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Deliverable D4.1

UE Policies and regulations baseline analysis

WP4 Assessment of regulatory and economic instruments

NENUPHAR

New governance models to enhance nutrient pollution handling and nutrients recycling

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Mercè Boy and Carla Febrer, UVIC/UCC	Elena Laborda and Bárbara Palacino, CIRCE Sergiy Moroz and Sara Johansson, EEB

Executive summary

In a context of ecosystems pressured by nutrient pollution and record-high fertiliser prices, the recovery of nitrogen and phosphorous from waste streams provides a solution to tackle both issues, allowing the supply of new fertiliser at a competitive price while enabling cleaner soil, air, and water systems. However, to effectively do so, an intensive political, regulatory and governance effort is required to bring all key stakeholders on board.

NENUPHAR was conceived to solve this need by developing new governance and value chain solutions addressing three waste streams widely present in the EU: manure, sewage sludges and dairy wastewaters, addressing four main innovations (i) a methodology for estimating N/P emissions from the application of a fertiliser on soil (ii) new governance models based on a network governance approach (iii) innovative economic and financial incentives for public and private entities; (iv) enabling technologies to treat manure, sludges and dairy wastewaters to recover the nutrient loads.

This document represents Deliverable 4.1 - Policies and regulations baseline analysis. It has been developed as part of Task 4.1 **Baseline analysis of EU- wide regulatory instruments**, from Work Package 4 - Assessment of regulatory and economic instruments. It outlines the results of **analysis of the current regulatory and economic instruments** applicable to the management of nutrient pollution and their recovery at a EU level, conducted within Work Package 4 (WP4) by UVIC/UCC. This document will serve as the basis developing the Task 4.2. **Definition of current regulatory instruments and competencies of each demo case** and Task 4.3 **Economic instruments to support the reduction of NP emissions**.

This deliverable presents a comprehensive baseline analysis of the European Union's current policies and regulations concerning nutrient management, with a particular focus on nutrient pollution and recovery systems. The report is structured around two core objectives: **a comprehensive review of EU regulations pertaining to nutrient management**, encompassing policies such as the European Green Deal and sector-specific directives; and a baseline analysis of **regulatory barriers, gaps and opportunities**. It identifies the principal obstacles to the control of nutrient pollution and the integration of recycled nutrients into the market, which include policy inconsistencies and the limited availability of economic instruments.

The findings illustrate the intricate nature of the EU's regulatory framework, characterised by a lack of coherence across sectors such as agriculture and wastewater management. Despite the implementation of initiatives such as the Common Agricultural Policy, financial incentives for nutrient recovery remain inadequate. Furthermore, advanced technologies encounter regulatory and economic obstacles, particularly in regions with constrained recycling capabilities. To achieve the EU's nutrient recovery objectives, the deliverable emphasises the necessity for more integrated governance and stronger economic incentives. These measures are crucial for the expansion of nutrient recovery technologies and the assurance that NENUPHAR's innovations are supported by a conducive regulatory environment.

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List of abbreviations and acronyms

ABPR - Animal By-Products Regulation

BS - Biodiversity Strategy

CAP - Common Agricultural Policy

CE - Circular Economy

CEAP - Circular Economy Action Plan

D - Deliverable

EBA - European Biogas Association

EC - European Commission

EDG - European Green Deal

EPRS - European Parliamentary Research Service

ESPP - European Sustainable Phosphorus Platform

EU - European Union

F2F - Farm to Fork Strategy

GA - General Assembly

H2020 - Horizon 2020; The 8th EU Framework Programme for Research and Innovation.

HEU - Horizon Europe; The 9th framework Programme of the EC for research, technological development and innovation activities.

INMAP - Integrated Nutrient Management Action Plan

JU - Joint Undertaking

ND - Nitrates Directive

NENUPHAR - New governance models to enhance nutrient pollution handling and nutrients recycling

SDGs - Sustainable Development Goals

SME - Small and Medium Enterprise

UWWTD - Urban Wastewater Treatment Directive

WWTPs - Wastewater Treatment Plants

WFD - Water Framework Directive

WP - Work package

WBCSD - World Business Council for Sustainable Development

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Introduction

The impact of Nitrogen and Phosphorus from fertilizers is significant, highlighting the urgent need for sustainable practices to recover these nutrients from waste streams. This will help to mitigate environmental degradation and protect ecosystems. As fertilizer prices continue to rise, it is important to prioritize action for cleaner soil, air, and water while ensuring the availability of new fertilizers at competitive prices. The NENUPHAR project, funded under Horizon Europe, aims to develop management and value chain solutions for manure, sewage sludge and dairy wastewater. The project introduces innovations such as estimating N/P emissions, novel governance models, economic incentives, and enabling technologies for nutrient recovery. NENUPHAR's approach will be demonstrated in diverse river basins and replicated in insular systems, advancing sustainable resource management across the EU.

Effective nutrient management is essential for sustainable agriculture and the protection of water resources. However, mismanagement of nutrients, particularly nitrogen and phosphorus, can have serious environmental consequences. Excess nutrients can contaminate water bodies, causing eutrophication, harmful algal blooms, and disturbances to aquatic ecosystems (European Environment Agency, 2020).

As the NENUPHAR project embarks on its mission to transform nutrient management practices, a critical first step is to understand the existing regulatory landscape within the European Union (EU). While nutrient management strategies are crucial for sustainable agriculture and a healthy environment, inconsistencies and potential barriers can impede progress. Ensuring effective nutrient management requires a clear-eyed assessment of the current situation.

An inventory of key policies and regulations and a detailed analysis of the implementation of different policies, trends, timelines, drivers, barriers, gaps, shortcomings in the demo countries and prospects for future policy development related to nutrient management is crucial for the success of the NENUPHAR project.

Through a careful review of relevant EU policies and regulations, we aim to:

- Identify key regulatory instruments: Identify specific EU policies and directives that regulate nutrient application, manure management and other practices that affect nutrient levels.
- Assess their impact on nutrients management practices: Assess how these policies influence and potentially constrain or incentivise different nutrient management strategies. Ensuring compliance with environmental objectives: Exploring how EU water quality legislation interacts with nutrient management practices to ensure that the project meets environmental sustainability objectives.

The analysis focuses on describing the general environmental practices in the EU and their application to nutrient management, as well as specific policies for nutrient management. A general description and the main barriers, gaps and opportunities are described. There is also a section describing the EU incentives

to achieve the policies. Mainly the incentives related to the Common Agricultural Policy and some other policies created to stimulate research and knowledge capitalisation.

By understanding and addressing these regulatory considerations, the NENUPHAR project can contribute to a more streamlined and efficient approach to nutrient management. This baseline analysis will be a valuable resource to guide project development and implementation towards a more sustainable future. As the project progresses, it will be essential to remain vigilant for any changes or updates to EU policies and regulations that may impact on the objectives of the NENUPHAR project.

This foundational analysis will be a valuable resource for project development and implementation. As the project progresses, it is crucial to adapt to any changes or updates to relevant EU policies and regulations.

1. EU Policies and Regulations Analysis

Intensive agricultural activities are a major source of nutrient pollution, particularly nitrate and phosphorus, which pose a significant threat to water quality (European Environment Agency, 2002). This pollution can lead to eutrophication, algal blooms, and oxygen depletion - all with negative impact on aquatic ecosystems (Drechsel et al, 2023). To address this problem, the EU has established an evolving comprehensive framework of policies and regulations since 1990s. These policies and regulations aim to achieve effective water management and prevent pollution (Margerum, and Whitall, 2004). This approach recognises the need for a comprehensive regulatory framework, as nutrient pollution comes from multiple sources. However, the main sources of nutrients from agriculture are the use of mineral fertilisers and the application of livestock manure.

This chapter provides an overview of the general and specific EU policies on nutrient management. With a general description of each policy, the implications in nutrient management, a review of gaps, barriers, and opportunities, and EU member states' approach.

1.a General policies for nutrient management

1.a.1 European Green Deal

The European Green Deal (EGD), introduced by the European Commission in 2019, is a comprehensive strategy aimed at steering the European Union towards a climate-neutral economy by reducing carbon emissions towards 55% by 2030 and achieving carbon neutrality by 2050 (Boix-Fayos and de Vente, 2023). It encompasses various sectors with the goal of promoting sustainability and environmental protection. This comprehensive strategy recognizes that environmental challenges are interconnected, and nutrient pollution from agriculture is a significant threat to achieving clean water and healthy ecosystems including its biodiversity (European Commission, 2019a).

The EGD aims to transform the Union's economy and society into a sustainable one, balancing economic growth with environmental protection. It outlines several key objectives for a new growth strategy such as:

- ✓ Climate Neutrality: achieving net zero greenhouse gas emissions by 2050 through significant reductions in all sectors.
- ✓ Circular economy: moving to a closed-loop system where resources are reused, and waste is minimised.
- ✓ Biodiversity conservation: halting and reversing biodiversity loss through habitat restoration and conservation.
- ✓ Zero Pollution: minimising pollution to air, water, and soil.
- ✓ Fair, healthy and environmentally friendly food systems.

- ✓ Investing in a sustainable future: mobilising public and private investment to support the green transition.

However, achieving the goals of the Green Deal will require the implementation of several interconnected strategies, including the new Circular Economy Action Plan, the 2030 Biodiversity Strategy (BS), and the Farm to Fork (F2F) strategy (Mowlds, 2020). The success of the EGD hinges on international cooperation, technological advancements, and mobilizing public and private investments.

Figure 1 European Green Deal, Source: EUROCOOP (2020).

The new mandate for the legislature 2024-2029 (currently under discussion) includes reaffirmed commitment to continue the implementation of the EU's Green Deal as well as to complement it with Clean Industrial Deal, thus confirming that EU institutions commit to step up efforts to tackle the triple climate, biodiversity and pollution crisis (von der Leyen, 2024).

- **Implications in nutrient management**

Nutrient management is a key aspect of the EGD and plays a crucial role in protecting water and achieving sustainable agriculture and soil health. A major challenge identified is the rapidly changing regulatory landscape for nutrient management (Happel et al., 2022). These dynamic regulatory frameworks can make it difficult for farmers and stakeholders to adapt their practices to meet evolving standards.

Furthermore, a lack of environmental awareness among suppliers of agricultural products has been highlighted as a dominant barrier to green supply chain management (Caldera et al., 2019). This lack of awareness may hinder the adoption of sustainable practices, including nutrient management, in agricultural supply chains.

Furthermore, the EGD emphasises the importance of sustainable competitiveness and eco-innovation for achieving prosperity in EU member states (Terzić, 2022). However, member states have flexibility in implementation of the Green Deal Strategies and legislation. This can lead to inconsistencies and weaknesses in national policies. Studies suggest that stricter national regulations and enforcement mechanisms are needed to ensure effective nutrient management across the EU. The transition from conventional ecological methods to more sustainable practices can be challenging, particularly in terms of changing established consumption patterns and promoting environmentally friendly approaches to nutrient management.

The EGD faces several challenges in relation to nutrient management. Although the EGD aims to create a low-carbon economy and improve environmental sustainability, several promised initiatives related to nutrient management have been dropped (e.g. Integrated Nutrient Management Action Plan) or postponed (e.g. Sustainable Food Systems Law). This lack of specific policies and instruments is a significant barrier to the sustainable use and conservation of nutrients within the broader framework of the EGD, leaving achievement of the targets on reduction of use of fertilisers under the EGD and/or Kunming Montreal Global Biodiversity Framework challenging (UNEP, 2022).

In addition, the EGD's emphasis on economic growth and technological progress may not fully incorporate the necessary measures for sustainable nutrient management. Its focus on green growth and economic development may not adequately address the need for sustainable nutrient cycles and resource efficiency and miss additional solutions that are likely to be required in terms of new governance models or transitioning to sustainable agriculture including reduction of livestock numbers and change in diets.

Furthermore, issues such as the reorganisation and mobilisation of the necessary funding, coupled with the lack of clear strategies to encourage compliance, further complicate effective nutrient management within the circular economy (Kallis and Butler, 2001).

- **Barriers, gaps, and opportunities**

The obstacles and barriers to integrated nutrient management under the EGD include regulatory changes, lack of environmental awareness, a policy focus on consumer preferences, challenges in transitioning to sustainable practices, and the resistance environmentally friendly approaches in agriculture. Addressing these barriers is essential to promote sustainable nutrient management practices and achieve the environmental goals set. In particular, the lack of targeted strategies, the prioritisation of economic growth over sustainable nutrient management, and the challenges related to policy implementation and resource allocation underline the need for specific policies and strategies to ensure efficient nutrient management within the broader framework of the EGD (Kallis and Butler, 2001).

Moreover, the implementation of circular economy business models by Small and Medium-sized Enterprises (SMEs) faces barriers that can impact nutrient management practices (Rizos et al., 2016). Policies at both the European and national levels need to focus on supporting green business models and greening consumer preferences to facilitate the transition towards sustainable nutrient management practices.

The EGD aspires to transition EU towards a sustainable future with a low-carbon economy and a circular approach while protecting and restoring our environment. However, a critical gap exists in its focus on nutrient management. The EGD needs clear strategies and specific policies to address how nutrients are used efficiently in agriculture and industry. This focus on emissions and circularity doesn't directly translate to attempting nutrient waste, which is essential for maintaining healthy soil, sustainable agricultural practices, and overall environmental well-being (Kuci and Fogarassy, 2021).

This policy gap needs to be addressed. By integrating specific policies for nutrient management within the EGD framework including in the promised Integrated Nutrient Management Action Plan, EU institutions can provide a policy framework that ensures a more comprehensive and effective approach to achieving environmental sustainability. These policies could encompass promoting resource efficiency, encouraging nutrient recycling practices, and incentivizing farmers to adopt sustainable nutrient management techniques (Kuci and Fogarassy, 2021).

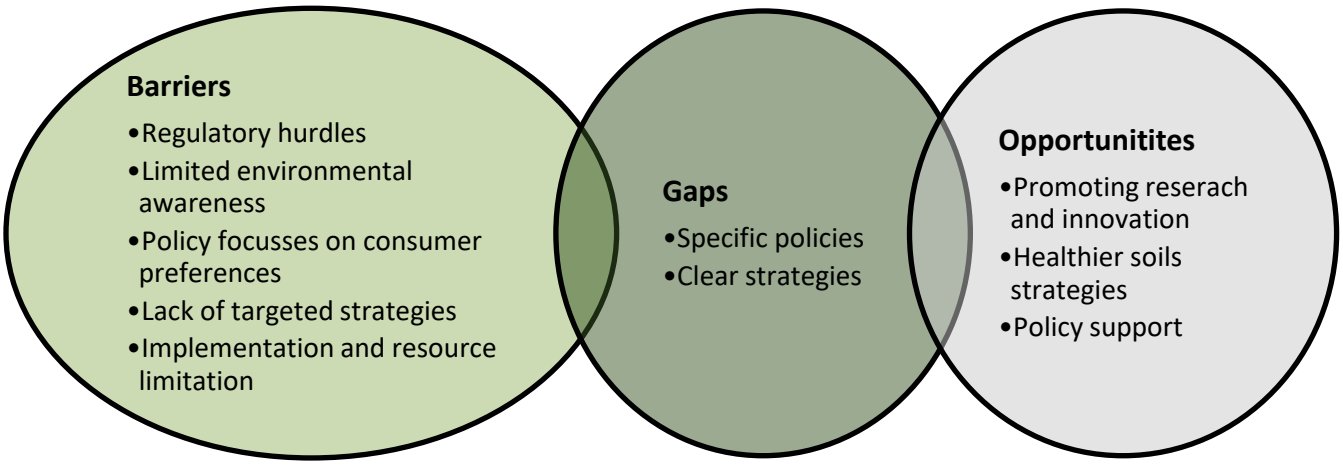

Figure 2 Barriers, gaps, and opportunities of the EGD.

Strengths: ▪ achieving climate policy goals ▪ start green, waste-free conversion ▪ maintaining economic growth ▪ increasing security of supply in material and energy use	**Weaknesses:** ▪ low level of innovation potential ▪ technical background and the unsuitability of basic systems for green development in underdeveloped parts of the EU ▪ various impediments to global economic dependence
Opportunities: ▪ rapid opportunity for economic growth ▪ green transformation of lending and investment programs ▪ a green insurance system can reduce business risk ▪ implementation of a closed material cycle instead of open waste streams	**Threats:** ▪ growing regional disparities in development ▪ energy price increase ▪ the sharpening of conflicts between energy and climate policy interests

Figure 3 EGD analysis. Source: Kuci and Fogarassy (2021).

The EGD presents both challenges and opportunities for nutrient management in agriculture. One of the unintended consequences could be restriction in the use of fertilisers, which can affect crop productivity. This challenge is linked to the actions of the EGD strategies, particularly in terms of maintaining an adequate nitrogen supply for crop growth, while considering the sensitivity of water resources to excess nitrogen. In addition, the EGD aims to reduce food waste, improve food distribution, and access, and mitigate the externalities of intensive agriculture, which also poses a significant risk of shifting the damage caused by intensive agriculture to other countries outside of the EU (Schunz, 2022). However, the EGD offers opportunities for sustainable nutrient management by promoting research and innovation for sustainable agriculture, contributing to healthier soils and supporting the transition to more sustainable agriculture through policies and strategies such as the Farm to Fork strategy (F2F), the Biodiversity Strategy (BS) and the Soil Strategy (SS). These initiatives provide tools to facilitate the transition to more sustainable agriculture and support the objectives of the Green Deal. The EGD emphasises the need for a holistic approach to sustainable agriculture, considering social, economic, cultural, technical and environmental aspects, and offers the potential for integrated land-use planning to optimise the provision of ecosystem services. In this way, the EGD provides an opportunity to address the challenges of nutrient management in agriculture through a comprehensive and integrated approach (Boix-Fayos and de Vente, 2023).

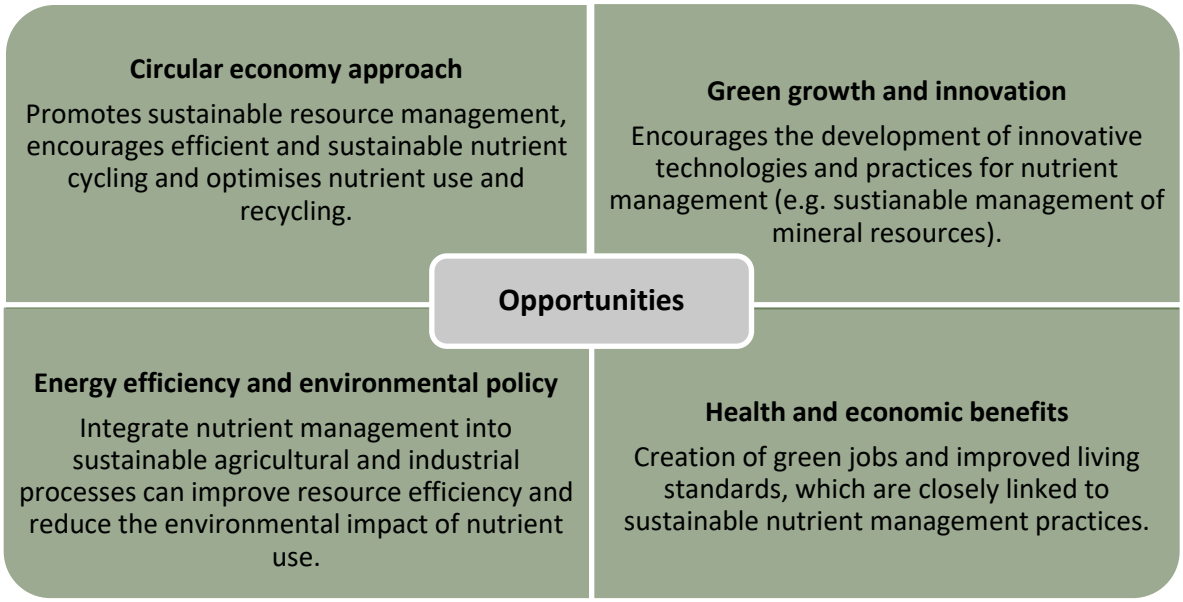

Figure 4 Main opportunities of the EGD.

