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Definition of current regulatory instruments and competencies of each demo case

WP4 Assessment of regulatory and economic instruments

NENUPHAR

New governance models to enhance nutrient pollution handling and nutrients recycling

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Contributors	Carla Febrer, Mercè Boy (UVIC-UCC) Bárbara Palacino (CIRCE)
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Authors	**Reviewers**
Elena Laborda, CIRCE Marta Cebrián, CIRCE	Bárbara Palacino, CIRCE Mercè Boy, UVIC-UCC Carla Febrer, UVIC-UCC Krisztina Miskó, AKI

Executive summary

This document represents Deliverable 4.2 “Definition of current regulatory instruments and competencies of each demo case”. This task is included in the WP4 of the project (Assessment of regulatory and economic instruments) and contributes to establish a framework of regulatory and economic instruments for the demosites within the project.

In particular, Task 4.2 has addressed the identification and assessment of national and regional legislation to ensure that demosites can meet the most relevant requirements applicable to each of them. To this end, an identification of national and regional legislation has been carried out by the partners involved in demosites and replicators, and a subsequent assessment to identify the legal requirements applicable to each demosite, as well as the barriers and opportunities.

This assessment has been complemented by three other activities related to legislation: a public questionnaire on regulatory barriers, a workshop with external stakeholders and a study of other similar projects that addressed legislative barriers.

After addressing the different approaches, it has been found that there are some topics that may be more problematic when working with nutrient recovery, such as restrictions related to fertilisation in areas classified as vulnerable zones, as well as other requirements derived from the quality of water bodies, the application of some residues to the soil or the difference between requirements for organic and inorganic fertilisers, among others. In some regions, the absence of regional legislation adds to these challenges by limiting the ability to adapt policies to local needs and reducing the overall effectiveness of nutrient recovery initiatives. The detection of regulatory obstacles is also addressed in the questionnaire and workshop sections, as well as in the study of other similar projects.

Despite these barriers, the analysis also revealed significant opportunities to enhance nutrient recovery. National strategies that promote technological innovation, such as those focusing on bioeconomy, provide a foundation for creating markets for recycled fertilisers. Additionally, greater collaboration between the public and private sectors, along with the development of research programs and training, can improve resource management.

To fully realise these opportunities, a more flexible regulatory framework that allows for regional adaptations is necessary. Ensuring the proper transposition of European regulations at both national and regional levels will be essential to consolidating a more sustainable and efficient resource management model across Europe, moving towards a circular economy that benefits all sectors.

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List of abbreviations and acronyms

AGM - Department of agriculture, livestock and environment (Spain)

APA - Ministry of Agriculture, Fisheries and Food (Spain)

BEK – Decree (Denmark)

C - Carbon

CAP – Common Agricultural Policy

CMC - Component Material Categories (Regulation (EU) 2019/1009)

D – Deliverable

EC – European Commission

ESNI – European Sustainable Nutrient Initiative

EU - European Union

EüM - Ministry of Health (Hungary)

FVM - Ministry of Agriculture and Rural Development (Hungary)

GA – General Assembly

GUDP - It supports development projects throughout the Danish food sector, covering the entire value chain, with the aim of promoting green and economically sustainable development.

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

LBK - Consolidated decree (Denmark)

N - Nitrogen

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

NVZ – Nitrates Vulnerable Zones

P – Phosphorus

R&D – Research and Development

SME – Small and Medium Enterprise

SR – Slovak Republic

VEJ – Guidance (Denmark)

WP – Work package

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Introduction

The recovery of nutrients from residual sources, such as organic waste and wastewater, has become a strategic priority for the European economy. This approach not only responds to the urgent need to mitigate the environmental impact associated with inefficient resource management, but also offers a unique opportunity to close the nutrient cycle and reduce dependence on imported mineral fertilisers. The circular economy, promoted through various European Union (EU) policies and initiatives, is strengthened by the incorporation of nutrient recovery practices, contributing to the sustainability and resilience of the European agricultural sector.

The EU-funded NENUPHAR (Nutrient Exchange Network to Optimize the Recovery of Phosphorus and Harmful Algae Reduction) project is a pillar in this transition towards sustainability. This project aims to develop and apply innovative solutions for nutrient recovery, with a particular focus on nitrogen and phosphorus, which are limited and critical resources. By addressing both technical challenges and regulatory barriers, NENUPHAR positions itself as a benchmark for other European projects pursuing similar objectives.

In this context, European regulation plays a crucial role in promoting nutrient recovery. Initiatives such as the European Green Deal lay the foundations for the creation of a regulatory framework that boost nutrient recovery and reuse. These regulatory frameworks not only guide Member States in adopting more sustainable policies, but also encourage investment in innovative technologies, such as those promoted by the NENUPHAR project, to optimize resource recovery from waste.

However, for these European initiatives to have a real and lasting impact, it is essential that Member States transpose these European regulations into their national and regional legislation. Effective transposition of EU regulations not only ensures legal compliance, but also adapts policies to local realities, allowing for a more tailored and effective approach to nutrient management at the local level. This adaptation process is crucial to foster the implementation of recovery technologies across Europe, taking into account the environmental and economic specificities of each region.

In many cases, national legislation becomes the key instrument to regulate and promote nutrient recovery. For example, laws regulating fertiliser use, organic waste management and wastewater treatment should be aligned with circular economy principles and encourage sustainable practices. Furthermore, it is crucial that these regulations include economic and financial incentives that motivate farmers and waste managers to adopt nutrient recovery technologies, such as those developed under the NENUPHAR project.

The success of initiatives such as NENUPHAR depends to a large extent on collaboration between different levels of government and the existence of a coherent regulatory framework to enable the implementation of their results. Member States must ensure that European regulations are effectively integrated into their

legislation, promoting resource management that is efficient, sustainable and aligned with the EU's circular economy objectives.

Cooperation between EU countries is also a key factor in this process. The creation of transnational networks, such as those promoted by NENUPHAR, allows the exchange of knowledge and best practices, facilitating the harmonisation of national regulations and the overcoming of technical and administrative obstacles. This is particularly relevant in nutrient recovery, where differences in national regulations can represent significant barriers to the adoption of innovative solutions.

Specifically, this deliverable is generated in response to task 4.2 of the NENUPHAR project:

> *Task 4.2 "Definition of current regulatory instruments and competencies of each demo case". This task will be focused on identifying and analyzing the current policy framework, taking into account the regional and national scope in each EU country where the demos of the project will be located in. The assessment aims at establishing a comprehensive overview of the regulatory framework for the correct implementation of the demos and ensure in each case the fulfillment of legal requirements. Public administrations and other stakeholders involved in nutrient pollution and nutrient management, as well as nitrogen and phosphorus emissions in rural/coastal and urban/ industrial environments, will be invited to take part in the process, participating in meetings and/or interviews to collect relevant information about the activities described in this task. Partners from each regional cluster will conduct an assessment of the transposed EU policies and existing national and regional regulatory framework that have relevance for nutrient pollution and nutrient recycling. Furthermore, a review of existing experiences in demo's countries related to nitrogen and phosphorous recovery will be collected, in order to identify the main barriers and measures undertaken for their overcoming.*

To address this task, different activities described in detail in this deliverable have been proposed, in particular:

- **National and regional legislation assessment:** The national and regional policies and legislation of the project lighthouses and replicators have been identified, and potential barriers and opportunities associated with this legislation have been identified.
- **Legislation barriers questionnaire:** Information on possible legal barriers at national and regional level has been collected through a questionnaire launched to stakeholders related to the different democracies, in order to enrich the analysis of regulations carried out and to be able to collect previously unidentified barriers and even barriers from other European Union countries.
- **ESNI workshop:** A workshop has been organised at the ESNI Conference (international event on recycling and nutrient management) in order to show the main findings obtained, as well as to encourage debate among the attendees and to exchange impressions and knowledge on legislative barriers at regional and local level.

- **Other existing experiences in demo's countries:** Analysis of other existing experiences within the democases countries, in order to identify the main barriers and measures undertaken for their overcoming.

In this deliverable there is a section detailing the methodologies developed to carry out above activities and the results obtained in each of them. Finally, there is a section on conclusions.

1. National and regional legislation assessment

The European project NENUPHAR, focused on the recovery of nutrients from waste streams, specifically nitrogen and phosphorus, stands as a key initiative for advancing towards more sustainable and efficient resource management. In this context, it is essential to conduct a thorough identification and analysis of the current regional and national regulations. This study will help understand the legislative framework governing the practices and technologies involved in the project, ensuring that all activities are carried out in full compliance with established legal requirements.

The legal compliance of technologies and installations aimed at the recovery of nitrogen and phosphorus is of utmost importance. Environmental and health regulations set rigorous standards to ensure that recovery processes do not negatively impact the environment or public health. The legislative analysis will therefore serve to ensure that NENUPHAR demonstrators and pilot projects are not only innovative and efficient, but also safe and sustainable from a legal and environmental point of view.

1.1 Methodology

This section will be focused on identifying and analyzing the current policy framework, taking into account the regional and national scope in each EU country where the demos of the project will be located in. The identification of legislative framework in national and regional scope has been done by the partners who have efforts in the Task 4.2 through desk-research, divided into groups according to the regional cluster they belong to within de project.

The regional clusters within this project and the nutrient flows they address are:

- **Ebro basin.** It includes legislation from one country (Spain) and two regions (Catalonia and Aragon). The flow to recover nutrients is manure waste.
- **Danube basin.** It includes legislation from two countries (Slovakia and Hungary) and two regions (Nitra and Győr). The flow to recover nutrients is dairy wastewater.

- **Lielupe basin.** It includes legislation from two countries (Latvia and Lithuania) and two regions (Zemgale & Kurzeme and Šiauliai). The flow to recover nutrients is sewage sludge waste.
- **Bornholm replicator**. It includes legislation from one country (Denmark) and one region (Bornholm). The flows to recover nutrients are manure, sewage sludge and dairy wastewater.
- **Cyprus replicator**. It includes legislation from one country and region (Cyprus). The flows to recover nutrients are manure, sewage sludge and dairy wastewater.

The partners involved in the task have identified the relevant legislation in each regional cluster and how it can affect to the democases, specially related to each waste addressed in the demo, detecting barriers and opportunities for more relevant policies and laws.

The legislations studied have been divided into different categories, according to the topic of the findings gathered:

- Nutrients: nutrient pollution and nutrient management/recycling (nitrogen and phosphorous)
- Waste: the residues addressed in the project (manure, sewage sludge)
- Soils: application to soils
- Water: water bodies and wastewater
- Fertilisers
- Activity requirements: building or product requirements, authorisations, circular economy

Below is a section for each of the project's regional clusters, which first identifies all the regulations studied at national and regional level, classified by the topics defined above (in blue). In addition, within each of the regulations, the barriers (marked with ×) and opportunities (marked with ✹) identified by the project partners in each regional cluster are included.

Finally, a final section of analysis of results is included, where a summary of the barriers and opportunities detected is included, commenting on the main findings for each category.

1.2 Legislation studied

Ebro basin

The following legislation has been studied in this regional cluster:

National legislation – Spain

- Royal Decree 1051/2022, stablishing standards for sustainable nutrition in agricultural soils [1]. *Fertilisers, Manure*
  - X *According to Royal Decree 1051/2022, manure, whether solid or slurry, may not be applied within five meters of the banks of rivers, lakes, standing water bodies, groundwater abstractions for human consumption, wells and springs.*
  - X *Fertiliser application is prohibited on certain types of land, soils and in certain periods.*
  - X *Specific conditions for temporary manure piling.*
  - X *Mandatory use of measures to reduce emissions when applying manure and organic materials.*
  - X *The Autonomous Communities may establish greater distances, especially in water bodies that do not comply with environmental objectives, to ensure greater protection of the environment and water quality.*

- Law 7/2022 of 8 April on waste and contaminated soils for a circular economy [2]. *Waste*
  - X *Declaration and delimitation of contaminated land.*
  - X *Obligation to decontaminate (period not exceeding three years).*
  - X *Suspension of building rights.*
  - X *Joint and subsidiary liability.*
  - X *Drawing up of inventories.*
  - X *Interconnection of the state inventory with the land Registry.*

- Spanish Bioeconomy Strategy [3]. *Activity requirements*
  - ✹ *Innovation and digitisation of the agri-food sectors.*

- Royal Decree 865/2010 of 2 July 2010 on cultivation substrates [4]. *Soils*
  - X *Only products belonging to one of the types included in the groups of Article 5 listed in Annex I may use the designation growing medium or growing medium component.*
  - X *For the inclusion of a new type in the list of growing media and growing medium components, it shall be demonstrated that its use on crops will not accumulate heavy metals in the soil, increase its salinity or incorporate contaminants. The possible effects of the application of the product on the physical and chemical properties as well as on the biological activity of the soil shall be specified. Information shall be provided on the evolution of the product in the soil and its mobility, specifying the risks of diffuse contamination and instructions for its correct use.*

- Order AAA/1072/2013 of 7 June 2013 on the use of sewage sludge in the agricultural sector [5]. *Sewage sludge*

