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WP4 Assessment of regulatory and economic instruments

NENUPHAR

New governance models to enhance nutrient pollution handling and nutrients recycling

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Executive summary

The governance of environmental issues has evolved markedly over recent decades, with a growing emphasis on flexible, multi-instrument approaches that integrate economic incentives, regulatory measures, and information-based tools. Nowhere is this shift more apparent than in agricultural nutrient management, where nitrogen (N) and phosphorus (P) surpluses continue to pose significant threats to ecosystems, climate, and public health. Recognizing the limitations of traditional command-and-control regulation, policymakers increasingly turn to economic instruments such as fertilizer taxes, subsidies, tradable permits, and nutrient offset schemes to internalize environmental costs and drive innovation.

Within this landscape, the European Union (EU) plays a leading role, advancing sustainability objectives through its Common Agricultural Policy (CAP), environmental directives, and circular economy strategies. However, persistent challenges - including fragmented governance, regulatory complexity, and financing gaps - have hindered the large-scale adoption of circular nutrient solutions. The NENUPHAR project responds to this gap by assessing the design, governance solutions, implementation, and impact of economic instruments across diverse EU contexts. The tasks of WP4 are closely interlinked, as they review the regulations applied in the EU, taking into account the national and regional specificities where the demos are located, and complementing these Task 4.3 offers a comprehensive framework for evaluating trade-offs, aligning financial tools with ecological indicators, and fostering policy mixes tailored to regional needs. In doing so, it contributes to the broader goal of transitioning toward sustainable, climate-resilient, and biodiversity-friendly agricultural systems.

Policy tools and instruments, examined in Task 4.3, are devices used to help turn a broad policy aim into a specific action. Instruments comprise a wide range of measures (legislation, expenditure, economic incentives, penalties, education, various forms of service delivery); more generally, incentives and obligations. Instruments, at the same time, are key categories, highlighting the relative political costs of action (e.g., persuading, sharing information rather than regulation or redistribution). The choice of a tool is basically the 'policy choice', and the patterns of policy choices characterize 'policy styles'. Within the scope of this task, economic instruments suitable for regulating the nitrogen and phosphorus cycles related to agricultural production will be examined, and an instrument that can be tested on demonstration sites within the framework of WP 5 of the Nenuphar project will be proposed

As part of this task, the current landscape, drivers, and barriers of innovative economic instruments (enforcing, encouraging, enabling) have been analysed aimed at reducing nitrogen and phosphorus emissions, with a particular focus on the novel value chain opportunities identified in WP3. The work was based on desk research and expert interviews and included a review of existing local and regional regulatory schemes at the demo site level. The types of instruments, financial parameters and success factors have been documented. Additionally, relevant indicators have been explored to assess scheme effectiveness and developed proposals for new fiscal and economic incentives tailored to the needs of public and private actors. These instruments are intended to support environmentally sound and efficient nutrient management.

The analysis emphasizes the importance of integrating these economic tools with robust regulatory frameworks and supportive information mechanisms to promote continuous environmental improvement and farmer engagement. To inform instrument selection, the project conducted extensive desk research and expert interviews, identifying drivers and barriers to the implementation of fiscal and market-based solutions across EU regions. Case studies on fertilizer taxes (e.g., in Sweden and Denmark), tradable permits (e.g., in New Zealand and the Baltic region), and targeted subsidies revealed that while many schemes reduce nutrient loads effectively, their outcomes are heavily shaped by local economic, political, and institutional contexts. Furthermore, challenges such as low price elasticity in fertilizer demand and the risk of adverse effects on food security and smallholder farmers have been examined, highlighting the need for compensatory mechanisms and redistributive policies.

Particular attention was given to the EU financing landscape, where small farms and agri-food SMEs face significant gaps in accessing long-term credit, especially for sustainability-oriented investments. Although the Common Agricultural Policy (CAP) and various regional schemes offer some support, these are often fragmented or overly complex. Findings underscore the importance of improving access to targeted, low-risk financing instruments—such as green loans and climate funds—that align with circular economy goals.

Building on these insights, the project developed a qualitative assessment framework to compare economic instruments based on their impact on sustainability criteria, including nutrient efficiency, import dependency, and circularity. This tool supports decision-makers in evaluating trade-offs and identifying governance units (e.g., fertilizers, soils, manure, waste streams) where interventions may be most effective. By encouraging context-sensitive mixes of economic and regulatory instruments, the tool fosters the design of adaptable policy portfolios. When applying the tool in practice, the need to involve stakeholders and experts from the beginning of the process has to be particularly stressed, to take into account their views and interests, and to implement a fair scoring or consensus-based assessment, in line with governance principles.

The task concluded with the identification of an economic instrument suitable for testing on WP5 demonstration sites. The selected instrument reflects regional needs, ecological thresholds, and financial feasibility, supporting the project's overarching aim of fostering a climate-resilient, biodiversity-friendly, and economically viable agri-food system through innovative nutrient governance.

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List of abbreviations and acronyms

CA - Consortium Agreement

CAP - Common Agricultural Policy

CBI - Climate Bond Initiative

CE – Circular Economy

CFA- Conservation Finance Alliance

CNTPs - Circular Nutrient Technologies and Practices

CWS - Clean Water Services

D - Deliverable

DNSH - Doing No Significant Harm

DoA - Description of Action

EC - European Commission

EIP – European Innovation Partnership

EQIP - Environmental Quality Incentives Program

FaST - Farm Sustainability Tool for Nutrients

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.

IPR - Intellectual Property Right

ITE - Innovation and Digitalization Support Group

JU - Joint Undertaking

LSRCA - Lake Simcoe Region Conservation Authority

MSS - Meeting the Minimum Social Safeguards

N - nitrogen NDCs - Nationally Determined Contributions

NEPIs - New Environmental Policy Instruments'

NRCS - Natural Resources Conservation Service

NRR - Nutrient Recovery and Reuse

OECD - Organisation for Economic Co-operation and Development

P - Phosphorus

PC - Project Coordinator

PINE - Policy Instruments for the Environment'

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

SC - Steering Committee

SME - Small and Medium Enterprise

WP - Work package

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1. Introduction

The governance of environmental issues has evolved markedly over recent decades, with a growing emphasis on flexible, multi-instrument approaches that integrate economic incentives, regulatory measures, and information-based tools. Nowhere is this shift more apparent than in agricultural nutrient management, where nitrogen (N) and phosphorus (P) surpluses continue to pose significant threats to ecosystems, climate, and public health. Recognizing the limitations of traditional command-and-control regulation, policymakers increasingly turn to economic instruments such as fertilizer taxes, subsidies, tradable permits, and nutrient offset schemes to internalize environmental costs and drive innovation.

Within this landscape, the European Union (EU) plays a leading role, advancing sustainability objectives through its Common Agricultural Policy (CAP), environmental directives, and circular economy strategies. However, persistent challenges—including fragmented governance, regulatory complexity, and financing gaps—have hindered the large-scale adoption of circular nutrient solutions. The NENUPHAR project responds to this gap by assessing the design, implementation, and impact of economic instruments across diverse EU contexts. It offers a comprehensive framework for evaluating trade-offs, aligning financial tools with ecological indicators, and fostering policy mixes tailored to regional needs. In doing so, it contributes to the broader goal of transitioning toward sustainable, climate-resilient, and biodiversity-friendly agricultural systems.

Policy instruments are devices used to help turn a broad policy aim into a specific action. Instruments comprise a wide range of measures (legislation, expenditure, economic incentives, penalties, education, various forms of service delivery); more generally, incentives and obligations. Tools, at the same time, are key categories, highlighting the relative political costs of action (e.g., persuading, sharing information rather than regulation or redistribution). The choice of a tool is basically the 'policy choice', and the patterns of policy choices characterize 'policy styles' (Cairney, 2020). Within the scope of this task, economic instruments suitable for regulating the nitrogen and phosphorus cycles related to agricultural production will be examined, and an instrument that can be tested on demonstration sites within the framework of WP 5 of the Nenuphar project will be proposed.

1.a. Types of policy instruments

The most common typology distinguishes four basic types of policy instruments (also known as "sticks, carrots, and sermons") (Trein, 2023):

- Rules and regulations (authority/sticks): use of laws and rules to permit or prohibit certain behaviors, enforced typically by public bureaucracies but sometimes also by private actors.
- Finances (treasure/carrots): allocation of funds, subsidies, or financial incentives to influence behaviors, such as social assistance programs or infrastructure investments.

- Information (nodality/sermons): information campaigns to educate or persuade the public, aiming to change behavior through communication rather than coercion or incentives.
- Organization: the government's capacity to act directly through its own agencies, including the coordination of different public sector organizations, especially in crisis management.

Further distinctions can be made based on coercion, directness, automaticity, and visibility (van Nispen, 2011):

- Coercion: the extent to which a policy tool restricts behavior as opposed to merely encouraging or discouraging.
- Directness: the extent to which a public agency is involved in all stages of the policy process.
- Automaticity: the extent to which a policy tool is utilizing the existing administrative structure.
- Visibility: the extent to which resources attributed to a policy tool show up in the budget end program review.

The characteristics of policy instruments were defined and explained by Levine et al. (1990) as follows:

- Certainty of the administrative process and the compliance of targets.
- Timeliness: extent to which the tool works quickly.
- Less cost: expense of the tool.
- Efficiency: extent to which the tool creates maximum outputs for a given input.
- Effectiveness: extent to which the tool is likely to achieve its goals.
- Flexibility: ease with which the tool can be altered to changing needs and circumstances.
- Visibility: the extent to which the program is well known or less well known (sometimes invisibility is an important goal).
- Accountability: extent to which implementers are accountable for their actions.
- Choice: degree of citizen choice afforded by the policy.

Mostly based on experiences from Asia, Bengtsson et al. (2010) provide an in-depth overview of the four main types of policy instruments used for sustainable materials management (Table 1).

Table 1. Overview of policy instrument types in environmental policies

Policy Instrument Type	Definition	Types	Strengths	Limitations
Command and control	Regulatory tools that mandate or prohibit specific behaviors, set standards, or restrict technologies/substances.	▪ Environmental quality standards ▪ Technical/emission standards ▪ Restrictions and bans	▪ Clear policy goals ▪ Proven effective for visible damages and point-source pollution ▪ Low setup cost	▪ Uniformity ignores firm-specific costs ▪ Static, little incentive for improvement ▪ Costly to monitor many entities
Economic instruments	Market-based incentives that internalize environmental/social costs into prices.	▪ Taxes/charges ▪ Subsidies ▪ Tradable permits ▪ Deposit-refund schemes	▪ Cost-effective ▪ Incentivizes ongoing innovation ▪ Flexible for different actors	▪ Requires strong institutions and enforcement ▪ Effects less predictable ▪ Complex to set correct price levels
Informational instruments	Policies that provide or require disclosure of information to enable informed choices.	▪ Government-provided information ▪ Mandatory information disclosure (e.g., labels, emissions data)	▪ Low implementation costs ▪ Empowers stakeholders	▪ Effectiveness depends on user awareness ▪ Limited if economic incentives are lacking ▪ Best as supplement
Voluntary agreements	Schemes where firms voluntarily commit to environmental improvements, sometimes negotiated with authorities.	▪ Unilateral commitments ▪ Private agreements ▪ Negotiated agreements (may be binding) ▪ Public programs	▪ Flexible ▪ Less burdensome for business ▪ Can motivate high performers	▪ Limited evidence of effectiveness ▪ May favor large firms ▪ Often only effective with threat of regulation

Source: own editing based on Bengtsson et al. (2010)

1.b Instruments for environmental policies

The evolution of environmental policy instruments over the past two decades was reviewed by Pacheco-Vega (2020). In the late 1990s and early 2000s, there was a notable shift away from traditional command-and-control regulation toward 'New Environmental Policy Instruments' (NEPIs) – primarily economic and information-based instruments. An early OECD (Organisation for Economic Co-operation and

Development) Working Paper (OECD/Barde, 1994) on economic instruments in environmental policy even traces the beginning of this transition back to the 1970s. This shift was partly driven by the perception that regulation stifled innovation and was resource-intensive. Rather than a wholesale abandonment of regulation, the past two decades have seen the rise of "policy mixes", combinations of regulatory, economic, and informational instruments.

Bouma et al. (2018) distinguish between two main concepts: policy objective mixes and policy instrument mixes. Policy objective mixes are the combinations of instruments aimed at achieving multiple policy objectives, while policy instrument mixes represent the combinations of instruments targeted at a single policy goal. The distinction is important for understanding the motivation, design, and evaluation of policy interventions. Designing and evaluating policy mixes requires clear structuring and a variety of assessment tools. Attention must be given to both the coherence of objectives (from policy sciences) and external societal impacts (from economic analysis). Advances in empirical and experimental methods are essential for improving policy mix design and evaluation in environmental policy.

Pacheco-Vega (2020) argues that policy mixes are better suited to address the complexity and uncertainty inherent in environmental governance, especially in areas like drinking water and solid waste management. This is reinforced by Buchholz and Rübbelke (2019): hybrid and flexible policy combinations tend to work best, especially when addressing multiple environmental and economic challenges. According to Wilts and O'Brien (2019), effective mixes should operate across multiple sectors, actors, and governance levels, address all life-cycle stages of resource use (production, consumption, end-of-life), and balance sectoral and cross-sectoral approaches to avoid problem-shifting and incoherence.

Through the example of climate policies, van den Bergh et al. (2021) analyze how different climate policy instruments interact when combined into a policy mix, focusing on their synergistic effects. The authors identify the following synergy types:

- Positive synergy: instruments reinforce each other, resulting in emissions reduction greater than separate implementation.
- Zero synergy: instruments are complementary but do not interact to enhance or diminish each other.
- Negative synergy: one instrument weakens the other's effectiveness; in extreme cases, the mix is less effective than the most effective stand-alone instrument (backfire).

Environmental economics has influenced sustainable development policies, but growing scepticism questions their effectiveness and political viability. Critics argue the policies ignore key trade-offs between the environment and the economy and that market-based tools like taxes and permits are unpopular. This scepticism is rooted in three myths: that pricing environmental harms damages the economy, that pricing environmental benefits harms nature, and that efficiency outweighs equity concerns. The fallacies around environmental pricing stem from misconceptions about its economic, environmental, and welfare impacts. Evidence shows carbon pricing has minimal negative effects on GDP or jobs, and undervaluing nature while subsidizing harmful activities distorts markets. Critics often overlook these issues or focus on the moral challenges of pricing nature. A key barrier to political acceptance is the unequal distribution of policy impacts, which can matter more than efficiency. Advancing environmental economics requires confronting these three fallacies to create more effective and politically viable sustainability policies. (Barbier & Burgess, 2025)

Cole and Grossman (1999) challenge the prevailing view among economists and legal scholars that economic instruments (such as effluent taxes and emissions trading) are always more efficient than traditional command-and-control (CAC) regulatory regimes for environmental protection. Instead, the authors argue that command-and-control regulation is not inherently inefficient. In certain contexts, CAC can be as efficient or even more efficient than economic instruments, depending on historical, technological, and institutional factors. A regulatory regime is nominally efficient if its social benefits exceed its social costs. A regime might be nominally efficient but less efficient than some other alternative: the same regulatory approach can be relatively efficient in one context but relatively inefficient in another. Policymakers should base regulatory regime selection on detailed, context-sensitive analysis rather than ideological or theoretical presumptions.

The free market alone cannot deliver adequate environmental protection because firms and consumers lack sufficient incentives to internalize environmental externalities, such as pollution or biodiversity loss. Conversely, direct government provision is often hampered by information deficits, bureaucratic inefficiencies, and principal–agent problems (where government agents may not act in the public's best interest). Neither leaving environmental protection solely to the free market nor fully nationalizing its delivery will yield optimal outcomes. Instead, effective environmental policy generally requires interventions that lie between these two extremes, tailored to the specific context and challenges of each environmental issue, using market-based tools complemented by targeted regulation and support (Hepburn, 2010).

European environment and climate policy has evolved over more than 40 years, expanding from targeted, single-issue interventions to more integrated and systemic approaches (EEA, 2016). This is in line with the concept of regulatory pluralism, advocating for a shift from fragmented, single-instrument approaches to coherent, strategic mixes (Gunningham & Sinclair, 1999). Bouwma et al. (2015) reviewed the evolution and current state of policy instruments and governance modes in the environmental policies of the European Union EU, with a focus on nature and biodiversity policy. It analyzes both academic literature and five major EU regulatory frameworks: the Habitats Directive, Renewable Energy Directive, Timber Regulation, Water Framework Directive, and the Common Agricultural Policy. In addition to the types of instruments identified earlier, they introduce knowledge and innovation instruments (research programs, learning networks).

Earlier EU environmental policies (e.g., Habitats Directive) relied heavily on strict, top-down, command-and-control regulation. Recent frameworks (e.g., Timber Regulation, Water Framework Directive) emphasize "due diligence"—requiring actors to follow certain procedures and risk assessments rather than comply with rigid prohibitions. This allows for more flexibility and adaptation by Member States and businesses. There is a clear trend away from purely regulatory approaches toward greater use of networking, information, and knowledge-based instruments. Newer regulations, such as the Timber Regulation and Renewable Energy Regulation, demonstrate increased trust in businesses and other non-state actors to achieve policy objectives, often through voluntary agreements, certification schemes, and self-regulation. Financial incentives are used to encourage compliance, and monitoring is often prioritized over direct control. Most EU frameworks now use a mix of instruments and governance modes. For example, the Common Agricultural Policy combines regulatory, financial, and knowledge instruments. Despite these trends, regulatory instruments remain important, especially for setting minimum standards and ensuring a level playing field across Member States (Bouwma et al., 2015).

The European Environmental Agency uses a structured framework to evaluate policies, focusing on inputs (resources dedicated to policy implementation), outputs (tangible results, e.g., infrastructure built), results (short-term effects on direct addressees), impacts (long-term effects on the environment and health), and external factors (other influences that may affect outcomes). Key evaluation criteria include relevance, effectiveness, efficiency, coherence (internal and external), and EU added value (EEA, 2016).

The EU aims to transition to a circular economy, requiring major regulatory changes. While various policy instruments exist across waste, product, and chemicals sectors, they are often fragmented, weak, and unevenly applied. To drive the systemic change needed, key policy failures must be addressed (Kautto & Lazarevic, 2020).

2. Economic instruments for environmental management

Economic instruments in environmental policies are 'those policy instruments which may influence environmental outcomes by changing the cost and benefits of alternative actions open to economic agents. They aim to do so by making the environmentally preferred action financially more attractive.' (OECD, 1997). The concept of taxing pollution to internalize environmental externalities dates back to Pigou (1920), but practical adoption was minimal until the 1970s. The Brundtland Report (1987) and subsequent OECD and EU initiatives advocated increased use of economic instruments for sustainable development, but actual implementation lagged behind policy rhetoric. Economic instruments hold significant promise for cost-effective and dynamic environmental policy, but their real-world application has been constrained by political, fiscal, and institutional factors. To realize their potential, policymakers must address design flaws, balance interests more equitably, and ensure that environmental effectiveness, not just revenue generation, guides their use (Andersen, 1995). The advantages of economic instruments are synthesized in Table 2.

Table 2. Some advantages of economic instruments in environmental policies

Advantage	Description
Automatic adjustment	Emission levels adjust automatically to taxes or prices, as polluters reduce emissions until marginal abatement cost equals the tax/charge rate.
Cost effectiveness (static efficiency)	Achieves objectives at minimum overall cost by equalizing marginal abatement costs; leads to substantial cost savings.
Incentive for continuous improvement	Provides a permanent incentive for environmentally friendly behavior and ongoing reduction of emissions; encourages technical change and innovation.
Flexibility	Offers flexibility to both authorities (easy to adjust rates) and stakeholders (freedom to choose compliance methods).
Revenue generation	Generates revenue through charges, taxes, or auctioned permits, which can be used for environmental or other public purposes.
Non-prescriptive approach	Does not mandate specific technologies or solutions; allows target groups to choose how to comply, fostering innovation and efficiency.
Effective for diffuse pollution	Well-suited to address non-point sources of pollution where direct regulation is impractical, but proxies can be taxed or charged.
Internalization of environmental costs	Incorporates environmental costs directly into the prices of goods, services, and activities, promoting sustainable consumption and production.
Behavioral change and innovation	Provides incentives for consumers and producers to change behaviour and stimulates the development of new, cleaner technologies.
Optimal resource allocation	Allocates natural resources to those who value them most, enhancing economic efficiency and environmental outcomes.

Source: own editing based on OECD/Barde (1994), Andersen (1995), UNEP (2004), Danish Environmental Protection Agency (2000).

OECD's 'Policy Instruments for the Environment' (PINE) database is a comprehensive, structured resource that compiles quantitative and qualitative information on economic and other policy instruments used globally to address environmental challenges. As of 2024, the database covers 4,590 instruments across 146 countries and 22 environmental domains, providing a unique tool for monitoring, analysis, and policy development.

The types of policy instruments tracked by the database are the following:

- Taxes and fees: these increase the cost of polluting products or activities to discourage their use and are widely adopted, making up over a third of instruments in the PINE database, with more than 1,980 taxes and 790 fees across 141 countries.
- Tradable permits and offsets: these allocate rights to emit or exploit resources and are used globally to address issues like climate change and resource scarcity. The PINE database lists over 170 systems in 52 countries, tracking details such as revenue, permit type, allocation method, and scope.
- Deposit-refund schemes: these add a surcharge to potentially polluting products, refunded when the product is returned, encouraging recycling and reuse. The PINE database includes 68 schemes in 29 countries, covering a range of products beyond bottles.
- Environmentally beneficial subsidies and payments: subsidies that reduce harmful environmental impacts, such as tax breaks for green investments or payments for conservation, are tracked in the PINE database, which lists over 1,340 such measures in 78 countries.
- Voluntary approaches: these are commitments by firms or industries to exceed environmental requirements, often negotiated with authorities or between private parties. The PINE database records 160 voluntary approaches in 25 countries, though many are not yet reported.

2.a Nutrient management policies and incentives

The flow of nitrogen (N) and phosphorus (P) through agriculture and the food system has grown exponentially, driven by population growth, higher living standards, and increased consumption of livestock products (Buckwell & Nadeu, 2016). Global annual social cost of N pollution is estimated at $200–$2000 billion; P losses to avoid freshwater pollution cost $250–$450 billion annually. N pollution contributes to climate change (via N_2O emissions), biodiversity loss, and air/water pollution. P pollution causes eutrophication, harmful algal blooms, and dead zones in coastal waters (Kanter & Brownlie, 2019). Between 1961 and 1988, annual surpluses of N, P, and K (potassium) increased rapidly. After 1988, these surpluses declined (N stabilized, while P and K continued to decrease) mainly due to reduced fertilizer use following the Soviet Union's breakup and political shifts in Eastern Europe. Increased environmental awareness and EU policy changes in the late 1980s further reduced N, P, and K surpluses in Europe by about 40%, 80%, and 60% per hectare, respectively, over three decades (by 2020). While these reductions influenced global trends, rising fertilizer use in countries like China, India, Pakistan, and Brazil has recently offset some of these declines (Ludemann et al., 2024). Many OECD countries have high nitrogen surpluses (25–50 kg N/ha in about half; >100 kg N/ha in a smaller group), with localized "hotspots" often masked by national averages (Andersen & Bonnis, 2021). The SDGs and Paris Agreement set ambitious goals for global sustainability and climate action, requiring integrated solutions that address multiple environmental challenges (Kanter & Brownlie, 2019).