In conclusion, the EGD offers possibilities to promote sustainable nutrient management through the circular economy approach, green growth, health and economic benefits, and the integration of nutrient management into energy efficiency and environmental policy. These opportunities match the EGD's broader objectives of a sustainable and competitive economy while meeting environmental and societal challenges (Kallis and Butler, 2001).

- **EU member states approach**

While the Green Deal presents opportunities for transitioning to more sustainable business models and clean energy production, there are challenges and shortcomings in its implementation across different EU countries.

There are likely to be unique challenges associated with implementing the EGD, such as decarbonising transport, improving exposure science in chemicals policy and managing change towards sustainable development. Knowledge, techniques, and technologies are already available to support the goals and expectations. However, there is a group of conditions that are missing and need to be worked on (political conditions, macro- and micro-economic conditions, corporate financial conditions, but also, and most importantly, human resource conditions, in addition to all economic conditions) (Szábó et al., 2022).

For instance, Spain is aligning its agricultural policy with the EGD objectives by promoting organic fertilisers, reducing chemical inputs, and improving soil health. Spanish Common Agricultural Policy (CAP) Strategic Plan includes relevant objectives, focusing on precision farming and efficient use of fertilisers to minimise environmental impacts (García Vaquero et al, 2021). Farmers will be incentivised to adopt sustainable practices such as cover crops and reduced tillage to reduce nutrient run-off (MAPA, 2023).

In conclusion, while the EGD offers a promising framework for achieving climate neutrality and sustainable development, addressing the specific challenges and shortcomings in demo countries like Spain, Hungary, Latvia, Lithuania, Slovakia, Denmark, and Cyprus requires tailored approaches that consider the unique socio-economic and environmental contexts of each nation.

1.a.1.a Circular Economy Action Plan

The Circular Economy Action Plan (CEAP) is a comprehensive EU strategy that promotes sustainability, resource efficiency, and circular practices. It includes initiatives to address nutrient recycling and reduce nutrient losses, promoting a more circular approach to nutrient management. It promotes a transition to a circular economy model, where resources are used more efficiently, waste is minimized, and products are designed for reuse and recycling. This includes measures to reduce single-use plastics, promote eco-design, and improve waste management.

The CEAP, launched on 11 March 2020, identifies 'food, water and nutrients' as one of seven key value chains to be addressed. As part of this initiative, the plan proposes the development of an Integrated Nutrient Management Action Plan (INMAP). The aim of this plan is to promote the sustainable use of nutrients and to stimulate the market for recovered nutrients. In addition, the plan suggests the possibility of revising directives on Urban wastewater treatment and sewage sludge, as well as exploring natural nutrient removal methods, such as the use of algae (European Commission, 2020a).

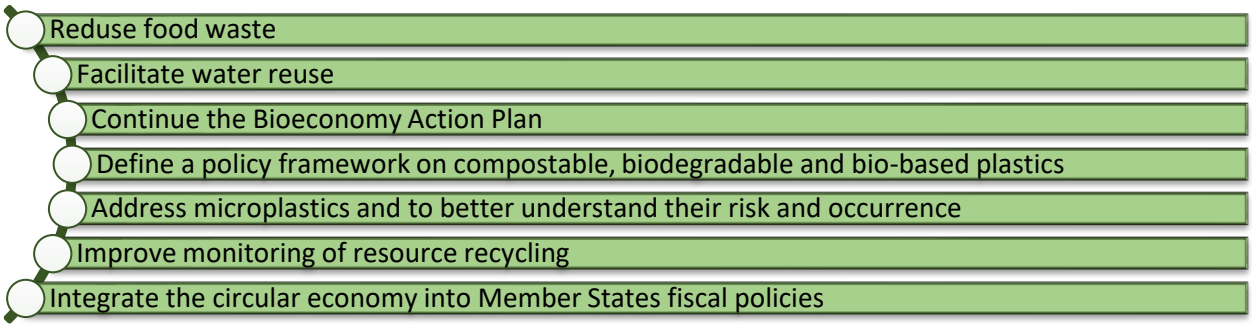

Figure 5 Main actions of the Circular Economy Action Plan.

- **Implications in nutrient management**

The European Union's Circular Economy Action Plan aims to reduce the significant environmental and economic impacts of nutrient pollution and promotes closing the loop on nutrient flows within the food system (European Commission, 2020a). The plan focuses on minimising nutrient losses, promoting sustainable nutrient management practices and encouraging the development of markets for recovered nutrients. As a holistic strategy, it can accelerate the adoption of such practices by setting targets for composting infrastructure and developing regulations for the safe use of recycled organic fertilizers in agriculture and promoting sustainable practices and reducing waste across the food and agriculture sector. (European Commission, 2020a).

Key actions of the CEAP, include:

1. Integrated Nutrient Management Action Plan (INMAP): The CEAP includes commitment for European Commission to develop the INMAP that addresses nutrient pollution at its source, increases the sustainability of the livestock sector, and promotes the recycling of organic waste into renewable fertilizers (ESPP,2020; Directorate-General for Environment, 2022).

2. Food Waste Reduction: The CEAP proposed a target on food waste reduction (also included in the EU Farm-to-Fork Strategy), which will address the significant resource, and environmental pressures associated with food waste (ESPP,2020).

3. Bioeconomy Strategy: The CEAP was set to ensure the sustainability of renewable bio-based materials, including through actions following the Bioeconomy Strategy and Action Plan.

4. Water Reuse: The CEAP aims to facilitate water reuse and recycling to reduce the environmental impacts of nutrient pollution.

5. Review of Directives: The CEAP included the commitment for the European Commission to review directives on wastewater treatment and sewage sludge to assess natural means of nutrient removal, such as algae.

6. Precise Fertilization Techniques: The CEAP was expected to promote the use of precise fertilization techniques and sustainable agricultural practices, particularly in hotspot areas of intensive livestock farming.

7. Market Observatory for Key Secondary Materials: The CEAP proposed a market observatory for key secondary materials to monitor resource recycling and improve the circular economy.

8. Monitoring Framework: The CEAP established a monitoring framework to track progress towards a circular economy and its benefits.

These actions are designed to reduce nutrient losses by at least 50% by 2030, while ensuring no deterioration in soil fertility. The plan also aims to reduce fertilizer use by at least 20% and stimulate markets for recovered nutrients.

- **Barriers, gaps, and opportunities**

The European Union's CEAP) faces several barriers and gaps when it comes to nutrient management. One of the main challenges is to stimulate the market for recovered nutrients from waste streams, as inconsistent regulations across the EU member states are hindering the circulation of recycled nutrients (Smol et al., 2019). In addition, there is a need for greater stakeholder awareness and education on nutrient recycling and the benefits of a circular economy. This is made more difficult by a lack of data and secondary markets (WBCSD, 2020). Traditional linear value chains and unsustainable diets exacerbate these problems (EBA, 2023).

However, the CEAP also presents significant opportunities. The potential for waste-based fertilisers to be CE marked could foster a robust EU-wide market for circular fertilisers (European Commission, 2020a). The Bioeconomy Strategy and Action Plan's focus on renewable bio-based materials supports circular approaches to nutrient management, while setting targets for nutrient recovery and reuse could encourage their uptake (Fertilisers Europe, 2020). In addition, efforts to reduce food waste can help minimise nutrient losses throughout the food value chain.

In summary, while the CEAP addresses critical barriers and gaps in nutrient management, it also highlights opportunities to improve nutrient recycling and sustainability through policy initiatives and market development.

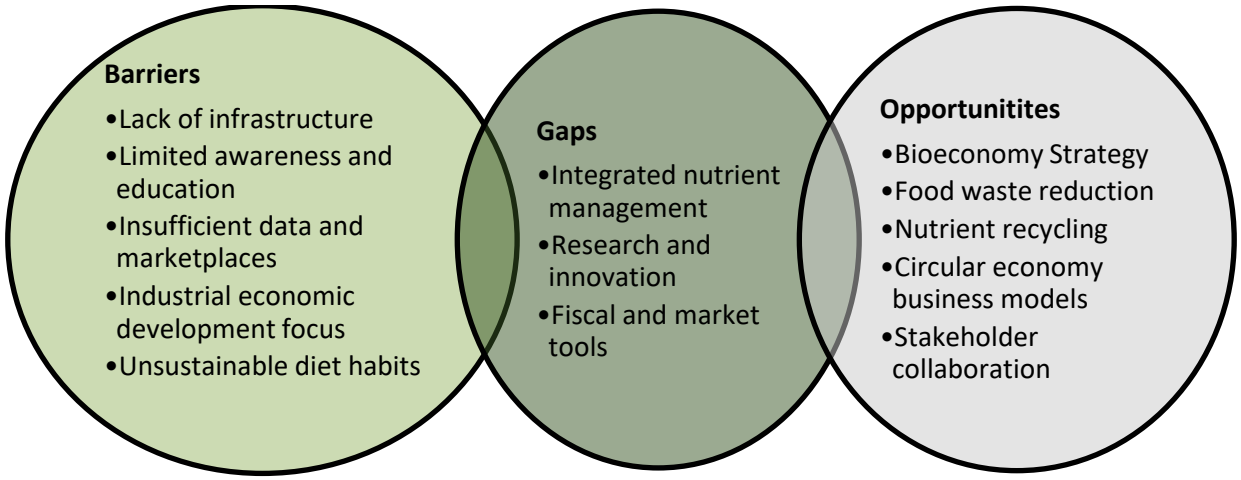

Figure 6 Barriers, gaps, and opportunities of CEAP.

- **EU member states approach**

The EU has taken a comprehensive approach to nutrient management, particularly the recovery of nutrients from the water and wastewater sectors, through the CEAP. The EU's CEAP emphasises the importance of recycled nutrients from organic waste as a distinct and valuable category of secondary raw material that can be returned to the soil as fertiliser. However, the circulation of fertilisers based on recycled nutrients has been hampered by different regulations, quality, and environmental standards across EU Member States (European Commission, 2020a). To address this, the EU proposed a revision of the fertiliser regulation to harmonise these differences (Stéphani, 2018).

In 2016, the EU published a proposal laying down rules for the placing on the market of CE-marked fertiliser products, with the aim of incentivising large-scale production of fertiliser in the EU from domestic organic or secondary raw materials (European Commission, 2020a). The Regulation sets out the conditions under which waste cases to be waste when contained in compliant EU fertiliser products and sets limits for contaminants in waste-based fertilisers. In addition, the Regulation aims to promote the sustainable development of an EU-wide market for fertiliser products (To, 2022).

In addition, the EU has identified the fertiliser industry as a key sector for the implementation of Circular Economy (CE) concepts, in particular the use of waste as a source of raw materials and the implementation of nutrient recovery technologies. The EU has also emphasised the importance of improving resource efficiency and developing innovative technological, organisational, financial and policy solutions to support the transition to a circular economy.

In addition, several European countries have introduced regulations and initiatives to improve the management of fertiliser raw materials, including mandatory recovery of biogenic raw materials such as phosphorus. These efforts are in line with the EU's objectives for sustainable development and resource efficiency (Fertilizers Europe, 2018).

Overall, the EU and its Member States are actively pursuing a multi-faceted approach to nutrient management under the CEAP, focusing on regulatory harmonisation, incentivising sustainable production and promoting resource recovery from waste.

1.a.1.b EU Bioeconomy Strategy

The EU Bioeconomy Strategy outlines a framework for the sustainable and prosperous utilisation of biological resources. Initially launched in 2012, the strategy was updated in 2018 to address evolving needs and opportunities (European Commission, 2018a).

The core goals of the Bioeconomy Strategy, as outlined in relevant EU documents, focus on achieving a "triple bottom line" approach that balances economic, environmental, and social well-being (European Commission, 2022a). The strategy encourages the efficient use of biological resources and minimises waste generation through a circular bioeconomy, where bio-waste becomes a valuable input for new products. Innovation is also a key objective, with the strategy driving advancements in bio-based products, processes, and technologies through research and development. An accompanying Action Plan details specific measures to achieve these goals as are shown in **Figure 7** (European Commission, 2018a).

Boosting Research and Innovation	•Investment in areas such as bioplastics and biofuels is required to develop new technologies and products.
Transforming the Workforce	•Individuals must be equipped with the requisite skills and training for bioeconomy jobs.
Increasing Investment	•Investment in the bioeconomy must be facilitated through policy changes and public-private partnerships.
Raising Consumer Awareness	•Consumer demand for bio-based products must be encouraged.

Figure 7 EU Bioeconomy Strategy Action Plan.

The European Commission's 2022 progress report highlights the positive contributions of the bioeconomy, including its role in job creation and generating economic value in bio-based product manufacturing (European Bioplastics, 2022). The EU Bioeconomy Strategy provides a roadmap for the transition towards a sustainable and innovative economy that leverages biological resources while protecting the environment and promoting social well-being.

- **Implications for nutrient management**

The EU Bioeconomy Strategy has important implications for nutrient management, aiming at sustainable management of natural resources, including the development of circular fertilisers from organic waste streams to replace fossil-based materials. The strategy promotes sustainable nutrient management practices to enhance the biodiversity benefits of primary production and protect soil health and ecosystems. Linked to the CEAP, it anticipates an integrated nutrient management strategy to improve nutrient recycling and reduce pollution (Hetemäki, 2017). The strategy emphasises the transition to a circular bioeconomy that reuses and recycles biological resources, including nutrients, to minimise waste and environmental impacts. It highlights understanding and operating within ecological limits to prevent pollution and ecosystem degradation. It also promotes regenerative agricultural practices to restore soil fertility, increase carbon sequestration and improve nutrient cycling. The Bioeconomy Strategy Progress Report highlights the need for better management of biological resources and sustainable consumption patterns, with a particular focus on sustainable nutrient management (European Commission, 2022a).

➔ Sustainable Management of Natural Resources
➔ Reducing Dependence on Non-Renewable Resources
➔ Circular Economy Principles
➔ Staying Within Ecological Boundaries
➔ Promoting Regenerative Agriculture

Figure 8 EU Bioeconomy Strategy main implications for nutrient management.

Overall, the EU Bioeconomy Strategy takes a holistic approach to sustainable nutrient management by promoting circular use, reducing dependence on non-renewable sources, respecting ecological limits and supporting regenerative agriculture, integrating nutrient management with wider environmental and climate objectives.

- **Barriers, gaps, and opportunities**

The EU Bioeconomy Strategy aims to promote more sustainable nutrient management by stimulating markets for recovered nutrients and includes a commitment to revise directives on wastewater treatment and sewage sludge (European Commission, 2022b). However, overcoming technical, economic and social barriers will be crucial to realising the full potential of the strategy in moving towards a circular bioeconomy for nutrients (M'bareka et al., 2023; Pender, 2023).

There are several barriers and gaps that need to be addressed. Technical challenges include recovering high quality, consistent nutrients from waste streams such as wastewater and sewage sludge (Vineta and Zeverte-Rivza, 2023; Pender, 2023). There are also regulatory barriers to the approval and commercialisation of recycled nutrient products to meet safety and quality standards (Pender, 2023). In addition, there is a lack of economic incentives or market demand for recycled nutrients compared to conventional fertilisers (Pender, 2023). There are also social acceptance issues surrounding the use of recycled nutrients in food production.

Despite these barriers, there are significant opportunities. The development of new technologies and business models to extract, process and market recovered nutrients from waste streams can overcome some technical challenges (Vineta and Zeverte-Rivza, 2023; Pender, 2023). Updating regulations to facilitate the safe and widespread use of recycled nutrient products can overcome regulatory barriers (Pender, 2023). Creating market-based tools and incentives can drive demand for sustainable nutrient sources (Pender, 2023). Raising awareness and acceptance of recycled nutrient products among farmers and consumers can help address social acceptability issues (Pender, 2023). In addition, exploring natural means of nutrient removal, such as algae, can be part of sustainable nutrient management (Vineta and Zeverte-Rivza, 2023).

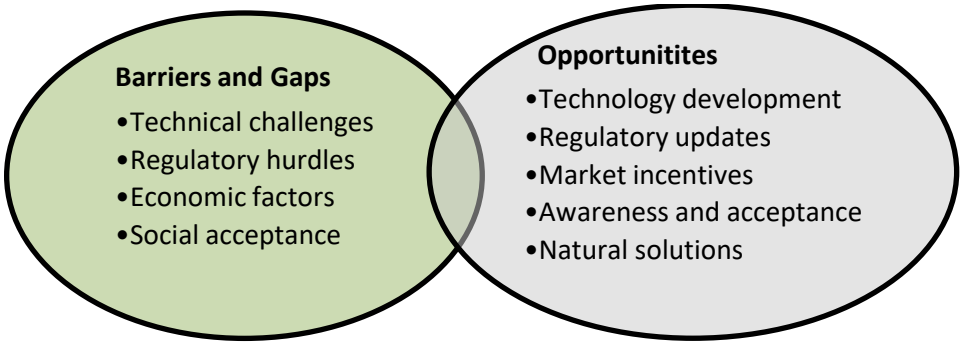

Figure 9 Barriers, gaps, and opportunities of EU Bioeconomy Strategy.

- **EU member states approach**

The EU Bioeconomy Strategy aims to accelerate the deployment of a sustainable European bioeconomy to contribute to the Sustainable Development Goals (SDGs) and the Paris Agreement (Hetemäki, 2017). Regarding Member States' approaches to the Bioeconomy Strategy focusing on nutrient management, as of December 2022, ten EU member states have national strategies dedicated to the bioeconomy: Austria, Germany, Spain, France, Finland, Ireland, Italy, Latvia, the Netherlands and Portugal. Seven countries are currently developing their national strategies: Czech Republic, Croatia, Hungary, Lithuania, Poland, Sweden, and Slovakia.

The Bioeconomy Strategy has five key objectives, two of which are particularly relevant for nutrient management. First, sustainable management of natural resources: the strategy aims to promote sustainable management of land, forests, fisheries and aquaculture. Indicators show mixed trends, with

some improvement in the sustainable management of fisheries but a decrease in the sustainable management of agroecosystems (Hetemäki, 2017).

Second, reducing dependence on non-renewable, unsustainable resources: the strategy aims to move away from non-renewable resources towards bio-based alternatives. Developments in resource and energy efficiency are largely positive, and the recovery of bio-waste is on the rise (Hetemäki, 2017).

There is an increasing need to focus on better management of land and biomass demand to meet environmental and economic needs in a climate-neutral Europe, and to work on more sustainable consumption patterns to ensure environmental integrity. Effective implementation of bioeconomy strategies across EU member states is key to achieving these nutrient management goals as part of the broader objectives of the EGD (Hetemäki, 2017).

1.a.1.c Farm to Fork Strategy

In the context of agriculture, the "From Farm to Fork" concept is highlighted as a crucial topic within the scope of the EGD (Ataseven, 2022). This concept underscores the need for a fair, healthy, and environmentally friendly food system, which directly relates to nutrient management practices in agriculture.

The Farm to Fork (F2F) strategy acknowledges the environmental impact of the food supply chain and aims to ensure sustainable food production by addressing the issue of excess nutrients, particularly nitrogen and phosphorus, in the environment. The strategy sets EU target to reduce nutrient losses by at least 50% while maintaining soil fertility and to decrease fertilizer use by at least 20% by 2030. Similar target is set in the EU Biodiversity Strategy and Zero Pollution Action Plan highlighting the importance of sustainable nutrient management for other Green Deal priorities. Specifically, the F2F strategy states that the European Commission commits to develop an INMAP to tackle nutrient pollution at its source and enhance the sustainability of the livestock sector (European Commission, 2023a) (also in the CEAP). However, despite substantial preparatory work on the INMAP by the EC services, the publication of the INMAP has been delayed *sine die.*

Figure 10 Farm to Fork Strategy. Source: *https://food.ec.europa.eu/horizontal-topics/farm-fork-strategy_en*

- **Implications for nutrient management**

The EU's F2F strategy has several important implications for nutrient management. The aim of the Strategy is to reduce nutrient losses by at least 50% by 2030, with no loss of soil fertility. This will require significant improvements in nutrient use efficiency through practices such as precision farming, targeted fertilisation and digital decision support tools (Yara, 2021).