- Royal Decree 506/2013 of 28 June 2013 on fertiliser products [6]. *Fertilisers*
  - X *The fertiliser must meet all the requirements of this Royal Decree in order to be marketed. It establishes the requirements for fertilisers:*
    - *Classification of fertilisers into groups*
    - *Packaging, identification and labelling*
    - *Registration for the marketing of fertilisers*
    - *Requirements for facilities (production processes)*
    - *Quality controls, traceability*
    - *Raw materials used (including wastes, animal by-products, agri-food by-products, organic materials, micro-organisms)*
    - *Limits for some risk parameters (pathogens, heavy metals)*
    - *Registration process*
  - X *This regulation does not allow compost to be placed on the market that has not been previously registered in the Register of Fertiliser Products of the Ministry of Agriculture, Food and the Environment.*

- Order APA/104/2022 of 11 February amending Annexes I, II, III and VI of Royal Decree 506/2013 of 28 June on fertiliser products. Amending Annexes I, II, III and VI to Royal Decree 506/2013 of 28 June on fertiliser products [7]. *Fertilisers*

- Royal Decree 817/2015, of 11 September, which establishes the criteria for monitoring and evaluating the state of surface waters and environmental quality standards [8]. *Water*
  - X *Economic and technological barriers: Due to the new practices and technologies that are not low cost, and insufficient financial incentives for the transition to sustainable practices. And limited access to advanced technologies.*
  - X *Compliance barriers: In the case of small farms, it is complicated.*
  - ✹ *Education and awareness of farmers: Promote and adopt good agricultural practices, as well as educate and train farmers to use best practices for surface waters and environmental quality standards.*

- Royal Decree 47/2022, of 18 January, on the protection of waters against diffuse pollution caused by nitrates from agricultural sources [9]. *Water*
  - X *The requirement for declaring a water as affected is increased:*
    - *Surface water affected: nitrates > 25 mg/l (previously 50 mg/l)*
    - *Affected groundwater: > 37 5 mg/l (previously 50 mg/l)*
  - X *The area where the tests will be carried out in this project is catalogued as "Nitrate Vulnerable Zone", code "La Clamor Amarga". Clamor Amarga is a surface water body with annual average nitrate level above 50 mg/L.*

- Royal Decree 665/2023, of 18 July, amending the Regulation of the Public Hydraulic Domain, approved by Royal Decree 849/1986, of 11 April; the Regulation of the Public Administration of Water, approved by Royal Decree 927/1988, of 29 July; and Royal Decree 9/2005, of 14 January, establishing the list of potentially soil-polluting activities and the criteria and standards for the declaration of contaminated soils [10]. *Water*

- Regulation (EU) 2020/741 of the European Parliament and of the Council of 25 May 2020 on minimum requirements for the reuse of water [11]. *Water*

- Royal Decree 1310/1990 use of sewage sludge in the agricultural sector [12]. *Sewage sludge*
  - X *Fertiliser section in the farm logbook.*
  - X *Fertiliser plan.*
  - X *Minimum good farming practice.*
  - X *General register of manufacturers and other economic operators of fertiliser products.*

- Royal Decree 1528/2012 of 8 November establishing the rules applicable to animal by-products and derived products not intended for human consumption [13]. *Manure*
  - X *The collection and transport of animal by-products must comply the health requirements from the point of generation to the demonstrator plant.*

- Regulation (EC) No 1069/2009 of the European Parliament and of the Council of 21 October 2009 laying down health rules for animal by-products of animal origin laying down health rules concerning animal by-products of animal origin [14]. *Manure, Activity requirements*
  - X *Manure is considered as a Category 2 animal by-product.*
  - X *Manure can be applied to land directly (if no health risk is identified), can be composted and transformed into biogas (if it has been pre-sterilised and does not present a health risk) and can be used for the production of organic fertilisers and soil improvers and placed on the market (in compliance with the requirements of Article 32).*
  - X *Animal by-products authorisation is needed to treat these products: Operators shall ensure that establishments or plants under their control are approved by the competent authority, where such establishments or plants carry out the transformation of animal by-products or derived products into biogas or compost.*

- Commission Regulation (EU) No 142/2011 of 25 February 2011 laying down detailed rules for the implementation of Regulation (EC) No 1069/2009 of the European Parliament and of the Council laying down health rules concerning animal by-products and derived products not intended for human consumption and Council Directive 97/78/EC as regards certain samples and units exempted from veterinary checks at the border under that Directive [15]. *Activity requirements*
  - X *Slurry is an animal by-product (Category 2), and as such the demonstrator must meet product treatment (sterilisation) requirements prior to its introduction to the biogas plant and its treatment in the stripping method. The treatment method to which the product must be subjected must ensure conditions of granulometry, temperature and pressure for a minimum time.*

- Regulation (Eu) 2019/1009 Of the European Parliament and Of the Council of 5 June 2019 laying down provisions on the making available on the market of EU fertiliser products [16]. *Fertilisers*
  - X *The cost of the new recovery technologies and the quality control of the recovered nutrients for their use in the agriculture, avoiding issues on humans/animals health.*
  - X *There is not a harmonization of regulations across the EU member states, so, it could be difficult to implement the nutrient recovery practices.*
  - X *An EU Declaration of Conformity is needed for each fertiliser product to be introduced in the market.*

- Spanish Circular Economy Strategy [17]**.** *Activity requirements*
  - ✹ *The new incorporation of advanced technologies*

Regional legislation – Catalonia and Aragon

- DECREE 153/2019, of 26 March, of the Government of Aragon, which regulates manure management and the management of manure and the procedures of accreditation and control [18]. *Manure*
  - X *Limiting applications of manure at the weekend and holidays.*
  - X *Organic fertiliser applications within 500 metres of population centres or recreational areas are prohibited from 3 p.m. on Friday until midnight on Sunday and from 3 p.m. on the eve of a public holiday until midnight on the day of the public holiday. Exceptions are applications with injectors that leave the fertiliser fully incorporated into the soil, as well as applications of products falling within the scope of the fertiliser or substrate regulations. In the event of adverse weather conditions or exceptional circumstances that reduce the days available for applications, the Directorate-General responsible for agriculture and livestock farming may agree by resolution to lift the ban established in this section for the period of time necessary to complete the fertilisation work in the municipalities affected.*

- ORDER AGM/83/2021, of 15 February, designating and modifying the Zones Vulnerable to water pollution by nitrates from agricultural sources in the Autonomous Community of Aragon and approving the V Programme for the Vulnerable Zones to water pollution by nitrates from agricultural sources in the Autonomous Community of Aragon and approving the V Programme of Action on the Vulnerable Zones of Aragon [19]. *Water*
  - X *The action programme establishes key requirements for the management of nitrogen fertilisers and manure use in nitrate-vulnerable zones. These requirements include compliance with the maximum allowed nitrogen amounts for crops, the classification of fertilisers according to their composition and availability, and restrictions on fertiliser application in waterlogged soils and sloping land. Minimum distances from surface waters and aquifers must also be respected. Additionally, nitrogen application is*

prohibited in non-productive areas, and the maximum allowable manure application is set at 170 kg N/ha per year.

X *For manure management, it is necessary to know the nitrogen content through tables, measurements or calculations, and follow specific measures for its proper incorporation into the soil. There are also requirements for the storage of solid manure and slurry. As part of the NENUPHAR project, biofertilisers obtained will be tested in vulnerable zones, following established regulations for nitrogen and phosphorus application, to compare agricultural yields and potential leaching in protected areas.*

- ORDER AGM/900/2021 of 29 June establishing the tool for calculating the nitrogen content of manure generated in pig holdings in the Autonomous Community of Aragon and determining the procedure for the recognition of the reduction of nitrogen content in manure generated by these holdings with respect to the standard values, and by standard values and amending Decree 53/2019, of 26 March, which regulates the management of manure and the procedures for accreditation and control [20]. *Manure*

- Aragon Circular Strategy [21]. *Activity requirements*

  X *The strategy does not present any strategic objectives focused on the agri-food sector as one of the main economies of the region.*

- Strategy of the Ebro River Basin Authority to combat high nitrate content in the waters of the basin (NITRACHE Strategy) [22]. *Water*

- Decree 40/2014, of 25 March, from Catalan Government, on the organization of livestock farms. Management of livestock farms [23]. *Manure*

- Decree 136/2009 of 1 September 2009 from Catalan Government, approving the action programme applicable to vulnerable zones in relation to nitrate pollution from agricultural sources and the management of livestock manure [24]. *Water*

- Management plan for the river basin district of Catalonia 2022-2027 [25]. *Water*

- Law 20/2009, of December 4, from Catalan Government, on prevention and environmental control of activities [26]. *Activity requirements*

  X *It is limited solely to environmental aspects, leaving out of its reach subjects such as the safety and health of people. However, Law 20/2009 does include the legislation relating to serious accidents.*

Danube basin

The following legislation has been studied in this regional cluster:

National legislation - Hungary

- Government Decision No 1242/2022 of 28 December 2022 on Hungary River Basin Management Plan 2021 [27]. *Water*

  X *Extended nitrate vulnerable areas (70% of the country, more than 65,000 ha).*

- X *The protection areas and structures in case of groundwater must be designated by an official decision.*
- X *Designation of water protection and ecological restoration strips.*
- X *Longitudinal control of watercourses, drainage.*
- X *Water retention, keeping water reservoirs or raising the water level for water drainage.*

- Government Decree 201/2001 (X.25.) on drinking water quality requirements and control procedures [28]. *Water*
  - X *Surface drinking water bases play only a small part in drinking water supply in Hungary, which are based on the highly sensitive to pollution, vulnerable drinking water bases.*
- Decree Nº 25/2002 of 27 December 2002 on the National Urban Sanitation and Treatment Implementation Programme [29]. *Water*
  - X *The lack of connections along the established sewer network is a unique problem in Hungary. Typical reasons for the lack of a ratio are vacant land, uninhabited property, financing problems for socially disadvantaged people and special technical circumstances.*

- 59/2008 (IV.29.) FVM Decree 4-9. on nitrate vulnerable zones [30]. *Water*
  - X *Economic, restructuring, carbon leakage barriers may arise. Prohibition of:*
    - *Installing or maintaining temporary manure piles without leakage protection.*
    - *Applying manure between 31 October and 15 February or on frozen soil, in a waterlogged area.*
    - *Fertilise areas with slopes steeper than 17% and planting on slopes steeper than 15% only with adequate erosion protection.*

- Government Decree Nº 306/2010 of 23 December 2010 on air protection [31]. *Water*
  - ✹ *Improving soil nutrient content and structure by incorporating manure into the soil according to the plant's nutrient requirements, avoiding the burning of manure (farmyard manure, deep litter manure).*

- Act CLXXXV of 2012 on Waste [32]. *Waste*
- Act XLVI of 2008 on the food chain and official controls [33]. *Activity requirements*
- 559/2023. (XII. 14.) Government Decree on activities to prevent the formation of biodegradable waste, detailed rules for waste management activities related to biodegradable waste and rules for the classification of compost produced from bio-waste [34]. *Waste*
- 28/2004 (XII. 25.) KvVM (ministerial) Decree on limit values for emissions of water pollutants and certain rules for their application [35]. *Activity requirements*
  - X *An authorisation granted by Article 89(3) of Act LIII of 1995 on the General Rules for the Protection of the Environment is needed.*

- Joint Decree No 68/2007 (26.VII.) FVM-EüM-SZMM (ministerial) on certain food hygiene conditions governing the production and placing on the market of foodstuffs and on official controls of foodstuffs [36]. *Activity requirements*
  - X *An authorisation granted in Article 20(3)of Act LXXXII of 2003 on Foodstuffs is needed.*

- Government Decree 50/2001 (IV. 3.) on rules for the use and treatment of wastewater and sewage sludge in agriculture [37]. *Activity requirements*
  - X *Non-food and non-fodder industrial crops, energy crops and seed crops may be irrigated on agricultural land under the derogations laid down in this Regulation.*

National legislation - Slovakia

- Act no 136/2000 Coll on fertilisers [38]. *Fertilisers*
  - X *Conditions of use of nitrogen fertilisers in vulnerable areas:*
    - *Obligation to respect the prohibited periods listed in Annex 2.*
    - *Requirements for the use of nitrogen fertilisers*
    - *Obligatory to draw up a plan for the use of nitrogen fertiliser substances every year.*
    - *Mandatory to respect the total nitrogen doses in mineral fertilisers, taking into account the amount of usable nitrogen in used agricultural fertilisers and fertiliser substances with bound organic nitrogen according to Annexes 4 to 6.*
    - *Respect the nitrogen doses applied in the form of agricultural fertilisers so that they do not exceed the nitrogen dose of 170 kg/ha per economic year.*
    - *Restrictions on the use of fertilisers on certain slopes*
  - X *Nitrogen fertilisers may not be applied in the area within 10 m of the boundary of the protection zone of the first level of the water resource at all levels of restriction.*

- Act No 188/2003 Coll on the application of sewage sludge to soil [39]. *Sewage sludge*
  - X *Conditions for sludge application (some methods are forbidden):*
    - *Sewage sludge or bottom sediments may only be applied on agricultural or forestry land where the concentration of dangerous substances is below the limit values specified in Annex nº 4.*
    - *Application of sewage sludge or bottom sediments to agricultural or forestry land not complying with these conditions is prohibited.*
    - *The maximum amount of hazardous substances that may enter agricultural land annually (for 10 consecutive years) if the limit values are respected, is determined in Annex nº 5.*
    - *Sewage sludge and bottom sediments may only be applied to forest soil by incorporation and during afforestation on soils where nutrient replenishment is necessary.*

X *When applying sewage sludge and bottom sediments, the total amount of nitrogen in the sewage sludge and bottom sediments must not exceed 75 % of the dose necessary to fertilise the agricultural crop.*

- Act no 220/2004 Coll on the protection and use of agricultural land [40]. *Soils*
  X *The owner or user is obliged to implement protective measures for:*
    - *Eroded soils*
    - *Compacted soils*
    - *Degraded soils*
    - *Maintenance of soil organic matter balance: use of management methods that do not exceed the limit value of soil organic matter balance (compost).*

- 364/2004 Water Act and amendment to the Act of the Slovak National Council No. 372/1990 Coll. on Criminal Offences as amended (Water Act) [41]. *Water*

- SR Government Regulation 269/2010 Coll. which stipulates criteria for achieving good water balance [42]. *Water*

- Decree of the Ministry of Agriculture, Regional Development and Environment of the Slovak Republic no. 418/2010, Coll. about the execution of some provisions of the Water Act in the sense of later regulations [43]. *Water*

Regional legislation – Hungary and Slovakia

According to the demosite partners assessment, in the case of Hungary and Slovakia, there are only strategies and programmes at national level and no regional level regulators. Therefore, no information on regional legislative framework has been included in the analysis.