Kanter and Brownlie (2019) examine the importance of coordinated approaches to managing nitrogen (N) and phosphorus (P) to support international environmental targets. The authors analyzed the Nationally Determined Contributions (NDCs) of 15 major countries, representing 75% of global emissions and nutrient use. Many NDCs mention fertilizer and manure management, but few explicitly adopt a joint N and P approach. A joint approach is relevant to at least 7 of the 17 SDGs, including those related to water quality, sustainable cities, and climate action. Joint N and P management is critical for achieving sustainable development and climate goals. Near-term policy opportunities include integrating nutrient targets into national climate plans, SDG implementation, and existing nutrient management frameworks. Future research should develop regionally differentiated frameworks and engage key stakeholders to ensure effective implementation.

OECD working paper (Andersen & Bonnis, 2021) explores how improved management of N in agriculture can deliver significant climate mitigation co-benefits, primarily by reducing greenhouse gas (GHG) emissions associated with both the production and use of mineral fertilizers. Most OECD countries rely on a mix of voluntary measures, regulatory limits (e.g., the EU Nitrates Directive), and mandatory codes of good agricultural practice. Taxes on mineral fertilizers have been effective in some countries (e.g., Sweden, Finland, Austria), reducing use by 6–11% at modest cost (EUR 0.09–0.6 per kg N abated). The paper proposes a farm-level nitrogen surplus tax (EUR 1–2 per kg N surplus) as a promising instrument, reflecting the external environmental costs of excess nitrogen and incentivizing more efficient use.

According to a report by the RISE Foundation (Buckwell & Nadeu, 2016), Nutrient Recovery and Reuse (NRR) involves capturing nutrients from waste streams (animal manure, sewage sludge, food chain waste) and reprocessing them for use in agriculture, thus reducing environmental leakage and reliance on imported or non-renewable resources. NRR supports the transition to a circular economy, diversifies nutrient supply, and adds resilience against supply disruptions, particularly for phosphorus and natural gas (used in nitrogen fertilizer production). The report outlines sixteen specific recommendations for advancing NRR in Europe, grouped into key action areas: 1. Improve data and monitoring; 2. Regulatory coherence between EU and national regulations; 3. Policy support, including public funding for R&D, pilot projects, and commercial scaling, and ensuring NRR is eligible for EU rural development and investment funds; 4. Circular economy initiatives (establishing standards, certification, and traceability for recovered nutrient products, promote best available technologies and knowledge exchange platforms); 5. Consumer and stakeholder engagement (awareness campaigns, funding research on contaminants and safety, educating food processors and retailers to create market demand for products grown with recovered nutrients); 6. Rethinking livestock production (reviewing the optimal scale and distribution of livestock production in the EU, considering health, environmental, and cultural factors).

The systematic review conducted by Teleshkan et al. (2024) evaluates how policy measures influence nutrient circularity, focusing on the adoption and effectiveness of circular nutrient technologies and practices (CNTPs) in agriculture and waste management. Enabling policies that facilitate the adoption of CNTPs and promoted nutrient circularity, include: incentive policies (e.g., tax deductions, feed-in tariffs, renewable energy credits), market support and harmonized legislation, and technological advancements and economic incentives, especially for anaerobic digestion and manure treatment. Some policies had limited or negative impacts. Mandatory manure spreading limits (e.g., EU Nitrates Directive) sometimes led to increased nutrient concentrations or unintended emissions due to lack of knowledge dissemination or insufficient farmer engagement. Levies on commercial fertilizers and removal of quotas could result in higher nutrient surpluses or economic inefficiencies. Support for certain waste recycling practices increased methane emissions in some cases. In sum, incentive-based policies are generally more effective than punitive measures (like taxes or levies) in promoting nutrient circularity, as they provide positive reinforcement and adaptability.

As pointed out by Scholz (2017), most of the phosphorus used in agriculture is mined and not recycled – over 80% is lost to landfills or the environment rather than reused. Phosphorus runoff contributes to environmental problems like algal blooms and marine dead zones, with significant ecological and economic impacts. A circular phosphorus economy aims to keep phosphorus in use and out of waste streams, reducing environmental harm and reliance on finite phosphate rock reserves. Achieving this requires improvements across the value chain, from more efficient mining and fertilizer application to better waste management and recycling technologies. The low cost of virgin phosphate rock undermines the economic case for recycling, despite environmental benefits. Regulatory drivers include waste management rules, the US Clean Water Act, and upcoming German sludge ordinances requiring phosphorus recovery. Market drivers include corporate sustainability initiatives and voluntary farmer programs (e.g., 4R nutrient stewardship). The author's suggestions include strategic phosphorus reserves (similar to oil reserves), market interventions (taxes or price controls), and water quality trading schemes (cap-and-trade for nutrient pollution).

The paper of Hoppe et al. (2016) critically analyses the transition toward sustainable nitrogen (N) and phosphorus (P) management in the food systems of the Netherlands and Finland between 1970 and 2015. Both countries have struggled to achieve fully sustainable N and P management in agriculture, largely due to systemic failures in direction, coordination, and institutional inertia. The Netherlands implemented stringent manure and nutrient regulations, such as the Manure Act, MINAS registration system, and compliance with EU directives. These measures reduced point-source pollution but struggled with diffuse agricultural sources. Finland relied more on voluntary economic incentives (e.g., agri-environmental subsidy schemes), fertilizer taxes (until EU accession), and less on strict regulation. Point-source pollution from industry and municipalities was effectively reduced, but agricultural nutrient management remains challenging. Both countries have made significant progress in reducing point-source nutrient pollution from industry and municipalities, largely due to technological innovation and regulation. One of the lessons learned is that strict regulation combined with flexible economic instruments (taxes, subsidies) can drive improvements, especially in agriculture.

The article of Barquet et al. (2020) examines the challenges and opportunities involved in transitioning towards a circular phosphorus economy in the Baltic Sea region, a critical area due to severe eutrophication and heavy reliance on imported phosphate rock. The current P cycle is largely linear: mined, used in fertilizers, and lost to runoff, leading to resource inefficiency and environmental harm. One of the barriers to a circular phosphorus economy is that current policies focus on pollution reduction rather than nutrient recovery and reuse. Waste-derived fertilizers face complex, fragmented regulations, making market entry difficult. The lack of harmonized standards and recognition for recycled fertilizers limits their competitiveness. Emerging circular business models and value chains, involving collaboration between wastewater treatment plants, fertilizer producers, and farmers, can facilitate nutrient recycling. Government interventions, such as subsidies or taxes reflecting environmental externalities, could support market development.

Scholz & Geissler (2018) propose a conceptual framework centred on the so-called ‘feebates’: a system combining fees (taxes) and rebates (subsidies) based on a sustainable reference point, to better align individual farmer incentives with societal and environmental goals. Feebates are economic instruments that combine penalty fees for overuse and rebates for underuse, relative to a reference point considered sustainable for both farm productivity and environmental protection. This approach can regulate both over- and under-fertilization, adapting to different regional needs: encouraging more use where soils are depleted, and discouraging excess where over-fertilization is a problem. The reference point for feebates should ideally be based on field-specific data, such as results from soil testing and nutrient balances to tailor incentives accurately. Feebates are highlighted as particularly flexible and able to address both over- and under-fertilization, but their effectiveness depends on robust data and proper operationalization.

Different financing strategies are associated with different stages of the product life cycle, as the company's financial needs and risks change over time. Capital requirements are highest during the introduction phase, as this is when the product is developed, launched and marketed, so it is common to involve venture capital or to apply for state or EU innovation grants. In the growth phase, revenues increase, but market expansion may require further investment, so bank loans or the involvement of strategic investors may be typical here. In the maturity phase, the product generates stable revenues, so financing is more focused on optimizing operations and preparing for new developments, often from internal sources. In the saturation and decline phases, reliance on internal resources (e.g., retained earnings) is more common, as external investors and lenders see risks in declining growth or market position (Damodaran, 2010).

2.b Subsidies as economic instruments

Subsidies are government payments to encourage certain activities that aim to incentivize behaviour change by providing financial benefits to firms, while reducing government revenue. Ideally, the value of subsidies should not exceed the benefits from the incentivized activity (Wall et al., 1997). These measures offer flexibility to polluters but do not make them internalize the environmental costs of their actions, meaning they often do not align with the "polluter pays" principle. Subsidies can unintentionally reward poor past environmental performers and may be inefficient if given to those who would act without incentives. Subsidies as net government expenses can distort the broader tax system. Despite drawbacks, subsidies may be justified when firms cannot capture enough benefit from an activity on their own, and desired behavior would not occur without external incentives. They are particularly useful when effective "polluter pays" mechanisms are unworkable.

Subsidies cover all forms of explicit financial assistance to polluters or users of natural resources, e.g. grants, soft loans, tax breaks, accelerated depreciation, etc. for environmental protection (Barde, 1999).

Earmarked revenues refer to funds collected from specific charges or taxes that are then allocated for particular environmental purposes. While the economic rationale for earmarking is debated, such schemes can increase public acceptance of environmental taxes and provide targeted funding for environmental initiatives, especially in contexts where public resources are limited. However, earmarking is considered a "second-best" solution in market economies because it restricts the flexibility of financial policy and may result in resources being allocated to outdated priorities or adjusting public services to revenue changes rather than actual needs (Danish Environmental Protection Agency, 2000).

Design and implementation of environmental subsidies require caution to avoid negative economic, social, and ecological consequences and to prevent long-term policy "lock-in" – as Segerson et al. (2024) warn. Subsidies are widely used to incentivize environmentally beneficial activities. They are often politically easier to implement than taxes or regulations because they provide direct benefits ("carrots") rather than imposing costs ("sticks"). Subsidies can be justified when they correct market failures by encouraging activities with positive externalities (benefits to society not captured by the market), such as research and development or ecosystem services. They can also help shift market shares toward cleaner products. However, subsidies can inadvertently increase overall market size, leading to greater resource use and environmental impacts, even if the share of "clean" products rises. Many subsidies lack "additionality," meaning they fund activities that would have occurred anyway, resulting in wasted public resources. Subsidies can also support harmful activities, like fossil fuel extraction, industrial agriculture, or overfishing, which undermine climate and biodiversity goals. Despite international commitments, harmful subsidies remain widespread and difficult to eliminate. Once established, subsidies create vested interests that resist their removal, making harmful subsidies persistent ("zombies of the tax code"). The concentrated benefits to specific groups make reform politically challenging, while the costs are spread across society.

2.c. Examples for subsidies addressing nutrient pollution

The EU's Common Agricultural Policy (CAP) is the main tool to support sustainable nutrient use in farming. CAP funds pay farmers for environmental practices that conserve nutrients. Under the 2023–2027 CAP, "eco-schemes" (voluntary Pillar-1 payments) reward practices like crop diversification with legumes, cover crops, reduced fertilizer use and precision farming. Pillar-2 Rural Development grants fund manure storage, precision equipment and organic farming to cut runoff. Cross-compliance links CAP payments to Nitrates Directive compliance (Nutrient Vulnerable Zones), effectively making farmers internalize the cost of excess nutrients. In total, CAP now earmarks a large share of its budget for environment/climate, including at least 35% of rural funds for green measures. Research and advisory support (e.g. the Farm Sustainability Tool for Nutrients, FaST) also help farmers optimize fertilizer use (EC, 2022; EC, n.d.).

Beyond CAP, the EU funds nutrient-recovery projects through Horizon and LIFE programmes. The European Investment Bank also provides support for Circular Economy financing through its InvestEU Advisory Hub. Many Member States offer national grants or tax breaks for circular nutrient projects. For instance, several wastewater utilities have received subsidies to install P-recovery (struvite) units so the recovered P can be used as fertilizer. Biogas/AD plants are subsidized (via feed-in tariffs or grants) in part for producing digestate (a recycled fertilizer). The EU's Circular Economy Action Plan similarly calls for supporting markets in recycled nutrients (e.g. through investment incentives for processing organic waste).

Szálteleki at al., (2024) investigate the effectiveness of European Union (EU) subsidies allocated to farms in Hungary's Southern Great Plain region between 2014 and 2021. The research examines whether these subsidies enhanced farm resilience by improving financial performance indicators such as profitability, liquidity, solvency, and employment capacity. The analysis, which encompassed all agricultural enterprises in the region, reveals that subsidies had a statistically significant positive effect only in the micro-enterprise category, particularly in terms of financial stability and efficiency. However, employment outcomes were worse among subsidized farms compared to their non-subsidized counterparts. These findings suggest that the subsidies may have supported the persistence of economically weak farms rather than fostering genuine competitiveness or job creation, thereby limiting the achievement of broader policy objectives.

Thorsøe et al. (2022) evaluate how the nine countries bordering the Baltic Sea have implemented agreed-upon measures under the Helsinki Convention to limit nutrient pollution from agriculture. Most countries rely heavily on "command-and-control" regulations, with limited use of economic incentives ("carrots") or informational tools ("sermons"). Countries like Denmark, Sweden, and Finland show better use of EU rural development funds for nutrient management, whereas Poland, Germany, and the Baltic states often prioritize agricultural competitiveness over nutrient reduction.

The UK has implemented significant funding through the Sustainable Farming Incentive (SFI), with the government committing £5 billion over 2 years to sustainable farming and nature recovery. The SFI now has more than 37,000 multi-year live agreements delivering sustainable food production and nature's recovery (GOV.UK, 2025). Additionally, the UK government offers £15 million through the Nutrient Management competition, part of the Farming Innovation Programme, providing funding to develop solutions addressing challenges related to nutrient management in soils and water (GOV.UK, 2024).

In the United States, the Environmental Quality Incentives Program (EQIP), administered by the USDA Natural Resources Conservation Service (NRCS), represents one of the largest conservation programs in the US. The NRCS has obligated over $10 billion through EQIP cost-share contracts between fiscal years 2005-2015, with over 260,000 participants implementing conservation practices covering more than 81 million acres. EQIP payment significantly reduces temperature, dissolved oxygen deficit, biochemical oxygen demand, and nitrogen levels in water bodies (Liu et al., 2023).

Also in the US, the National Fish and Wildlife Foundation's Innovative Nutrient and Sediment Reduction program partners target funding towards accelerated implementation of proven water quality improvement practices, focusing on partnership grants and managing upland agricultural runoff through farm-scale conservation systems (NFWF, n.d.). At the state level, North Carolina offers precision nutrient management cost-share programs with annual incentive payments per acre for three-year implementation periods (NCAGR, n.d.).

Canada has established the On-Farm Climate Action Fund with $704.1 million to help farmers tackle climate change. The fund supports beneficial management practices (BMPs) that store carbon and reduce greenhouse gases, specifically in nitrogen management, cover cropping, and rotational grazing practices. For 2025-2028, the program provides an additional $300 million to 13 recipient organizations across Canada, with maximum eligible funding of $75,000 per operation for organic farmers (ECOCERT, n.d.).

The World Bank has committed to stepping up efforts to help client countries repurpose harmful subsidies for better climate outcomes. The bank has scaled up work to develop deep dives providing countries options for repurposing subsidies, awarding grants to six pilot initiatives to realign fertilizer support and soil health programs in Bangladesh, Ghana, Indonesia, Mozambique, Malawi, and Tanzania (World Bank, 2024). The World Bank proposes shifting subsidies from high-emission foods to more sustainable options, focusing on reallocating funds to support less carbon-intensive agricultural practices (EHN, 2024).

The Green Climate Fund has approved 77 projects between 2015 and 2018, with 31 percent including agriculture components representing 29 percent of GCF funding. Among these projects, 41 are linked to Koronivia Joint Work on Agriculture topics, with improved nutrient use and manure management being one of the focus areas, though it remains among the least represented topics in the portfolio (FAO, 2018).

2.d. Experiences with environmental subsidies

A comprehensive analysis of government subsidies and their growing impact on global trade is provided by World Bank (Signoret & Molinuevo, 2023). Subsidies have become the most frequent form of government intervention in trade since 2008, surpassing tariffs and other non-tariff measures. Major economies (China, the European Union (EU), and the United States) account for about 75% of documented subsidy programs. Most are implemented at the subnational level. Subsidy measures vary around the world: in the EU, grants are predominant; in the US, tax incentives; and in China, grants are most common. Objectives range from sectoral competitiveness and technology transfer to environmental goals, though fossil fuel subsidies still outnumber those for clean energy. The unchecked rise of subsidies, especially among major economies, poses a serious threat to the global trading system by distorting competition, undermining the benefits of trade, and disproportionately harming developing countries. Current international rules are inadequate to address these challenges. The report calls for a new framework to identify, monitor, and address trade-distorting subsidies that includes focusing reform efforts on the most distortive subsidies, particularly those affecting global value chains and developing countries.

Jack et al. (2008) investigated the design and implementation of Payments for Ecosystem Services (PES) policies, drawing on broader experience with incentive-based environmental policy instruments. PES schemes compensate individuals or communities for actions that enhance ecosystem services such as water purification, flood mitigation, or carbon sequestration. It is part of a broader suite of market-based environmental mechanisms, including taxes, subsidies, tradable permits, and efforts to reduce market frictions. PES policies offer a promising, direct, and potentially more equitable approach to conservation, but their success depends heavily on context. No single PES design fits all situations; trade-offs among environmental effectiveness, cost-effectiveness, and equity are common.

OECD's 2022 report examines how to design agri-environmental payment schemes – voluntary programs that pay farmers to achieve specific environmental outcomes – so they are more cost-effective. The report introduces a framework classifying payment schemes along a spectrum from uniform, practice-based payments (paying for specific actions) to results-based payments (paying for measured or modelled environmental outcomes), including hybrid models that combine both approaches. Drawing on a literature review, policy simulations, and a multi-country choice experiment with farmers, the report identifies seven key design dimensions for cost-effective schemes:

- Clear, preferably quantifiable, policy objectives.
- Targeted payment designs that reflect spatial variation in costs and benefits.
- Tailored payment rates covering opportunity and transaction costs without overcompensation.
- Adjusted eligibility criteria (individuals vs. groups, depending on environmental goals).
- Consideration of farmer behavioral responses (risk, preferences) to increase participation.
- Assurance of strong additionality (payments lead to real environmental gains).
- Effective monitoring and enforcement to ensure payments are tied to actual improvements.

Hybrid payment models offer a balanced approach, addressing both budget constraints and the need for sufficient farmer participation. They allow policymakers to introduce results-based elements gradually, reducing financial risk for farmers and increasing scheme attractiveness. The best payment design depends on the environmental objective, local conditions, and farmer characteristics. There is no universal "best" scheme; flexibility and adaptation are key (OECD, 2022).

This study of Bär et al. (2024) examines how agricultural subsidies in Germany – both from the EU and national sources – can be reformed to better align with environmental and climate goals. Among other adverse environmental effects of agriculture, Germany's intensive use of fertilizers and pesticides leads to nitrate pollution and biodiversity loss. Agricultural subsidies in Germany are a mix of EU and national payments, tax incentives, and regulatory benefits. The EU's Common Agricultural Policy (CAP) is the largest source, with most payments based on land area, regardless of environmental performance. Only a small share is tied to environmental criteria. National subsidies include reduced VAT for animal products, tax exemptions for agricultural vehicles and diesel, and various grants for both environmentally harmful and positive practices. The majority of financial flows are classified as environmentally negative (CAP 1st pillar direct payments, reduced VAT on animal products, diesel tax concessions, and biofuel quotas) or ambivalent (some rural development and fisheries funds). Positive subsidies (greening payments, organic farming grants, peatland restoration, and some other rural development funds) are much smaller in volume. The study proposes economic instruments (levies or taxes) to internalize these costs, such as a nitrogen surplus levy and a risk-based pesticide tax, which could both reduce harmful inputs and generate revenue for environmental investments.

Molocchi (2021) evaluates how well Italian subsidies align with the EU's circular economy principles, using the Italian Catalogue of Environmentally Harmful Subsidies (EHS) and Environmentally Friendly Subsidies (EFS) as its data set. Agriculture saw more subsidies classified as friendly under the circular economy lens. Energy and transport saw fewer friendly subsidies from a CE perspective compared to the environmental one. The paper demonstrates that while there is significant overlap between environmental protection and circular economy objectives, important differences and potential contradictions exist. Approximately a quarter of Italian subsidies reviewed would require reclassification or policy adjustment when viewed through a CE lens. The findings highlight the need for integrated policy design and ongoing assessment to ensure public funds support both environmental sustainability and the transition to a circular economy.

Shen (2024) systematically analyses the eco-compensation horizontal transfer payment system (ECITPS) in China, using grounded theory to construct a comprehensive theoretical model. ECITPS serves as a mechanism to internalize ecological externalities by transferring benefits from resource consumers to suppliers, promoting coordinated regional development, and sharing fiscal burdens. It influences employment, industrial structure (shifting labour from primary to tertiary sectors), income distribution, and social welfare. The system's success depends on effective fund utilization, legal foundations, and institutional coordination. Current challenges include limited geographic and ecological coverage, insufficient cross-regional coordination, lack of authoritative enforcement, and inadequate incentives. The paper suggests that establishing specialized third-party departments, enhancing pilot programs, and innovating incentive mechanisms are crucial for system optimization.

Chen et al. (2022) investigated whether and how environmental subsidies impact CER among Chinese A-share listed firms from 2010 to 2020. Environmental subsidies in China have a significant positive effect on corporate environmental responsibility, particularly for non-state-owned and high-pollution firms, and in certain regions. However, their impact on emissions disclosure and governance is limited, and there is a risk of crowding out private R&D. The study underscores the need for nuanced, well-supervised, and complementary policy approaches to maximize the benefits of environmental subsidies for sustainable corporate development.

Green transfer payments in China, as implemented through the ESER (energy saving and emission reduction) policy, have a significant and lasting impact on reducing urban carbon emissions. The effect operates primarily by increasing green spaces and improving energy efficiency and is strongest in cities with more financial resources and developed financial markets. The findings support the continued use and expansion of such fiscal policies, provided they are managed transparently and assessed with clear performance metrics (Shi & Wang, 2023).

The collective insights from Chinese authors highlight the growing importance and complexity of fiscal instruments, such as eco-compensation payments, environmental subsidies, and green transfer payments, in advancing China's ecological transition and sustainable development goals. These mechanisms serve not only to internalize environmental externalities but also to reconfigure regional development dynamics, spur corporate responsibility, and reduce urban emissions through targeted fiscal support. Yet, their success hinges on overcoming key implementation challenges through institutional strengthening, cross-sectoral collaboration, and continuous policy refinement. Sustained efforts in these areas will be essential to maximizing the ecological, economic, and social dividends of China's green transformation.

2.e Tradeable permits and offsets

Tradable permits are a useful tool for managing resources that have traditionally been open to unrestricted use, such as air, fisheries, and water. Moreover, cap-and-trade is a government regulatory program designed to limit, or "cap," the total level of certain emissions – primarily carbon dioxide – from industrial activity. The government sets a cap on total emissions and issues a limited number of permits (allowances), each allowing a company to emit a specific amount. Companies can trade these permits, creating a market price for emissions and incentivizing reductions (Kenton, 2024).

By implementing tradable permits and quotas, it is possible to promote environmental sustainability, as these systems incentivize resource owners to use them responsibly in order to preserve the value of their permits or quotas. Forms of trading permits can be nutrient trading, carbon markets, climate credit mechanisms, fisheries quotas (catch limits), water quality markets, and water markets (CFA, n.d.).

For example, nutrient trading is defined by the Conservation Finance Alliance (CFA, n.d.) as follows:

"Measurable conservation outcome resulting from a trading system (or market) where nutrient reduction credits are established and traded. These credits can have a monetary value that may be paid to the seller for utilising management practices that reduce nitrogen, phosphorous, or sediment. In general, water quality trading utilizes a market-based approach that allows one source of water pollution to maintain its regulatory obligations by using pollution reductions created by another source. Trades can take place between point sources (e.g. wastewater treatment plants), between point and nonpoint sources (e.g. a wastewater treatment plant and a farming operation) or between nonpoint sources (such as agriculture and urban stormwater sites or systems). Systems can be voluntary or compliance."