The strategy promotes a more circular approach to nutrients, calling for the closing of nutrient cycles, the recovery and reuse of nutrients, and the use of organic fertilisers such as leguminous crops. This will help to reduce dependence on mineral fertilisers.

The implementation of the nutrient reduction targets will have a major impact on farm productivity and income, which needs to be carefully assessed. The strategy emphasises the need for a balanced approach that maintains food security.

According to the JRC assessment, measures included in the F2F strategy however ambitious, seem insufficient, to achieve the objective of 50% reduction in losses. In order to reach food and feed self-sufficiency of Europe within the environmental constraints, the necessary structural changes would involve transitions at the production level in combination with a transition in the current dietary patterns (Grizzetti et at al., 2023).

Overall, the F2F strategy pushes the EU agricultural sector towards a more sustainable, circular, and precision-based approach to nutrient management. However, challenges remain for farmers, such as ensuring the economic viability of the transition to these practices and securing access to the necessary infrastructure and knowledge (European Commission, 2020b). The success of the F2F strategy depends on working together with other policies, in particular the Nitrates Directive and the Common Agricultural Policy (CAP) greening measures, to incentivise nutrient-efficient practices.

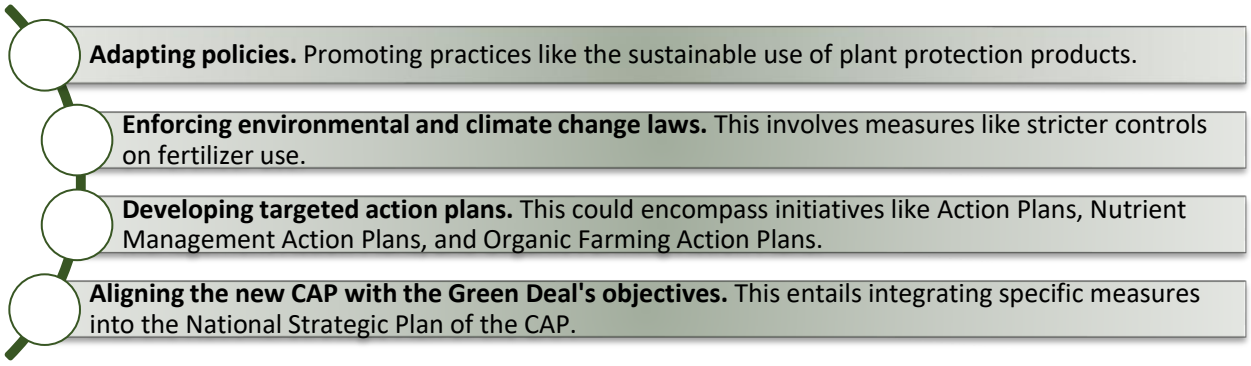

Figure 11 Farm to Fork Strategy key tools (Boix-Fayos and de Vente, 2023).

- **Barriers, gaps, and opportunities**

The F2F strategy implementation faces several barriers and obstacles in relation to nutrient management. The strategy sets an ambitious target of reducing nutrient losses by at least 50% by 2030, which will require significant changes in farming practices and technologies. There may be barriers to achieving this target in terms of cost, farmer acceptance and the need for new extension services and financial support (European Commission, 2020c).

One of the other challenges is the need to meet the nitrogen requirements of organic farming, which is limited by the use of mineral fertilisers. This poses the challenge of maintaining an adequate nitrogen supply for crop growth while considering the sensitivity of water resources to excess nitrogen. In addition, the F2F strategy aims to reduce the use of fertilisers by 20% within a decade, which presents a challenge in finding alternative methods to ensure adequate nutrient supply for agricultural production. The strategy recognises the need to establish an 'integrated nutrient management plan' to tackle nutrient pollution, but details of the specific actions to achieve this are still lacking (European Commission, 2020b). The transition proposed by the F2F strategy involves complexities related to maintaining yields, meeting nitrogen needs in organic farming, changing diets, food waste, distribution and access to food, and externalities to third countries. These challenges illustrate the complexity of the transition to a more sustainable agriculture and food system, which requires a holistic approach considering social, economic, cultural, technical and environmental aspects (Boix and de Vente, 2023). Ensuring farm profitability while implementing more sustainable nutrient management practices is identified as a key challenge that needs to be carefully addressed (Yara, 2021).

The strategy promotes circular nutrient approaches by encouraging the development of innovative recycled and bio-based fertilisers from organic waste, reducing dependence on synthetic fertilisers and opening new markets. Emphasising precision agriculture and digital tools will increase the efficiency of nutrient use, enabling precise application and data-driven decisions to improve farm management. Linking nutrient management with soil health and carbon sequestration creates synergies that improve soil productivity, resilience and climate change mitigation (Yara, 2021). The strategy's support for advisory services, financial instruments, and research/innovation can help overcome barriers and develop new solutions for sustainable nutrient management (European Commission, 2020b).

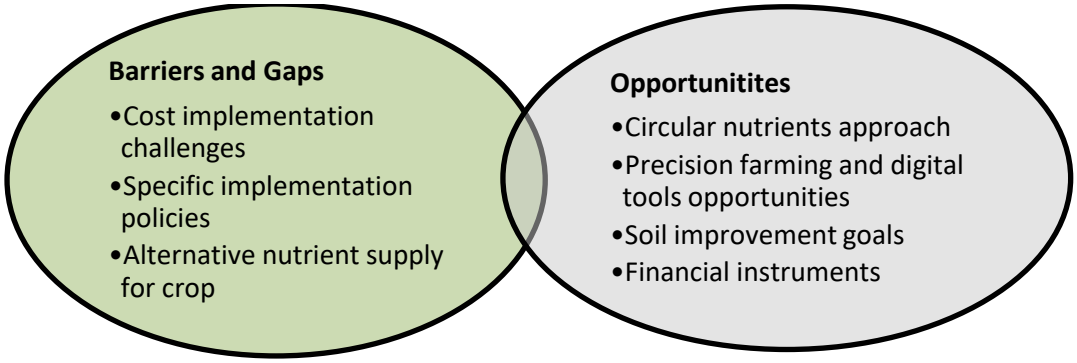

Figure 12 Barriers, gaps, and opportunities of F2F strategy.

Overall, the F2F strategy sets an ambitious agenda for transforming the EU's food systems and, despite significant challenges, offers opportunities to drive innovation and sustainable nutrient management practices.

- **EU member state approach**

The EU's F2F strategy is driving member states to take a more integrated and sustainable approach to nutrient management. The strategy calls for developing an INMAP to address nutrient pollution at the source (European Commission, 2020b). This will likely involve, incentives, and support for farmers to adopt more sustainable nutrient management practices.

The European Parliament's report on the F2F strategy emphasises the importance of closing nutrient cycles, recovering and re-using nutrients and promoting the use of leguminous crops to reduce dependence on mineral fertilisers. Member states will need to develop policies and programmes to support this transition.

Precision agriculture, targeted fertilisation and digital decision support tools are highlighted as key solutions to improve nutrient use efficiency and reduce losses (Yara, 2021). Widening access to these technologies for farmers across the EU will be a priority.

Ensuring the economic viability of farmers while implementing more sustainable nutrient management practices is a key challenge that member states will need to address through financial support, advisory services and market incentives.

Overall, the F2F strategy pushes for a more harmonised, circular and precision-based approach to nutrient management across the EU. However, the specific policies and programmes to achieve this will be developed and implemented at Member State level, with support and coordination from the EC (Mowlds, 2020).

1.b Specific legislation for nutrient management

1.b.1 The Water Framework Directive (WFD)

The Water Framework Directive (WFD) (2000/60/EC) and its daughter directives on groundwater and priority substances are the main pillar of the EU water policy. The WFD promotes a holistic approach to water management through integrated river basin management (IRBM). IRBM considers all water bodies (surface, transitional, coastal, and groundwater) within a river basin and requires member states to address pressures holistically (Mostert, 2003).

The Directive establishes the objective to (i) prevent deterioration and (ii) achieve good status for all water bodies: rivers, lakes, groundwater, transitional and coastal waters. Groundwater bodies achieve good status when their quantitative status and chemical status are at least good. Nitrates concentration in groundwater should not exceed 50 mg/L. Surface water bodies achieve good status when both their

ecological status and chemical status are at least good. The ecological status is an evaluation of water bodies that considers biological quality elements (e.g. phytoplankton, flora, fish), and information on physico-chemical and hydromorphological conditions of the water body. 'Nutrient conditions' contributes to the evaluation of the ecological status. However, there is a significant variation in thresholds nutrient concentrations that member states set to define the boundary between "good" and "moderate" ecological status across Europe (Poikane et al, 2019).

Member states are required to analyse the environmental impact of human activities on waters and develop River Basin Management Plans (RBMPs) every 6 years, including a Programme of Measures to achieve the environmental objective of good status. The measures include among others the implementation of the EU legislation on nitrates, urban wastewater treatment, industrial emissions. Measures also include the protection of water bodies for abstraction of drinking water, The Drinking Water Directive (Directive EU 2020/2184) (European Parliament, 2020), prescribes a maximum concentration of 50 mg/L of nitrate and 0.50 mg/L of nitrite for water intended for human consumption.

Nutrient pollution is one of the main pressures affecting the condition of water ecosystems. According to the second RBMPs, diffuse pollution, atmospheric deposition and point sources were indicated among the major pressures impairing surface and groundwaters. Specifically, 26% of surface water bodies reported impact of nutrient pollution and 17% of ground water bodies area reported impact of nutrient pollution (European Commission, 2019a).

Thus, the WFD has a significant influence on nutrients management. Specifically, the WFD mandates the implementation of pollution-control measures, which may be necessary in addition to those demanded by existing legislation regulating water quality and pollution. It also requires the establishment of criteria for the identification of significant and sustained upward trends in pollution, with starting points for trend reversals. Additionally, the Directive sets out the overall objective of measures for groundwater as the 'prevention or limitation of the input of pollutants'. This implies a shift from the traditional, infrastructure/supply-oriented modes of planning to a more ecosystem-based approach, formalizing the environment as a 'user' of water and establishing it at an equal footing with other human economic activities. Therefore, the WFD's influence on nutrients management is substantial, as it sets out specific measures and objectives to address pollution and maintain the quality of Europe's water resources (Kallis et Butler, 2001)

The fitness check evaluation of the WFD concluded that the directive and its daughter directives were fit for purpose, with room for enhanced effectiveness. Despite improvements in the protection of water bodies, the evaluation points to insufficient level of implementation by the member states and by sectors with a heavy impact on water such as agriculture, energy and transport. The fact that the WFD's objectives have not been reached fully yet is largely due to insufficient funding, slow implementation and insufficient integration of environmental objectives in sectoral policies, rather than deficiencies in the legislation. (European Commission, 2020d).

- **Implications in nutrient management**

The WFD plays a crucial role in managing nutrient levels across Europe. Its primary objective is to achieve good status for all water bodies, which involves tackling nutrient pollution from both direct and indirect sources. The WFD requires Member States to prepare River Basin Management Plans (RBMPs), which include measures to reduce nutrient inputs to water systems. These measures aim to protect and restore aquatic ecosystems to ensure their sustainable use. Current investments to reduce point and diffuse nutrient pollution are likely to result in only modest reductions in nutrient loads to European seas. However, the implementation of more stringent measures could significantly reduce nutrient export to the sea, potentially reducing nitrogen levels by up to 14% and phosphorus levels by up to 20% (Grizzetti et al., 2023).

While there is great potential to reduce nutrient pollution from agriculture, without changes in agricultural production and consumption patterns, these reductions may not be sufficient to meet EU water policy objectives in certain areas. Regional differences and ecosystem specificities need to be considered when setting nutrient restoration targets. Future measures could intensify the imbalance between nitrogen and phosphorus in receiving waters and affect aquatic ecosystems. It is therefore necessary to consider land-sea dynamics and to ensure coherence between measures implemented under different policy areas (Grizzetti et al., 2023).

- **Barriers, gaps, and opportunities**

Barriers and gaps hinder the effectiveness of nutrient reduction strategies in several ways. A major challenge is the quantification of the impact of the measures set out in the Water Framework Directive River Basin Management Plans (WFD RBMPs). This difficulty can hinder the successful implementation of these strategies. In addition, there is a lack of consistent and comprehensive data across Europe on additional measures under the Nitrates Directive Action Programmes or other related schemes. This data inconsistency makes it difficult to fully assess the impact of existing measures (Grizzetti et al., 2023).

Furthermore, effective policy targeting of nitrogen and phosphorus inputs to water systems does not consider the significant regional variability that needs to be addressed. Taking this variability into account is crucial for effective policy targeting. Furthermore, while nutrient reductions from agriculture have the potential to be substantial, current livestock and agricultural production and consumption practices may not change sufficiently in some regions to meet EU water policy targets. Without these changes, the desired reductions in nutrient pollution may remain out of reach (Grizzetti et al., 2023).

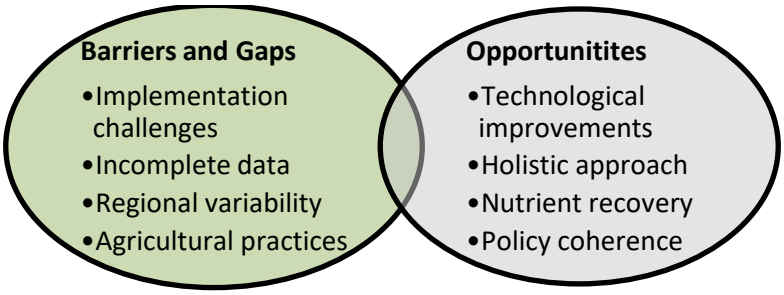

Figure 13 Barriers, gaps, and opportunities of the WFD.

There are several promising opportunities to improve nutrient management and reduce nutrient pollution. One such opportunity is to support technological improvements. Taking a holistic approach is another important opportunity. More effective nutrient management can be achieved by considering land-sea dynamics and evaluating policies across different policy areas in tandem. This integrated perspective ensures that all factors influencing nutrient pollution are comprehensively addressed. In addition, there is significant potential for nutrient recovery from wastewater, particularly in regions such as the Danube and the Adriatic. Exploiting this potential can contribute to further reductions in nutrient pollution. Finally, ensuring policy coherence is crucial for the alignment and consistency of measures across different policy areas. Achieving such coherence can lead to more integrated and effective strategies for reducing nutrient pollution, thereby increasing the overall impact of these measures (Grizzetti et al., 2023).

While the WFD provides a comprehensive framework for reducing nutrient pollution, implementation challenges, data gaps and the need for regional specificity are barriers to achieving its objectives. However, technological advances, holistic management approaches, nutrient recycling and policy coherence offer opportunities to overcome these barriers and improve the ecological status of European waters.

- **EU member states approach**

The WFD has significant implications for nutrient management in Europe. The WFD requires Member States to develop River Basin Management Plans (RBMPs) that include measures to reduce nutrient inputs to water systems. These measures are intended to protect and restore aquatic ecosystems and ensure their sustainable use (Grizzetti et al., 2023).

The WFD provides a framework for reducing nutrient pollution, but its effectiveness depends on the implementation of ambitious measures at member states level, especially in the agricultural sector, and on considering regional variability. The directive also highlights the need for a holistic approach that integrates nutrient management with other water-related policies to achieve the desired ecological status of water bodies.

1.b.2 Nitrates Directive

The Nitrates Directive (91/676/EEC) represents an EU legislation with the objective of reducing water pollution from agricultural sources, particularly nitrates (Grizzetti et al., 2023). Its primary goal is to protect water quality and prevent eutrophication by identifying Nitrate Vulnerable Zones (NVZs) and implementing action programmes to control nitrate leaching into water bodies. Member states are required to identify areas where water is particularly susceptible to nitrate pollution from agricultural land. In these NVZs, farmers are obliged to comply with specific measures designed to restrict the quantity of nitrates entering watercourses. These include limitations on the application of manure and chemical fertilisers. Furthermore, the directive encourages the implementation of optimal farming practices with the objective of reducing nitrate leaching into water bodies. This is achieved through the promotion of sustainable agricultural methods that safeguard water quality (Grizzetti et al., 2023).

Recognizing agriculture as a major contributor to nutrient pollution, the Nitrates Directive (91/676/EEC) specifically tackles nitrate pollution from agricultural sources. It mandates the designation of NVZs where nitrate concentrations in water pose a threat. Within these designated zones, member states must implement action programmes with mandatory measures. These measures can include:

- ✓ Restrictions on fertilizer application rates and timings.
- ✓ Promotion of manure management practices that minimize nitrogen losses.
- ✓ Establishment of closed periods for fertilizer application when leaching risks are high.
- ✓ Restrictions to land application of livestock manure in terms of time and location as well as maximum amounts to be applied to land every year.
- ✓ Minimum storage capacities for livestock manure.
- ✓ Measures based on a balance between the nitrogen requirements of the crops and the nitrogen supply to the crops from the soil and from fertilisation.

- **Implications in nutrient management**

The ND has a significant impact on nutrient management, on nitrogen fertilisation in agriculture (Středová et al., 2024). This directive provides a framework for reducing nutrient pollution from agricultural sources, but its effectiveness is limited by data limitations and regional variations (Grizzetti et al., 2023). While the ND aims to protect water quality by establishing NVZs and requiring specific action programmes, its effectiveness depends on adaptation to current climatic conditions and broader environmental policies (Středová et al., 2024). The directive has stimulated the adoption of more precise and efficient fertilisation techniques and the development of local nutrient management plans. Technological advances and policy adjustments are crucial to further reduce nitrate pollution and improve water quality (Grizzetti et al., 2023).

Table 1 Key points on how ND affect nutrient management (Středová et al., 2024).

Regulation and restriction	The ND imposes legal restrictions on agricultural practices to reduce water pollution from nitrate leaching. It requires the designation of 'Nitrate Vulnerable Zones' (NVZs) where farmers must follow mandatory action programmes and codes of good agricultural practice to manage nitrate pollution.
Nitrogen fertilisation restrictions	The ND restricts nitrogen fertilisation during the non-vegetation period (NVP), when temperatures are below 5°C, to reduce nitrate leaching into water bodies by limiting nitrogen applications when plant uptake is low.
Climatic zoning	ND uses climatic zoning based on historical data to optimise nitrogen application timing and reduce environmental impact.
Monitoring and evaluation	The ND requires continuous monitoring of water quality and nitrate levels to assess and improve the effectiveness of the directive.
Integration with other policies	The ND complements the WFD to improve water quality and promote sustainable nutrient management with ND measures included in RBMPs as basic measures and possibility to establish supplementary measures under the WFD where ND measures are not sufficient to reach the environmental objectives of the WFD.

- **Barriers, gaps, and opportunities**

The ND is crucial for managing nitrogen and protecting water quality, but it faces several barriers and gaps, with significant opportunities for improvement (Středová et al., 2024). A major barrier is poor implementation of the current regulations, which have not significantly improved water quality across Europe (European Commission, 2021a). Climate change has altered the non-vegetation period (NVP), making existing ND regulations based on outdated climate data less effective (Středová et al., 2024). Poor agricultural practices exacerbate water quality problems (Gomes et al., 2023; Musacchio et al., 2020). In addition, outdated action programmes and incorrect zoning, such as in the Gallocanta NVZ in Spain, further undermine nitrate reduction efforts (Orellana-Macías et al., 2020). Challenges of compliance and enforcement of the EU directives also persist.

Gaps include inconsistent data across Europe on ND action programmes, making it difficult to assess policy impacts (Grizzetti et al., 2023). Incomplete information on manure treatment and storage hampers understanding of its impact on pollution (Grizzetti et al., 2023). Regional variability in nitrogen and phosphorus reduction highlights the need for more tailored policies (Grizzetti et al., 2023). In addition, insufficient monitoring and knowledge of nitrogen behaviour hinders effective implementation (Středová et al., 2024).

