESSES** in the scale from 1 to 5, where 1 mean very low, 2- low, 3 - medium, 4 - strong, 5 - very strong. **You may use the same answer more than once.**

Mark only one oval per row.

	very low	low	medium	strong	very strong
Inconsistent composition and quality of raw materials, as well as their variable and local availability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Unstable nutrient composition, and the presence of contaminants (microplastics, pharmaceuticals) in fertiliser products	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
High investment and production costs and logistical difficulties	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Disrupted production continuity, seasonal availability of some raw materials	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Insufficient technological development (low TRL)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

What is the impact of these **OPPORTUNITIES** on the development of technology and the alternative fertilizer market?

8. Describe the impact of **OPPORTUNITIES** in the scale from 1 to 5, where 1 mean very low, 2- low, 3 - medium, 4 - strong, 5 - very strong. **You may use the same answer more than once.**

Mark only one oval per row.

	very low	low	medium	strong	very strong
EU actions and incentives to support the circular economy and pressure to reduce greenhouse gas emissions	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Geopolitical tensions causing increases in mineral fertilizer prices and restrictions on access to natural resources (natural gas, phosphates)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Building consumer trust through educational programs and training for farmers and advisors, or additional certification for alternative fertilizers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Potential access to EU funds for sustainable agriculture under the CAP	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Development of local distribution and waste management systems to ensure a steady supply of raw materials and product collection	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

What is the impact of **THREATS** on the development of technology and the alternative fertilizer market?

9. Describe the impact of **THREATS** in the scale from 1 to 5, where 1 mean very low, 2- low, 3 - medium, 4 - strong, 5 - very strong. **You may use the same answer more than once.**

Mark only one oval per row:

	very low	low	medium	strong	very strong
Strong dominance of mineral fertilizers in the market	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Lack of trust and knowledge, and concerns about the safe use (lack of labeling and certification) of AF among farmers and the public	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Complex legal regulations regarding various aspects of AF production and marketing (end-of waste status, complicated and costly registration procedures)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Lack of direct provisions promoting AF production and use in CAP	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Investment uncertainty in AF production and the lack of a stable sales market	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Acknowledgements

Thank you very much for taking the time to respond to the questions you sent - your insights are extremely valuable to us and are an important input for the upcoming report on gaps and challenges.

With kind regards,
 IUNG's Team

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