Nutrient offsets must be measurable, verifiable, and result in environmental benefits that would not have occurred otherwise. A permit applicant could either directly reduce nutrient loading at another source or pay for such reductions elsewhere in the same watershed, so the net impact of their activity is neutral or beneficial for water quality (Belinskij et al., 2018).

Tradable water pollution rights systems set caps on total pollutant emissions and allocate tradable permits to dischargers. While conceptually promising, trading pollution rights is complex due to the variety of pollutants and their localized impacts. Experience is limited but growing, with most examples from the US and Australia (Kraemer et al., 2004). Water quality trading is promoted as a cost-effective, market-based approach to achieve water quality goals, particularly for nutrient reduction. Its feasibility depends on sufficient market size (enough buyers and sellers), strong regulatory and economic drivers (e.g., permit limits, watershed caps), and clear program goals and pollution sources. Most successful programs involve trading between point sources (regulated facilities) and nonpoint sources (e.g., agriculture), leveraging cost differences in pollution reduction (Mascia & Gildesgame, 2021). Common trading structures are the following:

- Bilateral negotiations: direct trades between parties.
- Clearinghouses: centralized intermediaries manage trades and set prices.
- Exchanges: open, transparent markets for trading credits.
- Third-party brokers: independent entities facilitate trades.

When considering cap and trade, pros and cons need to be considered. On the positive side, the system is designed to motivate companies to lower their emissions by turning pollution reduction into a financial opportunity. Firms that manage to cut their emissions quickly can sell their unused allowances to others, effectively profiting from their environmental efforts. This market-driven approach can accelerate pollution cuts, as those who innovate fastest reap immediate rewards. Meanwhile, governments benefit as well, since auctioning off permits generates revenue that can be funnelled into public projects like infrastructure or social programs. For taxpayers, this means the financial burden of environmental policy is shared, and consumers gain the power to support cleaner companies through their purchasing choices. However, there are also complications. Sometimes, the caps set by authorities are too generous, allowing companies to pollute more than is ideal and delaying the shift to cleaner alternatives. In some cases, paying for permits or penalties is less costly for companies, especially those reliant on fossil fuels, than investing in new, cleaner technologies. The system is further weakened when permits are handed out for free, diminishing the incentive to reduce emissions. Ensuring compliance is another challenge; without robust monitoring and enforcement, companies may find ways to cheat. Additionally, the costs of compliance can trickle down to consumers, making goods and services more expensive. Finally, the effectiveness of cap and trade is limited by the lack of global standards: each country sets its own rules, so the impact varies widely, and the overall global effect may be diluted (Kenton, 2024).

The NutriTrade project (2014–2020, co-funded by INTERREG Baltic Sea) piloted nutrient trading and offsets among Finland, Sweden, and Estonia to reduce Baltic Sea eutrophication. NutriTrade built a voluntary offset platform (nutribute.org) where municipalities, companies or individuals can buy nutrient credits, while local farmers and fishers implement practices that cut loads. Initial pilots (2015–2018) implemented proven measures – e.g. gypsum field amendment (to bind P), removal of invasive fish, mussel farming – achieving on the order of 6 tonnes of P removed in total. The project developed robust verification and a cost-efficiency registry. While still largely experimental, NutriTrade showed how cross-border nutrient credits could be generated and sold. It is notable that the platform is modelled on carbon offset markets and allows "neutralizing" an entity's P footprint (Interact, 2023).

In Canada, Ontario's Lake Simcoe Protection Plan includes a Phosphorus Offsetting Program that effectively requires new large developments to achieve net-zero phosphorus loading. Under this program, developers purchasing offset credits from retrofit projects (e.g. stormwater pond upgrades, riparian plantings) can "neutralize" the P load of their development. The Lake Simcoe Phosphorus Offsetting Policy (launched in 2023) mandates zero-net-P for new development by buying credits, guided by the Lake Simcoe Region Conservation Authority (LSRCA). For example, LSRCA works with municipalities to retrofit stormwater systems as offset projects. This approach explicitly ties P management to an offset mechanism, although detailed credit accounting is managed by the LSRCA (LSRCA, n.d.).

Clean Water Services (CWS) in suburban Portland (Oregon, USA) runs one of the earliest large-scale trading programs. CWS's watershed-based permit (1990s onward) requires it to offset thermal and oxygen demand impacts via watershed projects. CWS releases reservoir water and funds stream restoration (riparian plantings) to generate "credits" that completely offset its wastewater plant temperature loads. Although the formal credits are thermal kilocalories, these same riparian restoration projects produce co-benefits in nutrient removal: CWS reports that 195 stream-planting projects (as of 2022) have cumulatively reduced ~10,300 lbs of nitrogen and 18,000 lbs of phosphorus from the Tualatin River watershed. In effect, CWS's program provides a watershed-scale offset for its point-source N/P discharges. The permit framework counts the planted shade as tradeable credits, giving CWS flexibility to meet stringent effluent limits at a lower cost than plant-based treatment (CWS, 2021, 2022).

In Waikato, New Zealand Lake Taupō is regulated under "Variation 5" of the Waikato Regional Plan (operative 2011), establishing an agricultural N-cap-and-trade scheme – the world's first for diffuse (non-point) N. Under this policy, farmland in the lake catchment is assigned individual nitrogen discharge allowances (NDAs) based on land use. Farmers may trade these NDAs between each other or sell them to a public fund (the Lake Taupō Protection Trust) which retires them to achieve a 20% N reduction target. In practice, industrial farmers who wish to intensify pay farmers who reduce N. Early evaluations report that by June 2014 the Trust had executed 23 trades (retiring ~151,000 kg N) and farmers had traded another ~17,600 kg N – about 17% of the total cap – indicating active participation. The Trust has used proceeds to permanently reduce N losses (mainly by retiring allowances). Although it is early to judge long-term water quality impacts, the scheme has successfully limited N increases and generated multi-million-dollar investment in low-N farming practices. (One analysis notes this as the first cap-and-trade limiting a lake's N load.) (Kerr et al., 2015).

In SE Queensland (Australia), Unitywater (a regional water utility) has innovated nutrient-offsetting projects to complement upgrades to its sewage treatment plants (STPs). A flagship is the Caboolture River Nutrient Offset Project (lower Caboolture River). Instead of immediately upgrading the Burpengary East STP, Unitywater stabilized eroding banks and revegetated 2.4 km of river, creating one of Australia's largest instream nutrients offset projects. These works reduce TN loads; the project is forecast to offset about 1.6 tonnes/year of total nitrogen being discharged from the plant. The Department of Environment approved counting these future load reductions as an "offset" against the STP's permit. Business-case analysis showed this method could defer more expensive treatment upgrades. Unitywater estimates the planting will effectively offset the N load of roughly 5,500 additional population equivalents on the STP. Unitywater has carried out other such projects (e.g. Upper Caboolture, Yandina Creek Wetland). These are not open markets per se but regulated nutrient offsets – they involve a permit-exempt pollutant (nutrient) being "neutralized" by an environmental improvement project (Unitywater, n.d.).

Nutrient Neutrality programs require that new developments must not increase nutrient loads entering local watercourses. These programs affect 74 Local Planning Authorities across England, with mandatory requirements for all residential developments to achieve 0% increase of nutrients entering watercourses. Commercial providers like Wild Capital offer high-integrity Nutrient Neutrality credits nationally, with schemes verified by Natural England and secured through legal agreements with local planning authorities. These credits discharge the 80-year management and monitoring liability to the provider, allowing developers to walk away from long-term obligations (Wild Capital, n.d.).

2.f Taxes, fees, duties and fertilizer tax

Taxes and fees are different instruments, although the two terms are often used to describe similar instruments, so the distinction between them is not always clear. Revenue from taxes flows into the general budget, while revenue from "fees" is allocated for specific purposes (ECOTEC, 2001). Levies are similar to taxes but differ in that they are generally paid in return for some direct service and are used to maintain the state apparatus, and in that they represent a one-off payment obligation (Public Service Online Lexicon, n. d.).

Perman (1999) classified the instruments used to reduce pollution. He distinguished three categories, which are as follows:

- Institutional approaches to facilitate internalisation of externalities
- Command and control instruments
- Economic incentive (market-based) instruments

Incentive-based instruments encourage individuals or businesses to voluntarily change their behaviour by altering the structure of benefits available to those affected. The table below shows the types of pollution reduction taxes and fees within the category of incentive-based instruments (Perman, 1999) (Table 3).

Table 3. Economic incentive (market-based) instruments – taxes and fees

Instrument	Description	Example
Emissions charges/taxes	Direct charges based on quantity and/or quality of a pollutant	Water effluent charges, Fertilizer and pesticide taxes
User charges/fees/natural resource taxes	Payment for cost of collective services (charges), or for use of a natural resource (fees or resource taxes)	User charges on municipal waste collection, treatment or disposal, Hazardous waste, wastewater user charges, Water extraction charges (thought to be effective in several Asian countries)
Product charges/taxes	Applied to polluting products	Vehicle tyres, disposables tax, plastic bags, nuclear waste, grants to ecological farming
Non-compliance fees	Payments made by polluters or resource users for non-compliance, usually proportional to damage or to profit gains	Sea dumping of oil from ships

Source: Perman (1999)

Kim et al. (1999) model nitrogen fertilizer taxes and evaluate constant-unit, variable-unit, and pollution-based tax schemes. It concludes that variable taxes offer the highest net economic benefits, especially when tailored to environmental targets.

In 2001, ECOTEC examined the use of environmental taxes and charges in EU countries and their environmental and economic impacts. Taxes in the countries examined were typically set at conservative, low levels. Although their environmental impact was positive, it was small compared to the problem being addressed. As the level of charges increased, environmental impacts also increased in most cases, although the positive impact on behaviour change was not always reflected in physical changes in the condition of the environment. However, even small changes in prices or costs send a moral signal about desirable behaviour, thereby contributing to increased environmental awareness.

According to Pearce (1990), in the case of fertilizers, pollution should ideally be taxed in proportion to the physical damage caused. However, nitrate emissions depend on a number of factors, making them almost impossible to measure and therefore tax. For this reason, the tax is levied on fertilizer use (Pearce, 1990 in Sjöberg, 2005). According to Matheson (2021), the use of agricultural inputs such as petroleum-based fertilizers and pesticides leads to diffuse (non-point source) emissions into air and water systems, which are inherently difficult to quantify and are influenced by site-specific factors such as topography and hydrology. To effectively internalize these externalities, the most appropriate fiscal instrument is a targeted upstream (address the inputs that lead to emissions) excise tax, calibrated based on average environmental emissions.

Based on Rougoor et al. (2001), the advantages and disadvantages of fertilizer taxes can be summarized as follows.

Advantages

- The main reason for using environmental taxes in environmental policy is the impact of negative externalities, because taxes or fees internalize external costs.
- Taxes can be an effective means of regulating fertilizer use and can contribute to reducing emissions when combined with regulation and education programs.
- One effect of taxes as economic instruments is that they can accelerate the innovation process and the spread of pollution-reducing technologies.
- They encourage producers and consumers to adopt more environmentally friendly behaviour and provide flexibility in choosing more environmentally friendly solutions.
- They can generate revenue for public authorities, which can be used for environmental protection spending.
- The system is easy to implement, and administrative costs are low.

Disadvantages

- The non-refundable tax affects the competitiveness of the agricultural sector and does not focus on actual local nitrogen problems.
- It is difficult to distinguish the impact of the fertilizer tax from other policy measures, agricultural product prices, other inputs (e.g., phosphate, potash and organic fertilizers) and technological developments such as the development of new varieties.

By taxing mineral fertilizers, this instrument aims to shift nitrogen inputs from polluting chemical fertilizers to less polluting substitutes, such as organic fertilizers, and to provide incentives to improve nitrogen efficiency (Gazzani, 2017).

2.g Country case studies on fiscal instruments

In this section, a search has been carried out for instruments aimed at reducing nutrient pollution and related experiences. Table 4 shows six countries used as examples: Sweden, Austria, Finland, Croatia, Denmark and the Netherlands.

In the case of Austria, Finland and Sweden had implemented fertilizer levies before their accession to the EU, one can learn from their experiences. In Croatia, in addition to manufacturers, importers, and distributors of mineral fertilizers, organizations that discharge wastewater must also pay a fee. The Netherlands and Denmark are the most intensive livestock farming countries in the EU and the amount of manure produced poses a serious environmental problem. The application of complex systems is presented using examples from Denmark and the Netherlands.

Table 4. Financial instruments (taxes, fees, levies) used to reduce of nutrients in selected countries

Country	Tools	Aim	When	Description	Effect	Source
Sweden	fertilizer tax	health and environmental objectives	1984-2009	Applied to N and P, and then to cadmium in P. N: from EUR 0.03 /kg of nitrogen (1984), to EUR 0.18 /kg of nitrogen (1994-2009). P: EUR 0.12 /kg of phosphorus (1993), Cd: EUR 3 /g (5 g Cd /tonne of phosphorus as a minimum threshold) The price regulation levy and fertilizer tax together were highest in 1991: EUR 0.24/kg N, EUR 0.50/kg P, accounting for 30-35% of the selling price.	- 50% reduction in phosphate fertilizers. - Cadmium tax: The average phosphorus content per ton decreased from 25 grams in 1995 to less than 10 grams in 2000. - A net reduction in nitrogen use could be of about 6%, which is about 10,000 tonnes of N a year.	Andersen (2018)
	price regulation levy on fertilizers	generating revenue for export subsidies	1982-1992			
Austria	fertilizer tax	generating revenue for export subsidies	1986-1994	EUR 0.25-0.47 / kg of nitrogen, but there were also levies on potassium and phosphorus. In 1986, the levy was 24% of the original fertilizer price.	- The use of nitrogen fertilizers fell by 17% in 1986 (Rougoor et al. 2001). - ECOTEC (2001) estimates that total fertilizer consumption fell by an average of around 3% per year, while prices rose by a total of around 10-12%. - Bäckman (1999) and Rougoor (2001) estimate that the demand for nitrogen fell by 2.5% due to price elasticity and by 5.5% due to psychological factors.	Rougoor et al. (2001), ECOTEC (2001), Bäckman (1999)
Finland	fertilizer tax	generating revenue for export subsidies	1976-1994	From EUR 0.005/kg to 0.44 EUR/kilogram of fertilizer (till 1992) or nitrogen.	Fertilizer prices rose by 62%, and nitrogen use decreased by 11%.	Rougoor et al (2001)
Croatia	water protection fee	for water protection and the construction of sewage disposal facilities	since 2011	Water protection fee: payable by organizations that discharge wastewater or produce, import, or trade mineral fertilizers. Fees for mineral fertilizers: HRK 1 per ton Calculation of water protection fee: based on the quantity and quality of the discharged water (EUR 0.13/m3 of wastewater discharged, EUR 0.00018/m3 of cooling water discharged (from 2013)). The basic fee is modified by the water pollution coefficient (k1) or the fee for units that treat		Regulation on amendments to the Regulation on the amount of water protection fees (2024), Water Manage

				their wastewater before discharge (k2).		ment Finance Act
Denmark	Fertilizer invoices and plans	aimed at reducing nitrogen leaching	since 1992	Farmers must draw up a fertilizer plan, calculate the nitrogen quota for their farm, and submit their fertilizer accounts. All suppliers must report the quantity and type of fertilizers sold to the supplier register.	By 2011, total nitrogen fertilizer use in Denmark had fallen by more than 30%, apparently without any significant loss of crop yields. Akenji and Lorek (2014) estimated a 45% decrease in nutrient balance from 1990 to 2011.	Retsinformation, (2020), Thorup-Kristiansen (2011), Akenji and Lorek (2014), Nemming and Hansen (2015)
	fertilizer tax	emission reduction	since 1998	DKK 5 (EUR 0.67) per kilogram of nitrogen since 1998. No tax is payable if the total nitrogen content of the fertilizer does not exceed 2% of the total weight of the fertilizer. The tax is payable on the nitrogen content of organic fertilizers in packages of up to 50 kg.		
	Animal feed mineral phosphorus tax	to reduce soil phosphorus saturation and leaching into surface waters	2005-2019	Tax on phosphorus in animal feed, rate of DKK 4 (EUR 0.53) per kilogram of phosphorus.	Since the introduction of the tax, the use of mineral phosphate in animal feed has fallen by around 2,000 tons (15%).	Eriksson et al., (2023)
	agricultural emissions tax (Green Tripartite Agreement)	reduce the country's nitrogen pollution and improve biodiversity	2024 (announced)	Pork and diary farms will pay around $40 per tonne of emissions (carbon dioxide equivalent) above the average in 2030, rising to around $100 by 2035. Pork and dairy producers will not pay taxes on 60% of average emissions per animal. Incentives to reduce nitrogen pollution will be introduced as well.		Searchinger and Waite (2024)
Netherland	Mineral Accounting System (MINAS)	reduce mineral surpluses and increase efficiency	1998-2003	Farmers had to keep records of their nitrogen and phosphorus inputs and outputs. A balance sheet was drawn up at farm level and the tax was paid on every kilogram exceeding a certain tax-free surplus per hectare.	In 2002 the nitrogen surplus was 34 % lower than in 1997 and phosphorus surplus decreased by 35%.	Olsthoorn and Fong (2005), Wright (2006)

Source: own compilation

Gazzani (2017) reviewed international case studies modelling the economic and environmental outcomes of nitrogen taxation, the most important findings of which are summarized in Table 5.

Table 5. Summary of the results of international case studies modelling the economic and environmental outcomes of nitrogen taxation, based on Gazzani (2017)

Country	Year	Tax rate	Result	Conclusion	Authors
Spain	2005	1,23 EUR/N kg;	It would significantly reduce nitrate losses and pollution levels by 10-60% depending on soil type. It would increase prosperity by EUR 0.32 million.	Taxes on mineral fertilizers, and especially on nitrogen, will bring about significant pollution reductions at low cost.	Martınez and Albiac (2006)
South Korea	2006	10% tax increase; 100% tax increase; 200% tax increase	10% tax increase: 1.5% decrease in fertilizer demand; 100% tax increase: 14.6% decrease in fertilizer demand, no decrease in yield 200% tax increase: 29.1% decrease in fertilizer demand, 22% decrease in yield	A 100% tax increase seems to be a more appropriate and effective measure, as it would only reduce farmers' incomes by 3% and rice production would remain virtually unchanged.	Kim and Stoecker (2006)
New Zealand	2007	5 USD /N kg (for farms with low and medium concentrations); 15 USD/ N kg (intensive farming)	This would result in a significant reduction in the demand for mineral fertilizers and significant environmental benefits.	The value of taxation should be differentiated according to different types of farming systems and should be very high for extensive farming in New Zealand.	Ramilan et al. (2007)
Spain	2009	0,20 EUR/N kg; 0,40 EUR/N kg; 1,00 EUR/N kg;	0.20 EUR/N kg: irrelevant reduction in fertilizer use, irrelevant environmental benefits; 0.40 EUR/N kg: more than 50% reduction in the nitrate balance indicator; 1.00 EUR/N kg: approx. 64.4% reduction in the nitrate balance indicator;	The economic impact on farmers' incomes appears consistent with the application of a nitrogen tax of EUR 0.40/N kg, which can be offset by incentives.	Gallego-Ayala and Gomez-Limon (2009)
Switzerland	2012	10%, 20% and 30%	0%: 5% reduction in N use; 20%: 9.65% reduction in N use; 30%: 13% reduction in N use	In this case, a small nitrogen tax is needed to reduce nitrogen use without causing obvious income losses for farmers.	Finger (2012)

Source: own compilation based on Gazzani (2017)

Gazzani (2017) concludes that the environmental benefits of a nitrogen tax and the extent to which it reduces pollution depend on the market price of agricultural products and are influenced by the elasticity of demand for fertilizers, which is linked to the income of agricultural producers. As his studies showed that demand for mineral fertilizers is very inelastic, he concluded that the tax rate would have to be relatively high in order to reduce demand for fertilizers. However, this would make food more expensive, as farmers would pass on the increased cost of fertilizers to consumers, which would adversely affect low-income groups. It is therefore important to compensate agricultural producers in order to avoid food price increases, for example by redistributing tax revenues among farmers, reducing employment and income taxes, or introducing compensation mechanisms for farmers who invest in nitrogen recycling plants and nitrogen removal technologies.

In the countries examined, the application of fertilizer taxes had an impact on nitrogen use and led to a reduction in nitrogen fertilizer inputs, thus positively influencing nutrient emission targets. For example, the fertilizer tax reduced excessive "insurance" fertilizer uses and promoted substitution with organic fertilizers, thereby also stimulating fertilizer trade between livestock farmers and arable crop producers. In addition, according to studies by Hofreither & Sinabell (1998) and ECOTEC (2001), the fertilizer tax sends a moral signal about desirable behaviour, thus contributing to increased environmental awareness; for example, it has influenced the environmental motivation of some Austrian farmers.

However, according to several studies (e.g., Rougoor et al. (2001) and Sjöberg (2005), Weckmann (2015) and Gazzani (2017)), the price elasticity of fertilizers is relatively low, meaning that high tax rates are needed to reduce demand, which could lead to a decline in farmers' competitiveness and an increase in food prices. It is therefore recommended to introduce a fertilizer tax in combination with other measures, as a broader package of measures would be more acceptable to farmers. In order to maintain the income of agricultural farms, it is important to redistribute the tax burden to farmers through other policy instruments and to combine this with regulation and education programs. It is important to ensure that the system to be developed does not involve excessive administration and overly complex regulations, and that it is in line with the EU Nitrates Directive and the measures of the common agricultural policy.

2.h Financing in the agri-food sector

In order to strengthen competitiveness and increase market share in international markets, five factors determine the financing needs of the agri-food sector: improving efficiency, expanding capacity, complying with regulations, and product differentiation. In addition, and particularly in the case of SMEs (Small and Medium Enterprises) operating in the agri-food sector, one of the main drivers of financing demand is the working capital requirements of companies.

For EU farmers, it is essential to invest in fixed assets, modernise production, increase cost efficiency and improve profitability. While agricultural cooperatives, integrators and input providers are in a better position to meet this need, producers require financing (Fi-Compass, 2020).

The financing gap refers to the unfulfilled credit demand resulting from limited or non-existent access to banking and financial products. The financing gaps for agriculture and agri-food enterprises represent an unmet financing demand from economically viable farms and agri-food SMEs. Unmet demand includes:

- a loan applied for but not obtained;
- financing refused by the potential borrower;
- a loan not applied for due to fear of rejection.

According to Fi-compass (2023) in 2022, the EU-24 agriculture sector faced a EUR 62.3 billion financing gap - a 33% increase compared to 2017 - driven by higher demand for external bank financing and larger loan sizes. The distribution of the financing gap by the agriculture sector in 2022 is represented in Figure 1.