The ND is currently undergoing the backward-looking fitness check evaluation with the evaluation report expected to be published in first half of 2025. There are opportunities to improve the ND especially in its implementation and enforcement. Updating the directive to reflect current climate conditions could improve its effectiveness (Středová et al., 2024). Technological advances in nutrient recovery, particularly in regions such as the Danube and Adriatic, offer potential for further reductions (Grizzetti et al., 2023). Site-specific management and improved policy coherence, together with stakeholder engagement, can also enhance the impact of the directive. Addressing the economic and environmental costs of excessive fertiliser use can encourage more sustainable agricultural practices (Grizzetti et al., 2023).

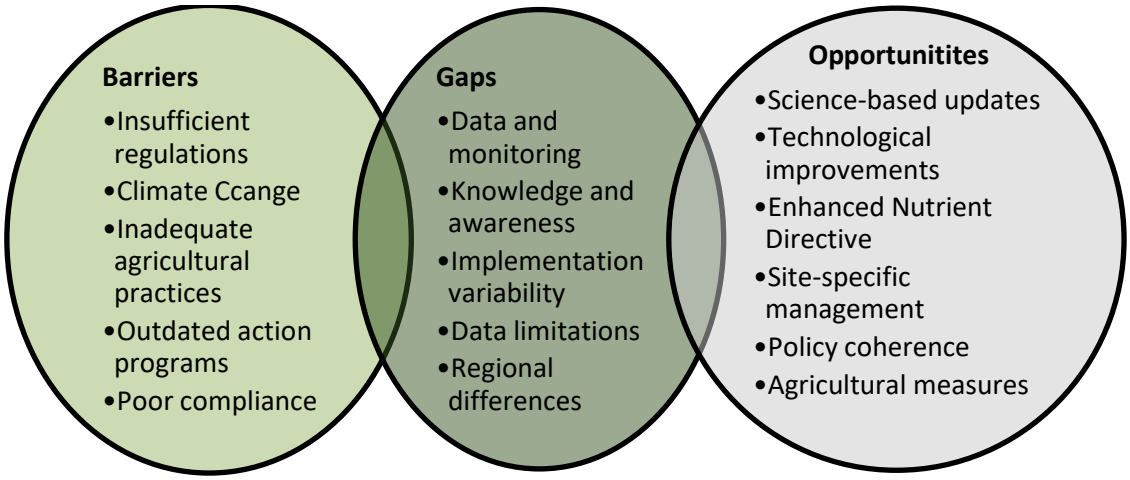

Figure 14 Barriers, gaps, and opportunities of the ND.

In conclusion, while the ND faces several barriers and gaps, addressing these through updates, technological advances and better integration with other policies offers significant opportunities to improve nutrient management and water quality.

- **EU members approach**

The ND is crucial for nutrient management and reducing water pollution from nitrate leaching from agriculture in all EU Member States. It requires the designation of NVZs, areas at risk of nitrate pollution based on factors such as soil type and hydrogeological conditions. Within NVZs, Member States implement codes of good agricultural practice, including restrictions on the application of nitrogen fertilisers and mandatory action programmes to improve water quality. Nitrate concentrations in surface and groundwater must be monitored and reports submitted to the EC every four years. Despite these efforts, major challenges remain: 14.1% of groundwater stations exceed the annual nitrate concentration limit of 50 mg/l, and 81% of marine waters and one third of rivers, lakes and coastal waters show signs of eutrophication (Grizzetti et al., 2023).

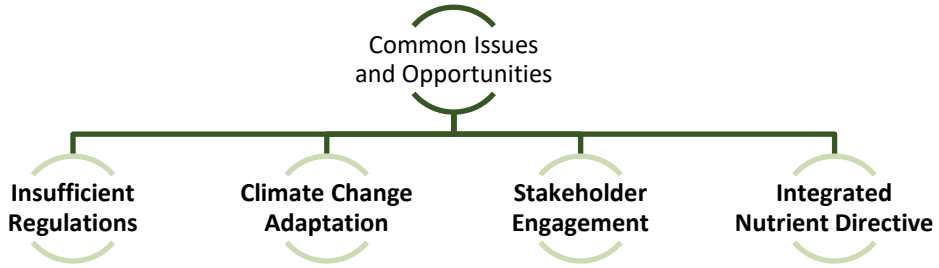

Figure 15 EU members key points of applying the ND.

Implementation of the ND varies due to differences in climatic conditions, agricultural practices, and policy interpretations. Common problems include inadequate regulations and action programmes, which continue to cause water quality problems in many regions. Updating the climate baseline of the ND to reflect current conditions and involving stakeholders such as farmers, policy makers and environmental organisations is essential for more effective implementation. In addition, there are calls for an integrated European Nutrient Directive to comprehensively regulate nitrogen and phosphorus application, support the EU Green Deal's Farm to Fork initiative and promote sustainable agriculture (Středová et al., 2024). Addressing these gaps and exploiting opportunities for improving its implementation is crucial for better nutrient management and water quality protection across the EU.

In summary, the ND is an important tool for nutrient management in EU Member States, but its effectiveness varies. Addressing the barriers and gaps, while exploiting the opportunities for improvement, is essential to improve nutrient management and protect water quality.

1.b.3 Waste Framework Directive

The Waste Framework Directive is the central piece of EU waste legislation that sets the basic concepts and definitions related to waste management, including definitions of waste, recycling, and recovery. It establishes the overarching legal framework for waste management in the EU, setting requirements, definitions, and targets to promote a more circular economy and protect the environment (European Parliament, 2008).

This directive requires waste management to protect human health and the environment and to avoid nuisances such as noise and unpleasant odours. It introduces the 'waste hierarchy', which prioritises waste prevention, followed by reuse, recycling, recovery and disposal as a last resort. It sets targets for EU countries to meet by 2020 and between 2025-2035, including recycling at least 50% of household waste by 2020 and 55-65% of municipal waste by 2025-2035. Additional requirements for the management of hazardous waste include labelling, record keeping and restrictions on the mixing of hazardous waste. The Regulation defines criteria for when waste ceases to be waste and becomes a product or secondary raw material, known as 'end-of-waste' criteria. EU countries are required to draw up waste management plans and waste prevention programmes. It also introduces the "polluter pays" principle and "extended producer responsibility" as key principles (European Parliament, 2008).

- **Implications in nutrient management**

The Waste Framework Directive does not directly address nutrient management. However, it provides a high-level framework that can support more sustainable nutrient management. Its emphasis on waste prevention, recycling and recovery is relevant to optimising nutrient flows and minimising losses to the environment.

Although the directive does not set specific requirements for nutrient management, it provides the overarching legal framework for waste management in the EU, which can influence how nutrients are managed as part of a more circular and sustainable approach. Complementing the broader waste management principles of the Waste Framework Directive, other EU directives such as the Urban WasteWater Treatment Directive and the ND also play a role in regulating the discharge and management of nutrients (EurEau, 2021).

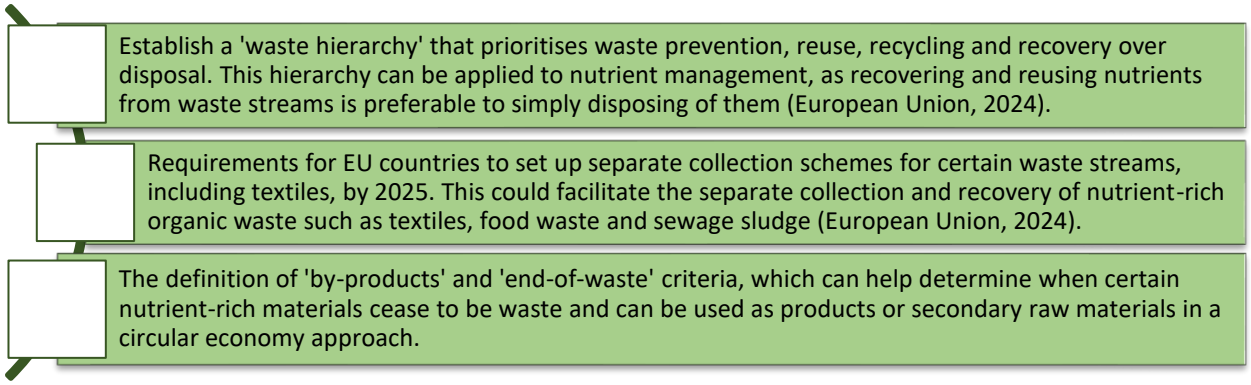

Figure 16 Implications in nutrient management of the Waste Framework Directive.

- **Barriers, gaps, and opportunities**

The Waste Framework Directive provides a legal framework for waste management in the EU and aims to decouple economic growth from the environmental impacts of waste generation. However, several barriers and gaps prevent the effective management of nutrients under the directive. There is a lack of clarity on key concepts in EU waste legislation, such as producer responsibility, reuse, and recovery (Rizos et al., 2015). In addition, the flexibility given to Member States allows them to deviate from the waste hierarchy, which prioritises waste prevention, reuse, and recycling (Rizos et al., 2015). Inadequate collection and implementation strategies, especially in regions and member states with less experience in bio-waste management, pose significant challenges (Zero Waste Europe, 2024). Some measures have limited capacity to achieve high levels of service coverage, participation, and quality of results, potentially failing to meet the EU mandate for separate collection of bio-waste (Zero Waste Europe, 2024). In addition, interrelated barriers are spread across EU Member States, requiring multiple transversal and vertical solutions to overcome them (Zero Waste Europe, 2024).

Despite these challenges, there are several opportunities to improve nutrient management under the Waste Framework Directive. Separate collection of bio-waste is crucial to achieving the Waste Framework Directive's recycling and landfill diversion targets (Zero Waste Europe, 2024). Harnessing the power of the EU's internal market, together with advances in data and technology, can transform resource use and enable a competitive and efficient market moving towards a circular economy (Eunomia Research & Consulting Ltd., 2023). Promoting product reuse, supporting the establishment and development of reuse and repair networks, and adopting public procurement criteria and quantitative targets for reuse can significantly improve sustainability (Ministry for the Ecological Transition and the Demographic Challenge, 2012). Establishing extended producer responsibility compliance requirements for producers, manufacturers and importers will promote product reuse and recycling (Ministry for Ecological Transition and the Demographic Challenge, 2012). Integrating waste prevention programmes into waste management plans, environmental programmes or sustainable consumption and production programmes can improve policy coherence (Ministry for the Ecological Transition and the Demographic Challenge, 2012).

To unlock the potential of the Waste Framework Directive for nutrient management, a significant increase in ambition is needed to create a coherent and consistent policy framework for a circular economy (Eunomia Research & Consulting Ltd., 2023). This will involve addressing the identified barriers and gaps, while taking advantage of the opportunities offered by the directive. A more ambitious and coherent policy framework is essential, clarifying key concepts, strengthening implementation, and better integrating nutrient management across EU policies for a truly circular economy.

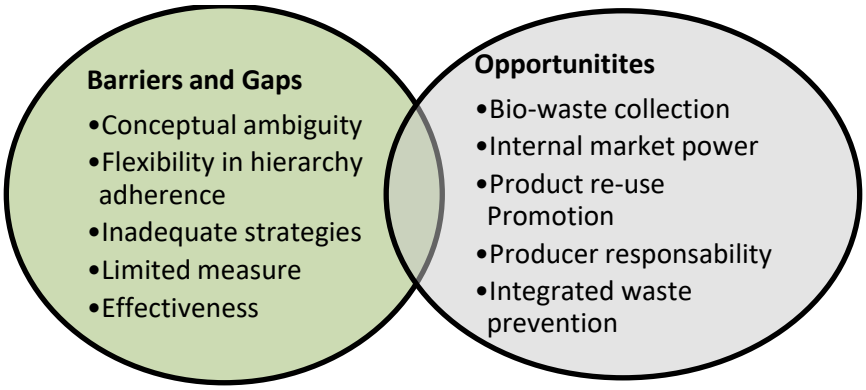

Figure 17 Barriers, gaps, and opportunities of the Waste Framework Directive.

- **EU member states approach**

The European Union's nutrient management strategy under the Waste Framework Directive aims to comprehensively address both point and diffuse sources of pollution. In addition, the Waste Framework Directive promotes the use of anaerobic digestion to treat organic waste, producing renewable biogas and organic fertiliser, helping to reduce dependence on fossil fuel-based fertilisers (EPRS, 2024). The directive also prioritises the prevention of food waste through a five-step waste hierarchy and includes measures to improve the measurement of food waste and set reduction targets for 2030 (EPRS, 2024).

However, several challenges hinder the effective implementation of these measures. The 2023 proposal to amend the Waste Framework Directive has been criticised for its perceived lack of ambition in waste prevention and the need for more harmonised extended producer responsibility schemes (ACR+,2024). Addressing these issues is critical to advancing effective nutrient management and reducing pollution across the EU.

1.b.4 Sewage Sludge Directive

The Sewage Sludge Directive (86/278/EEC) is a European Union regulation designed to ensure the environmentally sound use of sewage sludge in agriculture (European Communities, 1986). Its main objective is to reduce the risks associated with the spreading of treated sewage sludge on agricultural land, with a focus on protecting soil quality, water resources and public health from potential contaminants such as heavy metals and pathogens (Yunta et al., 2024). The directive sets strict treatment and quality standards for sewage sludge, requiring it to undergo appropriate processes to reduce pollutants before it can be used as a soil improver or fertiliser (Bauer et al., 2020). It includes comprehensive monitoring and reporting requirements to maintain compliance and assess the impact of sludge application on the environment (Bianchini et al., 2016).

The directive also reflects wider EU efforts to harmonise waste management practices across member states, in line with other regulations such as the Fertiliser Regulation (European Parliament, 2019). Recent updates and legislative reviews have aimed to improve the directive's effectiveness in addressing emerging environmental concerns and technological advances in sludge treatment (Neri et al., 2024). By setting these standards, the Sewage Sludge Directive supports sustainable agricultural practices and contributes to the EU's overall waste management strategy, promoting both environmental protection and the recycling of organic materials (Bauer et al., 2020; Yunta et al., 2024).

- **Implications in nutrient management**

The Sewage Sludge Directive (86/278/EEC) (European Communities, 1986) has a significant impact on nutrient management in agriculture by regulating the use of treated sewage sludge as a fertiliser. The directive requires that sewage sludge applied to agricultural land must meet strict quality standards to limit the presence of heavy metals and other contaminants, thereby ensuring that the nutrients it provides are both beneficial and safe (Bauer et al., 2020). By enforcing these standards, the directive helps to optimise the nutrient value of sewage sludge and promotes its effective use as a source of organic matter and essential nutrients such as nitrogen and phosphorus, which are crucial for soil fertility and crop growth (Bianchini et al., 2016). This regulation is in line with broader EU objectives to improve soil health and sustainability, while minimising potential risks associated with nutrient imbalances and pollutant accumulation.

In addition, the directive's emphasis on monitoring and reporting requirements plays a crucial role in the management of nutrient application from sewage sludge. Regular assessment of sludge quality and its effects on soil and crops will ensure that nutrient application practices remain within established limits,

thereby reducing the risk of environmental problems such as nutrient run-off and soil contamination (Yunta et al., 2024; Neri et al., 2024). This structured approach not only supports sustainable agricultural practices, but also integrates sludge management into the broader framework of waste recycling and resource recovery, contributing to a circular economy and reinforcing the EU's commitment to environmental protection and efficient nutrient management.

Figure 18 Main strategies of The Sewage Sludge Directive for nutrients management.

- **Barriers, gaps, and opportunities**

The Sewage Sludge Directive presents several barriers and gaps to effective nutrient management. A major challenge is the variability in how different EU Member States implement and enforce the directive. This inconsistency can lead to uneven sludge quality and nutrient management practices across regions, undermining the directive's goal of harmonising sludge use in agriculture. In addition, the advanced treatment technologies required to meet the stringent standards of the directive can be costly and technically demanding, particularly for smaller municipalities with limited resources. This economic and technical barrier may prevent effective compliance and hinder nutrient management efforts (Bauer et al., 2020; Neri et al., 2024).

Another significant gap is the directive's limited focus on emerging contaminants such as pharmaceuticals and microplastics. While traditional contaminants such as heavy metals are addressed, the increasing presence of these new contaminants in sewage sludge poses potential risks to soil health and nutrient cycling. Furthermore, the directive does not fully address the efficiency of nutrient recycling from sludge, which limits its effectiveness in optimising nutrient use and reducing dependence on synthetic fertilisers (Bianchini et al., 2016; Yunta et al., 2024). There is also a need for more comprehensive guidelines that consider the long-term effects of sludge application on soil structure and ecosystem health.

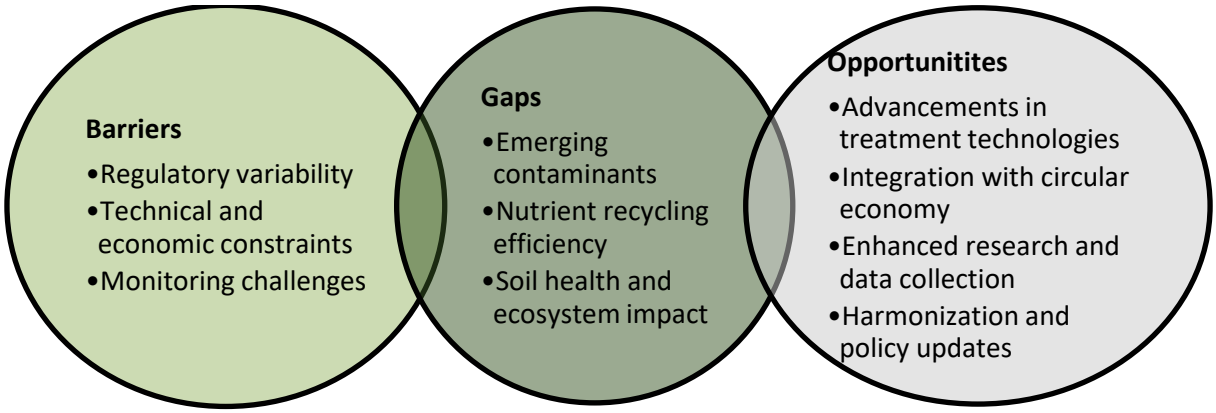

Figure 19 Barriers, gaps and opportunities of The Sewage Sludge Directive.

Despite these barriers and gaps, there are promising opportunities to improve nutrient management under the directive. Advances in sludge treatment technologies can improve the quality and nutrient recovery of sewage sludge, making it a more viable option for agricultural use. Integrating sludge management into a broader circular economy framework could optimise nutrient recycling and minimise reliance on synthetic inputs. Updating the directive to address emerging contaminants and improving research on sludge impacts can also help fill existing gaps and strengthen nutrient management practices (Neri et al., 2024). By exploiting these opportunities, the directive can better support sustainable agriculture and environmental protection.

- **EU member states approach**

The Sewage Sludge Directive (86/278/EEC) is implemented by EU Member States through the enactment of various national regulations. These regulations are designed to ensure the safe and effective management of treated sewage sludge when used in agricultural contexts. Additionally, they promote the reuse of treated wastewater from all urban wastewater treatment plants where appropriate. The directive sets quality standards for sludge, with the objective of minimising environmental and health risks. This is achieved by requiring that sludge meets specific criteria for contaminants and nutrient content. The majority of EU countries enforce these standards by implementing advanced treatment technologies and developing guidelines for the safe application of sludge to agricultural land. This is done with the aim of balancing nutrient recycling with environmental protection. It is incumbent upon EU Member States to encourage the recovery of valuable resources and to implement the requisite measures to ensure that sludge management routes are in conformity with the waste hierarchy set forth in Article 4 of Directive 2008/98/EC. Such routes shall be designed to maximize prevention; to prepare for reuse, recycling, and other forms of resource recovery, with particular attention to phosphorus and nitrogen, while taking into account national or local valorisation options; and to minimize adverse effects on the environment and human health.