X *The absence of regional legislation in Hungary and Slovakia is a significant legislative barrier, as it impedes adaptation to local needs, limits the efficiency and effectiveness of policies, creates inequalities in implementation, and delays responsiveness to emergencies or changes in local conditions.*

Lielupe basin

The following legislation has been studied in this regional cluster:

National - Lithuania

- Environmental requirements of biological waste composting and anaerobic treatment. Minister of the Environment of the Republic of Lithuania (January 25, 2007 by order no. D1-57) (Amendments by Order No. D1-713 of the Minister of the Environment of the Republic of Lithuania dated November 24, 2020) [44]. *Sewage sludge*

- X *Strict regulations regarding the application of composted sludge due to potential contaminants or pathogens. People have concerns about the use of composted sludge in agriculture due to its origin from sewage treatment plants. Overcoming public perception is a challenge. Ensuring the quality of composted sludge is difficult. Composted sludge is heavy, making transportation costly and logistically challenging, especially if the agricultural fields are located far from the treatment plants. Specialized equipment may be required for spreading composted sludge effectively on agricultural fields. Mitigating odor issues requires additional measures. Not all crops and soils may benefit from the application of composted sludge. Concerns about the environmental impact of using composted sludge, such as runoff and potential leaching of contaminants into the soil.*
- ✹ *Composted sludge can act as a carbon sink when applied to agricultural soils, it can improve soil structure, fertility, and water retention. Composted sludge can contribute to circular economy initiatives by closing the nutrient loop between urban and rural areas and promote resource efficiency, it can be used in alternative crop production systems. Good opportunities to apply in precision agriculture. Composted sludge can foster collaboration between various stakeholders to maximize the benefits.*

National - Latvia

- Republic of Latvia Cabinet Regulations No.362 Regulations Regarding Utilisation, Monitoring and Control of Sewage Sludge and the Compost thereof [45]. *Sewage sludge*
  - X *The regulations state that in order to use the composted sewage sludge as a fertiliser, the producer of sewage sludge or compost and the user of the fertiliser thereof agree on utilisation of sewage sludge or compost for the soil fertilisation, a relevant written certification shall be drawn up regarding the utilisation of sewage sludge or compost (hereinafter - certification), on the basis of the following documents: a copy of the quality certificate of a batch of sewage sludge or compost; research materials of the area soils, cartographic material with the areas marked in which it is intended to cultivate sewage sludge or compost. If sewage sludge or compost is cultivated repeatedly in the relevant area, only a copy of the quality certificate of sewage sludge or compost batch shall be attached to the certification.*
  - X *This means that every time that a farmer wants to use composted sewage sludge as a fertiliser, a document shall be drawn up and signed which might discourage farmers from using this resource (it is easier to use regular fertilisers.*

- Republic of Latvia. Cabinet Regulation No. 834. Adopted 23 December 2014. Requirements Regarding the Protection of Water, Soil and Air from Pollution Caused by Agricultural Activity [9 October 2018] [46]. *Water*
  - X *The regulations limit the time that the composted sewage sludge can be applied to the fields in NVZ. The period is shorter than in non-NVZ.*

Regional

According to the demosite partners, in the case of Lithuania and Latvia, there are no strategies for a specific region separately documented. Since the country is small, only strategies and programs at the national level are applicable.

Bornholm replicator

The following legislation has been studied in this regional cluster:

National - Denmark

- BEK nr 1393, 21/06/2021 - Waste water executive order [47]. *Water*
  - ✹ *Resource Recovery: It encourages the recovery of nutrients such as N and P from wastewater, which can be recycled and reused as fertilisers in agriculture, thus promoting circular economy principles and reducing dependence on synthetic fertilisers.*
  - ✹ *Innovation and Research: The legislation encourages innovation and research in sustainable wastewater treatment technologies and nutrient recovery methods, leading to the development of more efficient and cost-effective solutions.*
  - ✹ *Collaboration: It fosters collaboration between industries, municipalities, research institutions, and regulatory bodies to address nutrient management challenges collectively, promoting knowledge sharing and best practices.*
  - X *Infrastructure and Costs: Upgrading wastewater treatment plants to comply with stricter nutrient removal requirements can be costly, especially for smaller municipalities such as Bornholm.*
  - X *Regulatory Compliance: Strict regulatory requirements may pose challenges for industries and municipalities.*
  - X *Public Awareness and Acceptance: Lack of public awareness and acceptance of nutrient recycling practices, may interfere with the implementation of nutrient recovery initiatives. Bornholm population is somehow more conservative in order to protect landscape and nature. This blockage has been experienced with the biogas plant enhancement and Power2X.*

- BEK nr 1375, 30/11/2015 -Ordinance on special contribution for particularly polluted wastewater [48]. *Water*
  - ✹ *The law takes the polluter pays principle, meaning that better wastewater treatment and nutrients recovery will lower the pollution levels at the "end of the pipe", therefore lower the related costs.*
  - X *Cost Recovery Challenges: Implementing advanced nutrient removal and recovery technologies may result in increased operational costs for wastewater utilities, potentially leading to higher user fees or financial burdens for ratepayers.*

- BEK No 1001 of 27/06/2018 - Ordinance on the use of waste for agricultural purposes [49]. *Fertilisers*

- ✹ *There are no specific requirements for Waste listed in Annex 1 can be used for agricultural purposes without prior permission.*
- X *There are specific requirements for Waste not listed requires permission for agricultural use.*
  - *Waste must meet certain quality standards and should not contain significant amounts of harmful substances.*
  - *Waste must be analyzed according to specific procedures.*
  - *Waste producers must provide detailed declarations about the waste.*
  - *Waste storage and application must follow specific regulations.*
  - *There are restrictions on the amount of waste that can be applied per hectare per year.*
  - *Supervision and enforcement of regulations are carried out by municipal authorities and the agricultural authority.*
  - *Penalties are imposed for violations of the regulations, including fines.*

- BEK nr 1070 of 28/10/2019 - Decree on water quality and supervision of water supply installations [50]. *Water*
- LBK nr 126 of 26/01/2017 - Executive Order on Water Planning [51]. *Water*
- LBK No 520 of 01/05/2019 - Promulgation of the Act on Animal Husbandry and the Use of Fertilisers [52]. *Manure*
  - X *Liquid manure may only be applied by laying by tow hose, tug shoes or by trapping. Other methods of application, including application by irrigation cannon, are thus not permitted.*
  - ✹ *The requirements for application methods prevent ammonia evaporation and odour nuisances in relation to, for example, wide spreading. By applying liquid manure in these ways, nitrogen benefits crop to a greater extent and reduces ammonia deposition in natural areas. Odours from application are also reduced.*

- VEJ nr 9861, 02/11/2023 - Guidelines on the Fertiliser Use Order 2023-2024 [53]. *Fertilisers*
  - X *Article 5. Slurry application method and ammonia reduction technique (Articles 6 and 7):*
    - *Liquid manure may only be spread by drag hose, drag shoe or sedimentation. Therefore, other application methods, including application by sprinkler, are not permitted.*
    - *The requirements for delivery methods avoid evaporation of ammonia and odour nuisance in connection with, e.g. generalised. By applying liquid livestock manure in this way, nitrogen benefits crops to a greater extent and reduces ammonia deposition in natural areas. The odour of the shipment is also reduced.*
    - *Laying with trailer hose, trailer shoes or laying are all suitable techniques to meet the requirement of Article 10, subpara. 1 on the uniform distribution of fertiliser.*

- BEK nr 1166 of 13/07/2020 - Executive Order on the use of fertilisers in agriculture in the planning period 2020/2021 [54]. *Fertilisers, Nutrients*
  - X *The Article 20 talks about other organic fertilisers: The content of nitrogen and phosphorus in other organic fertilisers shall be determined by analysis of representative samples in accordance with the guidelines in section 17(3). Paragraph 2.*
  - X *By the way paragraph 1, the content of nitrogen and phosphorus in sewage sludge and composted household waste, etc. shall be determined in accordance with the Executive Order on supervision of sewage sludge etc. for agricultural purposes. Paragraph 4.*
  - X *For the calculation of the consumption of nitrogen in other organic fertilisers, the following proportions of the total nitrogen content in the fertiliser shall be used:*
    - *Sewage sludge: 45 per cent.*
    - *Composted household waste: 20 per cent.*

- March 2023 - Ministry Of the Environment and Ministry of Finance: Second opinion on the need for reduction of nitrogen in the third RBMP for 2021-2027, Phase I [55]. *Fertilisers, Nutrients*

Regional - Bornholm

- LBK No 553 of 24/04/2020 - Promulgation of the Act on payment rules for wastewater supply companies [56]. *Water*
  - ✹ *Resource improvements: Avoid pollution in the water due to the huge quantity of regulations and sanction payment.*
  - X *Infrastructure and Costs: Any new contribution to the facilities and their associated costs. As well as the adaptation of new technologies to avoid consumption that cannot be achieved in a conventional way.*

- Pursuant to the Act on payment rules for wastewater supply companies, cf. executive order no. 281 of 22 March 2007, with subsequent amendments. Act on payment statutes for Bornholm's wastewater[57]. *Water*
  - X *The financial boundaries in the Danish Water Sector Act are designed to protect citizens against price increase, while at the same time ensuring that the Danish utility companies work as efficiently as possible. But the framework becomes a challenge in the formation of new, innovative solutions benefitting the green transition.*

- According to article 13 of the "Sludge Order" - BEK No 1001 of 27/06/2018- Executive Order on the Use of Waste for Agricultural Purposes [58]. *Sewage sludge*
  - ✹ *Technology Integration: The legislation can leverage advancements in wastewater treatment technologies to improve sludge management processes, such as anaerobic digestion or thermal treatment.*

- ✹ *Data-driven Decision Making: Implementing digital systems for monitoring and managing sludge can enhance data collection, analysis, and decision-making processes, leading to more efficient resource allocation and environmental protection.*
- ✹ *Stakeholder Collaboration: Technology can facilitate collaboration among stakeholders involved in sludge management, including government agencies, municipalities, industries, and environmental organizations, fostering transparency and accountability.*
- ✹ *Environmental Sustainability: Adoption of innovative technologies can promote more sustainable sludge management practices, reducing environmental pollution and resource depletion.*
- X *Cost and Investment: Integrating advanced technologies into sludge management processes may require significant initial investments, posing a financial barrier for smaller municipalities or resource-constrained entities.*
- X *Regulatory Compliance: Compliance with stringent environmental regulations and standards, while crucial for protecting public health and the environment, can present challenges in terms of technology adoption and operational adjustments.*
- X *Capacity Building: Limited technical expertise and resources within government agencies or municipalities may hinder the effective implementation and management of advanced technologies for sludge treatment and disposal.*
- X *Public Perception and Acceptance: Resistance or scepticism from the public regarding new technologies or changes in sludge management practices could impede the adoption and implementation of innovative solutions.*

Cyprus replicator

The following legislation has been studied in this regional cluster:

National

- Council Directive of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources [59]. *Water*
- Water and Soil Pollution Control Law, 2002 (Law No. 106(I)/2002) [60]. *Water, soil.*

Regional

According to the demosite partners, in the case of Cyprus, there are no strategies for a specific region separately documented. Since the country is small, only strategies and programs at the national level are applicable.