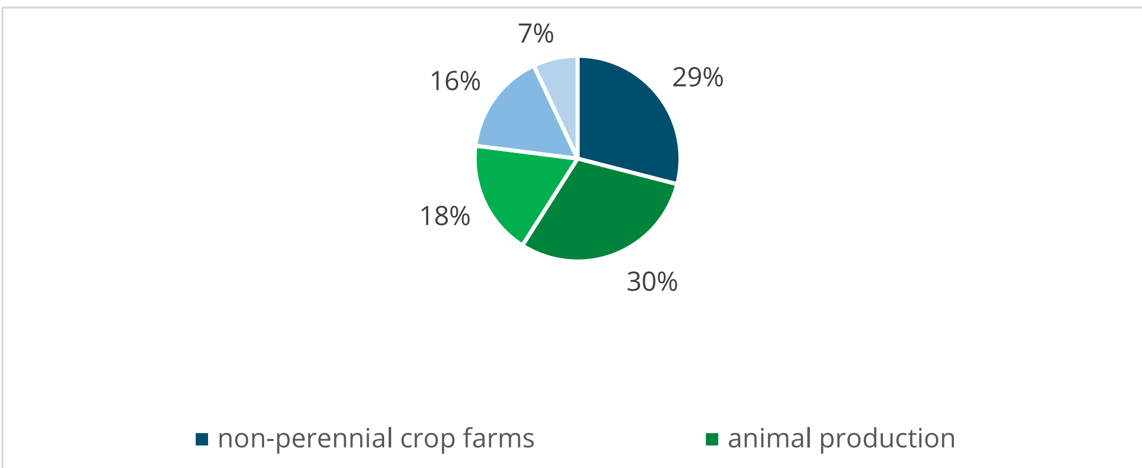

Figure 1. The distribution of the financing gap by the agriculture sector in 2022. Source: based on Fi-compass (2023)

The share of farms using bank loans rose to 22.7%, with increases in demand for short-, medium-, and long-term loans. The loan rejection rate was 4%, and 5% of farmers declined loan offers. 13.7% of farmers avoided applying out of fear of rejection. Higher average loan sizes, especially for small and medium farms, and a shift in farm demographics — decline in small farms and growth in large farms— widened the financing gap. Despite the decline in the number of small farms, they represent the majority of farms in the EU (75%), and access to financing is the biggest challenge for them. Small farms suffered of 61% of the agricultural finance gap, in 2022. Long-term loans are particularly difficult for them to obtain, as they carry higher risks. Large farms face far fewer obstacles to financing, representing only 15% of the total deficit. An analysis of the various financial products shows that 58%, of the financing gap is related to long-term loans, which is the biggest challenge for EU-24 farmers. Access to credit lines and short-term loans appears to be less difficult for EU-24 farmers.

In the case of agri-food companies, the financing gap in the EU-24 fell to EUR 5.5 billion in 2022, which is 53% lower than in 2018. The decrease is mainly due to a reduction in the financing gap for smaller companies and a decrease for medium-sized companies. Demand for bank products was 38% in 2022. The loan rejection rate was 5.4%, and the share of loans rejected by agri-food companies was 1.4% in 2022. The share of companies not applying for loans due to fear of rejection was 8.9%. The average loan amount for small businesses and the long-term loan portfolio of medium-sized businesses decreased significantly. Small businesses accounted for 73% of the agri-food financing gap in 2022, while medium-sized businesses accounted for 27% of the total gap. Access to long-term loans is the biggest obstacle for EU-24 agri-food businesses, as it is in the agricultural sector (Fi-compass, 2023).

Financial gaps in green investments in agrifood sector

According to Fi-compass (2023) the financial gap in case of green investments in 2022 was EUR 18.9 billion, or 30.4% of the overall financing gap in case of farmers and EUR 1.3 billion, or 24% in case of agri-food enterprises. The activities targeted for investment in case of farmers were

- Irrigation, drought and flood protection or other investments to manage climate change;
- Organic farming or other agro-ecological practices;
- Digital solutions or advanced engines to optimise the use of fertilizers and crop protection products;
- Reducing energy and fuel consumption and production of renewable energy such as solar panels or biogas plants.

In case of agri-food companies, the main targeted green investments were the following:

- Increasing energy efficiency (e.g. in buildings, production process);
- Producing renewable energy (e.g. solar, from waste or by-products);
- Improving environmental sustainability, including reducing greenhouse gas emissions (e.g. changes in the production process, sustainable packaging, input and raw material supplies, logistics and distribution);
- Adapting and increasing resilience to climate change (e.g. to extreme weather events, drought, supply shortages) Fi-compass (2023).

The main providers of finance to the agriculture sector are:

- cooperative banks, which are often is closer to the farming community than commercial banks,
- commercial banks,
- national promotional banks,
- agriculture cooperatives,

- leasing companies,
- private finance, i.e. loans from friends and family, because of the lack finance provided to the agriculture sector by financial intermediaries (Fi-Compass, 2020).

Green finance in the EU

In order to achieve the European Union's sustainability goals, it is necessary to establish a financing framework. Based on the report of a high-level expert group formed at the end of 2016 in response to a European Commission initiative, the Sustainable Finance Action Plan (COM/2018/097) was created and a comprehensive vision for the development of the EU's sustainable finance strategy was outlined.

The strategy sets out the necessary measures along three main objectives, which are as follows (European Commission, 2018):

1. directing capital flows towards sustainable investments,
2. addressing financial risks related to climate change, resource depletion, environmental degradation and social challenges; and
3. promoting transparency and a long-term perspective in financial and economic activities.

The transition to a sustainable economy requires enormous capital and investment, and states and governments do not have enough resources to make this transition solely through subsidies. The banking sector plays an important role in shifting savings from unsustainable investments to sustainable investments through lending, but incentives and regulations are needed to achieve this (Pókos-Kemény, 2023).

Bahl (2012) defines green finance as the financing of environment-friendly activities, green technology, and projects that reduce pollution. The G20 Green Finance Study Group (2016) and Brühl (2021) define green finance as the financing of investments that provide environmental benefits, such as reducing air, water, and soil pollution, reducing GHG emissions, improving energy efficiency, and mitigating and adapting to climate change. According to Ozili (2022), green finance is an innovation that offers alternative financing options for individuals, companies, and governments willing to finance and invest in green activities or low-carbon activities.

Taxonomy Regulation

In order to implement green financing and avoid greenwashing, it is essential that the environmental sustainability of individual economic activities can be determined based on the same criteria across the European Union. The Taxonomy Regulation (Regulation (EU) 2020/852) adopted in 2020 aims to establish a common framework. It defines six environmental objectives (Figure 2) and the economic activities which can be considered environmentally sustainable. Taxonomy alignment is the positive assessment that an eligible activity meets the applicable Taxonomy requirements to substantially contribute to at least one of the Taxonomy’s six objectives; while also doing no significant harm (DNSH) to any other objective; and meeting the minimum social safeguards (MSS). Technical screening criteria for determining the requirements for green economic activities set out in the Taxonomy delegated acts. Commission Delegated Act (EU) 2021/2139 and its supplementary Regulation 2023/2485 contain criteria on the climate change targets, and Commission Delegated Act (EU) 2023/2486 contains the screening criteria on environmental objectives. If economic activities are capable of meeting the technical screening criteria, they are considered eligible activities; if they also meet the criteria, they are considered aligned activities (European Commission, 2022).

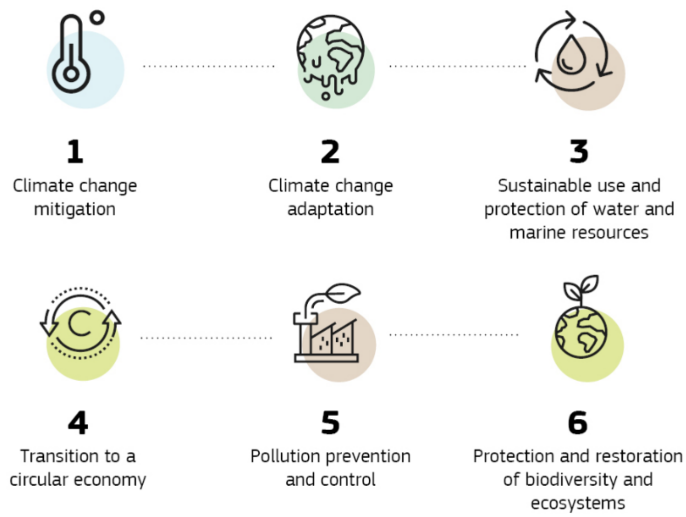

Figure 2. Six climate and environmental objectives of the Taxonomy Regulation. Source: https://ec.europa.eu/sustainable-finance-taxonomy/

Three of the environmental objectives of the taxonomy can be linked to the topic of circular nutrient management: the sustainable use and protection of water and marine resources, the transition to a circular economy, and pollution prevention and control. These three environmental objectives and the related green activities are presented in Table 6.

Table 6. EU taxonomy environmental objectives and the defined activities – related to the topic of circular nutrient management

Environmental Objective	Related activities
Sustainable use and protection of water and marine resources	protecting the environment from the adverse effects of urban and industrial wastewater discharges,
	protecting human health from the adverse impact of any contamination of water intended for human consumption
	improving water management and efficiency, including by protecting and enhancing the status of aquatic ecosystems
	ensuring the **sustainable use of marine ecosystem services** or contributing to the good environmental status of marine waters
Transition to a circular economy	uses natural resources, reducing the use of primary raw materials, **increasing the use of by-products and secondary raw materials,** or resource and energy efficiency measures,
	increases the **durability, reparability, upgradability or reusability of products**
	increases the **recyclability of products**
	substantially **reduces the content of hazardous substances**
	prolongs the use of products
	increases the use of **secondary raw materials** and their quality
	prevents or **reduces waste generation**
	increases the preparation for **the re-use and recycling of waste**
	increases the development of the **waste management infrastructure**
	minimises the incineration of **waste** and avoids the disposal of waste
	avoids and reduces litter
Pollution prevention and control	preventing or, **reducing pollutant emissions**, other than greenhouse gases
	improving levels of air, water or soil quality in the areas of the economic activities
	preventing or minimising any adverse impact on human health and the environment of the production, **use or disposal of chemicals**
	cleaning up litter and other pollution

Source: Based on Rózsa et al. (2025)

Green finance instruments

According to the European Commission report (2017) the common green financing strategies adopted in Europe are (i) 'green bonds' that are issued following green bond principles, (ii) 'green lending' by banks involved in green loan origination, and (iii) 'green equity investment'.

Green bonds

Green bonds support a specific investment or a specific branch of business within a company. A precondition for the use of green bonds is that the company - and therefore the investor - can determine in advance what the financing will be used for.

A green bond is a fixed-rate instrument designed to support climate-related or environmental projects. Green bonds are used to finance or refinance investments, projects, or expenditures that contribute to addressing climate and environmental issues. Governments and private companies use them to finance the transition to a more sustainable and low-carbon economy (European Parliament, 2023).

The European Union has established a clear standard for green bonds, known as the European Green Bond Standard, in order to promote the growth of the green bond market and to establish clear guidelines to increase market transparency. The voluntary Standard establishes monitoring of businesses conducting pre- and post-issuance assessments at the European level, guarantees levels of transparency, and defines green economic activities using the comprehensive criteria of the EU Taxonomy (European Commission, 2025).

According to research by Hadaś-Dyduch et al. (2022), the main issuers of green bonds in the V4 countries are typically the public sector and state-controlled companies. The public sector's involvement is essential for the development of the green bond market, as governments and their affiliated companies must take the first steps towards environmental sustainability. At the same time, greater attention should also be paid to private enterprises (financial and non-financial institutions), whose climate protection investments can be significantly facilitated by raising capital through the issuance of green bonds.

In 2024, the European Union played a leading role in the green bond market, accounting for 58% of global issuance. This represents an increase compared to previous years; in 2023, for example, the EU's share was 53%. Green bonds account for an increasing share of the total bond market in the EU, but even so, green bonds accounted for only 6.8% of total bond issuance in 2023. There are significant differences between Member States in the share of green bonds. In 2023, Denmark, Sweden and Finland, green bonds accounted for more than 16% of total bond issuance, while in six Member States – Bulgaria, the Czech Republic, Greece, Estonia, Cyprus and Lithuania – there were no green bond issuances at all (European Environmental Agency, 2024).

Green loans

Similarly to green bonds, green loans raise capital for green projects, but they are typically used by private companies and are smaller in value. Green loans and green bonds follow different but consistent principles, with both instruments requiring that 100% of the proceeds be used exclusively for green eligible activities. Projects using green loans must have clear, measurable environmental benefits. In the European Union, the framework for green loans is provided by the Green Loan Principles (GLP) published in 2018. The GLP aims to support environmentally conscious decision-making by lenders, borrowers and investors and to promote the achievement of positive environmental impacts. The Green Loan Principles have four pillars. First, the use of the loan must be clearly defined, i.e., it can only be used to finance projects with environmental benefits. A transparent project selection and assessment process must be ensured, and the funds involved must be separated and monitored. Finally, regular reporting on the use of the loan is required at least once a year and, where possible, measurable environmental impacts (e.g., CO_2 savings, energy savings, etc.) should be disclosed (World Bank Group, 2021).

Globally, green loans in the syndicated loan market totalled $638 billion, representing a 21% increase compared to 2023 and more than double the 2021 issuance (Sharpe, 2025).

Green equity

The aim of green equity is to encourage investors with green agendas to invest in companies with sustainable business models, i.e. green capital is allocated to companies that consider more than 50% of their revenues and investments to be green. Companies that meet the criteria for green equity include, for example, businesses and projects that support the circular economy, increase resource efficiency, and reduce waste. This includes designing recyclable products, promoting recycling practices, and minimizing the use of non-renewable resources. In addition, green equity capital can also be directed towards projects that preserve biodiversity, promote sustainable land use and protect ecosystems (Grönroos, 2023).

Factors influencing green financing

The involvement of private resources is essential for the green transition, and the number of sustainable financial instruments is growing. The shift of private funds towards green investments is primarily based on sustainability information architecture (disclosure requirements (e.g. CSRD, CSDDD), green taxonomies, related green financial regulations and products). These instruments are not sufficient on their own to achieve climate and other environmental sustainability goals, but they contribute to accelerating positive processes (MNB, 2024). The current EU regulatory framework for sustainable finance, a complex system according to Brühl (2022), which is fundamentally based on sustainability information architecture, has led to improved transparency regarding the environmental, social, and governance aspects of financial products, but it is questionable whether it is sufficient to mobilize more private capital for sustainable investments.

Based on Ozili's (2022) review of the literature on green finance, the most important factors that support and promote the spread of green finance are summarized in the table below (Table 7).

Table 7. Factors promoting green finance

Factors	
Main agents promoting the growth and development of green finance	Banks, institutional investors, research institutes, public agencies, central banks, financial regulators, international financial institutions, universities, commercial banks and private equity funds, European Investment Bank, European countries government agencies (Berensmann and Lindenberg, 2016; Ozili, 2019, Kim 2018 and Ozili 2022, Wang and Zhi, 2016)
Strategies for increasing green financing and investments	Enabling business environment; developing standards and rules for disclosure; financial and regulatory incentives; transparency in the definition of green finance; well-coordinated financial, environmental and regulatory policies; efficient legal framework for green bond operations; the collaboration of government and private firms (Berensmann and Lindenberg, 2016; Tu et al., 2020)
Reducing the risk of green investments	Creation of green credit guarantee schemes; return a portion of the tax revenue (Taghizadeh-Hesary and Yoshino 2019)
Using innovative technology	Using blockchain and other innovative technologies and creating supportive regulatory environment it needs (Zhang et al., 2018)
Central banks can use it(?) to reduce climate risk towards promoting a green economy	Imposing a climate change capital surcharge; (ii) imposing a fixed-rate risk capital; (iii) a reduction in lending to industries whose activities destroy the environment and climate; (iv) creating a climate bank; (v) requiring financial institutions to relocate their important assets to areas less prone to climate change events. (Ozili, 2021)

Source: based on Ozili (2022)

A fundamental prerequisite for the implementation of green financing is the measurement and verification of the environmental impact of green investments and projects. At the same time, compliance with green finance conditions and taxonomy requirements places a significant burden on actors, as supporting the environmental sustainability of investments with data is a complex task for both businesses and banks, requiring specialized knowledge and additional administration.

Green Finance Platform highlights that a number of microeconomic issues have hindered the mobilization of funds for green investments. For instance, investors' very short time horizons and long-term green investments have different maturity mismatches. Furthermore, there has frequently been a lack of coordination between financial and environmental policy measures.

At the same time, the geopolitical and macroeconomic conditions of recent years are significantly hindering the achievement of green goals. The COVID-19 pandemic and the crisis caused by the Russian-

Ukrainian war have kept inflation higher than desired in most countries, forcing central banks to keep interest rates high, which makes financing investments more expensive. Current geopolitical tensions continue to fuel uncertainty, which dampens the willingness of economic players to borrow loans, especially for longer-term investment loans such as green loans (MNB, 2024).

In order to scale up and crowd in private sector financing, governments can collaborate with a variety of actors to enhance capital flows and create creative financial strategies across various asset classes, particularly through capacity-building programs. To support the development of green finance The Green Finance Platform and the United Nations Environment Programme's (UNEP) Inquiry into the Design of a Sustainable Financial System ("the Inquiry") have launched the Green Finance Measures Database, which is a global compilation of green finance policies and regulations across over 100 developed and developing countries (Greenfinance.org, n. d.).

Sustainable finance in the Circular Economy (CE)

According to Kumar et al. (2024), green finance can act as a primary catalyst for the implementation of sustainable economic practices if this is in line with the interests of financial institutions. Their research shows that the factors limiting the financial performance of companies transitioning to a circular economy (CE) are as follows: (a) company size and primary capital costs, (b) challenges faced by small and medium-sized enterprises, (c) more complex business structures, and (d) higher risk, as the circular economy is a new concept that is not yet widely adopted and operates as a linear business system. Public policy and tax incentives can be effective ways to compensate for efforts to move towards a circular economy, and financial incentives through green financing, project support, and national, corporate, and consumer awareness are critical. A barrier is the lack of financial, institutional, and national benchmarks for evaluating the growth of companies operating in a circular economy.

Their research integrates existing theoretical knowledge with new empirical findings gathered during extensive field research conducted in Finland. Using these findings, they identify the driving and hindering factors of the circular economy, as well as its sources, criteria, and objects of financing.

Table 8. Synthesis of finance-related factors shaping CE business in the literature

Factors	
Company size	SMEs find it more difficult to obtain financing for CE
	SMEs are more sensitive to extra costs
	For SMEs, it is more difficult for them to obtain collateral for bank financing
	SMEs often have no time and/or knowhow to apply for financing
High upfront investment costs	High upfront investments (e.g., for technology, process implementations, innovation activities) are uncertain and sizable
	Lock-in for linear processes requires drastic changes and therefore sizable investments
Circular business models' capital funding	Circular Economy Business Models (CEBM) are seen as capital-intensive, with long payback times and unfamiliar risks
	Product-as-service (PaaS), as an example, demands large amounts of working capital
The role of public financial support	Public financial incentives are crucial in the CE transition
	Investments which are otherwise not profitable can be made feasible with public support
	Taxation requires changes to accommodate transition to CE
Current valuation and profitability of circular business models	Traditional financiers, in particular, do not trust the value of CE business and require a precedent of profitability and risks
	Traditional financial models do not take intangible assets and circular risk into account in valuations
	The profitability of CEBMs is often risky and realized over a long period of time

Source: Saarinen and Aarikka-Stenroos (2022)

Based on their comprehensive survey Saarinen and Aarikka-Stenroos (2022) drew conclusions and made recommendations for practice related to the financing of circular economy (Table 8).

The authors consider the public sector, state financial incentives, and state financing organizations to be particularly important in creating a level playing field for CE companies. In addition, it would be important to refine current public procurement policies, as current public procurement procedures favour traditional, linear businesses and do not value circular solutions offered by companies. Regulators also need to address tax issues: balancing the tax burden between labour and resources and differentiating between the taxation of renewable and non-renewable materials would make the circular economy much more viable from a financial perspective as an operating principle. According to their findings, different business models have different implications from a financing perspective.

From a financier's perspective, they concluded that the profitability of the CE business is the most important criterion for financing and that it is worth investing in making the business model financially viable. However, CE involves significant market, technological, cash flow, supply chain, regulatory, and end-user credit risks, which are not well understood in the financial industry or the assessment frameworks used. These risks should be reduced as much as possible, and companies should disclose the risks and measures taken to reduce them as fully as possible when applying for financing. In parallel, financiers need to significantly update their assessment methodologies for circular and linear risks to contribute to the CE transition.

In the authors' view, the CE transition will increase demand for financial products that are suitable for financing CE businesses and CE business models.

3.Local and regional experiences

The wider goal of task 4.3 is to collect and evaluate financial instruments related to the transition to a circular, low emission agricultural production. To achieve this, relevant information regarding the existing financial instruments to support the reduction of nitrogen and phosphorus emissions has been compiled. A dedicated data collection excel sheet was used, in which partners were requested to provide information of different financial instruments relevant for their regions such as loans, insurance tools, taxes which can be directly or indirectly enhance the nutrient cycle of N and P (tables).

Project partners were asked to fill the cells taking into consideration which instruments can be found in their country, and furthermore, which can be transformed into N and P nutrient cycling-related governance options or policy instruments. In this view, the policy related, and private sectoral tools are also part of the evaluation, however pilot or closed instruments were also included.

The partners enumerated different instruments, which directly or indirectly can be relevant for developing an enhanced policy or instrument for N and P cycling.

The Common Agricultural Policy (CAP)

The CAP according to ***eco-schemes*** defined and conditionalities for rural development (EAFRD) investments already dedicates techniques to fix nitrogen in soil (eg. GAEC 8: *Minimum share of at least 7% of arable land at farm level if this includes also catch crops or nitrogen fixing crops*). In CAP, ***support for sustainable crops*** aims to promote the rational use of resources by agricultural holdings in order to achieve a higher degree of environmental sustainability. The contribution of production systems such as integrated production, and other equivalents, reduces soil and water pollution and ensures long-term sustainable agriculture and protection of natural resources.

Modernization of irrigation systems **related long-term loans are often supported by government subsidies** and incentives to encourage adoption of technologies like drip irrigation and precision agriculture. Precision agriculture technologies related high-cost technologies like GPS-guided equipment, drones, and sophisticated soil sensors may also necessitate long-term loans to spread the investment cost. The main weak points of these supports are that without the support, the investments wouldn't be economically sustainable. The conditions often are restricted, additional payment cannot be obtained if the farmer doesn't have the right technology, which means limited target audience. The farmers criticize too complex regulatory requirements: CAP's stringent regulations and compliance standards can be challenging for farmers and project developers to navigate, potentially deterring participation in nutrient recycling initiatives. Some experts also agree that CAP has insufficient incentives for nutrient recycling: While CAP includes environmental measures, the specific incentives for recycling nutrients like nitrogen and phosphorus may be inadequate, limiting the adoption of circular practices.

Spain

Spanish agri-environmental aid for fertilization management combines ***technical support*** and ***grants*** to subsidise the costs of setting up and maintaining advisory services and technical support for sustainable fertilization.

Long term loan architecture's objective is financing technological innovation projects aimed at incorporating emerging technologies. They support the acquisition of new fixed assets that represent an important technological leap for the company carrying out the project. An example of a project could be the purchase of equipment for the recovery of nitrogen or phosphorus as a valuable raw material (Spain, CDTI Projects of I+D). A success factor is that they are loans at below-market interest rates to carry out projects with high innovative potential and are aligned with EU priorities (green policy). The main barrier of this instrument is the high budget proposed which may limit the entry of SMEs. Administrative complexity for project application is quite high.

Another long term loan financed tool is the financing of research projects that allow the development of new products or the improvement of existing equipment. Consortiums of several companies are created for the development of prototypes, for example, for nitrogen and phosphorus recovery (Spain, CDTI Program CIEN). The main barrier of this instrument is the high budget proposed which may limit the entry of SMEs. Administrative complexity for project application is quite high. CIEN projects span over multiple years, which can result in financial and operational uncertainty.