In Central European countries such as Poland and Hungary, implementation of the directive often faces challenges related to outdated infrastructure and varying levels of compliance. These countries are

working to improve their sludge management practices through EU-funded projects and technical assistance aimed at upgrading treatment facilities and improving sludge quality. Efforts are focused on aligning with EU standards while considering regional constraints and development needs. This includes improving monitoring and reporting systems to ensure that sludge application does not adversely affect soil and water resources (Bauer et al., 2020).

Overall, while the core objectives of the Sewage Sludge Directive are consistent across the EU, the specific approaches and challenges vary from country to country. Each Member State tailors its implementation to its own context, striving to meet EU requirements while considering national needs and priorities.

1.b.5 Fertilizers Regulation

Regulation (EU) 2019/1009 (European Commission, 2019d), which became effective on 17 July 2022, sets the standards for fertiliser products across the European Union. This regulation updates and expands the scope of fertiliser products to include those derived from both virgin and recycled materials, such as organic, organ mineral and bio-stimulant fertilisers. It introduces CE marking for fertilisers, ensuring that they meet EU health, safety and environmental standards and facilitating their free movement within the EU. The Regulation also emphasises sustainability by integrating recycled materials into the fertiliser market, supporting a circular economy and enforcing strict safety and quality controls to protect soil and reduce environmental impact.

- **Implications in nutrient management**

Regulation (EU) 2019/1009 introduces several key changes that significantly impact nutrient management in agriculture across the European Union. By including fertilisers made from both virgin and recycled materials, the regulation supports a circular economy and reduces reliance on synthetic products. This shift encourages the recovery and reuse of nutrients from waste streams, such as recovered struvite and phosphate salts, thus enhancing the sustainability of nutrient management practices. The regulation also mandates the CE marking for fertilisers, ensuring they meet rigorous health, safety, and quality standards, which provides farmers with reliable products and clearer information to optimise nutrient application. Additionally, it enforces limits on contaminants and pathogens are enforced to protect soil health and minimise environmental risks. Overall, this comprehensive framework not only promotes the use of innovative, recycled nutrients but also encourages a more uniform and environmentally responsible fertiliser market, ultimately promoting more efficient and sustainable agricultural practices.

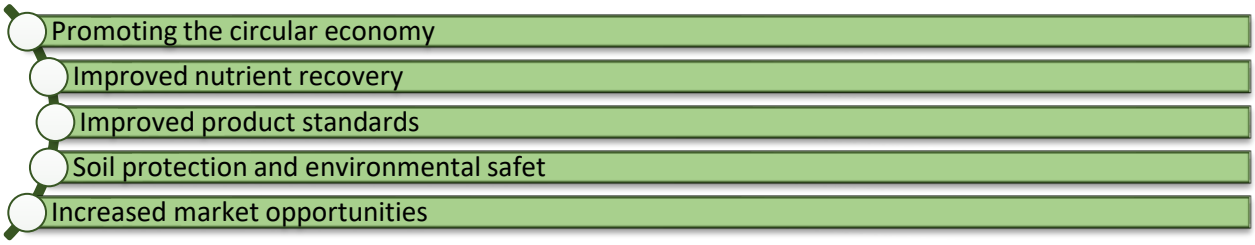

Figure 20 Main strategies of Fertilizers Regulation for nutrients management.

- **Barriers, gaps, and opportunities**

The implementation of Regulation (EU) 2019/1009 has highlighted several barriers, gaps and opportunities in nutrient management across the EU. A key barrier is the complexity of navigating different regulatory frameworks across member states, which creates compliance challenges for manufacturers and farmers. Despite harmonisation efforts, differences in national regulations hamper the consistent adoption of new practices. Furthermore, market acceptance of recycled fertiliser remains a hurdle due to concerns about its efficacy, safety and reliability (Løes and Rittl, 2019). The financial and infrastructural requirements to develop and scale up nutrient recovery technologies are also a challenge, especially for smaller producers (Valchev and Ribarova, 2022).

There are several gaps in the current framework, such as a lack of awareness and understanding among farmers and stakeholders of the benefits of recycled fertiliser. Insufficient data on the long-term impacts of these fertilisers on soil health and crop yields also highlights the need for robust monitoring and research. Integrating new fertiliser products into existing nutrient management practices is also a challenge.

However, the regulation also offers opportunities. It encourages innovation and research in nutrient recovery technologies, potentially leading to more efficient and sustainable fertiliser products (Valchev and Ribarova, 2022). Economic benefits for farmers and producers include reduced reliance on synthetic fertilisers and new revenue streams from recycled products. The uniform regulatory framework across the EU facilitates market expansion, allowing producers to offer their products more widely within Member States. In addition, the regulation aligns with the EU's broader sustainability and circular economy goals, providing stakeholders with opportunities to enhance their environmental credentials and contribute to the EU's goals of reducing waste and improving resource efficiency (Foggia and Beccarello, 2023).

Addressing these barriers and gaps, while taking advantage of the opportunities offered by Regulation (EU) 2019/1009, can significantly advance nutrient management practices, making them more sustainable and efficient in the long term.

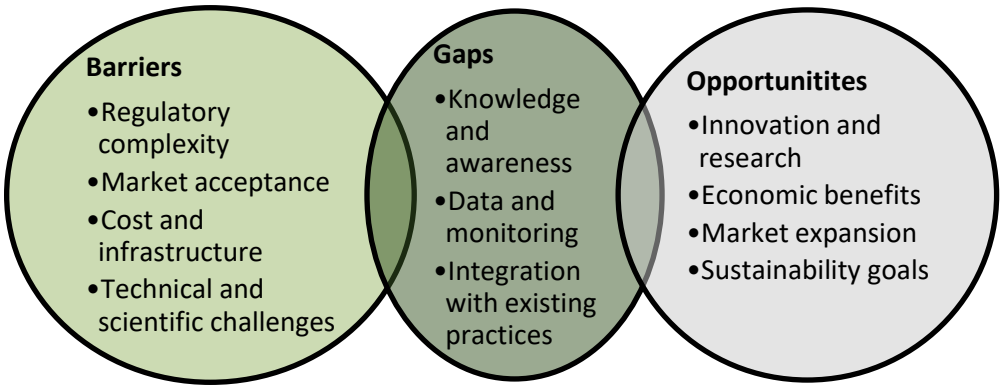

Figure 21 Barriers, gaps and opportunities of Fertilizers Regulation.

- **EU member states approach**

The EU Fertiliser Regulation (EU) 2019/1009 (FPR) regulates the marketing of fertiliser products throughout the EU, including organic and organo-mineral fertilisers, growing media, and bio-stimulants (Zhang, 2022). This regulation categorises products into seven types based on their function and intended use (European Chemical Agency, 2023) and imposes strict safety, quality and labelling standards to ensure their free movement within the EU.

Manufacturers must demonstrate compliance with these standards before they can affix the CE mark to their products. This involves completing various conformity assessment procedures, including the preparation of technical documentation, an EU Declaration of Conformity, and having the product assessed by an accredited Notified Body (Zhang, 2022). The Notified Bodies verify whether the product meets the necessary requirements and issue a certificate if it does.

Fertiliser products must be labelled in accordance with Annex III of the Regulation, and manufacturers must ensure traceability for effective market surveillance (European Chemical Agency, 2023). A transitional period will allow products placed on the market before 16 July 2022 under the previous rules to remain on the market (European Chemical Agency, 2023).

In summary, EU Member States are applying the FPR by enforcing CE marking, conformity assessment and labelling requirements to standardise the market while providing a transition period for adaptation.

1.b.6 Urban Wastewater Treatment Directive

The Urban Wastewater Treatment Directive (UWWTD), originally adopted in 1991 and subsequently revised, represents a fundamental component of EU legislation with the objective of safeguarding the environment from the detrimental impacts of urban wastewater discharges. The directive sets rigorous standards for the collection, treatment, and discharge of wastewater, particularly in urban areas with a population equivalent of over 2,000. In accordance with the stipulations of this directive, EU Member States are obliged to guarantee that wastewater undergoes an adequate degree of treatment prior to its release into water bodies. The principal objective of this process is to minimise the levels of pollution and its associated ecological impacts (European Commission, 2022).

The UWWTD is primarily concerned with the reduction of key pollutants, particularly nitrogen and phosphorus, which are the primary contributors to eutrophication. This is defined as the excessive growth of algae that depletes oxygen levels and endangers aquatic ecosystems. The directive requires the implementation of secondary (biological) treatment or more advanced treatment techniques in areas susceptible to eutrophication. These provisions are fundamental to the resolution of nutrient overload and the assurance of water quality within the EU (German Environment Agency, 2023).

- **Implications in nutrient management**

The UWWTD plays an important role in the management of nutrient discharges in the EU, particularly with regard to nitrogen and phosphorus pollution. These nutrients, often from urban wastewater, agricultural runoff and industrial sources, contribute to eutrophication - the accumulation of excessive nutrients in water bodies, leading to algal blooms and ecosystem degradation (German Environment Agency, 2023).

The 2023 recast of the UWWTD strengthens nutrient management by introducing stricter requirements for nutrient recovery and reuse. The revised legislation introduces more stringent controls for the removal of nitrogen and phosphorus. Wastewater treatment plants (WWTPs) serving populations exceeding 100,000 people equivalent (PE) are obliged to implement advanced nutrient removal technologies by 2035 in order to achieve the desired water quality objectives (European Biogas Association, 2023).

The directive encourages the utilisation of anaerobic digestion (AD) for the treatment of sewage sludge. This process allows for the production of biogas, the recovery of nutrients, and a reduction in greenhouse gas emissions. The recovery of nutrients from sludge, including phosphorus, can serve as a substitute for mineral fertilisers, thereby reducing reliance on imported fertilisers and contributing to a circular economy. These practices are in alignment with the European Union's stated goal of achieving energy neutrality in WWTPs by 2040. This deadline adds pressure to optimise nutrient and energy recovery processes in order to meet the EU's climate goals (European Biogas Association, 2023).

- **Barriers, gaps, and opportunities**

One of the main barriers to the comprehensive implementation of the directive is the considerable expense associated with the upgrading of existing infrastructure to align with the revised standards, particularly for smaller and medium-sized facilities. A significant obstacle to effective nutrient management is the dearth of data and monitoring of biogas and nutrient recovery processes in certain EU member states. Nevertheless, the directive also offers substantial potential for innovation in nutrient recovery technologies, particularly in the context of phosphorus, which is a crucial raw material for agriculture (European Biogas Association, 2023).

The directive presents an opportunity to enhance nutrient management by promoting extended producer responsibility (EPR), which entails the transfer of a portion of the financial burden associated with nutrient pollution from the general public to producers of consumer goods that contribute to nutrient loads, including fertilisers and pharmaceuticals. This is consistent with the polluter pays principle, which provides an incentive for the prevention of nutrient pollution at its source. Moreover, the transition towards anaerobic digestion for the treatment of sewage sludge allows for the generation of energy (through biogas) and the recycling of nutrients. This will contribute to the achievement of both climate and nutrient management objectives (German Environment Agency, 2023).

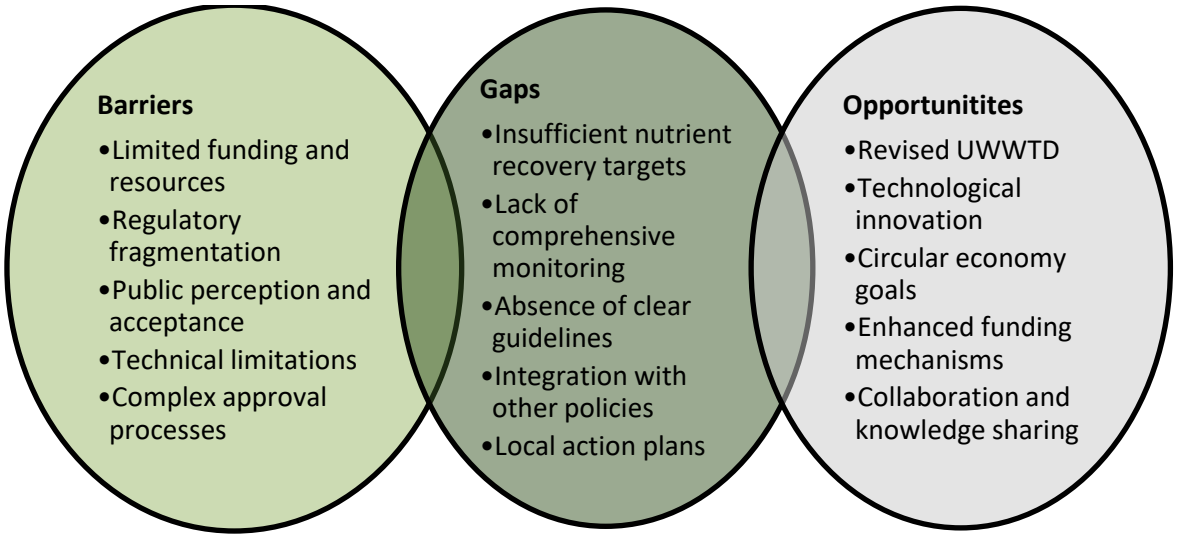

Figure 22 Barriers, gaps and opportunities of Urban Wastewater Treatment Directive.

- **EU member states approach**

The implementation of the UWWTD exhibits considerable variation across EU member states. While countries such as Germany and the Netherlands have been at the vanguard of adopting sophisticated nutrient removal technologies, others, particularly in Eastern and Southern Europe, are confronted with obstacles pertaining to financial resources and infrastructure development. The manner in which member states of the EU approach the management of nutrients within the framework of the UWWTD is contingent upon a number of factors, including the quality of local water sources, the economic capacity of the state in question, and the prevailing governance structures (German Environment Agency, 2023).

In conclusion, while the recast of the UWWTD presents a robust framework for nutrient management in the EU, challenges such as financial costs, technological gaps, and market readiness for recovered nutrients must be addressed for effective implementation across all member states. There is considerable variation between EU member states in their approaches to nutrient recovery. Germany, for instance, is a leading nation in this field, while other countries face significant barriers related to infrastructure and data availability.

1.b.7 Animal by-products Regulation

The Animal By-Products Regulation (ABPR), established by the European Union under Regulation (EC) No 1069/2009 and Commission Regulation (EU) No 142/2011, sets out comprehensive procedures for the handling of animal by-products (ABPs) not intended for human consumption (European Parliament, 2009). The main objectives of this Regulation are to protect public health, animal health and the environment by ensuring the safe collection, transport, processing and disposal of ABPs (European Commission, 2021b). Materials classified as ABPs include those from slaughterhouses, farms, food processing plants and other establishments, and are categorised according to risk level to ensure

appropriate disposal and recovery methods. By managing ABPs within this framework, the EU aims to reduce biosecurity risks while promoting the sustainable recovery of valuable nutrients and energy from these resources, thereby supporting the EU's overarching sustainability goals (European Parliament, 2009).

- **Implications in nutrient management**

ABPR employs an integral approach to nutrient management, providing a framework for the safe collection, processing, and disposal of animal by-products (ABPs). This regulation plays a key role in supporting the EU's circular economy initiatives by facilitating the recovery of essential nutrients, such as nitrogen and phosphorus, which are frequently employed in agricultural practices as fertilisers. By facilitating the recycling of nutrients from animal by-products through techniques such as anaerobic digestion and composting, the ABPR contributes to a reduction in the reliance on synthetic fertilisers, which are costly and environmentally detrimental (European Commission, 2021b). It has been demonstrated that the recovery of nutrients from animal by-products (ABPs) offers an alternative to chemical fertilisers and contributes to the reduction of greenhouse gas emissions from agriculture, which is in accordance with the environmental and climate objectives of the European Union (EU) (Scarlat et al., 2018).

- **Barriers, gaps, and opportunities**

ABPR has played a crucial role in advancing the recovery of nutrients across the European Union (EU), facilitating the safe reuse of animal by-products (ABPs) for agricultural purposes. Nevertheless, the high costs of infrastructure remain a significant obstacle, particularly for smaller facilities that lack the capacity to invest in nutrient recovery technologies such as anaerobic digestion (AD) and composting (Scarlat et al., 2019). Furthermore, the unequal distribution of technical resources and data monitoring across EU Member States impedes the implementation of a uniform approach to nutrient recovery, resulting in inconsistencies in compliance and limiting the regulation's potential for a unified impact on EU nutrient management (European Environment Agency, 2016).

The ABPR presents a significant opportunity to foster a circular economy by supporting technologies that reduce reliance on synthetic fertilisers and generate renewable energy from ABPs (Salemdeeb et al., 2017). This is despite the challenges that the initiative faces. The ABPR's promotion of the recovery of essential nutrients such as nitrogen and phosphorus align with the EU's sustainability and climate goals, assisting Member States in advancing resource efficiency and agricultural resilience. As EU Member States endeavour to surmount financial and logistical obstacles, the ABPR serves as a catalyst for innovation and sustainability in the management of nutrients across Europe (European Commission, 2021b).

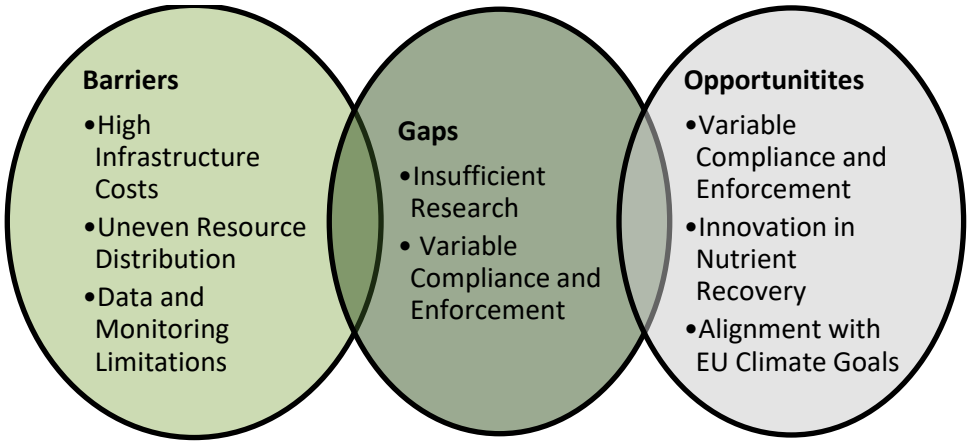

Figure 23 Barriers, gaps and opportunities of ABPR.

- **EU member states approach**

The implementation of the ABPR exhibits considerable variation across EU Member States, reflecting diverse economic conditions, regulatory frameworks, and agricultural practices. Germany and the Netherlands have been at the vanguard of the adoption of advanced nutrient recovery technologies, integrating them into their waste management systems and agricultural practices (Scarlat et al., 2019). These nations have established comprehensive systems for processing animal by-products, utilising methods such as anaerobic digestion and rendering. These systems comply with the ABPR and contribute to the goals of a circular economy by transforming waste into valuable resources, including biogas and organic fertilisers (European Commission, 2021b). Furthermore, the commitment of these countries to sustainable nutrient management is reflected in their investment in research and development, with the objective of enhancing recovery processes and reducing environmental impacts.

In contrast, a number of Eastern and Southern European countries encounter obstacles in the complete implementation of the ABPR, primarily due to financial limitations and the lack of developed infrastructure (European Environment Agency, 2016). These nations frequently encounter difficulties in meeting the initial costs associated with the implementation of nutrient recovery technologies, and they often lack the requisite technical expertise to ensure effective implementation. The disparity in regulatory enforcement and monitoring capacity serves to further complicate the situation, resulting in inconsistencies in compliance levels. Notwithstanding these challenges, there are opportunities for collaboration and knowledge-sharing among Member States, particularly through EU-funded initiatives aimed at supporting sustainable practices in agriculture and waste management (Salemdeeb et al., 2017). By enhancing regional cooperation and sharing best practices, EU Member States can collectively improve their nutrient management strategies under the ABPR, thereby contributing to the EU's sustainability and climate objectives.

1.c Soil health regulation

There are some regulations related to soil health that contribute by extension to nutrients management. Their influence varies based on their focus of action.