1.3 Results of the analysis

As a summary of the results obtained in the legal analysis in carried out from the partners, the regulations identified within each country have been classified into different themes related to the legislation topic in question: Nutrients, Waste, Soils, Water, Fertilisers and Activity requirements.

Two thematic matrices (one for barriers and one for opportunities) have been developed to show the comparison between countries and regions, followed by the explanations obtained. In cases where no barriers or opportunities appear in the table, it means that the partners of the demosites/replicators company have not identified them in the legislation studied.

Barriers

Table 1 Barriers detected in regulatory assessment by the partners.

	Barriers						
Country	Spain	Hungary	Slovakia	Lithuania	Latvia	Denmark	Cyprus
Nutrients	X						
Waste (Manure)	X					X	
Waste (Sewage sludge)	X		X	X	X	X	
Soils	X		X				
Water	X	X			X	X	
Fertilisers	X		X			X	
Activity requirements	X	X					

When comparing the results by themes based on the identified regulatory barriers, waste (sewage sludge) emerges as the area with the most barriers, affecting Spain, Hungary, Slovakia, Lithuania, Latvia, and Denmark. Barriers related to water have also arisen in several countries, such as Spain, Hungary, Latvia, and Denmark. Barriers related to nutrients have only been identified in Spain, while waste (manure) presents barriers in Spain and Denmark, indicating that the rest of the countries have not considered these barriers as relevant. Regarding soils, barriers are detected in Spain and Slovakia, while the issue of water presents barriers in Spain, Hungary, Denmark, and Latvia. In relation to fertilisers, Spain and

Slovakia have reported barriers, while the rest of the countries do not identify regulatory issues in this area. Regarding Activity requirements, barriers have been identified in Spain and Hungary.

In summary, waste (sewage sludge) and water are the areas most affected in several countries, while themes such as nutrients, soils, and fertilisers show a more limited geographical impact, with only a few countries reporting barriers.

In order to broaden the thematic analysis, within each of the regulatory topics studied, a more in-depth assessment has been made of the main requirements in each of them that pose barriers for the countries and regions participating in the project.

- ***Nutrients:***

The regulatory barriers related to nutrients often require that the nitrogen and phosphorus content in organic fertilisers be determined through representative sample analyses, ensuring compliance with certain quality standards. Additionally, materials such as sewage sludge or other organic waste are typically regulated in terms of nutrient levels, with the aim of ensuring their safety and suitability for agricultural use.

For the use of organic fertilisers, specific percentages of nitrogen content must be applied, meaning that farmers are required to follow strict analysis and application methods. These regulations aim to ensure that the use of organic fertilisers is controlled and safe, minimizing environmental risks and ensuring their effectiveness in agriculture.

- ***Manure:***

The main barriers to manure use include restrictions on its application near water bodies, where it is prohibited to apply solid or liquid manure within five metres of rivers, lakes, aquifers, and other water sources to prevent contamination. Additionally, the application of fertilisers, including manure, is prohibited on certain types of land, soils, and during specific periods to protect water and soil quality.

There are also specific conditions for temporary manure storage and a requirement to use measures to reduce emissions during application. In areas near population centres or recreational zones, organic fertiliser applications are restricted on weekends and public holidays, except in cases where methods that fully incorporate the fertiliser into the soil are used. Moreover, regional authorities may impose greater distances in areas where water bodies do not meet environmental objectives.

Manure is considered a category 2 animal by-product, which means it must meet sanitary requirements for transport and transformation into organic fertilisers or soil improvers. It can only be applied directly to the soil if it poses no health risk, or it can be composted or transformed into biogas after pre-treatment that ensures its safety.

- ***Sewage sludge:***

Regulatory barriers for sewage sludge focus primarily on the strict conditions for its application on agricultural or forestry land. Sludge or sediments may only be used on soils that meet stringent limits for

hazardous substances, and their application is prohibited on land that does not comply with these requirements. Additionally, there is a maximum limit of hazardous substances that may enter agricultural land annually, and sludge use is only allowed on forest soils through incorporation during reforestation. Another significant barrier is the concern about contaminants and pathogens that may be present in sewage sludge, leading to public distrust regarding its use in agriculture. Furthermore, transporting and applying composted sludge is costly and logistically challenging, especially when agricultural fields are far from treatment plants. Not all crops or soils benefit from its application, and additional measures are needed to mitigate odour and prevent runoff and leaching of contaminants.

Finally, the administrative process for using composted sludge as fertiliser requires obtaining written certifications and copies of quality certificates, which may discourage farmers from using this resource, as conventional fertilisers are easier to opt for. Moreover, adopting advanced technologies for sludge management may require significant initial investments, posing a financial barrier, particularly for smaller or resource-constrained entities.

- ***Soils:***

Regulatory barriers related to soils focus on restrictions for the use of certain products as growing media or components of growing media. Only products that belong to types included in a specific list may be used under these designations. To include a new type, it must be demonstrated that its use in crops will not lead to the accumulation of heavy metals in the soil, increase its salinity, or introduce contaminants. Detailed information on the product's effects on the physical, chemical, and biological properties of the soil, as well as its mobility and risks of diffuse contamination, must also be provided.

Another significant barrier is the obligation for landowners or users to implement protective measures for eroded, compacted, or degraded soils. They must also maintain the balance of organic matter in the soil by using management methods that do not exceed the limit values for soil organic matter balance, such as compost use. These regulations impose a range of technical and administrative requirements to ensure the protection and conservation of soil quality under various conditions.

- ***Water (including wastewater):***

Regulatory barriers related to water focus on several aspects, including economic, technological, and compliance barriers. One of the main obstacles is the high cost of new practices and technologies required for a transition to more sustainable water management. The lack of sufficient financial incentives and limited access to advanced technologies hinder the adoption of these solutions, particularly for smaller farms, which face greater challenges in meeting regulatory requirements.

In terms of compliance, the threshold for declaring water as affected by nitrate contamination has been tightened. For surface waters, the allowed nitrate level has been reduced to more than 25 mg/l, and for groundwater, the limit is now more than 37.5 mg/l (depending on the region and country, these limits may be even stricter). This reflects a tightening of water quality regulations to improve the protection of water resources and reduce pollution.

In nitrate-vulnerable zones, action programmes establish key requirements for the management of nitrogen fertilisers and manure use. Restrictions include maximum nitrogen amounts per hectare and prohibitions on applying fertilisers in waterlogged or sloping soils. Minimum distances from surface waters and aquifers must also be respected. Additionally, nitrogen application is prohibited in non-productive areas, limiting manure use to 170 kg of nitrogen per hectare per year.

- ***Fertilisers:***

The regulatory barriers related to fertilisers impose a series of strict requirements for products to be marketed. These include the classification of fertilisers into specific groups, packaging, identification, and labelling, as well as registration in an official register for marketing. Additionally, quality controls, traceability, and limits for certain risk parameters, such as pathogens and heavy metals, are established. Without meeting these requirements, products like compost cannot be placed on the market, posing a barrier to their introduction into agriculture.

Another significant barrier is the high cost of new nutrient recovery technologies and the quality control of the recovered nutrients for agricultural use, which must ensure safety for human and animal health. The lack of harmonisation of regulations across EU member states makes it difficult to implement nutrient recovery practices, as each country may have different regulations, complicating the process of compliance for fertiliser manufacturers and distributors.

Regarding nitrogen fertilisers, in nitrate-vulnerable areas, strict adherence to prohibited periods for their use is required, and an annual fertilisation plan must be prepared. Maximum nitrogen doses must also be respected, which cannot exceed 170 kg/ha per economic year. Furthermore, there are restrictions on the use of fertilisers on sloping lands and near water protection zones, limiting the areas where these products can be applied.

- ***Activity requirements:***

Regulatory barriers related to Activity requirements focus on the need for specific authorisations to treat products derived from animal by-products, such as slurry and other category 2 products. Operators must ensure that the facilities under their control are approved by the competent authority in order to transform these by-products into biogas or compost. This includes complying with strict treatment requirements, such as sterilisation, before introducing these materials into biogas plants.

Another important barrier is the lack of clear strategic objectives related to the agri-food sector in some regions. Despite being one of the main economies in certain areas, regional strategies do not specifically address the importance of this sector. Additionally, some regulations are limited solely to environmental aspects, leaving out crucial topics such as the safety and health of people. However, legislation on serious accidents is included in some laws.

Various authorisations under specific laws are also required to carry out activities related to environmental protection and food products.

Opportunities

Table 2 Opportunities detected in regulatory assessment by the partners.

	Opportunities						
Country	Spain	Hungary	Slovakia	Lithuania	Latvia	Denmark	Cyprus
Nutrients							
Waste (Manure)						X	
Waste (Sewage sludge)				X		X	
Soils							
Water	X	X				X	
Fertilisers						X	
Activity requirements	X						

Comparing the results per theme in terms of identified policy opportunities, in Denmark there are opportunities related to waste (manure). Similarly, for waste (sewage sludge) opportunities have been identified in Denmark and Latvia, while the remaining countries have not identified opportunities in this area.

For water, opportunities are identified in Spain, Hungary and Denmark, while the other countries have not reported any water-related opportunities. For fertilisers, Denmark is the only country to have identified opportunities in the area of regulation. On Activity requirements, Spain identifies opportunities in this area. No country identifies opportunities related to nutrients or soils.

In summary, Denmark stands out with the highest number of regulatory opportunities in different topics, especially in waste (manure), residues (sewage sludge) and fertilisers, while Spain and Hungary also show opportunities in water. Topics such as nutrients and soils do not present opportunities in any of the countries.

In order to broaden the thematic analysis, within each of the regulatory topics studied, a more in-depth assessment has been made of the main challenges in each of them that pose opportunities for the countries and regions participating in the project.

- ***Water:***

An opportunity is highlighted in the recovery of resources such as nitrogen and phosphorus from wastewater, which can be recycled and reused as fertilisers, fostering a circular economy and reducing dependence on synthetic fertilisers. Legislation also promotes innovation and research in wastewater treatment technologies and nutrient recovery, encouraging more efficient and cost-effective solutions. Collaboration between various entities (industries, municipalities, research institutions) is encouraged to manage nutrients jointly, reducing pollution levels and associated costs under the "polluter pays" principle. Opportunities also focus on educating and raising awareness among farmers, promoting sustainable agricultural practices and the use of appropriate methods to protect surface waters and meet environmental quality standards.

- ***Activity requirements:***

An important opportunity is identified in the innovation and digitisation of the agri-food sector, which will allow the incorporation of advanced technologies to improve the sector's efficiency and sustainability.

- ***Sewage Sludge***

Composted sludge offers a significant opportunity to act as a carbon sink, improving soil structure, fertility, and water retention. This sludge can close the nutrient cycle between urban and rural areas, promoting resource efficiency and being useful in alternative crop systems. There are also opportunities for its use in precision agriculture. Furthermore, the integration of advanced technologies, such as anaerobic digestion or thermal treatments, would improve sludge management. Data-driven decision-making enables more efficient resource allocation and greater environmental protection. Collaboration between stakeholders is also highlighted, which can increase transparency and accountability in sludge management, promoting sustainability.

- ***Fertilisers:***

No prior permits are required for the agricultural use of certain listed wastes, simplifying the process for their application in farming.

- ***Manure***

Manure application techniques help reduce ammonia evaporation and odour nuisances, while nitrogen is used more efficiently by crops, also reducing ammonia deposition in natural areas.

2. Legislation barriers questionnaire

2.1 Methodology

As a complement to the analysis of national and regional legislation applicable to each demo, a questionnaire related to legal barriers in nutrient management and nutrient pollution has been developed to address this issue in a wider range of stakeholders.

This questionnaire has been disseminated to the stakeholders identified in each regional grouping of the NENUPHAR project. A template with the questions considered is included in **Error! Reference source not found.**.

A link to fill in the questionnaire has been sent to the stakeholder emails collected in WP2 by different partners. The questions are designed to address the most relevant legislation related to nutrient management and nutrient pollution in the different countries where the stakeholders are from. Some questions give the user the opportunity to explain their experiences of legislation on these issues, and to comment on the barriers and opportunities they identify.

Regarding the methodology for the Implementation of the questionnaire, it is described below:

1. Design and preparation of the questionnaire

   The first step involved designing the questions for the questionnaire. It was crucial that the questions were aligned with the task's objectives and that they were clear, concise, and relevant in order to obtain valuable information from respondents.

   A draft of the questions was prepared by CIRCE team. Once the questions were finalised, the template for the questionnaire was designed using Microsoft Forms. This step included configuring the structure of the questionnaire, logically sequencing the questions, and including sections as necessary (as a brief explanation of the project).

2. Identification of Relevant Communication Channels

   The most effective communication channels were identified to distribute the questionnaire and ensure a high response rate. These channels include social media platforms of the NENUPHAR project and targeted email lists for key stakeholders (collected within NENUPHAR Task 2.2). In this case, the channels used have been:

   - Social media: X (formerly known as Twitter) and Linkedin. The questionnaire is free to any stakeholder that want to contribute.