Climate funds also exist in Spain: The Strategic Project for Economic Recovery and Transformation in the Agri-food Sector (PERTE Agroalimentario) is a Spanish government initiative aimed at enhancing the competitiveness, sustainability, and resilience of Spain's agri-food sector. By focusing on R&D, circular economy, and digital transformation, this initiative can drive technologies and systems that recover nitrogen and phosphorus, improving resource efficiency, reducing pollution, and supporting a more sustainable agri-food sector in Spain. In the first edition (February 2024), 161.6 million euros were awarded in the form of grants and 19.9 million euros in the form of loans. This Agri-Food PERTE combines the expertise of several companies from many sectors with that of technology centres and research centres to improve the sector's value chain. In addition, the financial resources will be of public and private origin and will lead to remedy the market failures and social challenges. The main barrier can be that the maximum aid per company and project varies depending on the project type, with specific caps for industrial research, experimental development, innovation, sustainability, and SME investments. Beneficiaries need to have to include in their proposals some actions related to traceability and food safety.

PERTE of Circular Economy's objective is to accelerate the transition to a sustainable and efficient economic model by promoting waste reduction, resource efficiency, and recycling. This tool supports projects across various sectors, including agriculture, that implement circular economy strategies. Projects focusing on the recovery and reuse of nutrients like phosphorus and nitrogen from agricultural waste streams could align with the objectives of this PERTE, contributing to resource efficiency and environmental sustainability. Investments made in 2022 provided support worth 492 million euros and are expected to mobilise resources in excess of 1.2 billion euros by 2026. Regarding the development of N & P cycling tools, this instrument can be useful for financing future developments as one of its objectives is to promote sustainability and circularity of production processes to improve the competitiveness and innovation of the industrial fabric within the framework of a circular economy. A potential barrier can be, that PERTE primarily targets sectors such as textiles, plastics, and renewable energy equipment. Projects centred on nutrient recovery, like phosphorus and nitrogen, may not directly align with these predefined sectors. This focus could limit the eligibility of nutrient recovery projects for funding. With substantial funding available, there is intense competition among projects across various sectors. In Catalonia relevant ***credit guarantees also*** exist. ICF Agroambiental (Catalan Institute of Finance) offers loans with preferential conditions to finance sustainability projects, including nutrient management.

Germany

In Bavaria, the Kulap tool is a ***subventio****n* for farmers who are treating their fields and forests in defined ecological manner. This program is very detailed in putting different subvention prices per specific ecological measures per landscape type. Widespread use in Bavaria due to low entrance barriers (e.g. keeping N and P limits in utilizing manure for fertilization or long-term observation of key nutrients in soils for adjusting fertilization needs). Main barrier identified is the needs established infrastructure of agronomic consultants, certified laboratories and sampling.

Latvia

Carbon Farming Initiatives also exist in Nenuphar regions. In Latvia the support is available for farmers who engage in carbon sequestration activities, like tree planting or practices that help store carbon in soil, contributing to both climate change mitigation and the preservation of agricultural productivity. An additional financial support promotes economic sustainability of farming, however comparatively new system - unknown risks may occur, eg. investments might be larger than compensation.

Slovakia

Farmers in **Slovakia** and the **Czech Republic** also manage their fields successfully using regenerative methods. Farmers obtain financial support by startup Carboneg, which rewards them for every ton of CO2 stored in the soil. The main success factor of the Slovakian system is that there is funding and an advice system for regenerative farming.

Farmers in Slovakia often use credit lines and overdrafts to complement the deductible part of CAP investment. Today, the agricultural sector in Slovakia is mainly given credit by two banks: UniCredit Bank and VÚB. Both banks want to help with mediation of financial instruments. Regulation of the Government of the Slovak Republic establishing the rules for providing support in agriculture in the form of direct payments. The main challenge of this instrument are high surrounding costs and cumulative costs.

In Slovakia an ***environmental fund*** exists, with the purpose of supporting primary agricultural production by means of a refund of part of the tax on mineral oils, in accordance with Article 44 of the Commission Regulation. Specifically, the subsidy is to be applied in the amount of the part of the mineral oil tax calculated on the basis of the standardised fuel consumption per hectare of a specific agricultural crop and per livestock unit. Also, in Slovakia an earlier in 2023 closed ***climate fund*** financed state aid scheme no. SA.54289(2019/XA) aimed to provide a subsidy for the compensation of damages caused by an adverse weather event that can be compared to a natural disaster.

Hungary

In Hungary, several tools are in place to promote nutrient flows. For instance, the **voluntary carbon market** supports regenerative farming practices that enhance soil carbon sequestration, with Nestlé providing funding and advisory services. The Agrár Széchényi Card offers **credit lines** to help farmers manage liquidity and cover unexpected costs, often used to complement EU CAP investments. The **fertilizer tax regulates** the use and marketing of fertilizing products, encouraging nutrient balance-based application. Additionally, the **Krizbi agricultural crisis insurance scheme** provides comprehensive risk management, covering weather, production, and market risks, based on collective data and requiring multi-year participation.

Beyond national tools, international and EU-level instruments also play a role. **Green loans**, regulated under EU taxonomy, offer preferential interest rates for environmentally beneficial investments, though their application in agriculture is still limited due to technical and administrative challenges. Climate funds seek investment opportunities that contribute to sustainability goals, such as emission reduction, renewable energy, and water management. These instruments vary in their direct impact on N and P cycling, but collectively they offer financial protection, incentives for better practices, and support for systemic transformation. Despite their potential, barriers such as administrative burdens, regulatory overlaps, and lack of information remain significant challenges to their broader adoption and effectiveness.

4. Analysis of drivers and barriers

This chapter examines the key drivers and barriers influencing the development, adoption, and effectiveness of innovative economic instruments aimed at reducing nitrogen (N) and phosphorus (P) emissions. These instruments, which include financial incentives, regulatory measures, and enabling tools, play a crucial role in supporting sustainable nutrient management. The analysis draws on insights from expert interviews and stakeholder consultations, as well as findings from the ESNI workshop, to highlight both enabling conditions and persistent challenges that affect implementation across public and private sectors.

4.a NENUPHAR Workshop at ESNI Conference

On September 18, 2024, NENUPHAR project hosted a dynamic workshop at the European Sustainable Nutrient Initiative (ESNI) conference. The workshop, titled “Hands-On Nutrient Management: Barriers and Opportunities in EU & Regional Legislation and Economic Strategies,” provided an interactive platform for stakeholders to explore the regulatory and economic instruments that can drive nutrient recovery across Europe.

The workshop transitioned into an interactive, practical format. Participants were divided into small working groups to engage in discussions on key issues such as manure management, sewage sludge reuse, and the treatment of dairy wastewater. Each group, supported by technical and economic experts from the NENUPHAR consortium, explored obstacles to efficient nutrient recovery — including regulatory hurdles, permitting difficulties, and limitations in waste processing infrastructure. At the same time, they identified possible improvements, such as creating enabling frameworks for nutrient reuse and improving market access for recovered products.

The workshop surfaced several recurring barriers, notably the absence of adequate financial incentives, fragmented legislation, and the need for clearer, more supportive regulations governing the use and commercialization of recovered nutrients. Participants exchanged experiences and proposed ways to address these issues, underlining the importance of enhanced regulatory backing and new economic instruments to encourage nutrient recovery initiatives.

The main finding highlights that one of the EU regulation’s biggest challenges is its insufficient adaptation to local and regional circumstances. Policymakers often apply a limited, uniform approach, while overly complex regulations slow down the emergence of innovative business models.

Although EU legislation successfully addresses water pollution and environmental protection, it unintentionally places smaller farmers at a disadvantage. These producers typically have lower output and higher resource demands, while the current framework tends to favour larger agricultural enterprises.

The main barrier is lack of economic tools that would stimulate change from traditional sources of fertilizers such as mineral to alternative sources such as composted sewage sludge or dairy wastewater.

Moreover, better dialogue and cooperation are needed between policymakers and the primary sector to ensure that regulations reflect on-the-ground realities. Policies should actively encourage circular business models that build on existing technologies, knowledge, and resources.

To support this, it is essential to identify practical, cost-effective solutions and foster value chain-based business models that create benefits for both the environment and local economies. There is the potential and the need to incorporate nutrients recovered from dairy wastewater/sewage sludge/manure systems in the nutrient supply system to be used in agricultural production and other activities. In order to achieve acceptance from the public and other stakeholders involved, research-based results on environmental safety and economic viability must be done.

4.b Expert interviews

Interview I. Green finance, finance of circular economy

Date: 17/07/2025

Green financing is not yet widespread in the circular economy. This is because the Taxonomy Regulation's delegated act on technical screening criteria for environmental objectives, including the circular economy, was published later than the screening criteria for climate change mitigation and adaptation. As a result, green loans were typically related to climate change, as this was more developed. However, financing for the circular economy was provided within the traditional framework, but this was not clearly separated, so it is not known how much lending took place in this area.

Green finance is supported by a strong regulatory framework, but its practical application is still limited. The Taxonomy Regulation is not well suited to regulating nutrient management in agriculture. The Climate Bond Initiative (CBI) has issued new, more detailed criteria, but these continue to focus on climate change mitigation. The benefits of green finance are currently mainly available to larger players who are better informed and able to comply with regulations (e.g. multinational retailers). Small and medium-sized enterprises (SMEs) often do not understand how the system works and are unable to issue green bonds, for example, due to high transaction costs. Green finance currently works well mainly at the two ends of the food supply chain, where there are concerted players: fertilizer manufacturers and retailers.

Documenting scalability is essential for the spread of innovative technologies. An overview of the entire product chain and the existence of appropriate incentives and regulatory frameworks are necessary for the evaluation of technologies.

New technologies are expensive to finance without market benchmarks, so initial support is needed to finance them, but they must eventually operate on a market basis.

The cap and trade system is difficult to apply to nutrient management because the effects are difficult to quantify and are often local. The effectiveness of tax and quota systems depends on how well they can be enforced. If they can be circumvented, they do not work well. Positive incentives can be more effective if they fit in with the operating logic of businesses.

Interview II: Innovation and Digitalization Support Group (ITE) – innovation-promoting projects, advisory system, knowledge transfer

Date: 24/07/2025

The establishment of ITE was preceded by an innovation potential survey conducted among Hungarian farmers and food processors. They work closely with the inistry of Agriculture, particularly within the framework of the BIOEAST initiative (e.g., BioeastUP, Boost4Bioeast projects). According to the survey, approximately 50% of respondents would be open to introducing circular models. The main motivation for those involved would be to gain financial benefits. The degree of openness depends on the level of education and the size of the farm. The fruit and vegetable sector and the small ruminant sector showed greater interest.

Support schemes and the role of the EIP: Support plays a key role in promoting innovation; without it, farmers will not embark on experiments. The European Innovation Partnership (EIP) aims to increase agricultural productivity and sustainability through innovative solutions. There are two types of EIP projects: "Top-down" calls for proposals based on ministerial policy objectives, and "Bottom-up" calls for proposals based on grassroots initiatives. The most important thing is that the results are incorporated into practice, e.g. into vocational training. Scaling is very important, and an acceleration program is needed in the final phase of EIP projects to help develop business models and transfer knowledge. Knowledge transfer also plays a key role in the spread of innovation.

The inflexibility of EIP applications and the lengthy evaluation and payment processes are a challenge, with previous bad experiences leading to a negative attitude on the part of farmers. It would be important to identify the so-called "silent actors" who do not have access to knowledge. Technical advisors play a key role in the dissemination of innovation, but they also need training. Their attitude towards learning innovative solutions is positive. One of the tasks of the CAP network is to promote innovative solutions and showcase good examples.

The detailed description of the interviews can be found in Annex 3.

4.c Financial instruments to support the reduction of N/P

Financial instruments – as outlined in Chapter 1 and 2 (based on e.g. OECD (1997, 2024); Teleshkan et al (2024); Bengtsson et al. (2010); Andersen (1995); Gazzani (2017); Rougoor (2001)) – play a key role in supporting the reduction of nitrogen (N) and phosphorus (P) emissions, which are major contributors to water pollution and ecosystem degradation. By providing targeted incentives, subsidies, tax benefits, or penalties, these instruments encourage both public and private actors to adopt more sustainable nutrient management practices. Effective financial tools can help unlock circular economy opportunities, promote innovation, and balance economic interests with environmental protection goals. Among the economic instruments available, market-based mechanisms such as **cap-and-trade systems** and **dynamic quota-tax hybrid models** offer flexible, cost-effective approaches to regulate nutrient emissions while promoting innovation:

- *Cap-and-trade for Nitrogen management*
- *Dynamic quota and tax hybrid system for Nitrogen management*
- *Cap-and-trade for Phosphorous management*
- *Dynamic quota and tax hybrid system for Phosphorous management*

Markets in pollution permits for managing environmental quality have been advocated by economists since early 1970's as a mechanism that can deliver pollution reduction targets at lower cost to regulated entities than traditional uniform command-and control approaches. This system explores whether a 'smart market' cap-and-trade scheme between non-point sources can offer meaningful, robust and policy amenable, advantages over alternative approaches for nitrogen management in a realistic setting.

A cap-and-trade system can be integrated into N and P cycling by treating nutrient emissions as tradable environmental commodities. According to Bryce et al, (2021), Hassan et al. (2022), Ishfaq et al. (2025), nutrient over-enrichment, particularly from agriculture, disrupts biogeochemical cycles, leading to eutrophication and ecosystem degradation. A cap-and-trade approach would set a regulatory cap on total allowable N and P emissions within a watershed or region. Entities (eg. farms, wastewater plants) that reduce their nutrient outputs below their cap could sell excess allowances to others who exceed theirs.

This market-based mechanism incentivizes cost-effective nutrient reductions and encourages innovation in nutrient management. Hassan et al. emphasize the importance of aligning ecological thresholds with economic instruments, suggesting that such systems can internalize environmental costs and promote sustainable nutrient use. By integrating ecological feedback and adaptive governance, cap-and-trade could help rebalance nutrient cycles while maintaining agricultural productivity.

Water quality trading initiatives exist all over the world (see Kraemer et al. (2004); Mascia & Gildesgame (2021); and particular examples in sub-chapter 2/e). Water quality trading is an approach to control pollutants from multiple sources that collectively impact water quality conditions. When more stringent regulatory standards are put in place, water quality trading allows one source of pollution to control a pollutant at levels greater than required and sell "credits" to another source, which uses the credits to supplement their level of treatment in order to comply with regulatory requirements. Pollutant reductions achieved through water quality trading must result in water quality that is as good as—or better than—what would be achieved through treatment and must not create pollutant "hot spots" (EPA, 2024).

As summarised in sub-chapter 2/f, the application of fertilizer taxes had an impact on nitrogen use and led to a reduction in nitrogen fertilizer inputs, and consequently positively influenced nutrient emission targets. At the same time, to avoid the decline of farmers' competitiveness, it is therefore recommended to introduce a fertilizer tax in combination with other measures, as a broader package of measures would be more acceptable to farmers.

Kim et al. (1999), Graveline (2019), and Röder (2020) conclude that variable taxes offer the highest net economic benefits, especially when tailored to environmental targets. A promising flexible financial instrument that could be adapted to nitrogen and phosphorus cycling—while accounting for Nenuphar demo businesses (wastewater treatment and nutrient recycling business models) – is a dynamic quota-and-tax hybrid system.

In the Beauce case study, Graveline (2019) demonstrates that combining flexible abstraction quotas with adaptive taxation yields more robust and cost-effective outcomes than using either instrument alone. Translating this to nutrient governance, a similar system could be designed where:

- Nutrient discharge quotas (for N and P) are allocated to agricultural producers, food processors, and wastewater treatment facilities.
- These quotas are adjusted annually based on ecological indicators (e.g. eutrophication levels, soil nutrient saturation).
- Entities exceeding their quota pay a progressive nutrient discharge tax, while those under the limit may receive credits or trade allowances.
- Recycling businesses—such as those recovering phosphorus from sewage sludge or producing struvite fertilizers—could earn nutrient offset credits that are tradable within the system.

This approach incentivizes innovation in nutrient recovery and reuse, aligns with circular economy principles, and internalizes environmental costs. It also allows for regional customization, which Graveline (2019) emphasizes as essential in systems with variable hydrological and economic conditions.

5. Assessment tool for economic and financial schemes

This chapter comprises a proposal for a qualitative governance analysis, aiming to discover and quantify stakeholders and decision-makers considerations about various non-monetary factors to compare different instruments related to N and P management. An integrated handbook to guide this process can be found in Annex 1. A more detailed version of the handbook will be published within the framework of WP 5 of the NENUPHAR project.

As the approach for the tool, the so-called Multiple-criteria decision analysis (MCDA) was used, which is a structured methodological framework used to evaluate, prioritize, and select among alternatives involving multiple, often conflicting, criteria. MCDA helps decision-makers systematically compare diverse policy or management instruments, balancing trade-offs across economic, environmental, social, and institutional dimensions. (Ren, 2020; Prato & Herath, 2007; Linkov et al., 2006)(more information, Annex 1).

The following process has been applied for the development of the interdisciplinary assessment tool:

- *Identifying objectives:* Understanding how new economic instruments for N and P cycling affect the sustainability goals and operation of farms and firms.
- *Identifying options for achieving the objectives: How* new environmental policy options affect governance units of N and P cycling.
- *Identifying the criteria to be used to compare the options*: Selection the criteria to reflect performance in meeting the objectives.
- *Assessment of the options*: What is the influence of the selected instrument on the governance unit? The impacts may have a positive, negative, zero effect or have a partial or conditional effect.
- *Making proposal*: How different economic instruments affect governance structures, hotspots and sectors. Where can the most positive effect be identified on different governance units?

At this purpose, a performance matrix (or consequence table) is used. Each column represents an economic instrument, and each row corresponds to the performance of the governance options against each assessment criteria. The matrix entries assess how each instrument performs against each criterion. The individual performance assessments in the case are expressed as 'bullet point' scores (*+ positive impact, - negative impact, o no impact, ∞ partial or* conditional impact) (Table 10).

5.a Defining objectives

The main purpose of this task is to define economic incentives and disincentives of instruments identified to assist public and private entities to take up financial solutions tailored to their needs. The goal is to encourage sustainable, circularity sound and efficient nutrient management. More closely, the aim is to identify which governance targets (N and P-related objects of regulations) need to be addressed by economic policy instruments.

5.b Identifying options and governance units

Policy options have been identified to address N and P fertilizers, fertilization and associated losses. Building on findings of the literature review (Heyl et al. (2012); Hasan et al. (2019); Brownlie et al. (2022); Gaske et al. (2025)) the assessment criteria and description of N and P management the identified governance units are as follows (Figure 3).

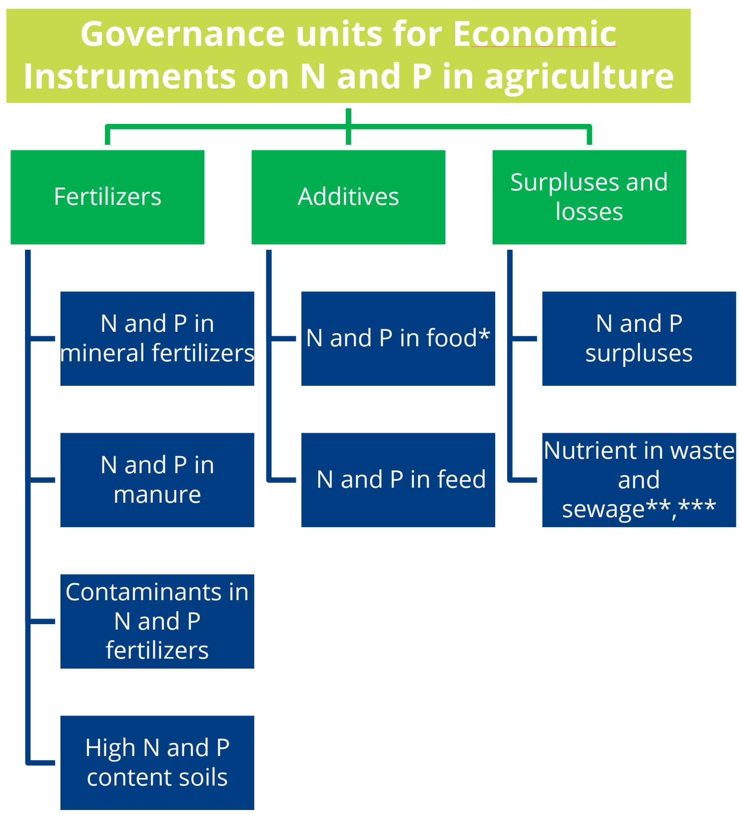

Figure 3. Governance units for Economic Instruments on N and P in agriculture. byproducts in Danube region; ** new fertilizers from manure in Ebro basin; *** composting sewage sludge in Lielupe.*

5.c Criteria for comparing options

Economic instruments applied to N and P should aim at enhancing nutrient use efficiency in various areas of nutrient use; reducing surpluses; nutrient imports minimisation; circular economy; sustainable agriculture and climate and biodiversity-related objectives. Based on Hassan et al. (2022) and Garske et al. (2025) the assessment criteria for sustainable P and N management have been identified. The sustainability criteria of strengthening the N-fixing crops in sowing structure represents a slight difference between N and P options (Table 9).

Table 9. Description of criteria; Source: own results based Garske et al. 2025

<table>
<tr><th colspan="2">N and P use efficiency</th></tr>
<tr><td>• Promotion of efficient, needs-based, site- and crop-specific fertilization and N-mobilizing management strategies based on nutrient management plan
• Reduction of N fertilization at highly supplied soils
• Avoidance of N losses
• Enhancement of N efficiency in animal feeding and soils</td><td>• Promotion of efficient, needs-based, site- and crop-specific fertilization and P-mobilizing management strategies based on nutrient management plan
• Reduction of P fertilization at highly supplied soils
• Avoidance of P losses
• Enhancement of P efficiency in animal feeding and soils</td></tr>
<tr><th colspan="2">N and P surpluses</th></tr>
<tr><td>• Reduction of eutrophication risk by N surpluses at farm and regional level</td><td>• Reduction of eutrophication risk by P surpluses at farm and regional level</td></tr>
<tr><th colspan="2">Fertilizer import dependency</th></tr>
<tr><td>• Minimization of N imports from other countries and saving N resources</td><td>• Minimization of P imports from other countries and saving P resources</td></tr>
<tr><th colspan="2">Circular economy</th></tr>
<tr><td>• Substitution of fertilizers containing N with organic fertilizers and recovered N
• Enhancing N-fixing crops in crop rotation
• In particular: promotion of N recycling</td><td>• Substitution of fertilizers containing rock phosphate with organic fertilizers and recovered P
• In particular: promotion of P recycling</td></tr>
<tr><th colspan="2">Sustainable Agriculture</th></tr>
<tr><td>• Compliance with climate and biodiversity goals of Paris Agreement and Convention on Biological Diversity
• In particular: increasing linking of livestock and arable farming and promoting organic farming and other agro-ecological production methods</td><td>• Compliance with climate and biodiversity goals of Paris Agreement and Convention on Biological Diversity
• In particular: increasing linking of livestock and arable farming and promoting organic farming and other agro-ecological production methods</td></tr>
</table>

Source: Own design based on Gaske et al. 2025

5.d Assessment and trade-offs

The following table (Table 10) illustrates the impact of economic instruments applied to different governance units on the assessment criteria presented for nutrient management. Each row represents a performance criterion (e.g., nutrient use efficiency, circularity, sustainability), and each column reflects a governance unit or source relevant to nutrient management. The matrix uses a qualitative scoring system: + positive impact; – negative impact; 0 no impact; ∞ partial or conditional impact. These ratings are based on expert knowledge and literature findings (Gaske et al., 2025) and serve as a basis for further discussion and refinement.

Table 10. The impact of economic instruments applied to different governance units.