1.c.1 Healthy Soils – New EU Soil Protection Strategy

The Healthy Soils – New EU Soil Protection Strategy**,** adopted in 2021, aims to address soil degradation and promote sustainable soil use across Europe (European Commission, 2020e). The strategy is part of the European Green Deal and focuses on improving soil fertility, protecting soil biodiversity, increasing organic matter and preventing soil erosion. The ultimate goal is to ensure that all EU soils are in good condition by 2050.

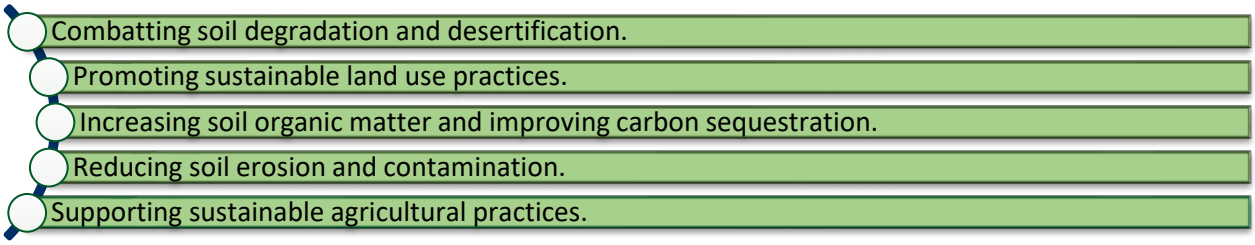

Figure 24 Main strategies of Healthy Soils – New EU Soil Protection Strategy.

- **Implications in nutrient management**

This strategy directly impacts nutrient management by promoting practices that maintain soil fertility and prevent nutrient loss. It encourages the use of organic farming, crop rotation, and cover crops, which help to maintain or improve nutrient cycling in soils. By focusing on improving soil health, the strategy ensures better nutrient retention, reduces the risk of nutrient leaching, and enhances the efficiency of fertilizer use (Panagos et al., 2015; Lal, 2020).

1.c.2 The Soil Monitoring Law

The Soil Monitoring Law is an EU initiative to provide a comprehensive system for monitoring and assessing the state of soils across Europe (General Secretariat of the Council of the European Union, 2024). It requires regular monitoring of soil health indicators such as organic carbon content, erosion rates, soil biodiversity and contamination levels. The legislation will provide the data needed to guide policy on sustainable soil use and protection.

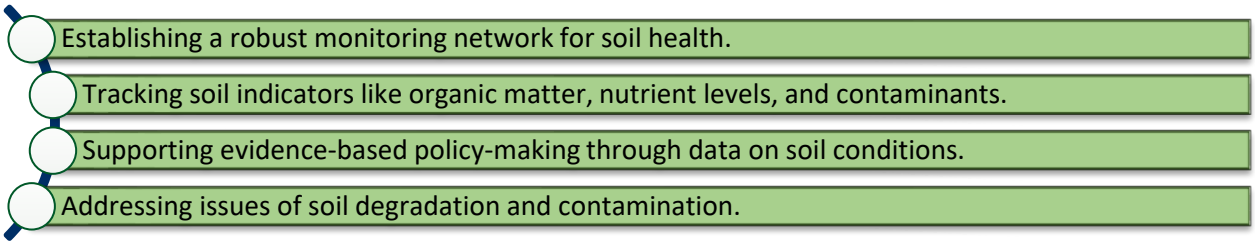

Figure 25 Main strategies of The Soil Monitoring Law.

- **Implications in nutrient management**

The law significantly influences nutrient management by ensuring that soil nutrient levels are subjected to regular measurement. The monitoring of these levels enables more informed decisions to be made about the timing and quantity of nutrient inputs, thus preventing the occurrence of either over- or under-fertilisation. Furthermore, it facilitates the identification of areas where soil nutrients are being depleted, thereby guiding the application of fertilisers or soil amendments to maintain soil fertility (Chabbi et al., 2017).

1.c.3 Mission Soil

Mission Soil represents a component of the EU's overarching Horizon Europe initiative, which is aimed at achieving a soil health target of 75% by 2030 (European Commission, 2023b). The mission underscores the pivotal role of soil in ensuring food security, regulating climate, and sustaining biodiversity. The initiative promotes sustainable soil management practices with the objective of maintaining ecosystem services and ensuring long-term agricultural productivity.

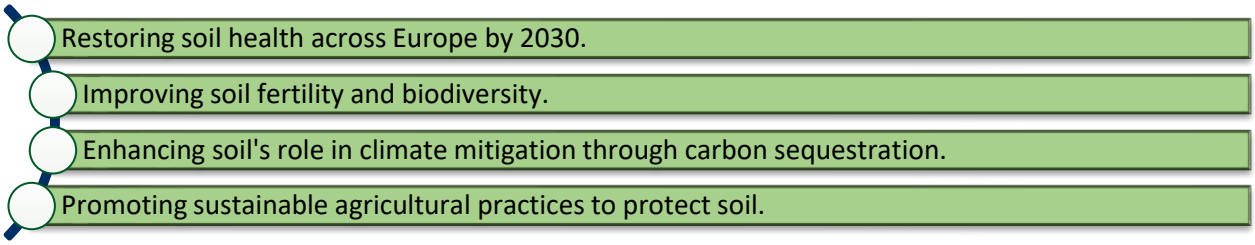

Figure 26 Main strategies of Mission Soil.

- **Implications in nutrient management**

The promotion of sustainable soil management by Mission Soil has the indirect effect of improving nutrient management. It encourages the implementation of practices such as crop rotation, reduced tillage, and the utilisation of organic fertilisers, which serve to maintain or enhance the natural nutrient cycling processes within the soil. Furthermore, the retention of nutrients in healthier soils reduces the

necessity for chemical inputs and prevents the leaching of nutrients into water systems (Kopittke et al., 2019).

1.c.4 EU Nature Restoration Law

The EU Nature Restoration Law, which was proposed in 2022, places an emphasis on the restoration of degraded ecosystems, including wetlands, forests, peatlands, and agricultural landscapes (European Commission, 2020e). This is with a view to enhancing biodiversity and ecosystem services. The law sets legally binding targets for the restoration of 20% of the EU's land and sea by 2030. This will contribute to climate resilience and biodiversity.

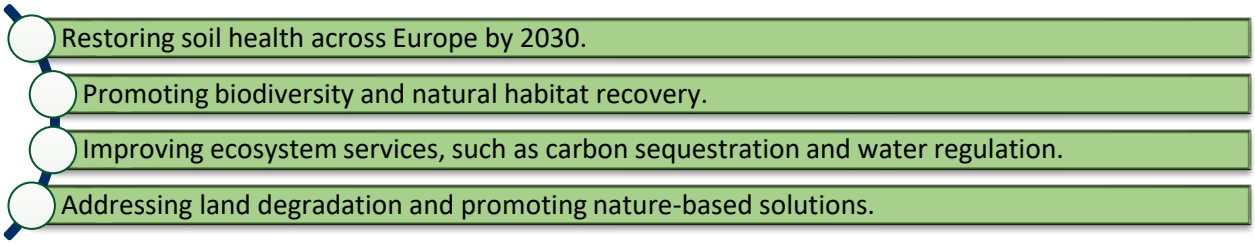

Figure 27 Main strategies of EU Nature Restoration Law.

- **Implications in nutrient management**

While the primary focus of the legislation is the restoration of natural habitats, it can also exert an indirect influence on nutrient management. The rehabilitation of ecosystems such as wetlands and forests enhance their capacity to function as nutrient sinks, thereby reducing the runoff of nutrients from agricultural lands into water bodies. Furthermore, restored ecosystems enhance soil health and fertility, which in turn supports the sustainable cycling of nutrients (Chabbi et al., 2017).

Each of these EU regulations plays a role in the management of nutrients. The Healthy Soils Strategy exerts the most direct influence through its focus on sustainable agricultural practices and soil fertility. The Soil Monitoring Law furnishes indispensable data for the guidance of nutrient management, while Mission Soil advocates the cultivation of salubrious soils that enhance the retention of nutrients. Ultimately, the EU Nature Restoration Law contributes to nutrient management indirectly by facilitating the restoration of ecosystems that enhance soil health and nutrient cycling.

2. EU Economic Incentives Analysis

Economic incentives have become a crucial instrument in modern government regulation. By strategically modifying the costs and benefits associated with different actions, governments can effectively influence the behaviour of individuals and businesses, promoting socially desirable outcomes (Tietenberg, and Lewis, 2016).

Economic incentives are defined as the factors that motivate individuals, businesses, or governments to undertake specific economic actions or make decisions (Godyń, 2022). Economic incentives are stimuli that seek to modify the behaviour of individuals or businesses, either through the offering of rewards (subsidies, tax breaks) or the imposition of penalties (taxes, fines). The fundamental premise is that by modifying the costs and benefits associated with various options, individuals will tend to select those that optimize their well-being, thereby aligning their decisions with political objectives.

They offer a number of distinctive advantages. Firstly, they are highly flexible, capable of addressing a wide range of policy goals and situations (Nordbeck et al., 2023). Secondly, they can be more efficient than direct regulations, as they provide individuals and businesses with the capacity to make informed decisions. Thirdly, economic incentives have the potential to stimulate innovation by creating new markets and opportunities. Furthermore, economic incentives are generally regarded as more socially acceptable than direct regulations, as they afford individuals greater freedom of choice (Godyń, 2022).

However, it would be remiss not to acknowledge the challenges that economic incentives present. The implementation of economic incentives can be costly for governments. Additionally, the outcomes of economic incentives can be difficult to predict, potentially leading to unintended consequences. Equity concerns may also arise, as economic incentives may disproportionately benefit certain groups. Finally, designing effective economic incentives requires a deep understanding of human behaviour and market dynamics (Nordbeck et al., 2023).

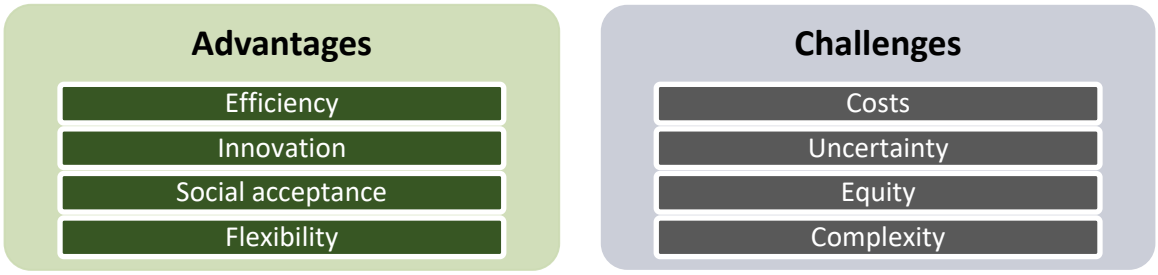

Figure 28 Advantages and challanges of economic incentives (Tietenberg, and Lewis, 2016).

Despite these challenges, economic incentives remain a valuable tool for government regulation. By carefully considering the potential benefits and drawbacks, governments can effectively use economic incentives to promote socially desirable outcomes (Tietenberg, and Lewis, 2016).

Economic incentives represent a highly effective instrument for the implementation of government regulation. By strategically modifying costs and benefits, governments can effectively influence behaviour and promote socially desirable outcomes. Despite the existence of certain challenges, the potential benefits of economic incentives make them a valuable addition to the regulatory toolkit.

A more comprehensive examination of the existing economic instruments utilized in agricultural policies and markets will be conducted in T4.3 Economic instruments to support the reduction of NP emissions. Nevertheless, it is worthwhile to commence an investigation into one of the principal economic instruments introduced by the EU with the objective of promoting sustainable nutrient management in agriculture. The combination of economic incentives with environmental targets encourages farmers and stakeholders in nutrient management to prioritise long-term sustainability over short-term gains. This chapter will analyse the Common Agricultural Policy (CAP), with a particular focus on the greening measures and the agri-environmental measures. These contribute to more sustainable agricultural practices and foster a shift in mindset among stakeholders towards a more holistic and ecologically conscious approach within this sector (Teleshkan et al., 2024).

2.a Common Agricultural Policy (CAP)

The Common Agricultural Policy (CAP) is a key policy framework established by the European Union (EU) to support its agricultural sector. Initially created in 1962, the CAP aims to ensure a stable supply of affordable food, support farmers' livelihoods, and promote sustainable agricultural practices across. The new CAP was launched in 2023 and aimed to be a key instrument to support the EGD, in particular the F2F and biodiversity strategies (Castellano, 2022).

This is the main EU agricultural policy that provides financial support to farmers. While not exclusively focused on nutrients, CAP encourages practices that improve nutrient management. The CAP plays a vital role in helping EU farmers cope with various challenges, thereby contributing to both EU and global food security. It supports farmers not only as food providers but also as stewards of the land and natural resources. Over the years, the CAP has evolved in response to changing economic conditions, consumer expectations, and societal concerns about the environmental impacts of agricultural production. Through a range of tools, the CAP aids EU farmers in addressing these challenges while promoting sustainability, resilience, and competitiveness (European Commission, 2023).

There are five main lines or objectives at the heart of the new CAP (Doukas et al., 2024):

- ✓ Food security: ensuring a stable food supply for EU citizens.

- ✓ Income support for farmers: providing financial support to farmers to maintain their livelihoods and stabilise their incomes.
- ✓ Sustainable agriculture: promoting environmentally friendly farming practices that protect natural resources and biodiversity.
- ✓ Rural development: supporting the economic development of rural areas, improving their quality of life and promoting job creation.
- ✓ Market stability: maintaining stable agricultural markets and preventing price volatility.

Figure 29 CAP objectives Source: EU Commission.

To achieve its objectives, the CAP employs several key strategies. Farmers receive direct payments based on the area of land they farm, which helps stabilize their income. These payments are often conditional on compliance with environmental standards through cross-compliance measures (Doukas et al., 2024). Additionally, the CAP includes specific agri-environmental measures that encourage sustainable practices, such as crop rotation, wetland conservation, and sustainable water management. Reflecting a strong commitment to sustainability, the CAP has reallocated resources from direct payments to rural development to bolster funding for environmental and climate policies (European Commission, 2023). This reallocation supports measures that link funding to measurable environmental and climatic outcomes, ensuring that financial support translates into tangible sustainability results (Doukas et al., 2024).

Member States are required to develop rural development programmes that fund projects aimed at enhancing the economic viability of rural areas and promoting sustainable agricultural practices. The CAP emphasizes collaboration with other EU policies to create a cohesive approach to sustainability and rural development. This integrated strategy aims to balance the needs of farmers with environmental conservation and rural development goals, ultimately fostering a more sustainable agricultural sector in the EU (European Commission, 2023). By addressing both immediate and long-term challenges, including

external shocks like climate change and geopolitical events, the CAP provides exceptional measures to mitigate potential negative impacts on agriculture (Doukas et al., 2024).

The CAP also focuses on the growing importance of environmental and social sustainability in EU farming. Direct payments now come with enhanced conditions, such as Good Agricultural and Environmental Conditions (GAEC), which include maintaining permanent grassland, ensuring crop rotation, and requiring non-productive areas on farmland (European Commission, 2023), all removed in 2024 for its simplification. Eco-schemes, which account for a significant portion of CAP expenditures, provide incentives for farmers to adopt climate- and environment-friendly practices, such as organic farming, agro-ecology, and carbon farming. Furthermore, the CAP supports social sustainability through measures that promote animal welfare, alternative production systems, and improved workers' rights (Doukas et al., 2024).

In terms of trade, the EU continues to promote international cooperation and greater trade flows through agreements with both developed and developing countries. This not only adds value through sustainable growth but also ensures the EU can respond effectively to crises, as demonstrated by the establishment of Green Lanes during the COVID-19 pandemic and Solidarity Lanes following the invasion of Ukraine. These measures help maintain stable trade flows and mitigate market volatility, contributing to global food security (European Commission, 2023).

Innovation and digitisation are central to the CAP's strategy for improving farming practices and maintaining competitiveness. Research and innovation in areas such as precision farming, automated processes, and advanced breeding techniques are essential for enhancing production efficiency while protecting natural resources. The adoption of digital tools allows farmers to optimize crop yields and animal performance, ensuring transparency and sustainability throughout the food chain. By leveraging these advancements, the CAP helps EU agriculture adapt to challenges and seize new business opportunities, ensuring a resilient and sustainable future for the sector (Doukas et al., 2024).

3. Experts' and workshop results

3.a Stakeholder Interview Analysis on EU Nutrient Management Policies

This chapter presents the findings of five key interviews with experts in the field of nutrient management within the context of the European Union. The interviews aim to identify the most influential policies, the barriers and opportunities in the implementation of these policies, as well as the economic incentives and possible improvements for nutrient management within the EU. The interviews were conducted with experts from various sectors, all contributing to the development of new governance models and value chain solutions for nutrient recovery from waste streams.

- **Key Policies Influencing Nutrient Management**

During the interviews, the respondents consistently identified several EU policies that currently play a critical role in nutrient management.

The **Green Deal**, with its focus on reducing nutrient losses and promoting circular economy practices, was considered essential in aligning various sectoral policies related to nutrient management. Moreover, the new **Circular Economy Actin Plan**, expected in 2025, was flagged as a key upcoming piece of legislation with potential to bolster nutrient recycling by setting ambitious targets and creating new opportunities for waste valorization.

The **Water Framework Directive** (WFD) represents a substantial legislative contribution to this field. The directive was identified as playing a pivotal role in the regulation of water quality. However, stakeholders emphasised the absence of a robust connection with agricultural policies, particularly the **Common Agricultural Policy** (CAP), which constrains the directive's capacity to effectively regulate nutrient losses. Despite its potential, the CAP currently lacks mandatory requirements for nutrient balance management, which experts view as an untapped opportunity to enforce more effective nutrient recycling practices.

It was concluded that the **Urban Wastewater Treatment Directive** (UWWTD) represents a significant opportunity for the advancement of nutrient recovery, contingent upon the implementation of the necessary amendments.

Interviewees also underscored the importance of the **EU Fertilising Products Regulation** and the **Animal By-Products Regulation** in nutrient recovery. The current complexity in obtaining authorizations for nutrient-rich materials from waste, especially under the **Organic Farming Directive** and **Animal Feed Regulations**, was highlighted as a barrier to promoting circularity. The Nenuphar project reaffirmed that regulatory coherence across these frameworks is essential for unlocking the potential of nutrient recycling, particularly phosphorus and nitrogen

Furthermore, other relevant frameworks, including the **Soil Health Directive** (which is currently under development), the **Waste Framework Directive** and a range of fiscal policies, were also discussed. However, it was acknowledged that there are frequently limitations in their implementation and scope.

- **Barriers, Gaps and Opportunities in Policy Implementation**

The interviewers identified several EU policies that are currently of critical importance regarding the management of nutrients. The **Water Framework Directive (WFD**) has been identified as a pivotal policy for regulating water quality. However, many interviewees have highlighted its limited effectiveness due to a lack of integration with agricultural policies, particularly the **Common Agricultural Policy (CAP)**. The CAP has the potential to enforce more effective nutrient management practices, but currently lacks mandatory requirements for nutrient balance management. This was perceived by interviewees as a significant missed opportunity for the promotion of more effective nutrient recycling practices across EU member states.

Additionally, the **Urban Wastewater Treatment Directive (UWWTD)** was identified as a pivotal policy with the potential to markedly impact nutrient recovery, particularly given its scheduled revision in 2024. A considerable number of participants expressed optimism that the revised UWWTD could establish new phosphorus recovery targets and potentially extend these to nitrogen. In addition to these key frameworks, policies such as the EU Fertilising Products Regulation and the Animal By-Products Regulation were frequently mentioned. It was highlighted that these policies are restrictive, particularly regarding the approval of products recovered from waste for use in organic farming and animal feed.

However, the implementation of these policies is hindered by several legal, technical, and financial barriers. One of the most significant challenges identified was the regulatory incoherence between different EU directives. For instance, the **Water Framework Directive** emphasises nutrient losses as a major obstacle to achieving good water quality status, yet there is no evident mechanism within the CAP to address these losses through funding. This gap makes it challenging to enforce consistent practices across the agricultural sector.