- Mailing: Contact lists from each democase and replicator were used for targeted email distribution to stakeholders in the sector.

3. Questionnaire launch

The questionnaire was launched in the first days of August 2024 and the deadline to contribute is the final of September.

This methodology ensured a structured and effective process for collecting data through the questionnaire, guaranteeing that the results obtained were representative and useful for the project's objectives.

2.2 Results of the questionnaire

The questions and answer are shown below:

1. Country

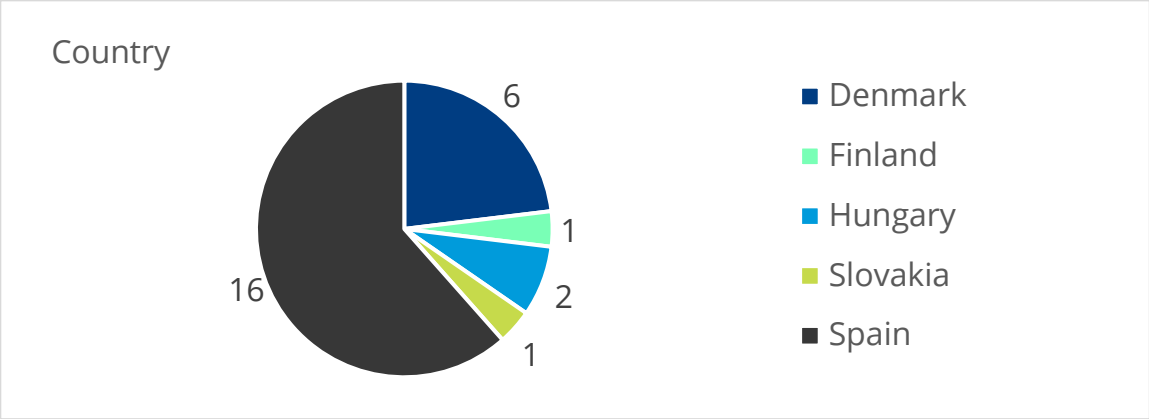

Figure 1. Questionnaire on legislation. Profile of respondents (Country).

As can be seen, the majority of participants (16 out of 26) are from Spain, while the remaining participants are distributed (in order of magnitude) between Denmark, Hungary, Slovakia and Finland.

2. Region

The next graph shows the regions from which the survey respondents come. Following the 'Country' figure, the majority of respondents come from Spain, specifically from the region of Aragon. The next regions with more participants are Castilla y León (Spain) and Bornholm (Denmark).

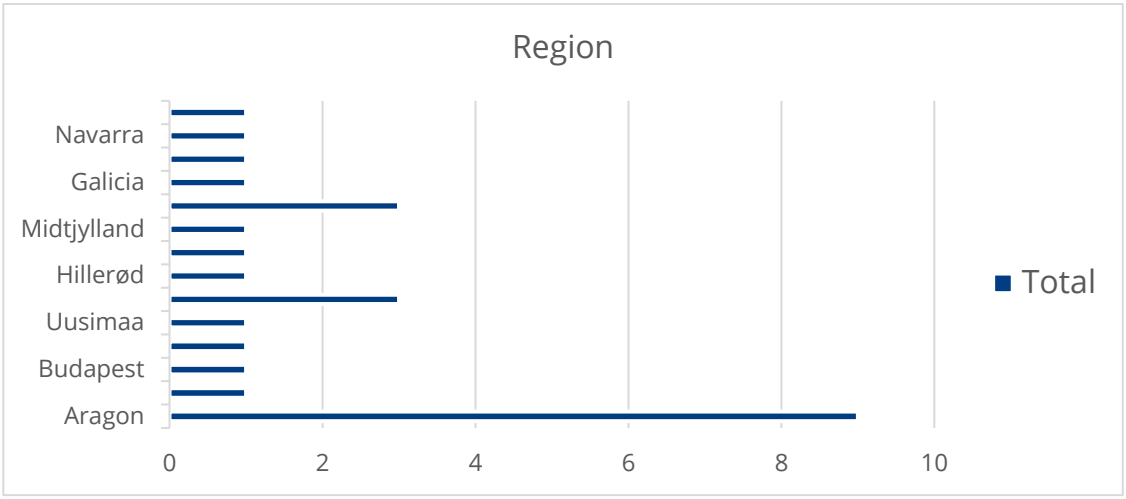

Figure 2. Questionnaire on legislation. Profile of respondents (Region).

3. Type of stakeholder

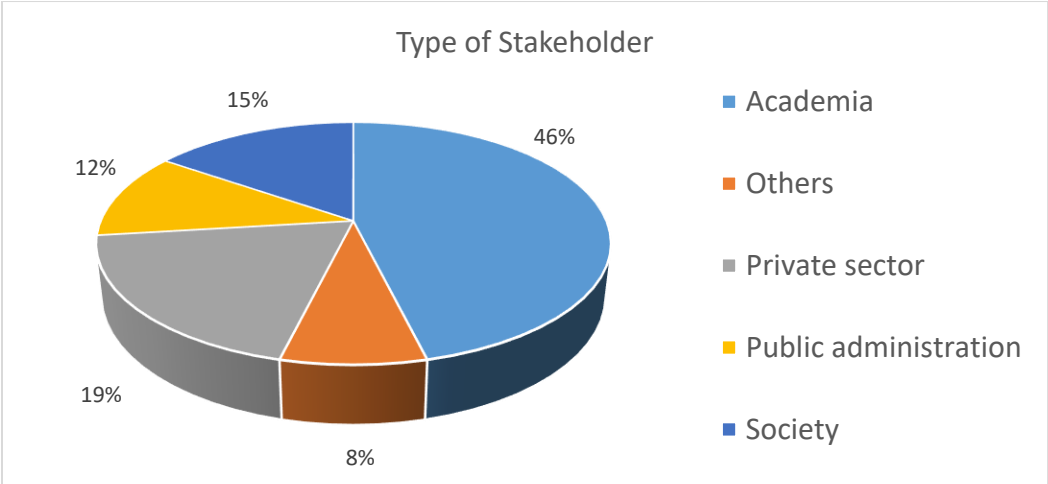

Figure 3. Questionnaire on legislation. Profile of respondents (Type of stakeholder).

The highest percentage of participants belong to the stakeholder type Academia, followed by the Private Sector, Society, Public Administrations and finally the Other sector.

4. **Do you work or have you worked in any sector or activity related to nutrients (mainly nitrogen and phosphorus)? Example: activities related to waste, fertilisers, wastewater treatment, circular economy, livestock industry, etc.**

Table 3. Questionnaire on legislation. Answers to question nº4.

Responses
No (7 responses)
Yes (19 responses): ○ Wastewater treatment nutrient recovery. ○ Composting facilities, waste managers and livestock & crop industry. ○ Involved in some projects related to livestock and treatment of different types of waste. ○ Organic fertiliser producer. ○ Agriculture and livestock. ○ Wastewater activities. ○ Scientist. I have worked with aspects related to all the topics in the example. ○ Fertilisation research (organic and inorganic), water and nutrient cycles. ○ Management laboratory. Fertiliser and soil analysis for nutrient management: training and dissemination. Agricultural sector. ○ Impact of fertilisation in downstream ecosystems. ○ Use of compost of sewage sludge and urban biowastes as organic amendments.

The responses to this question reveal a significant involvement in nutrient management activities. Of the 26 responses received, 19 participants stated that they work or have worked in related sectors, while the remaining 7 participants indicated that they have no experience in this field.

Among the affirmative responses, the most popular topic in which participants work or have worked is waste management with a focus on nutrient recovery. This includes activities related to wastewater treatment, composting of sewage sludge and sludge from the agricultural and livestock industry. Another part of the participants is linked to the agricultural sector, mainly in relation to fertilisation, both organic and inorganic. Some respondents were involved in research and dissemination in relation to nutrient management.

5. **Have you encountered any barriers or difficulties in your activity arising from the application of nutrient-related regulations in your country/region? Example: authorisations and licences, restrictions on nutrient recovery or application, restrictions on land application, lack of clear legislation, overlapping legislation, etc.**

Table 4. Questionnaire on legislation. Answers to question nº5.

Responses
No (8 responses)
Yes (17 responses): Legislative restrictions for land application. Restrictions on land application, restrictions on land application and overlapping legislation. Limitations are placed on organic amendments or amendments from the recovery of waste or by-products due to nutrient contamination in the field, but not on mineral fertilisers. Lack of coherence in legislation and regulation, due to for example that the renewal of the legislation takes place little by little, sector by sector, one law at a time Monitoring and compliance with existing regulation. There is a lack of control on real practices within fertilizing and nutrient-related regulations. At national level exist a lack of clear legislation that overlaps with waste managing practices for private and public institutions. There are restrictions on land application. Licenses, authorization, lack of legislation (2019/1009). One barrier is that an environmental permit must be obtained from the local municipality when applying biochar. This requirement can be administratively burdensome. Limitations of application of organic nitrogen, but not mineral nitrogen. Restrictions on the application of organic fertilisers in vulnerable areas (170 kg N organic/ha year). It is a big problem in places where double crops are grown and there are many livestock farms. Periods of application. Lack of clear legislation, overlapping legislation. Poor acceptance by farmers.
Not relevant

When asked whether they have encountered any barriers to their activity arising from the application of nutrient-related regulations in their country/region, a total of 26 responses were counted, of which 17 respondents indicated that they had encountered barriers, while 8 respondents stated that they had not experienced any difficulties. Only one respondent answered as 'Not relevant'.

The most frequently mentioned barrier among the respondents is related to the limitations imposed on the application of nutrients to the soil, especially in vulnerable areas or with specific restrictions for organic fertilisers. A second most frequent barrier among the responses was the lack of coherence and overlapping of legislation, and obstacles in licensing and authorisations, where respondents mentioned that bureaucratic procedures and the need for specific permits complicate the implementation of good nutrient-related practices. Responses also reflected a general dissatisfaction with the inequalities between the use of organic and mineral fertilisers, and the low acceptance by farmers of certain practices related to nutrient management.

6. **Are there financial or technical support mechanisms for stakeholders to comply with nutrient management regulations in your country/region? If not, answer "No".**

Table 5. Questionnaire on legislation. Answers to question nº6.

Responses
No (10 responses)
Yes (13 responses): Nitrate sensitive areas in GAEC. There is not as much legislative and financial support as there should be. There are some programs that support research to improve livestock waste treatment and management. Some, but they are inadequate. Few should promote these tools more. E.g. subsidies for biogas production. Yes, technical Support. Technical support, although not sufficient. Yeah. They are starting but they are not clear or accessible to all farmers.
Not enough
Not sure
I don´t know

In the third question of the questionnaire the responses obtained on the existence of financial or technical support mechanisms regarding compliance with nutrient management regulations, 13 indicated that some mechanisms do exist, while 10 indicated a lack of support or were unsure of their existence. Three respondents answered, 'Not enough', 'Not sure' and 'Don't know' to this question.

Some respondents acknowledge the existence of technical and financial support mechanisms (Subsidies for biogas production, Programs supporting research to improve livestock waste treatment and management, etc.), although they stress that they are insufficient or limited, as they do not cover all the needs of stakeholders, mainly farmers. One respondent highlighted the need to promote more support tools. Another group of respondents expressed uncertainty or lack of knowledge about the existence of support mechanisms, reflecting a possible lack of communication or accessibility of these programs.

7. **What improvements would you suggest to the existing regulatory framework in your country/region to better manage nutrient pollution or its recovery? If not, answer "No".**

Table 6. Questionnaire on legislation. Answers to question nº7.

Responses
No (5 responses)
Yes (20 responses): Financial support for farmers for recycled nutrients and new legislation. Increased legislation to encourage nutrient recovery and legislation, to encourage field Application of organic amendments without as much or as much nutrient restriction as mineral fertilisers. There must exist clear and long-term studies outpointing the positive/negative impact of new nutrient recovery technologies (digestates, manure...) and its application on real soils in order to support and limitate its market towards the real regulatory protection of natural soils and water resources. Supported and more regular soil analysis, better farmer knowledge on the topic. Clearer regulation. To be able to use organic fertilisers with the same restrictions as mineral fertilisers, not more, as the regulations currently stand. More control on correct application and register. Analysis of actual production to determine crop requirements. promotion of the use of livestock waste. More flexibility in the regulation. Very strict rules can lead to non-optimal actions - e.g. crops harvested before maturity, because catch crops must be planted. Or too much bare soil in spring, with increasing precipitation, if winter crops cannot be sown because of regulation. Control the number of fertilisers per crop and not per year in the Vulnerable Zone, regardless of whether it comes from organic or inorganic fertilisers. That is, increase the

limit on the amount of organic fertiliser in those crops that need it, so as not to have to depend on mineral fertiliser.

Slurry cooling, designer slurry.

More databases are needed to develop new guidelines.

Control.

More technical support based on site-specific data (residual effects of fertilisers, fertilisation and irrigation with saline water...).