Assessment criteria	Nutrient use efficiency	Nutrient surpluses	Nutrient import dependency	Promoting circular economy			Sustainable agriculture		
	Promoting efficient, site adapted & needs-bases fertilization	Avoiding hotspots and eutrophication of water bodies	Reducing import from other countries	N and P from recyclates	N fixation	Promoting organic fertilizers	Organic farming	Linking livestock and arable farming	Biodiversity
Rock phosphate and N production raw material									
Fertilizers									
N and P in manure/ organic fertilizer									
Nutrient input in highly supplied soils									
Nutrient in food									
Nutrient additives in feed									
N and P in waste streams&sewage									

Source: Own design based on Gaske et al. 2025; + positive impact - negative impact 0 no impact ∞ partial or conditional impact

In addition, Table 11 includes a collection of questions to support decision-making. These questions help determine whether a given instrument has a clear positive, negative, or neutral impact on each governance unit. These questions are intended to understand impacts on rock phosphate or N fertilizer use, however the manure, inputs in highly supplied soils, food and feed additives, surpluses and waste streams and sewages. Questions for further consideration are also included. For answering, thus making decisions about effects of economic instruments for traceability and justification purposes replication, a new table for every assessment criterion is recommended. The table with answers may help to comment the difficulties of introducing a new governance structure, organic and conventional differences, pricing effects and the relevance of the questions for sectors not affected.

Some of the questions may clarify challenging parts of the regulations, eg. economic instruments addressing rock phosphate differ from conventional to organic farming, because only soft ground rock phosphate use is allowed in organic farming (Annex II Commission Implementing Regulation (EU) 2021/1165). The questions may denote to preferred or linking of sectors contribute better for environmental sound nutrient management. Interactions between nutrients are an important part of the evaluation, as noted by Bernhardt (2013). Phosphorus reduction should be approached carefully because interactions between phosphorus and nitrogen can inhibit the capacity of lakes to denitrify when input phosphorus loads are reduced—thus inadvertently increasing nitrogen loads delivered to coastal waters. Therefore, there is a high substitution potential for rock phosphate with recycled P from waste streams or organic P fertilizers that can be both, animal-derived or plant-based.

Table 11. Impact on assessment criteria for sustainable N and P management

Assessment criteria ***(for criteria to find the relevant questions)***										
Nutrient efficiency	**Nutrient surpluses**	**Import dependency**	**Promoting circular economy**			**Sustainable agriculture**				
Promoting efficient, site adapted and needs-bases fertilization	Avoiding hotspots and nitrate accumulation of water bodies	Reducing P import from other countries	N and P from valorised wastes	N fixation	Promoting organic fertilizers	Organic farming	Linking livestock and arable farming	Biodiversity		
Nutrient efficiency										
• How does the higher cost for fertilizers affect the business model? • In which sector does the effect occur?										

Nutrient surpluses
• When does overfertilizing occur? • Are nutrient hotspots affected by instruments?
Import dependency
• Could economic instrument make imports more/less attractive? • Is there any effect on options by the economic instrument? • Do higher prices increase the use of a cheaper product? • Do P additives in feed limit the import dependency?
Promoting circular economy
• Are organic and recycled fertilizers that substitute fertilizers promoted? Do higher prices for rock phosphate put them in a better competitive position? • Are other organic fertilizers apart from manure affected by EI, as an important part of the circular economy? • Is there a higher demand for recycled fertilizers due to high manure prices? Do low inorganic fertilizer prices affect the demand for recycled phosphate additives?
Sustainable agriculture
• Are organic and recycled fertilizers that substitute N or PR fertilizers being promoted? Do higher prices for rock phosphate put them in a better competitive position? • Are other organic fertilizers apart from manure affected by EI, as an important part of the circular economy? • Is there a higher demand for recycled fertilizers due to high manure prices? Do low inorganic fertilizer prices affect the demand for recycled phosphate additives?
Further consideration
• For rock phosphate regulation, global governance is required • Combined taxation on fertilizers appears effective, which likely induces positive effects on eutrophication and on climate protection as demand for energy- and emission-intensive synthetic N fertilizers declines. • The import, sale or purchase of all N or RP fertilizers, regardless of their origin, is subject to a quantitative limitation • A tax levied only on the purchase of farm manure does not consider large manure quantities produced on farms with high livestock numbers • Manure and organic fertilizers being heterogeneous, an accurate quantification of P content and hence taxation is challenging • Pricing P input on highly supplied soils fails because measurement effort of soil P content is very high. Enforcement issues and administrative burdens are enormous • Pricing P surpluses is too complex for existing administrative habits • A tax on P content in wastewater and waste from households, companies along the food value chain, farms, biogas production and industry limits N and P losses and thus enhances overall P use efficiency, but without impacting N and P fertilization • For point sources such as wastewater treatment plants, trading in pollution rights appears conceivable

- Economic instruments for N and P in sewage and waste should be combined with an obligation to recover N and P from these waste streams for the production of N and P recyclates

Source: Own design based on Gaske et al. (2025)

5.e Making a proposal

The final stage of the decision-making process is to formulate a recommendation based on the analysis of trade-offs. This involves:

- Identifying which economic instruments provide the greatest positive impacts across governance units.
- Highlighting where effects are concentrated or distributed (e.g., by sector, region, or production system).
- Recognizing that optimal policy mixes often require combining economic and regulatory instruments.

The tool offers a structured way to support decision-making on N and P management, aligning with broader goals like the right to food, climate action, and biodiversity conservation. However, there is no "one-size-fits-all" solution. Nutrient governance must be context-specific, and decisions should be adapted to the needs and constraints of different actors.

Following Multiple-criteria decision analysis (MCDA) principles (see more information in Annex), the final decision-making may sometimes be taken by officials and sometimes by Ministers, depending on its political content. The role of the NENUPHAR project is to provide interdisciplinary insights and support a multi-stakeholder governance approach to nutrient management.

5.f Examples of weighting proposals by waste

In order to illustrate how weighting criteria may vary across sectors and pollution sources, the following tables provide examples of weighting proposals for three key nutrient sources: the milk processing industry, pig manure, and sewage sludge (Table 12, Table 13, Table 14). These weights are based on expert judgement and literature synthesis and are intended as discussion starters within the context of WP 5. While indicative, these values highlight sector-specific priorities and trade-offs that can support targeted policy design.

Table 12. Weighting criteria for milk processing industry

Milk processing industry			
Assessment criteria	Weight	Explanation	Sources
Promoting efficient, site-adapted, needs-based fertilization	5%	While this mainly applies upstream (e.g. feed production), effluent and sludge from milk processors can be reused as fertilizer. Indirect relevance through landscaping or site greening.	Velasco-Sánchez et al. (2025), Garske et al. (2021), Saliu & Oladoja (2021), Kolev Slavov (2017), Ashekuzzaman et al. (2020), Stasinakis et al. (2022), Schoumans et al. (2015), Kleemann et al. (2015), De Boer et al. (2018), McIntosh et al. (2022), Walsh et al. (2022), Giulianetti de Almeida et al. (2023), Pires et al. (2021), Rebouillat & Ortega-Requena (2015), Einarsson et al. (2018), Spears et al. (2003), Kwapinska et al. (2023), Hu et al. (2021), Mabrouk et al. (2023), Linehan et al. (2024), Schwendel et al. (2015), Chmelíková et al. (2021), Watson et al. (2019), Alderkamp et al. (2025), Reinsch (2021)
Avoiding hotspots and nitrate accumulation in water bodies	25.0%	Wastewater from milk processing plants can contribute significantly to nutrient loading in surface waters, leading to eutrophication. Preventing nutrient pollution aligns with water quality regulations.	
Reducing P import from other countries	10.0%	An indirect, national-level benefit resulting from the successful recovery and reuse of P that can displace synthetic P use. Its relevance is higher upstream at the farm/feed level.	
N and P from valorised wastes	25.0%	The milk processing industry generates nutrient-rich effluents (whey, wastewater with N and P). Valorisation (e.g. anaerobic digestion, struvite recovery) is crucial for nutrient recovery and circularity.	
N fixation	2.5%	Minor relevance, as the aim is to recover excess N from organic waste, not to fix more from the atmosphere. Contradictory results on the impact of organic waste materials on crops' N fixation.	
Promoting organic fertilizers	12.5%	Encourages using dairy processing sludge instead of synthetic inputs, aligning with circular economy.	
Organic farming	5.0%	Benefits nutrient cycling and lowers synthetic fertilizer reliance but is an upstream (farm) measure. While processors can serve organic markets, the decision-making for organic practices occurs at the farming level. However, processors may support it through sourcing or labeling.	
Linking livestock and arable farming	5.0%	Potential to return nutrients back to farms via processed by-products. Applies primarily to integrated farms, less to independent processing facilities.	
Biodiversity	10.0%	Mitigating nutrient pollution aids biodiversity (reduces eutrophication and species loss).	

Table 13. Weighting criteria for pig manure

Pig manure			
Assessment criteria	Weight	Explanation	Sources
Promoting efficient, site-adapted, needs-based fertilization	15.0%	Pig manure is highly variable in nutrient content and prone to overapplication. Efficient supply tailored to crop needs minimizes runoff and improves nutrient use efficiency. Ensuring manure nutrients are applied at the right rate, time, and place is fundamental.	Möller & Müller (2012), Goulding et al. (2007), Antolín-Rodríguez et al. (2019), Izmaylov et al. (2022), Jones et al. (2018), Aneja et al. (2024), Bouraoui & Grizzetti (2011), Delin et al. (2024), Jongbloed & Lenis (1998), Garske & Ekardt (2021), Luostarinen et al. (2020), Molina-Moreno et al. (2017), Hollas et al. (2022), De Vrieze et al. (2019), Liebetrau et al. (2021), Matiz-Villamil et al. (2023), Howe et al. (2024), López Fenández et al. (2023), Rayne & Aula (2020), Kamilaris & Prenafeta-Boldú (2021), Yost et al. (2022), Reganold & Wachter (2016), Seo et al. (2017), AHDB (2018), Beily et al. (2023), Köninger et al. (2021)
Avoiding hotspots and nitrate accumulation in water bodies	20.0%	Concentrated pig production can lead to nitrate leaching into groundwater and eutrophication of water bodies. Reducing nutrient overload in vulnerable areas is paramount.	
Reducing P import from other countries	5%	Less directly relevant to pig manure treatment itself, though some treated manure products can partially replace imported P.	
N and P from valorised wastes	15.0%	Pig manure treatment technologies like anaerobic digestion or struvite recovery can recover both N and P. By recycling nutrients from manure, waste can be reduced and the need for synthetic fertilizers decreases.	
N fixation	2.5%	Minor relevance, as the aim is to recover excess N from organic waste, not to fix more from the atmosphere. Contradictory results on the impact of organic waste materials on crops' N fixation.	
Promoting organic fertilizers	12.5%	Treated pig manure is a key organic fertilizer. Its outcomes (nutrient efficiency, reduced imports, etc.) overlap with other criteria.	
Organic farming	5.0%	Organic agriculture emphasizes improving the soil with compost additions and animal and green manures. Pig manure can be used in organic systems under restrictions. Processes that effectively eliminate pathogens and stabilize nutrients are required.	
Linking livestock and arable farming	15%	Closing nutrient loops by redistributing pig manure to arable land (e.g. manure transport schemes, nutrient trading between regions) improves circularity and reduces regional nutrient imbalances.	
Biodiversity	10%	Nutrient overload from untreated manure can cause eutrophication in aquatic ecosystems and alter plant communities on land, leading to loss of species.	

Table 14. Weighting criteria for sewage sludge

Sewage sludge			
Assessment criteria	Weight	Explanation	Sources
Promoting efficient, site-adapted, needs-based fertilization	10.0%	Precision application of treated sludge (at the right rate, time, and place) aligns nutrients with crop demand. However, precise control is harder compared to synthetic fertilizers.	Foley et al. (2012), UK Government (2018), Rengel (2020), Bornø (2023), Markowicz et al. (2021), Karlsson (2019), Lebeau (2023), EPA (2025), Leino et al. (2025), Hough (2024), Kominko et al. (2024), Jumasheva et al. (2023), Fijalkowski et al. (2017), EC (2017), Rasinger (2021), Liu et al. (2025), Fernando-Foncillas et al. (2021), Kwapinski et al. (2021), Egle et al. (2016), Di Costanzo et al. (2021), Shaddel et al. (2019), Sugurbekova et al. (2023), Seleiman et al. (2020), Campos et al. (2019), Balkrishna et al. (2025), Mabrouk et al. (2023), Alford (2021), Buckwell & Nadeu (2016), USDA (2015), Calmels (2022), FAO/Pescod (1992), EEA (2024), Fernández-Marcos (2024), Deshoux et al. (2023)
Avoiding hotspots and nitrate accumulation in water bodies	20.0%	Poorly managed sludge spreading can lead to nitrate leaching and eutrophication. Preventing regional nutrient hotspots and nitrate pollution in water bodies is critical for environmental and human health.	
Reducing P import from other countries	15.0%	P from sludge is a substitute for mineral P fertilizers, reducing import dependencies.	
N and P from valorised wastes	25.0%	Sewage sludge is a key source of recoverable nitrogen and phosphorus, with several existing or emerging recovery technologies.The process must also ensure that the resulting product is not laden with contaminants.	
N fixation	2.5%	Minor relevance, as the aim is to recover excess N from organic waste, not to fix more from the atmosphere. Contradictory results on the impact of organic waste materials on crops' N fixation.	
Promoting organic fertilizers	5.0%	Sewage sludge itself, when properly processed to meet safety standards, can be an effective P-rich fertilizer or soil conditioner. Sludge-based products like struvite and composted biosolids are slow-release organic fertilizers.	
Organic farming	2.5%	Use of sewage sludge in organic farming is restricted or excluded by most organic certification bodies due to contaminant concerns. Emerging technologies for nutrient extraction and purification may enable future compatibility with organic standards.	
Linking livestock and arable farming	5.0%	The separation of animal and crop production has led to nutrient deficits in arable farming, often compensated with mineral fertilizers. Sludge-derived products can help close this gap by reconnecting urban nutrient sources with agricultural land.	
Biodiversity	10.0%	Impact on soil microbiota and plant diversity depends on sludge quality: can be positive (organic matter, microbiome) or negative (nutrient pollution, contaminants).	

These weights are not definitive but serve as a preliminary framework for discussion among stakeholders and experts. Their inclusion here aims to anticipate questions or gaps that might emerge during partner reviews or during the elaboration of WP5.

6. Conclusion

Environmental policy has undergone significant transformation over the past few decades, shifting from rigid, top-down regulation to more flexible, mixed-instrument approaches. Traditionally dominated by command-and-control tools, such as bans and technical standards, environmental governance increasingly relies on market-based incentives and informational strategies to address complex, evolving challenges like pollution, biodiversity loss, and climate change.

This shift is largely driven by dissatisfaction with the inefficiency and innovation-stifling nature of pure regulation. As a result, contemporary policy frameworks often combine economic instruments (like taxes, subsidies, and tradable permits), informational tools (such as disclosure requirements and labelling), and voluntary agreements, allowing for more tailored, cost-effective, and adaptable interventions.

The European Union exemplifies this evolution. Early environmental policies, like the Habitats Directive, relied heavily on regulation. Newer frameworks, like the Timber Regulation and the Water Framework Directive, emphasize due diligence and place greater trust in non-state actors, leveraging their capacity through certification schemes, learning networks, and self-regulation. These "policy mixes" are now central to managing complex systems, combining clear regulatory baselines with incentives that promote innovation and stakeholder engagement.

Despite this diversification, regulation remains foundational, particularly for setting minimum standards and creating a level playing field. Ultimately, environmental protection can neither be left entirely to free markets – due to inadequate incentives – nor fully controlled by the state, given bureaucratic limits. Effective policy must navigate between these extremes, integrating instruments that balance coercion, flexibility, efficiency, and accountability.

Economic instruments have emerged as key policy tools for promoting environmental sustainability by influencing behaviour through market-based mechanisms. These tools – such as taxes, tradable permits, deposit-refund systems, subsidies, and voluntary approaches – aim to internalize environmental costs and provide flexible, cost-effective, and innovation-friendly alternatives to traditional regulation.

These mechanisms are particularly relevant for managing nutrient pollution from agriculture, where nitrogen (N) and phosphorus (P) surpluses have caused widespread environmental harm. While Europe has made progress reducing nutrient surpluses since the 1990s, global fertilizer use continues to rise, especially in major agricultural economies like China and Brazil. Effective nutrient management must therefore integrate multiple instruments, combining regulation with financial incentives to reflect regional needs and ecological realities.

Some promising approaches are:

- Fertilizer taxes, proved successful in reducing nitrogen use in countries like Sweden and Austria.
- Feebate systems, which reward efficient use while penalizing overuse, adapted to local nutrient baselines.

- Nutrient Recovery and Reuse (NRR) strategies, which support circular economy goals by converting waste into fertilizer.

It is important to remark that incentive-based policies tend to outperform purely punitive ones. They do not only encourage behavioural change and innovation but also enable stakeholders to choose compliance methods that suit their specific contexts. However, the effectiveness of these tools requires robust data, harmonized regulations, and stakeholder engagement, particularly to overcome barriers in scaling circular nutrient technologies and addressing fragmented governance.

A transition toward sustainable nutrient management, and by extension, climate objectives and SDGs, will depend on better coordination between policies, institutions, and actors, as well as sustained investment across the life cycle of innovations, from development (via public grants) to commercialization (via strategic financing).

Subsidies play a complex role in environmental policy. They are commonly used to incentivize environmentally beneficial behaviours by offering financial support, such as grants, tax breaks, soft loans, and feed-in tariffs, but they can also generate unintended consequences. While subsidies are politically attractive (“carrots” rather than “sticks”) and can correct market failures or support underfunded green initiatives, they often fall short of aligning with the "polluter pays" principle and risk rewarding actions that would occur without incentives, thereby wasting public resources.

Globally, many environmental subsidy programs aim at reducing nutrient pollution and promoting a sustainable agriculture. The EU’s Common Agricultural Policy (CAP), for instance, links payments to environmental practices (e.g., crop diversification and precision farming), while additional EU and national funding supports technologies like phosphorus recovery and anaerobic digestion. Countries including the UK, US, Canada, and China have implemented similar schemes, often achieving measurable environmental improvements, as in the U.S. EQIP program which has notably reduced nutrient loads in waterways.

Still, subsidies can reinforce harmful practices, such as fossil fuel extraction or intensive agriculture, creating entrenched interests that resist reform. This persistence, referred to as "zombie subsidies", poses a barrier to sustainability and distorts competition in international trade. Reforms are proposed to repurpose such subsidies, namely implementing nitrogen surcharges or shifting funds toward sustainable agricultural practices, but remain politically difficult due to the concentrated benefits and diffuse societal costs.

Effective subsidy design is critical. Best practices include clearly defined environmental goals, result-based payment models, strong monitoring mechanisms, and attention to additionality. Payment for Ecosystem Services (PES) and hybrid models are gaining traction, offering frameworks that balance environmental effectiveness, cost-efficiency, and farmer participation.

Cap-and-trade programs and nutrient trading schemes have increasingly emerged as market-based tools to manage environmental pollution, especially in the water and air sectors. These systems work by placing a cap on total emissions or discharges, allocating a fixed number of permits or credits, and allowing entities to trade them, thereby creating financial incentives for pollution reduction.

In the context of water quality, nutrient trading allows polluters to meet regulatory obligations by purchasing credits generated by others who reduce nutrient runoff. This can involve bilateral trades, central clearinghouses, open exchanges, or the use of third-party brokers to facilitate transactions.

Multiple case studies illustrate the diverse implementation of these instruments:

- NutriTrade (Baltic Sea) piloted voluntary nutrient offsets across Finland, Sweden, and Estonia, demonstrating cross-border trading and cost-effective nutrient reductions through practices like gypsum field applications and mussel farming.
- In Canada, Ontario's Lake Simcoe Protection Plan enforces a zero-net phosphorus load rule for new developments, achieved through purchase of retrofit project credits facilitated by local authorities.
- Clean Water Services in Oregon offsets point-source thermal and nutrient discharges via stream restoration projects that both improve water quality and meet regulatory requirements at lower cost.
- Lake Taupō in New Zealand implemented the world's first agricultural nitrogen cap-and-trade system, assigning and trading nitrogen discharge allowances among farmers, effectively curbing diffuse pollution through market incentives.
- Unitywater in Queensland, Australia, opted for regulated nutrient offset projects like riverbank restoration over costly sewage plant upgrades, successfully offsetting nitrogen loads from population growth.
- In England, legally mandated Nutrient Neutrality programs require residential developments to avoid increasing nutrient loads into water bodies, with commercial providers now offering verified credits to developers, transferring long-term environmental liabilities.

While these systems offer scalable and flexible means to meet environmental goals, their success hinges on robust regulatory frameworks, accurate monitoring, and sufficient market participation. When well-designed, they can reduce costs, drive innovation, and deliver measurable environmental benefits, though challenges like permit oversupply, enforcement gaps, and variable national policies still pose barriers to global effectiveness.

Fertilizer taxes, as economic instruments, have demonstrated potential to reduce nutrient pollution, particularly nitrogen and phosphorus emissions, by internalizing environmental externalities and altering producer incentives. Evidence from various countries, including Sweden, Austria, Finland, Denmark, and the Netherlands, shows that such taxes can lead to measurable reductions in fertilizer use, improve nutrient efficiency, and stimulate environmentally conscious behaviour among farmers.

For instance, Sweden's fertilizer tax (1984–2009) resulted in a 50% reduction in phosphate fertilizer use and a 6% drop in nitrogen use, amounting to roughly 10,000 tonnes per year, while cadmium content in phosphorus fertilizers was significantly curtailed. Austria's tax led to a 17% decrease in nitrogen use in its first year, and Finland's tax saw nitrogen use decline by 11%, with fertilizer prices rising by 62%. Denmark combined taxes with mandatory fertilizer planning and reporting, leading to a 30%+ reduction in nitrogen use without compromising yields.

The effectiveness of these taxes depends on their design. Variable or pollution-based tax schemes tailored to environmental targets tend to yield the highest net benefits, as shown in modelling studies (e.g., Kim et al., 1999; Gazzani, 2017). However, since demand for fertilizers is typically price inelastic, high tax rates are usually required to achieve significant environmental outcomes. This poses risks: higher food prices, reduced competitiveness in the agricultural sector, and potential income losses for farmers, particularly in lower-income groups.

To address this, successful implementations often combine fiscal instruments with regulatory measures, education, and targeted compensation schemes. Redirecting tax revenues to support farmers adopting greener practices helps mitigate economic drawbacks while enhancing policy acceptance. Moreover, administrative simplicity and alignment with broader environmental and agricultural policies, such as the EU Nitrates Directive, is crucial for effectiveness and political feasibility.

In summary, while fertilizer taxes alone may not be a silver bullet, when integrated into a comprehensive policy package, they can significantly contribute to reducing agricultural nutrient pollution, incentivizing innovation, and promoting sustainable land use practices.

The financing landscape in the EU agri-food sector, particularly for green and circular economy (CE) investments, is characterized by substantial unmet demand and structural challenges, especially for small and medium-sized enterprises (SMEs). In 2022, EU agriculture faced a financing gap of €62.3 billion, an increase of 33% since 2017, driven largely by higher loan demand, larger loan sizes, and demographic shifts favouring large farms, even though small farms comprised 75% of EU farms and accounted for 61% of the financing gap. SMEs, especially small farms and agri-food businesses, continue to struggle with access to long-term loans due to perceived higher risks.

Green investments face similar barriers. In 2022, green financing gaps amounted to €18.9 billion for farmers and €1.3 billion for agri-food enterprises. Priority areas include sustainable irrigation, energy efficiency, waste reduction, and renewable energy. Despite the growing policy focus, access to affordable long-term credit for these investments remains limited, especially given rising interest rates and market uncertainty caused by geopolitical and macroeconomic tensions.