Another significant challenge is the slow and complex approval process for recovered products, particularly under the **Organic Farming Regulation** and the **Animal Feed Regulation**. In both cases, products are assessed based on their origin rather than their quality, which significantly impedes the utilisation of recycled nutrients in farming and feed applications. Additionally, interviewees have highlighted that wastewater treatment plants currently lack sufficient incentives to recover nutrients like phosphorus and nitrogen, despite their considerable potential for reuse in fertiliser production.

Although these barriers, the interviews revealed several important opportunities. The forthcoming revision of the Urban Wastewater Treatment Directive provides an opportune occasion to introduce more rigorous nutrient recovery targets, particularly for phosphorus, and potentially for nitrogen as well. Amending the Organic Farming Regulation to shift the focus from product origin to product quality could prove an effective means of reducing the EU's dependency on imported fertilisers and facilitating the recovery of nutrients from waste streams.

- **Economic Incentives and Strategic Opportunities**

The role of economic incentives in enhancing nutrient management across Europe was a recurring topic of discussion. Some of interviewees proposed that the CAP should provide explicit funding for nutrient recycling initiatives and introduce cross-compliance requirements that integrate water quality considerations from the Water Framework Directive. It was argued by many that the current structure of the CAP compensates for environmental losses but does not provide sufficient incentives for innovation or efficiency in nutrient management. A more market-oriented approach would facilitate the uptake of recycled nutrients and stimulate demand for products derived from waste streams.

In a forward-looking perspective, the interviewees put forward a number of key recommendations for the improvement of EU nutrient management policies. Firstly, there is a pressing need for greater alignment between the CAP and the Water Framework Directive, ensuring that nutrient management practices are integrated into agricultural funding mechanisms. Secondly, the development of the Integrated Nutrient Management Action Plan (INMAP), as previously committed to under the EU Green Deal, is regarded as a crucial step towards achieving the objective of reducing nutrient losses by 50% while maintaining soil fertility. A majority of the interviewees emphasised the necessity of a prompt and comprehensive implementation of the plan. Ultimately, future EU policies must adopt a more circular economy mindset, promoting the recovery of valuable nutrients such as phosphorus and nitrogen from waste and ensuring their reintegration into agricultural and industrial processes.

In conclusion, the insights gathered from these interviews serve to illustrate the intricate nature of the regulatory framework that governs nutrient management in the EU. While current policies, such as the Water Framework Directive, the Common Agricultural Policy (CAP) and the Urban Wastewater Treatment Directive (UWWTD), play a pivotal role, their effectiveness is often undermined by regulatory fragmentation and gaps in implementation. On the other hand, upcoming policy revisions and potential amendments offer significant opportunities to enhance nutrient recovery and recycling. By addressing the identified barriers and seizing these opportunities, Europe can move closer to a circular economy and reduce its dependency on imported fertilisers, while also mitigating the environmental impacts of nutrient pollution.

3.b ESNI workshop

In this chapter there will be an analysis of the results of the participatory workshop that was leader in the context of ESNI Conference in Brussels on the 18th of September 2024. The aim of this participatory activity was to involve different stakeholders to discuss on nutrients management regulations and economic instruments, their gaps, barriers and opportunities.

Following a brief introduction to the NENUPHAR project, 39 attendees were split into six groups to discuss different topics on nutrient legislation. Each group, focusing on manure, sewage sludge, or dairy wastewater, was moderated by a NENUPHAR partner with a technical expert and a note-taker.

The workshop highlighted the central role of EU legislation, such as the Nitrates Directive and the Water Framework Directive, in shaping nutrient management strategies in Member States. These frameworks set limits on the application of nitrogen and phosphorus to prevent environmental degradation, but their rigidity can inhibit innovative nutrient recovery solutions. For example, the Nitrates Directive's limit of 170 kg N/ha/year often restricts more flexible approaches to nutrient cycling, particularly in regions with significant agricultural production. Countries such as the Netherlands, which have historically been granted higher thresholds, now face a return to stricter limits, further complicating efforts to integrate nutrient recovery into sustainable agricultural practices.

However, several barriers limit the effective implementation of nutrient recovery systems across the EU. A major obstacle is the **regulatory inflexibility**, which does not take into account local variations in waste production and nutrient needs. In some areas, such as Catalonia, strict biosecurity regulations make it difficult to expand biogas plants or manure treatment facilities, while in other regions, such as Latvia, a lack of awareness of recovered nutrient products hinders uptake. **Financial constraints** are also significant, with many farmers and businesses struggling to meet the high up-front costs of nutrient recovery infrastructure, further inhibiting the development of business models that could integrate these systems into existing agricultural practices.

Despite these challenges, the workshop identified several opportunities to improve nutrient management through more **tailored economic strategies** and **regulatory adjustments**. Economic instruments such as subsidies for nutrient recovery technologies, green loans and incentives for circular economy practices could help reduce the financial burden on farmers and businesses. In addition, the **Renure approach**, which focuses on reducing nutrient levels in manure, offers a viable way to make EU regulations more adaptable to regional contexts, thereby supporting a more flexible nutrient management system. By encouraging greater cooperation between Member States, sharing best practice and raising awareness of the economic and environmental benefits of nutrient recovery, the EU could significantly advance its nutrient management objectives.

In conclusion, the workshop highlighted the need for both regulatory reform and economic incentives to unlock the potential of nutrient recovery systems across the EU. While current EU legislation provides a framework for managing nutrient pollution, it often fails to consider regional differences in nutrient use and recovery capacity. Addressing this gap requires a more flexible regulatory approach, tailored financial support and increased awareness among stakeholders. If these challenges are met, nutrient recovery could play a critical role in both reducing environmental damage and providing a sustainable source of fertiliser, contributing to a more circular, resilient agricultural economy.

4. Conclusions

The comprehensive baseline analysis of EU policies and regulations related to nutrient management, as presented in Deliverable D4.1, serves to illustrate the intricate complexity and interconnectivity of these legislative frameworks. This analysis is of great importance to gain an understanding of the regulatory environment and the economic incentives that influence nutrient management practices across the European Union.

The European Green Deal establishes the overarching vision for the sustainable transformation of the EU's economy. It is a critical driver for nutrient management, as it aims to transform the EU into a modern, resource-efficient, and competitive economy. The principal objectives are the reduction of greenhouse gas emissions, the decoupling of economic growth from resource utilisation, and the achievement of a net zero emissions target for greenhouse gases by 2050 while protecting and enhancing ecosystems and reversing biodiversity decline. Similarly, the Circular Economy Action Plan advocates the efficient utilisation of resources in accordance with the principles of reduction, reuse and recycling. These developments have significant implications for nutrient management, encouraging the recycling of organic waste into valuable nutrients for agricultural use, thus closing the nutrient loop.

The EU Bioeconomy Strategy places an emphasis on the development of a sustainable bioeconomy, with a particular focus on the importance of sustainable agricultural practices that minimise environmental impacts. The utilisation of biological resources and innovations is facilitated in order to enhance the efficiency of nutrient utilisation and to reduce the dependency on chemical fertilisers. Furthermore, the objective of the Farm to Fork Strategy is to ensure that food systems are fair, healthy, and environmentally friendly. The strategy addresses every stage of the food chain, from production to consumption, with the objective of reducing nutrient losses by improving the efficiency of nutrient use and minimising the environmental impact of food production.

The implementation of specific policies is important regarding the management of nutrients. The objective of the Water Framework Directive (WFD) is to prevent deterioration and achieve a good status for all water bodies. It encompasses measures to regulate pollutants, including nutrients, with the objective of safeguarding water quality from the detrimental effects of agricultural runoff and nutrient pollution. The Nitrates Directive provides a specific framework for addressing nitrate pollution from agricultural sources. It establishes action programmes and designates vulnerable zones with the objective of managing and reducing nitrate leaching into water bodies, while promoting sustainable nutrient management practices.

The Integrated Nutrient Management Action Plan needs to be published in order to provide a systematic and unified approach to nutrient management, integrating policies across sectors with the objective of ensuring a balanced input and output of nutrients, thus preventing over-application and nutrient losses. The Waste Framework Directive provides the foundation for waste management and resource efficiency, emphasising the recycling of organic waste into useful products such as compost and bio-based fertilisers, as a means of supporting nutrient recycling. The Sewage Sludge Directive establishes regulatory frameworks governing the utilisation of sewage sludge in agricultural settings, with the objective of

ensuring its application is safe for the environment and human health. The promotion of treated sludge as a nutrient source contributes to the circular economy. Ultimately, the Fertilizers Regulation guarantees the quality, safety, and efficacy of fertilizers utilized within the European Union. The legislation includes provisions for organic and waste-derived fertilisers, providing support for their role in sustainable nutrient management.

The implementation of economic incentives, as exemplified by the Common Agricultural Policy (CAP), also exerts an influence on the management of nutrients. The CAP provides financial assistance and incentives to farmers to encourage the adoption of sustainable practices. The policy includes specific measures for nutrient management, such as agri-environment-climate measures and eco-schemes, which encourage the adoption of practices that enhance nutrient use efficiency and reduce environmental impacts. Unfortunately, the recently adopted CAP Simplification Regulation removed some of the most significant improvements to the CAP's environmental delivery: mandatory standards on habitat for nature and crop rotation, thus making achievement of sustainable nutrient management more challenging.

In conclusion, the results presented in this deliverable demonstrate the importance of integrating regulatory reform, economic support and technological innovation. This analysis highlights the need for the harmonisation of nutrient management regulations across EU member states, ensuring consistency while allowing for regional flexibility. The establishment of a more cohesive framework would facilitate the implementation of an integrated EU-wide approach to nutrient management. Furthermore, the development of stronger economic incentives is essential, including the creation of a market for recycled nutrient products and the implementation of financial mechanisms that reduce the barriers to adopting nutrient recovery technologies.

It is equally important to provide support for innovation in the field of nutrient recovery. It is recommended that the EU should give priority to the allocation of funding for research, development and pilot projects, while simultaneously updating regulatory frameworks with a view to encouraging the safe and efficient reuse of recovered nutrients across a range of sectors. Moreover, it is imperative to cultivate collaboration between the agricultural, wastewater, and environmental sectors to develop integrated solutions. Governance models that facilitate public-private partnerships and stakeholder engagement should be prioritised to ensure cross-sector cooperation.

Deliverable 4.1 provides a comprehensive roadmap for addressing these challenges, identifying key regulatory barriers and economic gaps. By aligning future project activities with these insights, NENUPHAR has the potential to make a significant contribution to the development of a more sustainable and circular approach to nutrient management across Europe.

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6. Annexes

ANNEX 1 Technology center director interview

Name and institution	BETA Technological Center, Spain
1) In your opinion, what are the current most influential EU policies on nutrient management? In what way? (Preliminary list of general and specific policies: European Grean Deal, EU Circular Economy Action Plan, EU Bioeconomy Strategy, Nitrates Directive, The Water Framework Directive, CAP, etc.)	
Nutrients management is a transversal EU topic with different levels of regulation. Challenges that involve above all an increase in the cost of production which is one of the main limitations and that production potential/food sovereignty is lost. Environmental regulation little social and economic perspective (collateral effects), only environmental perspective. The principal EU policies for nutrients management are: - Nitrates directive à Mainly regulates nitrogen application. - Water framework Directive à Mainly regulates nitrogen application. - Waste framework Directive à emission limitation. Emissions are not regulated together independently of the sector, but each sector has its own regulations (industry, primary sector, ...). - Fertilizers Directive à many limitations, no state-level transposition. At the Spanish level it has been applied without adapting (very restrictive). Declaration of mutual recognition. For better nutrient management, there is a need for a specific nutrient directive for P. Phosphorus Directive which would include phosphorus as a nutrient to be managed and regulated. Nowadays, we depend on P from other countries. The Nitrates Directive is very focused from a pollution point of view, but from a phosphorus point of view a broader view is needed. It would also be interesting to have a Food Safety Directive for the management of nutrients. Inclusion and promotion of organic fertilisation as a strategy to increase productivity. Nutrients management it's an important part of Food Security.	
2) In relation to the previous answer, what are the main barriers (i.e. legal, technical, financial, social, etc.), gaps and opportunities for its implementation to improve nutrient management? Please, list them for all the policies identified in the previous question.	

A general problem with the EU policies is that there is intersection between policies.

EU Bioeconomy Strategy	
Barriers	High costs. Many DGs involved in order to face new challenges efficiently, e.g. nutrient recovery, DG health x food safety issues. There are regulations that limit and block the avenues of valorisation and hinder the objective of meeting new marketing challenges (The EU itself makes it unprofitable (e.g. biofertilisers, ...)).
Gaps	A stringent phosphorus recovery policy is needed because we are phosphorus dependent. Opportunities to address new goals.
Opportunities	There are problem-solving technologies
Nitrates Directive	
Barriers	Regulations are not adapted to different contexts. There is a lack of a broader vision for its application (e.g. optimisation and maximisation of production, ...). The current approach has a limited and outdated vision because it regulates applications based on applicable quantities. A forward-thinking vision that incorporates technology, nitrate uptake efficiency and nitrate enhancement strategies is required.
Gaps	Limits the application of nutrients of organic origin (sludge management). Has a limited and outdated vision because it regulates the application based on applicable quantities, a vision that includes technology, efficiency of nitrate absorption and strategies to increase productivity
Opportunities	Regulation by zones and countries, ensures the extraction of N There are many strategies for the improvement of nutrient management and application

3) From your experience, how is the transposition and implementation of these policies at national level? *(NENUPHAR demo-site countries: Spain, Hungary, Slovenia, Latvia, Lithuania, Denmark and Cyprus)*

In the case of Spain, there are 17 autonomous communities that regulate and increase the complexity of the application.

Difficulties in the integration of environmental legislation into agricultural policy (to be consistent and supportive of farm management).

Difficulties in regulating at basin level (Ebro) when it is limited to the municipal level. Authority that regulates the basin (water use), but agrarian and agricultural regulation and fertilisation depend on the Autonomous Community. Difficulty in applying a common policy to a basin.

There is an authority that manages a basin, but if the agrarian and agricultural regulation and fertilisation depends on each CCAA, if a basin is in more than one CCAA, it is complicated to make a common policy on a commune.

Big challenge: how to get the regulators to have a consistent regulatory framework.

Examples:

- Fertiliser Directive: it is not compulsory to transpose, only Spain has done so. It is much more restrictive than any other country and farmers use mutual recognition instead of the national directive.

4) From your point of view, what are the most strategic EU economic incentives for nutrient management?

In order to mitigate a policy with significant environmental restrictions, it is essential to address the economic and social impacts to overcome market-level barriers and obstacles.

The primary sector suffers from increased costs as a result of environmental policies.

These days, the PAC only compensates for losses.

Efficient nutrient management must take place at market level (minimum use with maximum efficiency). The market must be encouraged.

Market incentives are the most viable. Applying environmental measures without economic measures will lead to market failure.

Efficient nutrient management must be done from a market perspective: minimum nutrient use and maximum efficiency.

One should not rely solely on European subsidies, as this creates an inefficient system that does not take productivity into account.

Monitoring strategies for mineral fertiliser companies are needed.

5) In your opinion, which would be the ideal next steps for improving EU policies for nutrient management? What future policies should focus on?

It is necessary to consider an integrated vision that takes into account the following axes: environmental, ecosystemic, economic and social, including food sovereignty. It is essential to adopt a realistic perspective involving economic activity and the private sector, with policies that encourage economic and market dynamics.

EU regulation is very difficult and slow to change, so it needs to be consistent and anticipate current changes. To speed up the adaptation of regulations to reality, it is necessary to use science for policy

and to improve governance. Although a lot of money is spent on research and development, it is often not used to modernise policy.

It is essential to have a complete view of all the policies being implemented, not only from an environmental point of view, but also from an economic and social point of view, including food sovereignty, industrialisation and biodiversity. In addition to being difficult to modify and update, an overabundance of European regulations can limit development and force dependence on resources from other countries.

A stable framework is needed with rules that can be more easily changed as a result of innovation, research, the market/economy and social impact. Instruments are needed that do not block development and improvement.

There are opportunities and challenges for the Fertiliser Directive, such as RENURE (Recovered Nitrogen from Manures) and the use of sewage sludge, which need to be considered to adapt the regulations to current needs.

6) Is there anything else you would like to add regarding nutrient management policies?
In order to ensure effective cooperation, it is crucial to have an appropriate working space where these actors can meet and discuss best practices. It is also essential to draw up position papers in order to lay the foundations for agreements and joint actions to tackle common challenges. These position papers must be developed in collaboration with the administrations of the Autonomous Communities (CCAA) involved. A handbook of good practices will be an indispensable tool to guide the actions of the different actors and ensure that all activities are carried out in a sustainable and coordinated manner. The commitment to reach interregional or international agreements is fundamental to the efficient sharing of basins. This commitment involves proposing joint actions and regulating activities on the basis of common challenges, while providing a framework for cooperation that benefits all stakeholders. The NENUPHAR project should have a significant impact at the international and interregional level in shared basins. The project is based on a regulatory framework that allows cooperation and coordination between different actors with responsibilities in the basin. In the case of the Ebro basin, these could be Guissona, Vallcompanys, Grupo Jorge, among others.

ANNEX 2 Innovation company interview

Name and institution	EasyMining, part of Ragn-Sells Group

1. In your opinion, what are the current most influential EU policies on nutrient management? In what way? (Preliminary list of general and specific policies: European Grean Deal, EU Circular Economy Action Plan, EU Bioeconomy Strategy, Nitrates Directive, The Water Framework Directive, CAP, etc.)

The Urban Wastewater Treatment Directive (2022/0541), the Organic Farming Regulation (2021/1165) and the Animal Feed Regulation (767/2009). If the regulations are revised properly, they could strengthen the incentives to recover and reuse nutrients.

Other important policies are:

- Water Framework Directive
- CAP
- Fiscal policy / CBAM
- Taxonomy
- Soil Health Directive
- Waste Framework Directive
- Animal By-Products Regulation
- EU Fertilising Products Regulation.

7. In relation to the previous answer, what are the main barriers (i.e. legal, technical, financial, social, etc.), gaps and opportunities for its implementation to improve nutrient management? Please, list them for all the policies identified in the previous question.

The Organic Farming Regulation (EU 2021/1165)	
Barriers	Nutrients/products need to be added to the list of approved materials in the Organic Farming Regulation (EU 2021/1165) for use in organic farming. The current legislation, however, is focused on origin instead of quality, which makes it very time-consuming and resource-consuming, if not even impossible, to get a product recovered from waste on the list.
Gaps	
Opportunities	Amendments to the Organic Farming Regulation would ensure the EU's farming sector's supply of fertilisers for organic farming. It would help reduce the EU's dependency on imported fertilisers and decrease the CO2 emissions from the mining and production of fertilisers.