Coherence, aiming at improving nutrient recycling.

Promotion of soil analysis and fertilisers (mainly organic ones). Promote the use of mineral nitrogen analysis prior to contributions to the soil (rapid response from laboratories). Advice. Promotion of investments in equipment that improves distribution and variable dosage supported by remote sensing.

Presence of extension service technicians in the agricultural areas, who could help farmers.

A regional support for increase organic fertilisation based in biowastes.

Tighter rules for discharges to receiving waters.

Stronger regulations join to financial support.

The fourth question also received a total of 26 responses, with 20 respondents stating that they had suggestions for further improvements to the regulatory framework to better manage nutrient pollution or its recovery, while 5 respondents indicated that they had no suggestions. Only one person responded as 'Don't know'.

Among the affirmative responses, the most respondents suggested increasing financial and technical support for farmers to encourage the use of recycled nutrients and improve farming practices. In addition, the need for greater consistency and clarity in regulations on nutrient recovery was highlighted, which would allow for a more equitable and effective implementation of regulations. Another recurring theme was the demand for a regulatory framework that imposes the same restrictions on organic fertilisers as on mineral fertilisers, thus promoting their use. Reinforced control and monitoring of the correct application of fertilisers was also proposed, along with a greater emphasis on soil and crop analyses to optimally adjust nutrient dosages. Some respondents pointed to the importance of developing databases and conducting long-term research on new nutrient recovery technologies and their impact, as well as tightening regulations related to discharges into water bodies.

8. **Do you know of any success stories or projects in which nutrients have been recovered from waste streams for reintroduction into the value chain, which could serve as models for good practice? Example: European projects, local initiatives, etc. If not, answer "No".**

Table 7. **Questionnaire on legislation. Answers to question nº8.**

Responses
No (9 responses): No, but we have to promote the circular economy in Irrigable Areas. No. I know of cases in the literature, but not of practical examples nearby.
Yes (17 responses): Vermicomposting - company Bio - hnojiva Sea2land, Fertimanure... (European projects). Some from the Netherlands and Belgium, but those are rather unique environments, and those models are not that suitable for the more sparsely populated Northern European countries. At regional level, in Aragon there are some local initiatives that are studying different ways to treat the slurry so that it can be applied later as fertiliser. Phosphorus extracted from the surplus water before the slurry goes into the heat kettle Proyecto LIFE ES-WAMAR. Se crearon centro gestores de estiércoles de los cuales dos siguen funcionando a fecha de hoy, valorizando el purín porcino como fertilizante. Local initiatives. 2020 Nutri2Cycle (closed in 2022) Use of digestate from biogas plants. I guess struvite is such a story. I am, however, not completely certain about the actual value of it as fertiliser. Many, e.g.: the GUDP project called "GØDP". The EU Ferticycle project. Local initiatives of reuse of drainage water of irrigation, which has in a lot of cases, a high concentration of nutrients. As a biogas plant, we can recycle important nutrients for both industry and agriculture. Ammonia Trapping. National projects to recover struvite for sewage sludge and manure. We were involved in the project Greater Bio. There is more knowledge about it somewhere, maybe contact Gate21. There was a follow-up project that I think was called power to bio perhaps, which continues to work on some of the things. Local and international projects, local and manufacturing initiatives.

In the last question, there were still a total of 26 responses as in the rest of the questions, of which 17 participants mentioned positive examples of projects where nutrients have been recovered from waste

streams for subsequent reintroduction and the remaining 9 people indicated that they did not know of any success stories.

Respondents who answered 'Yes' referred to various EU-funded projects, such as Sea2land, Fertimanure, Ferticycle, etc. As well as national projects, such as Bio-hnojiva, and regional and local initiatives. In addition, some highlighted success stories focused on specific technologies for nutrient recovery (biogas plant). Regarding the respondents who answered 'No', two respondents commented on their answer. One of them mentioned having read about the topic in the literature, but not knowing of practical examples nearby, while another suggested the importance of fostering the circular economy in Irrigated Areas to promote this type of initiatives.

3. ESNI workshop

3.1 Methodology

Another approach to complete an overview of possible barriers and opportunities arising from regional and national regulations in the countries participating in the NENUPHAR project was a workshop at the ESNI international congress on nutrients (18-19 September 2024, Brussels).

Within this congress, a session was organised in order to obtain barriers and opportunities related to the regulation, at the same time as the project was presented to the stakeholders attending the event. During this workshop, working groups were organised according to the different wastes studied in the project, and a discussion time was encouraged among the participants to share their knowledge and impressions on regional and local regulations, and on how to obtain possible improvements to overcome regulatory barriers in nutrient management.

The composition of the different groups is shown in table 8.

***Table 8*. Composition of the ESNI Workshop groups.**

Groups	Composition
Group 1: Manure	One technical expert from UVIC One person from EEB taking notes One person from AKI to address economic instruments 4 people audience
Group 2: Manure	One technical expert from CIRCE One person from UVIC taking notes 4 people audience

Group 3: Sewage sludge	One technical expert from ZSA One person from CIRCE taking notes 5 people audience
Group 4: Sewage sludge	One technical expert from LBTU One person from CIRCE taking notes One person from AKI to address economic instruments 5 people audience
Group 5: Dairy wastewater	One technical expert from SZE One person from UVIC taking notes One person from AKI to address economic instruments 5 people audience
Group 6: Dairy wastewater	One technical expert from SUA One person from EEB taking notes 3 people audience

In each group, a partner from NENUPHAR was designated as a spokesperson, who has the responsibility to share the main conclusions after the round table. To guide the debate, a list of questions was facilitated to moderators to address legislation topics in the discussions:

- Is there any regulatory/economic instrument in your country or region that promote nutrient recovery?
- In your opinion, which are the main barriers that prevent or hinder nutrient recovery? (authorizations/licenses, waste-treatment, etc.)
- Is there a friendly framework for marketing and application of nutrients recovered from waste?
- How can we encourage regulatory/economic instruments nutrient recovery? Do you know of any cases/experiences that recover nutrients from waste?

The discussion time was also used by AKI to gather information about economic and financial instruments, so in the groups where AKI was participating, some economic questions were also addressed with the audience:

- Are there existing economic instruments to promote nutrient flows using dairy wastewater/sewage sludge/manure systems? What are the specialities of these instruments?
- Are there financing gaps in agri-food sector for shift to a nutrient cycling business model? Dairy wastewater/sewage sludge/manure systems require additional operative or investment related financing?

- Which are the main barriers or failures of using the right economic tools in nutrient management?

3.2 Results of the workshop

The main conclusions obtained are shown below, divided into the different working groups and waste.

Groups 1 and 2: Manure

In Catalonia, there are significant government investments aimed at supporting biogas plants, particularly those focused on the primary sector, with a special emphasis on manure processing. This demonstrates the region's commitment to promoting nutrient recovery. Similarly, in Latvia, between 2009 and 2011, there was a special investment programme that supported the development of biogas plants in Lithuania, showing some level of regional support for nutrient recovery initiatives.

However, several barriers prevent or hinder further progress in nutrient recovery. In Catalonia, stringent biosecurity criteria have made it difficult to open new biogas plants, which limits the capacity for processing manure and other organic waste. Additionally, there is a general lack of awareness and resistance to adopting new technologies, which slows down the acceptance of nutrient recovery systems. In Latvia, the lack of knowledge about available nutrient recovery products and technologies remains a significant obstacle. Farmers and industry participants are still learning how to apply recovered nutrients effectively, and the variability in product quality makes precise application difficult.

At the European level, the EU's Common Agricultural Policy (CAP) network provides a framework for exchanging information through expert groups, offering a forum for discussions about nutrient recovery and other agricultural innovations. While this facilitates the sharing of knowledge, it does not directly resolve local barriers to marketing and applying recovered nutrients.

Encouraging the use of regulatory and economic instruments for nutrient recovery has proven challenging. For instance, in Catalonia, recent regulatory changes have made it more difficult for producers to sell their recovered nutrient products, which creates additional obstacles for nutrient recovery systems to flourish. This highlights the need for more supportive policies that incentivise rather than hinder the sale and use of recovered nutrients.

Financing gaps also pose a major challenge in the agri-food sector's transition to a nutrient cycling business model. Nutrient recovery facilities require large upfront investment costs, which can be a significant barrier for smaller producers. Additionally, the pricing of recovered nutrient products must be competitive to ensure they are a viable alternative to traditional fertilisers. Without adequate financial support and investment, many farmers and businesses may struggle to adopt these systems, further limiting the potential for nutrient recovery at a broader scale.

In the Netherlands, nutrient recovery is significantly influenced by the EU Nitrates Directive, which regulates manure application at 170kgN/ha per year. There was a temporary modification to allow 250kgN/ha with mineral compensation, but this year the limit will be reduced back to 170kgN/ha. This reduction is expected to lead to an increase in the use of mineral fertilisers. Additionally, the Netherlands exports a large volume of chicken manure, particularly to France, due to the high nitrogen levels in the manure. Flanders, similarly, exports solid manure fractions to France for fertiliser production, indicating that cross-border nutrient flows are already part of the business model in some regions.

The barriers to nutrient recovery include mismatches between the production and application of manure. Manure is produced year-round, but there are only two seasons during which it can be applied, creating logistical challenges for storage and use. Furthermore, there is a lack of business models that effectively promote the use of manure as a resource, which hampers progress in this area. In Catalonia, for example, there is a strong bioeconomy strategy that promotes biogas and biomethane through incentives, but national regulations limit the application of recovered nutrients. These regulations are often not adapted to the realities of waste production and distribution, resulting in concentrated waste and distribution issues.

There is a recognised need for a more supportive framework for the marketing and application of nutrients recovered from waste. Developing the right business models is crucial to promoting the use of manure and other recovered nutrients. For example, Norway has found success in using fish sludge through regional cooperation, where relationships between regions facilitate the closed-loop use of these resources. This type of regional collaboration could serve as a model for other countries.

To encourage the adoption of regulatory and economic instruments for nutrient recovery, EU regulations need to be more flexible and tailored to the needs of individual member states and regions. A common regulatory framework, like the Water Framework Directive, is necessary, but it must allow room for regional adaptation. The Renure approach, which focuses on treating manure to reduce nitrogen and phosphorus levels, is seen as a potential way to tailor EU regulations to specific country contexts. Regulatory decisions should be based on proven data and should support regional flexibility in nutrient management.

Economic instruments for promoting nutrient flows, particularly through the use of dairy wastewater, sewage sludge, and manure systems, are already being developed. For example, in 2023, new regulations on mineral fertiliser enterprises were introduced to protect the internal European market, limiting imports from external sources such as Russian enterprises. This regulatory approach highlights the potential for policy to protect local industries while promoting sustainable nutrient management practices. Opportunities for nutrient recovery are particularly evident in sectors like chicken manure and fisheries, where waste can be transformed into valuable resources. More practical, policy-driven approaches are needed to unlock these opportunities and create a thriving market for nutrient recovery.

Groups 3 and 4: Sewage sludge

In Germany, the P project focuses on phosphorus recovery through struvite recuperation. However, this process faces regulatory restrictions due to high levels of phosphorus already present in the soil, with established limit values. As a result, most sewage sludge is sent for incineration. Struvite, a by-product of the recovery process, is classified as CMC12 under EU legislation, which influences how it is handled and applied. In Turkey, sewage sludge can be used after undergoing chemical, biological, or membrane-based treatments, but there is no specific agricultural legislation in place to govern this. Since there is no obligation to analyse soils, these assessments are not commonly conducted, which limits the potential for more sustainable nutrient recovery practices.

In Latvia, nutrient recovery is more structured, as sewage sludge must be centralised in wastewater treatment plants that perform composting activities. After 12 months of composting, the sludge must be further treated before it can be applied to soils. There are strict limits on heavy metals, and a national strategic plan governs the process. Farmers are required to test both the soil and the sewage sludge to ensure that the nutrients applied match the soil's needs. However, farmers face the challenge of a short timeframe to carry out these analyses after the harvest, which can be a limiting factor in the effective recovery of nutrients. In Lithuania, a comprehensive national law regulates the application of sewage sludge to soils. It is mandatory to take soil measurements and calculate specific parameters before applying sludge. However, there is some flexibility in the timeline for sample collection, as the results may vary depending on conditions. The law also sets limits for various parameters, but there is ongoing discussion about the need for more flexible instruments to better adapt to specific soil needs. For example, if the soil has high nitrogen but normal phosphorus levels, the amount of sludge applied should be adjusted accordingly. There is a call to increase the limits for some parameters, so that not all decisions depend solely on soil conditions. Recovery should not be the sole solution; instead, a combination of different approaches would be more effective.

One of the main barriers to nutrient recovery is the lack of affordable fertilisers for farmers and their limited knowledge of the potential benefits of using recycled nutrients. Financial support for farmers is crucial to overcoming these challenges, as the adoption of nutrient recovery practices can be costly without assistance. Providing this support would facilitate the transition to more sustainable agricultural practices.