The EU has attempted to address these challenges through regulatory frameworks like the Taxonomy Regulation, which provides criteria to define environmentally sustainable activities and reduce greenwashing risks. Instruments such as green bonds, green loans, and green equity investments are increasingly used to direct capital towards sustainable projects. However, these tools are still underutilized, green bonds accounted for just 6.8% of the EU bond market in 2023, and the private sector remains hesitant due to high risks, complex reporting standards, and the novelty of circular models.

The transition to a circular economy intensifies these financing challenges. CE business models carry high upfront costs, unfamiliar risks, and long payback periods, which are poorly matched to traditional financing assessment frameworks. SMEs, in particular, encounter hurdles in collateral access, administrative burden, and lack of tailored financial products. Public sector involvement, including targeted incentives, procurement policy reforms, and tax adjustments, is therefore essential to de-risk CE investments and stimulate capital flows.

The NENUPHAR project's assessment of financial instruments supporting nutrient cycling in agriculture across several European regions reveals a diverse and evolving landscape of public and private initiatives aimed at reducing nitrogen (N) and phosphorus (P) emissions. These instruments range from direct subsidies to advanced loan systems and carbon farming incentives.

Germany's Bavaria showcases a structured and accessible ecological subsidy system (Kulap), encouraging sustainable practices with detailed compensation schemes. However, it relies heavily on established advisory infrastructure, which may limit scalability.

Under the Common Agricultural Policy (CAP), EU-wide eco-schemes already promote nitrogen-fixing techniques but suffer from overly complex regulations and insufficient incentives specifically targeting nutrient recycling.

Spain exhibits a robust mix of regional and national financial tools. These include agri-environmental subsidies, preferential loans through institutions like ICF Agroambiental, and funding programs like CDTI's R&D project loans (Proyectos de I+D, CIEN). Spanish initiatives, including the PERTE Agri-food and Circular Economy initiatives, inject significant investment into sustainable innovations. However, high entry costs and administrative hurdles limit access, particularly for SMEs. Additionally, the broader sectoral focus of PERTE may inadvertently deprioritize nutrient-specific projects.

In Slovakia, farmers utilize credit lines and benefit from state aid that primarily targets fuel costs and weather-related damages. Regenerative farming is emerging as a promising model, supported by start-ups like Carboneg offering carbon credits, showing potential for both climate and nutrient benefits.

Initiatives across the board face common barriers: inadequate incentive structures, complex application procedures, and restricted accessibility for smaller stakeholders. Despite these, a clear shift is evident toward integrating environmental goals with financial mechanisms, supporting the EU's push toward a circular and low-emission agricultural model.

The NENUPHAR project identifies significant barriers and opportunities in the shift toward sustainable nutrient management, particularly regarding nitrogen (N) and phosphorus (P) emissions. A major insight from its workshop at the ESNI Conference was the misalignment between EU-wide regulations and local conditions. Uniform, complex policies often hinder innovation, especially threatening the viability of smaller agricultural producers. These actors typically lack the resources to adapt, while the regulatory environment tends to favor larger entities.

A core obstacle remains the absence of strong financial incentives that could drive adoption of alternatives to traditional fertilizers, i.e. those derived from sewage sludge or dairy wastewater. Combined with fragmented legislation and infrastructure limitations, these issues stall the wider uptake of circular nutrient solutions.

To overcome these challenges, the project emphasizes the need for more adaptive and enabling economic tools. Among the most promising are market-based instruments — notably cap-and-trade systems and dynamic quota-tax hybrids. These frameworks treat nutrient emissions as tradable assets or adjustable quotas, incentivizing reductions through flexible, cost-effective means. Such systems reward proactive actors and internalize environmental costs.

The report concludes that linking financial mechanisms to ecological indicators (e.g., eutrophication levels) and offering incentives for nutrient recovery, like tradable credits for recycling businesses, can align environmental objectives with innovation and local development. These instruments, if carefully tailored to regional conditions, could rebalance nutrient cycles, reduce pollution, and foster sustainable agricultural practices across Europe.

The NENUPHAR project presents a structured, multi-criteria assessment tool to evaluate and guide the adoption of economic instruments aimed at improving the governance of nitrogen (N) and phosphorus (P) management in agriculture. The overarching goal is to align N and P use with sustainability, circular economy, and climate-biodiversity objectives.

The assessment framework is built on five key steps: identifying objectives (e.g. promoting efficient fertilization), defining governance units (e.g. fertilizers, manure, food/feed additives), establishing sustainability-driven comparison criteria (e.g. nutrient efficiency, import dependency, circularity), evaluating trade-offs, and proposing policy mixes.

The tool shows that some instruments yield clear environmental benefits:

- Enhanced nutrient use efficiency via site-specific and needs-based fertilization strategies.
- Waste recycling and organic fertilizers improving circular economy performance.
- Linking livestock and arable farming, and promoting organic farming, supporting biodiversity and climate goals.

However, several challenges and limitations are identified:

- Administrative burdens and measurement difficulties for instruments targeting nutrient surpluses or fertilization in nutrient-rich soils.
- Difficulty quantifying the P content in manure-derived fertilizers, complicating taxation.
- Potential unintended consequences, such as changes in lake biochemistry from poorly balanced nutrient management, reinforcing the need for holistic approaches.
- Disparities between conventional and organic farming rules (e.g. rock phosphate use) necessitate tailored regulations.

The analysis stresses that no single economic instrument offers a comprehensive solution across all governance units and sustainability goals. Instead, a policy mix combining economic and regulatory tools is preferred. This mix should be context-sensitive and coordinated across sectors and governance levels to optimize nutrient cycling, reduce eutrophication risks, and mitigate climate and biodiversity impacts.

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8. Annexes

ANNEX 1 Integrated assessment handbook

1. Introduction

The purpose of this tool is to comprise an interdisciplinary proposal for a qualitative governance analysis, aiming to discover and quantify stakeholders' and decision-makers' considerations about various non-monetary factors to compare different instruments related to N and P management. It aids in assessing economic instruments (e.g., taxes, subsidies) and emerging criteria by comparing them across multiple criteria such as nutrient use efficiency, import dependency, circular economy and sustainability in managing nutrient cycles. The end users of the analyses will be the demo site corporate decision makers. However, public policy can also utilize the results to decide which instrument fits better to their needs.

The N and P cycles are central to environmental sustainability, and this tool can help policy actors, corporate decision makers, economic, innovation and technology expert stakeholders related to agriculture, water quality protection, wastewater and sludge management to evaluate strategies across several key application areas.

2. Methodological Background

Multiple-criteria decision analysis (MCDA), also known as multi-criteria decision making (MCDM), is a structured methodological framework used to evaluate, prioritize, and select among alternatives involving multiple, often conflicting, criteria. MCDA helps decision-makers systematically compare diverse policy or management instruments, balancing trade-offs across economic, environmental, social, and institutional dimensions. (Ren, 2020; Prato & Herath, 2007; Linkov et al., 2006)

When designing a tool for interdisciplinary governance analysis – especially to compare instruments for N and P management across non-monetary criteria – selecting an appropriate weighting method is crucial. Stakeholder's scores and weights are combined to produce an overall ranking of instruments: each governance instrument is assessed against all criteria using scales (quantitative or qualitative). Alternatives are ranked, with explicit representations of trade-offs and sensitivities to changes in weighting or data. This guide introduces the weighting and evaluation methods only briefly. For detailed information on these techniques the deeper investigation of literature is recommended.

3. Step-by-Step Guide to Using the Tool

1. *Define the problem*

Proposals for new fiscal and other economic incentives and disincentives are required to assist public and private entities to take up financial solutions tailored to their needs and with the goal to encourage environmentally sound and efficient nutrient management. At this purpose, an integrated assessment tool supports the entities and policymakers to consider all necessary parameters for choosing the most appropriate solutions.

2. Stakeholder involvement

Stakeholders are individuals, groups, or organizations who have an interest or influence in a project or decision. Actors, from corporate decision-makers at demo sites to public policy bodies, need to balance nutrient use efficiency, circular economy aspects, and sustainability – none of which can be measured in purely financial terms.

MCDA systematically incorporates stakeholder and decision-maker preferences when evaluating various governance instruments, promoting legitimacy and acceptance. The phase of stakeholder engagement includes collecting qualitative stakeholder opinions, perceptions, and preferences, when criteria weights are established through participatory processes (workshops, surveys, expert panels), reflecting the relative importance assigned by stakeholders. It is followed by translating qualitative feedback into quantitative measures (e.g., via scoring, weighting, ranking).

3. Identify alternatives

Among the economic instruments available, market-based mechanisms such as cap-and-trade systems and dynamic quota-tax hybrid models were chosen for evaluation, as they offer flexible, cost-effective approaches to regulate nutrient emissions while promoting innovation in N and P circular economy:

- *Cap-and-trade for Nitrogen management*
- *Dynamic quota and tax hybrid system for Nitrogen management*
- *Cap-and-trade for Phosphorous management*
- *Dynamic quota and tax hybrid system for Phosphorous management*

4. Establish evaluation criteria

The evaluation of the expected impact of different economic instruments, i.e. flexible quota and taxes or cap-and-trade systems, against the specific assessment criteria for N and P management apply. The selection of the evaluation criteria is based on scientific literature on potential N and P governance problems and sustainable N and P management as well as on N and P use.

For answering the questions, expert involvement is required. An expert is defined as someone who is knowledgeable in the field at the level of detail being elicited. In this project, experts represented different academic fields within the social, economic and food sciences. For assessment purposes see the questions Table 11.

5. Assign weights to criteria

The following weighing methods are widely recognized for their suitability in MCDA, sustainability assessments, and stakeholder-driven governance evaluations:

- *Direct rating* is a weighting approach where stakeholders assign weights directly to criteria on a pre-defined scale (e.g., 0–10, 0–100). *Points Allocation* requires stakeholders to distribute a fixed number of points (e.g., 100 points) across different criteria according to their importance. (Keeney & Raiffa, 1993; Belton & Stewart, 2002; Dodgson et al., 2009; Doyle et al., 1997)
- *Swing weighting* helps stakeholders and decision-makers express the value they place on improving each criterion from its worst to its best possible level ("swing"). This method makes trade-offs explicit and is especially valuable when criteria differ in scale, units, or impact. (Keeney & Raiffa, 1993; Belton & Stewart, 2002; Dodgson et al., 2009; Goodwin & Wright, 2014)
- *Analytic hierarchy process (AHP)* enables decision-makers to break down a complex problem into a hierarchy of goals, criteria, sub-criteria, and alternatives. The method uses pairwise comparisons to derive quantitative weights for each criterion, reflecting their relative importance based on stakeholder judgments. (Saaty, 1980, Saaty & Vargas, 2012; Schmoldt et al., 2001)
- *Simple multi-attribute rating technique (SMART)* is a linear additive method designed to help decision-makers assign weights to criteria and score alternatives in a transparent, straightforward way. Each criterion is assigned a weight reflecting its relative importance, and each alternative is rated for its performance on each criterion. The overall value of each alternative is calculated as the weighted sum of its scores across all criteria. SMARTER (Simple Multi-Attribute Rating Technique Exploiting Ranks) is a streamlined version of SMART, designed to reduce cognitive burden by relying on rank order rather than direct weight assignment. (Edwards & Barron, 1994; Taherdoost & Mohebi, 2024)
- *Conjoint analysis* involves presenting respondents with a set of hypothetical scenarios (profiles or alternatives), each defined by different combinations of attributes and levels (e.g., policy instruments with varying impacts on nutrient use efficiency, import dependency, etc.). Respondents evaluate or rank these scenarios, allowing researchers to infer the relative importance (weights) of each attribute. In *discrete choice experiments (DCE)* respondents are asked to choose their preferred option from a set of alternatives in repeated choice tasks. DCEs are grounded in random utility theory and are widely used to estimate the trade-offs stakeholders are willing to make between criteria. (Louviere et al., 2000, 2010; Alriksson & Öberg, 2008)
- *Delphi method's* purpose is to achieve a reliable group consensus on complex issues by gathering and refining expert opinions through several rounds of anonymous questionnaires and feedback. The method is used to determine the relative importance (weights) of various criteria by aggregating the informed judgments of multiple stakeholders or experts. (Linstone & Turoff, 2002; Richey et al., 1985a,b; Lin et al., 2019)
- *Best-worst method (BWM)* streamlines the process of pairwise comparisons by focusing on the most and least important criteria, minimizing cognitive burden and improving consistency compared to traditional methods like AHP. (Rezaei, 2015, 2016; Atan & Temur, 2023)

- *Extended stepwise weight assessment ratio analysis (SWARA)* was originally developed to streamline the weighting process by allowing experts to rank and assess the relative importance of criteria in a stepwise manner. The extended SWARA incorporates enhancements such as handling uncertainty (e.g., fuzzy or interval data), integrating expert reliability, or adapting to group decision-making contexts. (Keršulienė et al., 2010; Zolfani et al., 2018)
- *Entropy weighting* method is grounded in information theory, where entropy measures the degree of uncertainty or disorder in a dataset. In MCDA, it quantifies the amount of information provided by each criterion across alternatives. Criteria with greater variability (dispersion) among alternatives are considered more informative and thus receive higher weights. Unlike subjective weighting methods (e.g., direct rating, Delphi), entropy weighting relies solely on the data, minimizing personal or group bias. (Zhu et al., 2020; Mat Kasim & Jemain, 2020)
- *Summarize the results*

The most effective economic instruments for improving nutrient governance are those that perform highest scores across multiple evaluation criteria, including environmental effectiveness, economic efficiency, administrative feasibility, and social acceptability.

Scores and weights are combined to produce an overall ranking of instruments: each governance instrument is assessed against all criteria using scales (quantitative or qualitative). Alternatives are ranked, with explicit representations of trade-offs and sensitivities to changes in weighting or data.

Techniques used in the evaluation phase of multi-criteria decision analysis provide a clear framework for structuring problem criteria and alternatives, enabling incorporation of decision-makers' preferences through weights, allowing explicit modelling of trade-offs. They are suitable for both quantitative and qualitative criteria as long as scales are appropriately defined. These methods can be applied to both small and large sets of alternatives and criteria. It can be challenging that they require significant data input, including accurate criteria weights and value functions, which can be difficult to obtain. Outcomes depend on how criteria and weights are defined, introducing potential subjectivity and bias. Systematic and precise inputs are demanded, that can potentially be overwhelming for non-expert users.

Some of the well-known evaluation techniques:

- *Multi-attribute value theory (MAVT)* provides a systematic and quantitative framework to compare and rank multiple options when decisions must account for various, often conflicting, criteria. MAVT structures the evaluation process by defining a set of criteria, assigning weights to these criteria according to stakeholder preferences, and scoring alternatives on each criterion. The weighted scores are then aggregated to compute an overall value for each alternative. (Belton, 1999; Jaffar et al., 2014; Angelis & Kanavos, 2017)
- *ELECTRE (Elimination and choice expressing reality)* is used in the scoring phase to establish an "outranking" relation among alternatives by assessing whether one alternative is at least as good as another, considering all criteria. ELECTRE does not simply score alternatives using additive

techniques; instead, it uses pairwise comparisons combined with thresholds and outranking relations to evaluate which alternatives outperform others under uncertainty and imprecise information. It is particularly useful when criteria are not easily aggregated into a single overall score and when uncertainty or conflicting preferences among stakeholders exist. ELECTRE works well with qualitative and imprecise data. It reflects the reality that not all alternatives can be strictly ranked. It applies a non-compensatory logic: significant shortcomings on one criterion are not offset by strengths in others. ELECTRE methods (e.g., ELECTRE I, II, III, TRI) vary in complexity, but all involve deriving outranking relationships among alternatives to inform decision-making (selection, ranking, sorting). (Roy, 1991; Figueira et al., 2005; Govindan & Jepsen, 2016; Taherdoost & Madanchian, 2023)

- *PROMETHEE (Preference ranking organization method for enrichment evaluation)* helps structure and simplify the complex process of scoring and ranking alternatives in MCDA by integrating preference functions, weighting, and visualization tools to support transparent and evidence-based decision-making. In the evaluation phase, PROMETHEE operates by first constructing preference functions for each criterion that quantify the preference of one alternative over another. These preferences are aggregated using criterion weights to compute the positive and negative outranking flows. The final step involves ranking alternatives based on net outranking flows: PROMETHEE I provides a partial ranking with possible incomparabilities, while PROMETHEE II offers a complete ranking by considering net flows. PROMETHEE can integrate both quantitative and qualitative criteria, making it useful for decisions involving mixed data types. PROMETHEE supports graphical tools like GAIA planes and sensitivity analysis features, allowing decision-makers to understand the influence of criteria weights on the final ranking. (Brans & Vincke, 1985; Brans & De Smet, 2016; Wu et al., 2019; Taherdoost, 2023; Pohl & Geldermann, 2024).
- *TOPSIS (Technique for order of preference by similarity to ideal solution)* is applied after defining criteria and assigning weights. It quantitatively scores each alternative by calculating its geometric distance to the ideal (best) and anti-ideal (worst) solutions. The method assumes that the best alternative should have the shortest distance to the ideal solution and the farthest from the anti-ideal one, allowing decision-makers to rank alternatives accordingly. TOPSIS is valued for its clarity and logical consistency in MCDA applications. Its primary strength lies in balancing all criteria to reflect both the best and worst-case scenarios. However, reliance on accurate weight assignments and the need for numerical data input are notable challenges. (Hwang & Yoon, 1981; Behzadian et al., 2012; Zavadskas et al., 2016)

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ANNEX 2 Information from partner

Collected information from partners using pre-structured questions in Excel spreadsheet format.

Excel queries

The wider goal of T4.3 is to collect and evaluate financial instruments related to transition to a circular, low emission agricultural production. The tighter aim of this work and however this Excel querie is to collect relevant information regarding the existing financial instruments to support the reduction of Nitrogen and Phosphorous emissions.
The Data requirements sheet collects information of different financial instruments as loans, insurance tools, taxes which can be directly or indirectly enhance the nutrient cycle of N and P.
We kindly ask project partners to fill the cells taking into consideration, which instruments can be found in their country, furthermore which can be transformed to N and P nutrient cycling. In this view, the policy related and private sectoral tools, can be an important part of evaluation, however pilot or closed instruments too.

Where	Information required	Instructions and further hints
Column A	Economic instruments	The list consist main economic tools existing in agricultural policies and markets. Some of them are stronger relationship with N and P nutrient management, hovewer some of them are far from these goals. Expand or skip the lines, where relevant.
Column B	Title	To a better identification of programmes, please use the accurate country language for titeling
Column C	Country/region	For the easier identification, please, specify the country or region where the instrument is in power.
Column D	Relevance	The dimension of tool can be international (most likely EU), national, regional or local. Please fill the most appropriate category.
Column E	Short description of instrument, relevance in N and P cycles	Please define the instrument choosen.
Column F	Policy background	Legislative document regulating the financial instrument: *law, directive, decision, communication, etc.*
Column G	Success factors	*Opportunities for new financing formulas, income stabilisation, better practices etc.*
Column H	Barriers	*Additional administrative burden, overlapping with other regulations, lack of information etc.*
Column I	Further informations (eg. Website, social media, contacts)	You are expected to fill information of access further information, website, institutions, social media access and contact persons
Column J	Personal experiences, responses from local players	Please leave here your personal experiences and/or further opinions of local players on financial instrument operation
Column K	Comments, limitations	Cells dedicated to write special comments

SPAIN

Economic Instrument (choose from list or, if other, specify)	Title	Country/region	Relevance (choose from list)	Short description, relevance in N and P cycles	Policy background	Success factors	Barriers	Further information (eg. Website, social media, contacts)	Personal experiences, responses from local players	Comments, limitations
Voluntary carbon markets	Carbon credits	Hungary	local	Regenerative farming to enhance carbon sequestration in soil. Nestlé is supporting a programme that includes funding and advice to help farmers transition to renewable farming.	n.r.	funding and advice system for farmers	transform entire landscape systems and regions into soil-renewing agriculture	https://www.nestle.hu/fenntarthatosag/eghajlatvaltozas/talajmegujito-mezogazdasag		
Credit lines/overdrafts	Agrár Széchényi kártya	Hungary	national	It helps micro, small and medium-sized enterprises and primary producers to overcome temporary liquidity problems and cover their unexpected expenses.	n.r.	farmers often use this tool for complement the deductible part of CAP investment	surrounding costs, cumulative costs	https://www.otpagrar.hu/Hitelltermekek/AgrarSzechenyiKartya		
Taxes	Fertiliser tax	Hungary	national	Fertilising products, shall apply to their authorisation, storage, placing on the market and use.	36/2006. (V. 18.) FVM regulation	taxes impose a cost on farms for polluting activities	the mineral fertilizer application should be based on nutrient balance calculation			
Compensation funds	Krizbi (agricultural crisis insurance scheme)	Hungary	national	A farmer who is a member of a crisis insurance scheme shall be entitled to crisis insurance compensation if the conditions are fulfilled. It is a comprehensive risk management tool combining elements of insurance and support.	92/2023. (III. 29.) national regulation	provides financial protection not only against weather damage but also against production, economic and market risks	for access to funding it is necessary to have three year in system the calculation is based a collective, FADN based data	https://www.aki.gov.hu/termek/a-mezogazdasagi-kockazatkezelesi-rendszer-mukodesenek-ertekelese-2022/		
Commercial bank loans	green loans	EU	international (e.g., EU)	Loans for green environmental goals at lower interest rates	Regulation (EU) 2020/852	Banks can provide loans at preferential rates for investments which contribute to green goals	Green loans are not yet widespread. Taxonomy is regulating green loans in Eu, but the necessary technical screening criteria to help clarify the interpretation in agriculture and the food industry have not yet been published. Additional administration for farmers, special expertise for banks is necessery.			
Climate funds		Hungary	national	They look for target companies and investment opportunities that contribute directly or indirectly to achieving sustainability goals, reducing emissions, improving sustainable quality of life, generating renewable energy, increasing efficiency in energy storage, transport, use, solving global water problems, among others.				https://www.klimaalap.hu/		
Climate funds	Just Transition Fund	EU	international (e.g., EU)	Financial instrument within the Cohesion Policy which aims to provide support to territories facing serious socio-economic challenges arising from the transition towards climate neutrality. The Just Transition Fund will facilitate the implementation of the European Green Deal. The financing will be focused on the development of circular economy companies, among others.	Regulation (EU) 2020/0006	Key support to economically depressed regions Boost economic diversification by supporting new green industries in these regions. Highly innovative industrial developments	Heavy reliance of these regions on carbointensive activities. Lack of local stakeholder interaction.	Just Transition Fund		
Long term loans >5 years	CDTI Proyectos de I+D.	Spain	national	Financing of technological innovation projects aimed at incorporating emerging technologies. They support the acquisition of new fixed assets that represents an important technological leap for the company carrying out the project. An example of a project could be the purchase of equipment for the recovery of nitrogen or phosphorus as a valuable raw material.	n.r.	Loans at below-market interest rates to carry out projects with high innovative potential and aligned with EU priorities (green policy).	The high budget proposed may limit the entry of SMEs. Administrative complexity for project application	CDTI - I+D		
Long term loans >5 years	CDTI Programa CIEN	Spain	national	Financing of research projects that allow the development of new products or the improvement of existing equipment are financed. Consortiums of several companies are created for the development of prototypes, for example, for nitrogen and phosphorus recovery.	n.r.	Competitive lending (similar to previous example) Creation of multisectoral collaboration networks (technology centers, universities, agri-food and waste companies, among others) to boost their value chains.	The high budget proposed may limit the entry of SMEs. Complexity of Application Process, e.g. consortium formation. CIEN projects span multiple years, which can result in financial and operational uncertainty.	CDTI Programa CIEN		