The Animal Feed Regulation (767/2009)	
Barriers	Similar to the Organic Farming Regulation, the Animal Feed Regulation asses nutrients/products based on their origin rather than their quality. The use of recovered nutrients from wastes "obtained from the various phases of the urban, domestic and industrial wastewater" and "solid urban waste" in animal feed (Annex III, point 5) is not allowed.
Gaps	
Opportunities	With the help of chemical recycling, phosphorus can be recovered from sewage sludge ash and turned into a clean recycled product, free from contaminants like cadmium. We, therefore, do not see why sewage sludge ash should be classified as a prohibited material under the feed regulation (767/2009, Annex III, point 5). Instead, once sewage sludge has been incinerated into ash, the "treatment" of the sludge should be considered finalised and the ash a safe starting point for the manufacturing chain for feed.
The Urban Wastewater Treatment Directive (2022/0541)	
Barriers	Today, wastewater treatment plants have very few incentives or requirements to recover nutrients from wastewater and sewage sludge. Also, the waste hierarchy is another structural barrier. It does not take the resources that can be extracted from waste into consideration, which results in a large part of the resources being lost. In a circular economy, yesterday's waste actors play an important role in separating valuable resources from dangerous substances and ensuring that only the desired raw materials with high-quality fulfilling product standards are circulated. The waste hierarchy drives businesses to a waste logic, with a focus on treating waste. We need to change this and go from waste logic to product logic
Gaps	
Opportunities	The revised directive says that the Commission should draft delegated acts, including phosphorus reuse and recycling rates. This is also an opportunity for the Commission to include similar requirements for nitrogen.
8. From your experience, how is the transposition and implementation of these policies at national level? *(NENUPHAR demo-site countries: Spain, Hungary, Slovenia, Latvia, Lithuania, Denmark and Cyprus)*	

9. From your point of view, what are the most strategic EU economic incentives for nutrient management?
10. In your opinion, which would be the ideal next steps for improving EU policies for nutrient management? What future policies should focus on?
As the European Environment Agency states in its report on urban wastewater treatment plants, these facilities could, with the use of new techniques and innovation, ”act as resource hubs providing reclaimed water, energy, nutrients and organic materials for reuse, recycling and recovering”. For this to happen, the Commission needs to have a holistic approach to the development of new legislation, meaning when revising and putting forward new legislation, they should all contribute to the foundation for stricter requirements on the recovery of nutrients from treatment plants and other relevant nutrient streams.
11. Is there anything else you would like to add regarding nutrient management policies?
Introducing a long-term goal to allow phosphorus recovery from all relevant (phosphorus-rich) wastewater/ashes could facilitate nutrient management.

ANNEX 3 Consulting company interview

Name and institution	Proman Management GmbH

1. In your opinion, what are the current most influential EU policies on nutrient management? In what way? (Preliminary list of general and specific policies: European Grean Deal, EU Circular Economy Action Plan, EU Bioeconomy Strategy, Nitrates Directive, The Water Framework Directive, CAP, etc.)

Nitrates Directive – limiting input

Fertilising Products Regulation – enabling recycled products

Mission Soil, Mission Ocean – driving research

Animal By-Products Regulation – limiting inputs

2. In relation to the previous answer, what are the main barriers (i.e. legal, technical, financial, social, etc.), gaps and opportunities for its implementation to improve nutrient management? Please, list them for all the policies identified in the previous question.

EU Bioeconomy Strategy	
Barriers	Non-competitiveness of recycling technologies
Gaps	Pollution not being penalised, e.g. polluting sewage plants / utility companies do not pay for spills and eutrophic lakes (e.g., lake Windermere) and beaches where swimming is forbidden.
Opportunities	Products admission to organic farming; potential other niche markets.
EU Bioeconomy Strategy	
Barriers	Cost of ecosystem services and/or nature-based solutions for farmers
Gaps	CAP may be considered the most powerful environmental program in the EU but it is only marginally linked to ecosystem services.
Opportunities	At EU-level link CAP and Green Deal / Bioeconomy Strategy directly, don't rely on member states regulations.

3. From your experience, how is the transposition and implementation of these policies at national level? *(NENUPHAR demo-site countries: Spain, Hungary, Slovenia, Latvia, Lithuania, Denmark and Cyprus)*

Denmark has several good legal acts enforced or planned: N, P and Corg effluent tax from wastewater treatment plants, future CO2 emission tax for farming;

Catalunya has effective food waste legislation. Don't know any target-oriented regulation in other partner countries; why don't member states not copy best practices in other member states? German speaking countries (Switzerland, Germany, Austria) have enforced a P-recycling obligation from sewage sludge (Switzerland also from slaughterhouse residues) which is a low hanging fruit as citizens = the polluters because it is their pee and poo – must pay for potential additional costs compared to landfilling ash in larger agglomerations (smaller agglomerations are allowed to continue with sludge application on land, in Austria <20000 pe, in Germany <50000 pe – not in Switzerland where land application is forbidden). Citizens may need to pay 1-5 €/year, it is not a big burden and could be a leap forward.
4. From your point of view, what are the most strategic EU economic incentives for nutrient management?
Strategic incentives may be derived from supply chain resilience. If we would implement a real mission (like the moon landing, with all efforts bundled, not a watered-down weak research focus) and focus research on inventing / developing green N (ammonia) technologies, we may be able to replace gas reforming based ammonia production. Also, CCU technologies should be developed with much more efforts.
5. In your opinion, which would be the ideal next steps for improving EU policies for nutrient management? What future policies should focus on?
Bold policies are needed while most politicians don't dare to take decisions and just pursue populistic policies.
6. Is there anything else you would like to add regarding nutrient management policies?
If member states implement P-recycling obligation, they must coordinate policies within the Federal States, set strictly enforceable goals with penalties for non-compliance. Member states should learn from mistakes in Switzerland and Germany.

ANNEX 4 Independent research and consulting organization interview

Name and institution	LeAF BV, Wageningen, the Netherlands.

1. In your opinion, what are the current most influential EU policies on nutrient management? In what way? (Preliminary list of general and specific policies: European Grean Deal, EU Circular Economy Action Plan, EU Bioeconomy Strategy, Nitrates Directive, The Water Framework Directive, CAP, etc.)

Water Framework Directive
CAP
Urban Waste Water Treatment Directive
Fiscal policy / CBAM
Taxonomy
Soil Health Directive
Waste Framework Directive
Animal By-Products Regulation
EU Fertilising Products Regulation

Commission Delegated Regulation (EU) 2023/1605

EU sewage sludge directive (86/278/EEC)

2. In relation to the previous answer, what are the main barriers (i.e. legal, technical, financial, social, etc.), gaps and opportunities for its implementation to improve nutrient management? Please, list them for all the policies identified in the previous question.

Sewage sludge	
Barriers	Sewage sludge is a too broad term. There are vast differences between sludges from different sectors, and hence different opportunities and risks (eg sludge from agro-food vs sludge from urban WWTP's vs sludge from industrial processing sites).
Gaps	
Opportunities	

3. From your experience, how is the transposition and implementation of these policies at national level? *(NENUPHAR demo-site countries: Spain, Hungary, Slovenia, Latvia, Lithuania, Denmark and Cyprus)*

No experience in these countries

4. From your point of view, what are the most strategic EU economic incentives for nutrient management?

Enforce safe nutrient cycling through legislation (eg CAP). Also, enforce fertilizer producers to include a certain % of recovered resources in their products.
5. In your opinion, which would be the ideal next steps for improving EU policies for nutrient management? What future policies should focus on?
See ESPP answers Harmonise the different related and interdependent regulations. Eg the process requirements mentioned in ABP and FPR for compost differ. Now end-points are determined in the ABP-chain, which are too stringent for end users, thereby discouraging composting conform FPR. Make FAQ's and guidelines about the regulations more accessible/ findable. Interpretation of regulations is often difficult due to the complexity and hierarchy. This is essential in developing nutrient products based on resources recovered from residues.
6. Is there anything else you would like to add regarding nutrient management policies?
See ESPP. We look forward to the outcomes of this project.

ANNEX 5 Nutrients management platform interview

Name and institution	ESPP (European Sustainable Phosphorus Platform)
1) In your opinion, what are the current most influential EU policies on nutrient management? In what way? (Preliminary list of general and specific policies: European Grean Deal, EU Circular Economy Action Plan, EU Bioeconomy Strategy, Nitrates Directive, The Water Framework Directive, CAP, etc.)	
Green Deal Proposed new Circular Economy Act CAP (Common Agricultural Policy) Organic Farming Directive Water Framework Directive Urban Waste Water Treatment Directive Sewage Sludge Directive Waste Framework Directive Fiscal policy Soil policy Taxonomy Animal By-Products Regulations Animal Feed Regulations EU Fertilising Products Regulation Priorities for future EU policies	
2)In relation to the previous answer, what are the main barriers (i.e. legal, technical, financial, social, etc.), gaps and opportunities for its implementation to improve nutrient management? Please, list them for all the policies identified in the previous question.	
Green Deal **Proposed new Circular Economy Act** EU Circular Economy Act announced for 2025: Ursula von der Leyen COM presidency candidacy document and Jessica Rockwell mission letter. The exclusion of fertilisers from the EU's sanctions on Russia illustrates our dependency on imports. Russia today still accounts for around one fifth of EU fertiliser imports (N, P and K) (Eurostat). Food security: the EU is self-sufficient in food production, but this is only possible because of import of raw materials necessary for agricultural production and food processing, in particular phosphorus (necessary for fertilisers and for animal feed, and around 90% imported) and nitrogen fertilisers (import dependency has increased, as EU production has fallen because of natural gas prices). Increasing nutrient recycling (in particular phosphorus) from sewage, manures and from other organic wastes, is key to the resilience of the EU food system. There is an absence of recent data concerning nutrient potential of sewage and organic wastes compared to current EU fertiliser use, but a study in Sweden Member States suggest that phosphorus from sewage alone could cover nearly half of mineral fertiliser use.	

Tighter phosphorus discharge limits and the extension of P-removal requirements in the revised UWWTD will increase the amount of phosphorus potentially available for recycling and reuse in sewage / sewage sludge.
Ambitious "reuse and recycling" targets, under the revised UWWTD, should respond to the EU's objectives of food system resilience and circular economy.
'Phosphate rock' (meaning phosphorus in any form: fertiliser, food, chemicals, …) is on the EU Critical Raw Materials List since 2014. It was not considered for possible inclusion into the sub-list of "Strategic" Raw Materials in the 2024/1252 act because this sub-list concerns only electronics, renewable energy and aerospace and does not cover food products, animal feeds, nor raw materials necessary for food production. A process should be engaged to identify 'Strategic' food security input materials, comparable to the definition of 'Strategic' (industrial) raw materials, and with comparable actions (monitoring, supply and recycling).
This would facilitate coherence with EU policies on nutrients, in particular: Green Deal (Farm-to-Fork and Biodiversity Strategies) nutrient loss reduction targets, Circular Economy, Integrated Nutrient Management Action Plan, Soil Health, Common Agricultural Policy, energy policy (for nitrogen fertiliser production).

CAP (Common Agricultural Policy)

Barriers

See above link to Water Framework Directive
Need to ensure that Member State implementation plans for CAP respect Green Deal nutrient management objectives (Farm to Fork and Biodiversity strategy nutrient loss reduction targets, Circular Economy policy nutrient recycling objectives)

Gaps

Farm nutrient balance is not obligatory (FaST tool only "advisory", no obligation to implement balance)
Nutrient management and nutrient recycling not included in most MS action plans.
Cross-compliance (conditionality of subsidies) is currently not effectively ensured for the Water Framework Directive. Water basin action plans, and nutrient loss reduction objectives defined by water basin management committees (with the aim of achieving Quality Status objectives) should be obligatory for farmers (condition of CAP subsidies). Where necessary to achieve Quality Status objectives, agricultural nutrient management plans should be obligatory under both the Water Framework Directive and CAP.

Opportunities

Revision starting currently
CAP offers major opportunities and potential funding for agricultural nutrient management and recycling policies.
Include nutrient management plans (balanced fertilisation) and nutrient loss reduction measures (buffer strips, nutrient traps, intercropping …) as obligatory measures in catchments of eutrophication Sensitive Areas and nutrient recycling actions in GAECs and SMRs of national Implementation Plans.

Organic Farming Directive

Barriers

Process for acceptance of additional recycled nutrient materials as authorised inputs is unclear and very slow.

EGTOP Opinions concern one specific company product and process, so making their translation into Organic Farming Regulation problematic, and meaning that the assessment / regulatory acceptance process is slow and inefficient (examining of products one by one rather than definition of criteria).
Undefined term "not of factory farming origin" for certain recycled nutrient materials, with different interpretations in different Member States.

Gaps

Absence of clear criteria as to which recycled nutrient materials are potentially acceptable in Organic Farming and which are not: origin of materials ? (sewage? food waste ? food industry and abattoirs ? manure ?), which nutrients (P, N, K …) ?, solubility / plant availability of nutrients ? criteria concerning processing inputs ?

Opportunities

The EU Organic Farming Regulation 2018/848 art.5(c) specifies as a "general principle" of Organic Farming "the recycling of wastes and by-products of plant and animal origin as input in plant and livestock production".
Organic Farming has a recognised need for phosphorus and potassium inputs to avoid current trends of soil depletion (see SCOPE Newsletter n°149)

Water Framework Directive

Barriers

No link to CAP cross compliance – nutrient losses are identified locally as an obstacle to achieving Good Water Quality Status, but there is no tool for implementation (no local funding, not taken into account in CAP funding) – note – same problem for herbicides/pesticides, soil erosion

Gaps

Recycling and circular economy not mentioned.

Opportunities

Art. 9 of the Water Framework Directive: "Member States shall take account of the principle of recovery of the costs of water services, including environmental and resource costs …"

Urban Waste Water Treatment Directive

Barriers

Need to ensure mechanism to pass on cost of P recovery and recycling to water consumers

Gaps

Opportunities

Revised 2024 (pending publication). Commission can fix phosphorus "recovery and recycling rates". Nitrogen recovery will be assessed.

Sewage Sludge Directive

Barriers

Risks of refusal of sew age sludge valorisation in agriculture because of consumer or supermarket / food industry concerns, perception or marketing ("not grown in sewage").

Gaps

The existing Sewage Sludge Directive does not address microplastics nor organic contaminants (pharmaceuticals, industrial organic pollutants, e.g. PFAS), nor antimicrobial resistance.
Sewage sludge quality certification schemes are variable between Member States and are in some cases perceived as "industry controlling industry" (lack of credibility).

Opportunities

Sewage Sludge Directive revision currently proposed.

Should reaffirm the objectives of nutrient reuse and recycling (as per the revised Urban Waste Water Treatment Directive), taking into account greenhouse emission reduction objectives of wastewater treatment (including possible carbon storage in soil) with use of sewage sludge in agriculture only if:
- treated to enable energy recovery where feasible
- applied only according to crop nutrient needs (spreading plan and farm nutrient balance)
- taking into account nutrient availability in sludge
- ensuring protection of soil health (in particular organic contaminants)

The Directive revision should ensure EU-wide validation of sludge quality certification systems, and establishment of a structured EU dialogue between supermarkets, food industry, farmers, consumer organisations and NGOs, science and water industry to develop consensus acceptance of sleuge quality requirements, certification and monitoring.

Waste Framework Directive

Barriers

EU End-of-Waste status is not available for recycled nutrients for non-fertiliser uses, nor for non-nutrient materials recovered from wastewaters.

National end-of-Waste status in one Member State is often not recognised in other Member States.

Gaps

The current EU and national 'End-of-Waste' process needs to be revised to facilitate recycling whilst ensuring safety, by emphasising product quality and safety, rather than input materials (origin)

Opportunities

Create a single EU market for waste (recycled materials), especially for critical raw materials (including phosphorus), as specified in the mission letter from Ursula von der Leyen to new Environment Commissioner Jessica Rockwell mission letter).

Fiscal policy

Barriers

Essentially MS not EU competence

Gaps

Opportunities

Transfer fiscal burden from jobs to eco-taxes (climate emissions, resource consumption).

Provide fiscal incentives and other tools to support market demand for recycled nutrients, as specified in the mission letter from Ursula von der Leyen to new Environment Commissioner Jessica Rockwell mission letter).

Soil policy

Barriers

At present, no EU policy on soil quality

Gaps

Need for a soil policy comparable to the Water Framework Directive

Proposed Soil Health Directive does not include local soil management plans.

Opportunities

Proposed Soil Health Directive (not yet adopted) will provide monitoring, but probably no clear obligation to improve soil quality and protect soil.

Integrate soil health management into Water Framework Directive: Quality Status objectives, obligatory management plans.

Taxonomy

Barriers
Gaps
P-recovery from sewage is included, but not P-recovery from other sources, not N-recovery
Opportunities
Animal By-Products Regulations
Barriers
The ABP Regulations were written to address the BSE crisis and are today inappropriately conservative, preventing safe nutrient recycling.
Gaps
Category1 ABP ash is currently excluded from the EU Fertilising Products Regulation, despite decades of safe use in the UK, and despite that incineration is required in order to treat Cat1 material
Opportunities
EFSA Opinion underway on Cat1 ash use in fertilisers.
In that BSE is nearly inexistent in the EU, the ABP Regulations could be revised to ensure safety in this context whilst enabling appropriate nutrient recycling.
Animal Feed Regulations
Barriers
Currently exclude use of any nutrient recovered from manure or wastewater, irrespective of the treatment and recovery process. This inappropriately excludes recovered phosphates from ashes.
Gaps
Opportunities
Where there are no pathogen safety concerns (process ensures pathogen elimination by heat or chemical treatment, or evidence shows absence of pathogens in final product), recycled nutrient materials should be assessed on the basis of quality and contaminant levels, not by initial input material.
EU Fertilising Products Regulation
Barriers
Current process to asses and authorise additional materials or processes into “CMCs” is slow and complex
Gaps
Opportunities
NMI study underway
R&D
R&D needs identified by ESPP:
- recovery of stripped ammonia as compressed gas
- P-recovery upstream from sewage upstream of cement kiln combustion
- extraction of useful phosphorus chemicals from iron phosphates
- low-energy production of P4
Permanent (every year) monitoring of nutrient flows in Europe (EU total, and each Member State or autonomous region) to identify flows in different uses, secondary materials flows (potential for recovery), imports and exports. This should include all forms, e.g. imports of phosphorus in animal feed. Such monitoring is required by Art. 20 of the EU Critical Raw Materials Regulation 2024/1252: EU monitoring of CRM trade flows and obstacles to trade, demand, supply and supply concentration,

production, bottlenecks, price volatility. This monitoring information (aggregated) will be made publicly available.
3) From your experience, how is the transposition and implementation of these policies at national level? *(NENUPHAR demo-site countries: Spain, Hungary, Slovenia, Latvia, Lithuania, Denmark and Cyprus)*
ESPP no input – European organisation
4)From your point of view, what are the most strategic EU economic incentives for nutrient management?
CAP
5)In your opinion, which would be the ideal next steps for improving EU policies for nutrient management? What future policies should focus on?
Priorities for future EU policies Bring into CAP cross-compliance with Water Framework Directive local water quality status CAP funding for nutrient management and recycling Market "pull" policies for recycled nutrients: create market demand for secondary material, single market for waste, especially for critical raw materials, as specified in the mission letter from Ursula von der Leyen to new Environment Commissioner Jessica Rockwell mission letter). See ESPP draft position 2024:    ESPP proposals market pull policies Inclusion of P4 and Purified Phosphoric Acid as a "Strategic" material: see joint Declaration 2023:    Declaration P4 PPA SRMs v20_9_23.pdf
6)Is there anything else you would like to add regarding nutrient management policies?
As the European Environment Agency states in its report on urban wastewater treatment plants, these facilities could, with the use of new techniques and innovation, "act as resource hubs providing reclaimed water, energy, nutrients and organic materials for reuse, recycling and recovering". For this, future EU legislation needs to take a holistic approach to nutrient recycling, ensuring coherent

inclusion into critical raw material, agricultural, water, waste, health and animal feed regulations, to combine reductions of nutrient losses with increasing reuse and recycling rates.

Improved harmonisation of policies for nutrient stewardship is needed. The "Integrated Nutrient Management Action Plan' (INMAP) announced under the EU Green Deal has not yet been developed. This Plan should be developed and published in order to support the Green Deal objective to reduce nutrient losses by 50% without deteriorating soil fertility, as fixed by the Farm-to-Fork and Biodiversity Strategies, in synergy with nutrient recycling.

INMAP should be coordinated with the future EU Circular Economy Act.

See ESPP positions on INMAP 2021 and 2022:


ESPP input INMAP v27_3_21.pdf


ESPP input EU INMAP 26_4_22.pdf

Complexity of regulation, and interactions between different regulations, can be significant obstacles to nutrient recycling implementation by operators and to investment. Commission 'FAQ's can facilitate interpretation by clarifying specific operator questions (for example the detailed FAQ developed for the EU Fertilising Products Regulation). However, such FAQs should not be limited to a single regulation and should cover relevant interactions between regulations (Commission inter-service FAQ development).

We look forward to the outcomes of this project.