To encourage the use of regulatory or economic instruments for nutrient recovery, it is important to prioritise the market entry of recovered fertilisers. In countries like Belgium, where fertilisers often exceed legal limits, more should be done to expedite the use of recycled nutrients. This could involve subsidies for producers of recycled fertilisers, making them more competitive in the market. Moreover, decisions should be based on concrete data regarding phosphorus and other nutrient levels in the soil. Farmers who apply recycled nutrients should be given the opportunity to conduct soil analyses more frequently, as this would allow them to tailor their fertilisation practices more effectively. However, a general lack of

awareness among farmers remains a significant obstacle. Raising awareness about the benefits of nutrient recovery is essential for widespread adoption of these sustainable practices.

In Latvia, the government adopted a sewage sludge strategy last year after two years of preparation. Although the management plan has been developed, it is still pending governmental approval. The preparation of these documents was supported by a previous project, and now partners are collaborating with NENUPHAR to transfer knowledge from that earlier initiative. While Latvia currently lacks economic instruments for nutrient recovery, the country is heavily involved in LIFE-integrated projects, working closely with public administrations. These efforts offer promising prospects for future incentives and more structured approaches to nutrient recovery. In contrast, Greece does not have regulatory or economic motivation to address sewage sludge management.

Despite housing one of Europe's largest wastewater treatment plants near Athens, the sludge is not applied to soils. Instead, after drying, it is given to cement companies, as there are no economic drivers to introduce new regulations or reuse the sludge for fertilisation. European Union regulations permit the application of 30-50% of sewage sludge, which could present a positive change for Greece if applied. On Cyprus, all sludge produced by wastewater treatment plants is provided to farmers for free. The regulations allow this, but the quantity of sludge used depends on the analysis of both the sludge itself and the soils it is applied to. In Germany, ongoing work focuses on developing certification systems for nutrient recovery, especially phosphorus, which has been identified as a critical raw material.

A transition period until 2029, dependent on the size of facilities, is currently in place for phosphorus recycling. Farmers have been consulted, but sewage sludge has the lowest acceptance rate among them. There is ongoing discussion that using local sewage sludge could reduce imports from countries like Russia. Composting, in particular, is considered a more efficient method of eliminating microorganisms than freezing the sludge. The economic condition of composting, rather than buying nitrogen fertilisers, is also seen as beneficial, given the rising costs of synthetic fertilisers.

One of the main barriers to nutrient recovery is the lack of necessary infrastructure in many regions. In numerous areas, composting facilities are insufficient, leading to reliance on incineration as the primary method of sludge disposal. Small local communities, in particular, are hesitant to adopt novel technologies, viewing them as unfeasible—a concern that has been highlighted in both Germany and Latvia. Another issue is the lack of market supply, as long distances and a shortage of traders make nutrient recovery and distribution more challenging. For nutrient recovery to be successful, it is essential to ensure that the systems proposed are both safe and sustainable, a message that must be effectively communicated to primary producers. The principal problem is a lack of trust in the economic sustainability of nutrient recovery systems. This sentiment is shared in Greece and Hungary, where farmers are reluctant to embrace initiatives, they do not perceive as economically viable in the long term. Farmers need to see potential revenues for themselves in order to participate, and more training is required to build their confidence in nutrient recovery. The NENUPHAR project is making progress by involving farmers in

discussions and sharing the experiences of wastewater treatment plants in Latvia and local farms, as well as capacity building efforts on the topic.

In Latvia, the marketing and application of nutrients recovered from waste is relatively straightforward. Composting fields is neither expensive nor complicated, and the process can be completed in just one day. However, many of the applications are outsourced, and there is a growing consensus that promoting labelling for recovered nutrients would be beneficial. One crucial aspect of expanding this market is the inclusion of fertiliser companies. If the transition to recovered nutrients is not handled carefully, many workers in the conventional fertiliser industry could lose their jobs. Green jobs must be created, and fertiliser companies should be brought closer to farmers to integrate these new products into their portfolios. This transformation should not solely focus on farmers; it must also involve the existing players in the fertiliser market. If wastewater treatment plants handle all aspects of nutrient recovery, they could sell the recovered products to companies instead of distributing them directly from farmer to farmer.

In terms of encouraging regulatory or economic instruments for nutrient recovery, Latvia's small size means that there are relatively few players in the market, making it easier to transfer knowledge gained from projects to institutions. However, there is still a need to synchronise the equipment and measurements required for effective sludge monitoring. Voluntary policy schemes, such as climate-neutral regions and regional strategies, could include nutrient recycling as part of their initiatives. Public procurement processes could also be used to select the most appropriate technologies for nutrient recovery. Additionally, it is crucial to highlight the environmental benefits of nutrient recovery, particularly in relation to the damage being done to the Mediterranean Sea. By showcasing how improved wastewater management can benefit tourism and protect natural resources, there may be greater support for implementing nutrient recovery systems.

Groups 5 and 6: Dairy wastewater

In Ecuador and Bolivia, environmental regulations impose heavy fines and charges on those who fail to treat wastewater, with a significant reduction in costs for industries that comply. This aligns with the polluter pays principle, which aims to penalise those who pollute and reward those who take responsibility for waste management. In Bolivia, for example, the brewery industry faces strict laws where wastewater quality must meet certain standards, or the facility risks closure. These restrictive laws are in place to ensure industries adhere to environmental standards. However, such stringent policies, while effective, primarily target larger industries and may not address the challenges faced by smaller producers.

One of the major barriers to nutrient recovery is the economic and infrastructural gap in many regions. Small dairy producers, for instance, often do not have the resources or opportunity to treat their wastewater. The economic status of a country or region plays a significant role, as insufficient capital prevents the construction of new wastewater treatment facilities. Additionally, there is a general lack of

knowledge among policymakers and the private sector regarding the potential economic benefits of waste valorisation. This gap in awareness limits the development of nutrient recovery initiatives. Even when policies are in place, they are often poorly implemented or monitored, resulting in what is referred to as "fake policy"—rules that exist on paper but are not effectively enforced.

When it comes to the marketing and application of nutrients recovered from waste, there does not appear to be a well-established or widely known framework. Participants in various discussions have not identified any significant regulations or market systems that facilitate the use of recovered nutrients. This highlights a critical gap in the policy landscape and suggests that more needs to be done to create market-friendly frameworks for nutrient recovery.

Encouraging the use of regulatory or economic instruments for nutrient recovery requires foundational data and statistics. Before any policy instruments can be implemented, it is essential to establish preliminary accounting systems to measure the amount of nutrients present in the waste stream. This will help policymakers understand the magnitude of the problem and craft solutions based on accurate data. One potential economic instrument could be the introduction of subsidies that support the development of specialised sewage systems distinct from urban systems. In Hungary, for example, a development fund provides incentives to farmers and industries to adopt technology that reduces pollution. Similarly, in countries like India, banks offer general loans, which could be adapted into green loans to further encourage sustainable practices.

In some regions, economic instruments already exist to promote nutrient flows using dairy wastewater, sewage sludge, or manure systems. For example, in Bolivia, banks offer green credits to farmers at low-interest rates, along with capacity-building activities focused on green technologies like solar panels. While this programme is small, it demonstrates the potential for financial tools to support sustainable nutrient management practices. However, these programmes need to be scaled and adapted to different contexts for broader impact.

One of the main barriers to using effective economic tools in nutrient management is the requirement for non-refundable support, which often demands a certain percentage of investment from the farmer's own funds. This poses a challenge for smaller farms that may not have the necessary financial resources. Additionally, access to support and services is not always democratically distributed, as seen in India, where certain regions or groups may have less access to financial benefits. There is also a lack of infrastructure in some areas, as evidenced by Egypt’s organic agriculture sector, where businesses struggle due to inadequate facilities for processes like demoisturising organic matter. Addressing these gaps is crucial for the successful implementation of nutrient recovery initiatives worldwide.

In Finland, the regulatory framework supporting nutrient recovery, particularly phosphorus (P) recycling, is relatively soft, allowing for some flexibility in implementation. However, there is limited awareness of any specific economic instruments that directly support nutrient recovery. One existing initiative is the creation of platforms or marketplaces aimed at facilitating the exchange of recovered nutrients, but this approach is still in its early stages and lacks widespread adoption.

Several key barriers hinder nutrient recovery efforts. Financially, the cost of recovering nutrients from waste streams is often higher than using conventional mineral fertilisers, making it a less attractive option for farmers. Additionally, there is a cultural barrier, as many farmers are permitted to use sewage sludge, but contracts with major food companies typically prevent them from doing so. This discourages the use of nutrient recovery systems. Regulatory challenges also play a role, as farmers are required to conduct sampling every five years, which deters them from applying manure or nutrients recovered from secondary materials.

To encourage the adoption of regulatory or economic instruments for nutrient recovery, existing examples show that companies in wastewater treatment are already extracting phosphorus from wastewater streams, producing phosphoric acid and composting the phosphorus. The challenge lies in getting larger food companies to accept the use of sewage sludge, while manure remains less accepted. Increasing overall awareness about the benefits and safety of recycled fertilisers is essential to broader adoption. Educating farmers and food companies about the advantages of these systems could help overcome the cultural and regulatory barriers currently in place.

There are no widely known economic instruments promoting nutrient flows from dairy wastewater, sewage sludge, or manure systems in Finland. However, there is an exception for manure, where farmers receive subsidies for re-using it, providing some financial incentive. Digestate facilities have been built, though it remains unclear whether the state participated in their financing. Despite these efforts, the financial and regulatory support for nutrient recovery remains underdeveloped, particularly for wastewater systems.

The agri-food sector faces significant financing gaps when shifting towards a nutrient cycling business model. Dairy wastewater, sewage sludge, and manure systems require both operational and investment-related financing, which are currently insufficient. There is a clear gap in the development of regulatory and economic instruments to support this shift. While manure recycling is slightly more advanced in terms of financial support, wastewater treatment systems are severely lacking, and awareness of existing opportunities remains low among stakeholders. Without stronger financial backing and regulatory incentives, nutrient recovery in these sectors will continue to struggle.

4. Other existing experiences in demo's countries

Following the description of the Task 4.2, "a review of existing experiences in demo's countries related to nitrogen and phosphorous recovery will be collected, in order to identify the main barriers and measures undertaken for their overcoming".

To meet this requirement, desk research has been carried out to find other projects (at different levels) addressing nutrient recovery and management in the same countries where the NENUPHAR demos are taking place.

When selecting similar projects, aspects such as the main theme and status (preferably completed or well-advanced projects, in order to obtain more detailed information) were taken into account. It was also decided to work on this comparison with European projects, as these are projects that usually address legislative barriers and are highly involved in governance structures and how to improve them in order to favour nutrient management at all levels. Following these premises, the following projects have been selected:

- FERTIMANURE (2020-2024): Innovative nutrient recovery from secondary sources – Production of high-added value FERTIlisers from animal MANURE.
- SEA2LAND (2021-2024): independence and security in the supply of nutrients to European agricultural systems, mitigating the existing nutrient imbalance in Europe.
- MED4WASTE (2021-2023): new governance models for integrated and efficient urban waste management policies across the Mediterranean, with particular emphasis on organic waste & circular economy through adapting waste management plans, policies and other management actions and regulatory drivers in the selected territories.
- POWER4BIO (2018-2021): emPOWERing regional stakeholders for realising the full potential of european BIOeconomy.
- NUTRI2CYCLE (2018-2023): assess the current Nitrogen (N), Phosphorus (P) and Carbon (C) flows looking into existing management techniques in different farms across Europe and analysing their related environmental problems.

Once similar projects have been identified, a literature review was conducted to identify the legal barriers related to nutrients in these countries and the measures taken to overcome them. The main conclusions drawn from the evaluation are shown below:

Lack of Regulatory Harmonisation

One of the most frequently mentioned obstacles in projects such as SEA2LAND and NUTRI2CYCLE is the lack of harmonisation between national and European regulations on bio-based fertilisers and animal by-products. This misalignment makes it difficult to adopt bio-based products in the European market, as each country may have different requirements, preventing the creation of a unified market for these products. For example, in the FERTIMANURE project, it is mentioned that the certification of fertiliser products derived from manure, such as ammonium sulphate, can take up to 2-3 years in Spain due to regulatory barriers, delaying their commercialisation.

To mitigate this barrier, SEA2LAND suggests that exhaustive research conducted in various R&D projects (such as those funded by HORIZON) should be considered when developing new fertiliser regulations. Additionally, the creation of a unified regulatory framework at the European level would facilitate the introduction of bio-based fertilisers across all member states, reducing the discrepancies between national regulations.

Social and Administrative Acceptance

Social acceptance of fertilisers derived from waste and by-products is another critical barrier, highlighted in projects like FERTIMANURE and NUTRI2CYCLE. Although these products have high agronomic value and can compete in the fertiliser market, their origin (e.g., manure or sewage sludge) generates distrust among farmers and consumers. Additionally, obtaining the necessary certifications for these products to be officially recognised as fertilisers can be a lengthy and complex process in some countries, such as Spain, which discourages their adoption.