Other	PERTE (Strategi	Spain	national	The Strategic Project for Economic Recovery and Transformation in the Agri-food Sector (PERTE Agroalimentario) is a Spanish government initiative aimed at enhancing the competitiveness, sustainability, and resilience of Spain's agri-food sector. By focusing on R&D, circular economy, and digital transformation, this initiative can drive technologies and systems that recover nitrogen and phosphorus, improving resource efficiency, reducing pollution, and supporting a more sustainable agri-food sector in Spain.	Real Decreto-Ley 36/2020	In the first edition (February 2024), 161.6 million euros were awarded in the form of grants and 19.9 million euros in the form of loans. This Agri-Food PERTE combines the expertise of several companies from many sectors with that of technology centres and research centres to improve the sector's value chain. In addition, the financial resources will be of public and private origin and will lead to remedy the market failures and social	The maximum aid per company and project varies depending on the project type, with specific caps for industrial research, experimental development, innovation, sustainability, and SME investments. Beneficiares need to have to include in their propossals some actions related to traceability and food safety.	PERTE Agroalimentario		
Other	PERTE of Circula	Spain	national	Objective: Accelerate the transition to a sustainable and efficient economic model by promoting waste reduction, resource efficiency, and recycling. Scope: Supports projects across various sectors, including agriculture, that implement circular economy strategies. Potential for Nutrient Recovery: Projects focusing on the recovery and reuse of nutrients like phosphorus and nitrogen from agricultural waste streams could align with the objectives of this PERTE, contributing to resource efficiency and environmental sustainability.	n.r.	Investments made in 2022 provided support worth 492 million euros and are expected to mobilise resources in excess of 1.2 billion euros by 2026. With regard to the development of N & P cycling tools, we believe that this instrument can be useful for financing future developments as one of its objectives is to promote sustainability and circularity of production processes to improve the competitiveness and innovation of the industrial fabric within the framework of a circular economy.	The PERTE primarily targets sectors such as textiles, plastics, and renewable energy equipment. Projects centered on nutrient recovery, like phosphorus and nitrogen, may not directly align with these predefined sectors. This focus could limit the eligibility of nutrient recovery projects for funding. With substantial funding available, there is intense competition among projects across various sectors.	PERTE of Circular Economy		
EU EAFRD, CAP support	CAP	EU	international (e.g., EU)	The CAP contributes to the sustainable development of rural areas through three long-term objectives: fostering the competitiveness of agriculture and forestry, ensuring the sustainable management of natural resources and climate action, and achieving a balanced development of rural economies and communities.	The legal basis for the common agricultural policy is established in the Treaty on the Functioning of the European Union. The CAP 2023-27 is covered by three regulations, which generally apply since 1 January 2023: Regulation (EU) 2021/2116 Regulation (EU) 2021/2115 Regulation (EU)	The CAP includes specific agri-environmental measures that encourage sustainable practices, such as crop rotation, wetland conservation, and sustainable water management. 70% of Europeans believe the EU, through the CAP, is fulfilling its role in ensuring a sustainable way to produce food.	**Complex Regulatory Requirements**: CAP's stringent regulations and compliance standards can be challenging for farmers and project developers to navigate, potentially deterring participation in nutrient recycling initiatives. **Insufficient Incentives for Nutrient Recycling**: While CAP includes environmental measures, the specific incentives for recycling nutrients like nitrogen and phosphorus may be inadequate, limiting the adoption of circular practices.	CAP – Common Agricultural Policy		
Credit guarantee bank loans	ICF Agroambien	Catalonia	regional	Loans with preferential conditions to finance sustainability projects, including nutrient management.						
	Support for sust	Catalonia		To promote the rational use of resources by agricultural holdings in order to achieve a higher degree of environmental sustainability. The contribution of production systems such as integrated production and other equivalents reduces soil and water pollution and ensures long-term sustainable agriculture and protection of natural resources.	Common Agricultural Policy (CAP)					
Compensation funds	Agri-environmer	Catalonia								
Compensation funds	Agri-environmental aid for fertilization management	Catalonia	regional	Grants to subsidise the costs of setting up and maintaining advisory services and technical support for sustainable fertilisation.	Commission Regu	Technical support in fertilization				
		Spain	national	Long-term loans for irrigation modernization are	Common					

Compensation funds	Agri-environmental aid for fertilization management	Catalonia	regional	Grants to subsidise the costs of setting up and maintaining advisory services and technical support for sustainable fertilisation.	Commission Regu	Technical support in fertilization				
Long term loans >5 years	Modernization of irrigation systems	Spain	national	long-term loans for irrigation modernization are often supported by government subsidies and incentives to encourage adoption of technologies like drip irrigation and precision agriculture.	Common Agricultural Policy (CAP)					
Long term loans >5 years	Precision agriculture technologies	Spain	national	High-cost technologies like GPS-guided equipment, drones, and sophisticated soil sensors may also necessitate long-term loans to spread the investment cost.	Common Agricultural Policy (CAP)					
Medium term loans 1.5-5 years	Investments in manure management systems	Spain	national	**Government programs may provide financial support** for investments in technologies that reduce nutrient losses from manure, such as anaerobic digesters and	Nitrates directive					

SLOVAKIA

Economic Instrument (choose from list or, if other, specify)	Title	Country/region	Relevance (choose from list)	Short description, relevance in N and P cycles	Policy background	Success factors	Barriers	Further information (eg. Website, social media, contacts)	Personal experiences, responses from local players	Comments, limitations
Compensation funds	Environmental Fund	Slovakia	national	Providing funding to applicants in the form of grants or loans to support projects in the framework of activities aimed at to achieve national environmental policy objectives at national, regional or local level.	Act No. 587/2004 Coll. on environmental fund	Support for addressing environmental problems by providing subsidies in various sub-areas (e.g. including the construction of wastewater treatment plants and public sewerage systems)	The Ministry of Environment annualy limits the list of applicable activities and subjects who can request the support.	https://www.slov-lex.sk/ezbierky/pravne-predpisy/SK/ZZ/2004/587/20240927		
Charges	Charges for the discharge of waste water into surface waters	Slovakia	national	Specifies charges for the discharge of wastewater into surface waters for each pollution indicator based on the concentration and amount of wastewater. The average annual pollution concentrations in abstracted surface waters shall be demonstrated by the polluter by the results of analyses of samples of abstracted surface waters which he shall obtain from the watercourses manager.	GOVERNMENT REGULATION No. 755/2004 Coll. laying down the amount of unregulated payments, the amount of fees	Cost for the amount of produced wastewater.		https://www.slov-lex.sk/ezbierky/pravne-predpisy/SK/ZZ/2004/755/20240309		
Fine	Fine for violation of the Public Water Supply and	Slovakia	national	The state authority imposes a fine if the producer discharges wastewater into surface or ground water without the authority's permission or in bad quality.	Act No. 364/2004	Cost for polluting the surface waters when the limits fefined in Government regulation 269/2010 (line below) are		https://www.slov-lex.sk/ezbierky/pravne-predpisy/SK/ZZ/2004/364/20241025		
		Slovakia	national	Specifies limit values for pollution indicators for sewage effluents, urban waste water and special waters discharged into surface waters or groundwater, in particular for their discharge in	GOVERNMENT REGULATION 269/2010 laying down			https://www.slov-lex.sk/ezbierky/pravne-predpisy/SK/ZZ/2010/269/		
National carbon markets	Carbon credits	Slovakia	local	Regenerative farming to enhance carbon sequestration in soil. Farmers in Slovakia and the Czech Republic also manage their fields successfully using regenerative methods. Farmers who farm in this way are offered financial support by startup Carboneg, which rewards them for every ton of CO2 stored in the soil.	Law no. 414/2012 Coll. on trading with emission quotas Directive 2003/87/EC of the European	funding and advice system for regenerative farming	transform entire landscape systems and regions into soil-renewing agriculture	www.carboneg.eu		In addition to cooperation with farmers, the project also offers support to companies that are already actively reducing their carbon
Credit lines/overdrafts	UniCredit Bank and VÚB Bank	Slovakia	national	Today, the agricultural sector in Slovakia is mainly given credit by two banks: UniCredit Bank and VÚB. Both banks want to help with mediation of financial instruments.	436/2022 Coll. - Regulation of the Government of the Slovak Republic	farmers often use this tool for complement the deductible part of CAP investment	surrounding costs, cumulative costs			Farmers are most looking for long-term loans, which they use to buy land, invest in buildings and new
Taxes	Fertiliser tax	Slovakia	national	Fertilising products, storage, placing on the market and use.	245/2005 Coll. - Decree on the certification of fertilizers	taxes impose a cost on farms for fertiliser application activities, limits and rules	the mineral fertilizer application should be based on nutrient balance calculation	https://www.zakonypreludi.sk/zz/2016-151		legislative conditions on the method of processing the annual balance
Tax reduction		Slovakia	national	CHALLENGES eligible applicants for submitting applications for state aid measures in the form of environmental tax rebates (GREEN OIL 2024). The purpose of the aid is to support primary agricultural production by means of a refund of part of the tax on mineral oils, in accordance with Article 44 of the Commission Regulation. Specifically, the subsidy is to be applied in the amount of the part of the mineral oil tax calculated on the basis of the standardised fuel consumption per hectare of a specific agricultural crop and per livestock unit.	Council Directive 2003/96/EC of 27 October 2003 restructuring the Community framework for the taxation of energy products and electricity	Support in the form of tax reductions under Directive 2003/96/EC (Art. 44) up to 94.29 %	The subject of the scheme is the establishment of conditions for the provision of aid in the form of discounts on environmental taxes according to Directive 2003/96/EC for entities operating in the agricultural primary production sector	https://www.mpsr.sk/sk/index.php?navID=347&id=13887		
Price regulation of drinking water usage and wastewater production		Slovakia	national	Price regulation of the production, distribution and supply of drinking water by public water supply, and disposal and treatment of waste water by public sewerage	Act No. 250/2012 Coll. on regulation in the network			https://www.slov-lex.sk/ezbierky/pravne-predpisy/SK/ZZ/2012/250/		
Climate funds		Slovakia	national	state aid scheme no. SA.54289(2019/XA) to provide a subsidy for the compensation of damages caused by an adverse weather event that can be compared to a natural disaster. but finished in 2023				https://www.mpsr.sk/schema-statnej-pomoci-na-nahradu-skod-sposobenych-nepriaznivou-poveternostnou-udalostou-ktoru-mozno-prirovnat-k-prirodnej-katastrofe/161---14171/		

LATVIA

Economic Instrument (choose from list or, if other, specify)	Title	Country/region	Relevance (choose from list)	Short description, relevance in N and P cycles	Policy background
Medium term loans 1.5-5 years	Agriculture input suppliers	Lithuania	national	Government programs may provide financial support for investments in technologies that reduce nutrient losses from manure, such as anaerobic digesters and improved storage	Nitrates directive, Lithuanian Rural Development
Compensation funds	Modernization and reconstruction of tile	Lithuania	national	Government programs may provide financial support for investments in reconstruction of old drainage systems along with implementation of nutrient outflow reduction measures.	Nitrates directive and EU Water framework
Compensation funds	Subsidies to farmers who engage in environmentally friendly farming	Lithuania	national	Government provides subsidies to farmers who engage in environmentally friendly farming practices (Organic farming; biodiversity preservation; soil protection)	EU's Common Agricultural Policy (CAP)
EU EAFRD, CAP support	Rural Development Programs	Lithuania	national	Lithuania's rural development programs help farmers implement measures that promote sustainable farming practices, improve infrastructure, and enhance rural communities. This includes projects to improve the environmental sustainability of farms, such as planting trees, wetlands restoration, and	EU's Common Agricultural Policy (CAP)
Climate funds	Carbon Farming Initiatives	Lithuania	national	Support is available for farmers who engage in carbon sequestration activities, like tree planting or practices that help store carbon in soil, contributing to both climate change mitigation and the preservation of agricultural	EU's Common Agricultural Policy (CAP)
EU EAFRD, CAP support	Subsidies for Eco-Friendly Technologies	Lithuania	National	Farmers may receive subsidies for adopting new technologies that reduce emissions or improve the environmental sustainability of their operations, such as precision farming, renewable energy installations on farms or energy-efficient machinery.	European Agricultural Fund for Rural Development (EAFRD) and Lithuanian Rural Development Program (RDP)

LITHUANIA

Economic Instrument (choose from list or, if other, specify)	Title	Country/region	Relevance (choose from list)	Short description, relevance in N and P cycles	Policy background	Success factors	Barriers	Further information (eg. Website, social media, contacts)
Investment Support Scheme	Compensation for Investments in infrastructure and/or technology	Latvia	national	Latvia's Rural Development Plan helps farmers implement measures that promote sustainable farming practices, improve technology and infrastructure, and enhance rural communities. This includes projects to improve the environmental sustainability of farms, such as wetland restoration, and enhancing biodiversity. Firstly the farmer has to make a project application, then make the investment (own funds or loan) after approval, and then partial compensation can be obtained.	EU's Common Agricultural Policy (CAP)	Without the support, the investments wouldn't be economically sustainable.	The farmer has to develop a business plan as a basis for the investment and usually take out a loan.	
Climate funds	Carbon Farming Initiatives	Latvia	national	Support is available for farmers who engage in carbon sequestration activities, like tree planting or practices that help store carbon in soil, contributing to both climate change mitigation and the preservation of agricultural productivity	Private Initiatives (e-agronom)	Additional financial support promotes economic sustainability of farming	Comparatively new system - unknown risks. Investments migh be larger than compensation.	
Ecoscheme Support	Subsidies for Eco-Friendly Technologies	Latvia	national	Farmers may receive additional payment (additional to regular payments) for using new technologies that reduce emissions or improve the environmental sustainability of their operations, such as precision farming.	EU's Common Agricultural Policy (CAP)	Additional financial support promotes economic sustainability of farming	Additional payment cannot be obtained if the farmer doesn't have he right technology - limited target audience.	https://agriculture.ec.europa.eu/common-agricultural-policy/income-support/eco-schemes_en

HUNGARY

Country/region	Relevance (choose from list)	Short description, relevance in N and P cycles	Policy background	Success factors	Barriers	Further information (eg. Website, social media, contacts)	Personal experiences, responses from local players	Comments, limitations
Hungary	local	Regenerative farming to enhance carbon sequestration in soil. Nestlé is supporting a programme that includes funding and advice to help farmers transition to renewable farming.	n.r.	funding and advice system for farmers	transform entire landscape systems and regions into soil-renewing agriculture	https://www.nestle.hu/fenntarthatosag/eghajlatvaltozas/talajmegujito-mezogazdasag		
Hungary	national	It helps micro, small and medium-sized enterprises and primary producers to overcome temporary liquidity problems and cover their unexpected expenses.	n.r.	farmers often use this tool for complement the deductible part of CAP investment	surrounding costs, cumulative costs	https://www.otpagrar.hu/Hiteltermekek/AgrarSzechenyiKartya		
Hungary	national	Fertilising products, shall apply to their authorisation, storage, placing on the market and use.	36/2006. (V. 18.) FVM regulation	taxes impose a cost on farms for polluting activities	the mineral fertilizer application should be based on nutrient balance calculation			
Hungary	national	A farmer who is a member of a crisis insurance scheme shall be entitled to crisis insurance compensation if the conditions are fulfilled. It is a comprehensive risk management tool combining elements of insurance and support.	92/2023. (III. 29.) national regulation	provides financial protection not only against weather damage but also against production, economic and market risks	for access to funding it is necessary to have three year in system the calculation is based a collective, FADN based data	https://www.aki.gov.hu/termek/a-mezogazdasagi-kockazatkezelesi-rendszer-mukodesenek-ertekelese-2022/		
EU	international (e.g., EU)	Loans for green environmental goals at lower interest rates	Regulation (EU) 2020/852	Banks can provide loans at preferential rates for investments which contribute to green goals	Green loans are not yet widespread. Taxonomy is regulating green loans in Eu, but the necessary technical screening criteria to help clarify the interpretation in agriculture and the food industry have not yet been published. Additional administration for farmers, special expertise for banks is necessery.			
Hungary	national	They look for target companies and investment opportunities that contribute directly or indirectly to achieving sustainability goals, reducing emissions, improving sustainable quality of life, generating renewable energy, increasing efficiency in energy storage, transport, use, solving global water problems, among others.				https://www.klimaalap.hu/		

ANNEX 3 Expert interviews

- **Interview I: Green finance, finance of circular economy**

  Date: 17/07/2025

Q: What is the situation of green finance in the EU, in Hungary? How is the green finance in the agri-food sector? Do you know any examples of the finance of the circular economy? What are the main obstacles?

A: Based on his previous banking experience, there had not yet been any green lending for taxonomy purposes aimed at the transition to a circular economy. This is because the Taxonomy Regulation's delegated act on technical screening criteria for environmental objectives, including the circular economy, was published later than the screening criteria for climate change mitigation and adaptation. As a result, green loans were typically related to climate change, as this was more developed. However, financing for the circular economy was provided within the traditional framework, but this was not clearly separated, so it is not known how much lending took place in this area.

The green finance framework has a massive regulatory base, with many regulatory and standardization elements in place, but its practical application is much more limited.

There is an existing regulatory environment for nutrient management in agriculture that is not easy to navigate. The EU taxonomy regulation did not really fit well with this. The taxonomy relied heavily on the Climate Bond Initiative (CBI), i.e. the market world, within which sector-specific expectations were developed. The Taxonomy took over a significant part of this. This spring, the CBI published its significantly revised sector-specific criteria for agriculture, which are much more detailed but still tend to emphasize climate change mitigation.

Circular nutrient management is not priced in by financiers. That is why it does not work.

An important question is where and what technological options are available. Incentives must steer the process in the right direction – opportunities and incentives must work together effectively.

Q: What financing instruments could be used to promote the spread of technologies developed in NENUPHAR?

Upscaling activities play an important role, and documenting the scaling up of technology is important. These play an important role in innovative technologies so that we know whether they work on a larger scale. So far, this has been achieved through community funding. It is important to see the technological possibilities throughout the entire product chain and to have incentives and regulatory frameworks in place. These are the conditions for operation.

Products and technologies that have no benchmarks on the credit market become expensive to finance because they are risky for banks. Until experience has been gained, it is worth using support, but once the relevant experience has been gained with the technology and a certain stage has been reached, public funding should no longer be used.

The transparency of data and information plays an important role. Losses in efficiency and/or harmful effects that are socially undesirable must be quantified adequately. If we can quantify the damage that has been avoided, this can be incorporated into the financing. It is important to document the monitoring process.

Q: Have you seen life cycle risk analysis at banks?

A: No, banking logic is often stuck in short-term thinking. This is problematic.

Banking logic has been limited in its forward thinking. In contrast, there is now a lot of pressure on them, for example, there is an expectation for forward-looking thinking specifically in relation to climate change. The appropriate mechanisms and feedback loops are in place to ensure that the results achieved have a real impact.

Q: What is your opinion on the application of the cap and trade system in nutrient management?

A: It is important that it must be very quantifiable and easily measurable in the case of point source pollution.

However, the mechanism is more complex for nutrients and much more difficult to quantify than for CO_2. In addition, the impacts are very often local in this case.

Q: What is your opinion on tax and quota systems?

A: The question is how easy they are to enforce. There are regulatory frameworks in place – if sanctions can be avoided, then they are not effective. Therefore, positive incentives are considered better.

It must fit in with the logic and practice of normal business operations. If it does not fit, then it will be ignored, and companies will prefer to pay the penalty rather than comply. It is important to know the mindset and practices of the economic actors concerned.

Q: To what extent was it possible to obtain more favourable loans under green financing?

If externalities are internalized, i.e., become measurable and demonstrable, non-green solutions become riskier for banks and therefore more expensive.

There are already systems on the market that can be integrated into internal banking operations to address this transition risk.

If the data is entered at the transaction level, the transition risk can be continuously priced at the transaction level. The pricing is fed back to the emission intensity of the given customer – there are already specific tools for this, and there are banks that use them.

- **Interview II: Innovation and Digitalization Support Group (ITE) – innovation-promoting projects, advisory system, knowledge transfer**

  Date: 24/07/2025

Q: As a colleague of the Innovation and Digitalization Support Group (ITE), do you have any experience with implementing a circular economy model? Have you encountered any good practical examples? Perhaps specifically in relation to nutrient management?

A: An innovation potential survey was conducted among farmers and food processors in Hungary, which served as the basis for the establishment of the ITE and the European Innovation Partnership (EIP). This also touches on the topics of the circular economy and nutrient management.

We work closely with the Department of Agricultural Modernization at the Ministry of Agriculture, and we jointly developed the BIOEAST initiative, which focuses on circularity and includes several projects such as BioeastUP and Boost4Bioeast. So ITE has an integral connection with these.

Practical examples include projects related to soil regeneration farming.

Q: How open are stakeholders to innovation and the circular economy?

A: In the survey mentioned above, 50% of respondents would be open to implementing circular models. The main motivation for this would be financial benefits. Openness depends on education and business size. The circular economy was mentioned most often by those in the fruit and vegetable sector and small-scale livestock farming. Agricultural advisors are also open to the idea.

Innovative solutions currently reach farmers mainly through other economic actors (e.g. input distributors). However, these are not independent actors and often sell their own products.Q:

Q: How necessary is support in promoting innovation, in making it economically viable for players to seek innovative solutions?

A: It plays a key role. They will not start experimenting on their own.

In the case of fruit and vegetable cooperatives, 2% of CAP funding must be spent on R&D. This can help innovation, but often even the cooperatives themselves do not know what to do with it. This is where they need help.

Q: What kind of support is available for innovation?

A: The EIP is specifically designed for this purpose. EIP stands for European Innovation Partnership. The EIP supports projects that contribute to the productivity and sustainability of the agricultural economy and help strengthen rural communities through innovative solutions. EIP projects are based on cooperation between actors from different professional backgrounds. In these operational groups, farmers, advisors, researchers, and businesses work together to solve real problems.

The projects support the development and dissemination of innovative solutions that can be applied in practice.

There are two types:

TOP-Down EIP: the Ministry determines and supports the achievement of policy objectives, thus defining the topic and the expected results. A limited number of applications are supported.

Bottom-UP EIP: topics are shaped based on bottom-up demands; approximately 63 applications were funded.

The key point is that the process should not stop here, but that the results should be taken further and embedded in practice. For example, the question arose as to how the results of EIP projects could be incorporated into vocational training. There was an example of this in the German CAP support unit, where the topic of innovation is incorporated into vocational education in the form of modules.

To this end, dialogue between stakeholders would be important, and an accelerator program would be needed, which could be used in the final phase of EIP projects for the purpose of business model development, knowledge transfer, etc. The Finns, for example, outsourced this task to an accelerator company. This could be a good example.

The inflexibility of EIP applications and previous negative experiences do not help to foster further cooperation and joint work. The problem is that the results of these projects are not guaranteed, as they are complex projects involving multiple actors and are therefore riskier. The evaluation of applications and the payment process are lengthy. This application is not aimed at the masses, but it can serve as a showcase and a good example and encourage others. The aim is to draw the attention of others to new solutions.

It is difficult to reach farmers through participation in innovation applications; it is easier to reach universities and consultants. It is difficult for farmers to obtain information about non-mainstream solutions, and those who are interested have to seek knowledge abroad. There are not enough good examples in Hungary and there is less dissemination of knowledge.

There are so-called silent actors who do not have access to knowledge. It would be important to map out how they obtain knowledge and how they can be approached. The expert advisory system is important in this respect, but great emphasis must also be placed on their training.

One of the tasks of the CAP network is to promote innovative solutions and showcase good examples.