To overcome this barrier, the SEA2LAND project proposes increasing understanding of the production and application of bio-based fertilisers through pilot demonstrations. These pilots will showcase the benefits and safety of these products in real-world contexts, which could improve social perception and accelerate market acceptance. Additionally, creating specific incentives for farmers to use locally produced fertilisers would reduce transportation costs and promote sustainability.

Lack of Incentives and Financial Support

The lack of economic incentives and limited access to financing are recurring barriers mentioned in several projects, including SEA2LAND, POWER4BIO, and MED4WASTE. In the context of transitioning to a circular economy and adopting nutrient recovery technologies, many farmers and small businesses lack the financial resources needed to implement these solutions. For instance, MED4WASTE highlights the need to create a supportive environment for startups and small and medium-sized enterprises (SMEs) through economic incentives that encourage separated waste collection and the use of bio-based fertilisers.

SEA2LAND recommends creating incentives to encourage farmers to shift towards sustainability by using bio-based fertilisers instead of traditional mineral-based ones. It also suggests the establishment of specific funding schemes for sectors involved in nutrient management, as well as for companies

processing fishery and aquaculture by-products, incentivising their use rather than accumulation or disposal.

Technological and Infrastructure Barriers

The development and implementation of advanced technologies for nutrient recovery require significant investments and the existence of adequate infrastructure, which presents a major technological barrier. This is noted in projects like FERTIMANURE and POWER4BIO, where it is mentioned that although the technologies for producing fertilisers from manure or sludge exist and are technically feasible, they are not commonly implemented in agricultural operations due to costs and the lack of local infrastructure.

MED4WASTE recommends optimising the use of existing infrastructure for waste and nutrient treatment, as well as upgrading facilities that do not meet current regulatory standards. To facilitate the adoption of these technologies, it is crucial to develop public and private financing mechanisms to help businesses acquire and operate state-of-the-art technologies, such as biogas plants or biomass logistics centres, as highlighted in POWER4BIO.

Lack of Awareness and Training

The lack of awareness and training regarding nutrient recovery technologies and their benefits is a critical barrier identified in projects like MED4WASTE and NUTRI2CYCLE. Many farmers and companies are unaware of the environmental and economic advantages of using bio-based fertilisers, which limits their adoption. MED4WASTE emphasises the importance of education and awareness programmes targeting all actors involved in the waste and nutrient value chain to foster the transition towards a circular economy.

To overcome this barrier, it is recommended to create training and awareness programmes for farmers, entrepreneurs, and decision-makers. These programmes should focus on the benefits of using bio-based fertilisers, the importance of sustainable waste and nutrient management, and the opportunities offered by the circular economy. POWER4BIO also mentions the need to increase awareness of the bioeconomy concept to ensure bio-based products gain wider acceptance in the market.

Difficulties in Managing Organic Waste

Proper management of organic waste is another key barrier highlighted in the MED4WASTE project. Although there have been advances in creating legal frameworks for waste management, many Mediterranean countries still face challenges in implementing waste management policies at the local and regional levels. A prominent example is the lack of coordination between different public administrations in countries like Spain, where landfill tax rates and waste treatment centres are not aligned with national and regional targets.

To address this challenge, MED4WASTE proposes the creation of integrated municipal waste management plans that involve all stakeholders and promote a circular approach. It also suggests implementing

separate collection systems and encouraging the participation of social enterprises in waste management, which could improve the sector's efficiency and sustainability.

Slow Progress in the Bioeconomy

Although several projects, such as POWER4BIO and NUTRI2CYCLE, recognise the potential of the bioeconomy to drive sustainability and efficiency in nutrient management, they also note that progress has been slow due to a lack of regulatory and financial support. In regions like Nitra, Slovakia, the infrastructure for biomass management is relatively developed, but there are still difficulties in mobilising resources and optimising the biomass supply chain, limiting the growth of the bioeconomy.

To accelerate this process, it is proposed to create regional innovation and development centres that promote the use of biomass in industrial and agricultural sectors. POWER4BIO also suggests implementing new financial instruments, such as regional innovation funds and innovation vouchers, to support bioeconomy-related projects.

Complex Certification Processes

In several projects, such as FERTIMANURE and NUTRI2CYCLE, lengthy and complex certification processes for bio-based products are mentioned as barriers to their acceptance as fertilisers. These processes often involve multiple administrative requirements and technical analyses, which discourage producers from using products like struvite or phosphorus-rich ashes from thermal treatments.

To resolve this barrier, NUTRI2CYCLE suggests simplifying certification processes at both the national and European levels and developing harmonised criteria to facilitate the introduction of innovative products to the market. Furthermore, it is proposed that European fertiliser regulations be expanded to include products like biochar and struvite, opening up new market opportunities.

Lack of Standardisation for Bio-Based Products

Another barrier mentioned in NUTRI2CYCLE is the lack of standardisation for bio-based products, such as fertilisers derived from manure or digestates. Many of these products lack stability, homogeneity, and predictability, making it difficult for the industry to accept them, which limits their use in agricultural applications.

To overcome this barrier, it is recommended to develop clear quality standards and norms for bio-based fertilisers. This would improve their stability and homogeneity, facilitating their acceptance in the market and promoting nutrient recycling.

Opportunities to Improve Legislation

Finally, many projects propose improving existing legislation on nutrient and organic waste management. In particular, they highlight the need to update regulations to include innovative products like biochar and improve organic waste management through specific incentives and regulations. Additionally,

NUTRI2CYCLE emphasises the importance of continuing to develop new technologies for nutrient recovery and encouraging collaboration between public and private sector actors.

In summary, while there are significant regulatory, social, and technological barriers to nutrient management, the analysed projects offer several measures and recommendations to facilitate the transition to a circular economy, promote the use of bio-based fertilisers, and improve sustainability in organic waste and nutrient management.

5. Conclusions

The importance of national and regional regulations is crucial for the success of nutrient recovery in Europe. Each country and region present a different regulatory framework, which can either create barriers or provide opportunities for the adoption of sustainable technologies. For initiatives like the NENUPHAR project to achieve their maximum impact, it is essential to overcome existing regulatory barriers, such as the lack of coherence between national and European regulations, bureaucratic complexities, and the low public perception of recycled fertilisers. Harmonising regulations, alongside creating financial incentives and support programmes, is key to facilitating the transition towards a circular economy that promotes nutrient recovery and long-term sustainability.

In general, the main obstacles identified by the partners in national and regional legislation relate to the operational and administrative difficulties in reintroducing recovered nutrient flows into productive cycles, as well as the lack of regulatory harmonisation and the need to comply with environmental criteria for receiving environments. The bureaucratic complexity involved in obtaining the necessary licences and the need to adapt traditional agricultural practices also represent significant barriers. In many countries, strict regulations on the application of waste to soils limit its use in agriculture, while water management regulations impose additional restrictions, complicating the adoption of circular practices.

The absence of regional legislation in some countries is a significant legislative barrier, as it impedes adaptation to local needs, limits the efficiency and effectiveness of policies, creates inequalities in implementation, and delays responsiveness to emergencies or changes in local conditions.

Despite these barriers, several opportunities were identified that could facilitate nutrient recovery. Denmark, for example, has a regulatory framework that promotes technological innovation, and there are incentives for the use of biogas and waste treatment. In other countries, such as Spain and Lithuania, national bioeconomy strategies provide opportunities to promote nutrient recovery technologies and create a market for recycled fertilisers. Furthermore, cooperation between the public and private sectors, as well as the promotion of research programmes, offer great potential for improving resource management.

The questionnaires revealed that actors involved in nutrient management face regulatory barriers, such as the lack of coherence in regulations, as well as administrative and operational barriers regarding the use of organic versus inorganic fertilisers. There is also recognition of the need to provide financial support to farmers to promote sustainable practices and the importance of fostering training in new nutrient recovery technologies.

Regarding similar experiences in participating countries, projects have been identified where progress has been made in nutrient recovery. These projects have identified the lack of harmonisation of regulations between European countries as a key barrier and recommend the creation of unified regulatory frameworks to facilitate the adoption of bio-based products. Additionally, the importance of improving public perception and encouraging acceptance of these products among farmers and consumers is highlighted.

To encourage nutrient recovery, a more flexible regulatory framework is needed to allow for regional adaptations and the development of economic instruments to promote nutrient flows through key sectors (agriculture, industry, etc.). The correct transposition of European regulations at national and regional levels is essential to ensure the success of initiatives such as NENUPHAR and to consolidate a more sustainable and efficient resource management model. Only through coordinated effort and policy integration at all levels can we move towards a future where the circular economy is a reality across Europe.

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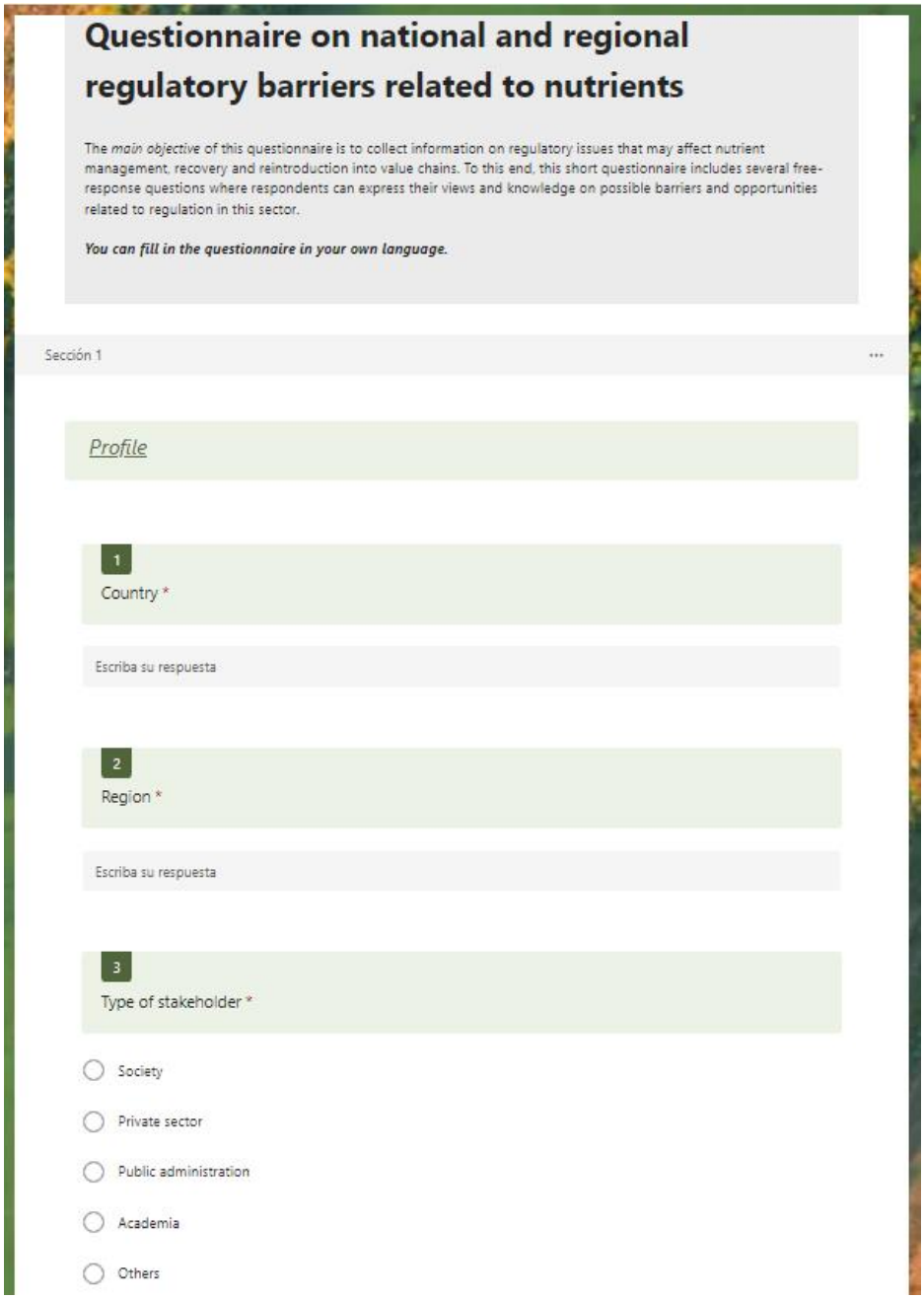
7. Annexes

ANNEX 1

LEGAL BARRIERS QUESTIONNAIRE



Questionnaire on national and regional regulatory barriers related to nutrients

The *main objective* of this questionnaire is to collect information on regulatory issues that may affect nutrient management, recovery and reintroduction into value chains. To this end, this short questionnaire includes several free-response questions where respondents can express their views and knowledge on possible barriers and opportunities related to regulation in this sector.

You can fill in the questionnaire in your own language.

Sección 1

Profile

1 Country *

Escriba su respuesta

2 Region *

Escriba su respuesta

3 Type of stakeholder *

- Society
- Private sector
- Public administration
- Academia
- Others